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CENTRAL UTAH COAL FIELDS:

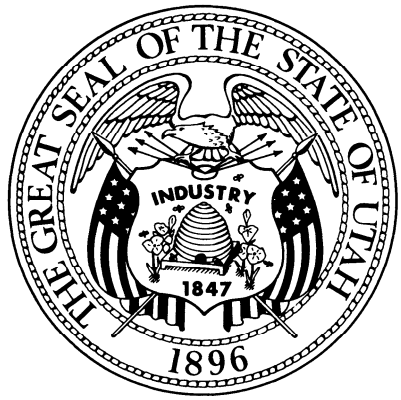
Sevier-Sanpete, Wasatch Plateau, Book Cliffs and Emery

by H. H. Doelling

A Survey of Palynomorphs from Several Coal-bearing Horizons of Utah

Coal in Utah-1970

Economic Evaluation of Utah Coal-1972



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PREFACE TO UTAH COAL FIELDS:

SOUTHWESTERN, NORTHERN, EASTERN AND CENTRAL

Coal, first discovered in Utah in 1849, reached an annual production figure of 1 million tons in 1900. Now (1970) between 4 and 5 million tons are produced annually. Coal, widespread and abundant in the state, underlies at least 15,000 square miles amounting to 18 percent of the total area. The Goose Creek-Grouse Creek lignite fields are in addition. These figures, however, project an exaggerated potential worth for Utah. If one excludes areas where the coal is more than 3,000 feet below the surface, the figure drops to 7.8 percent of the land area. If one further eliminates areas where individual coal beds are less than 4 feet thick, the total drops to 4.0 percent of the State's area or less than 3,400 square miles. In this 3,400-square-mile area the average coal bed is 6.21 feet thick. This figure cannot be used to estimate the coal resources of a particular Utah area, but serves to show the true importance of coal in an area1 sense. Coal beds greater than 25 feet thick have been discovered in Utah and in many cases more than one such seam is present in a single area. Practically all the operating mines of Utah are extracting coal from beds exceeding 8 feet thick.

The present study began in June 1969 when Dr. A. P. Talboys, National Air Pollution Control Administration, approved a cooperative demonstration grant with the Utah Geological and Mineralogical Survey (UGMS) to accumulate all coal data concerning the quantity, quality and location of Utah coal since 1849. Direct exploration of areas inadequately represented by previous data, as well as for publication of the results, were included in the contract. For every three federal dollars granted, one state dollar was involved.

The work consists of three volumes and divides Utah coal info regions: southwestern Utah, northern and eastern Utah and central Utah. Each of the volumes is subdivided further into coal fields (Preface, figure la), areas and quadrangles; geographical data, geology, mines and development, land ownership and control, coal quality and reserves are treated. A bibliography for each field and the principal source of work for each quadrangle are given. The last volume also summarizes, analyzes and compares the data of all three volumes to present Utah's total coal picture, and as highlights, contains a forecast of expected coal activity and a new study of coal palynology.

The magnitude of the work and the short time to complete it increased the possibility of incorporating technical flaws, but the Utah Geological and Mineralogical Survey believes timeliness is paramount and trusts this will be taken into account by the reader.

Hopefully this work will lead to an efficient and productive use of the state's coal resources and, at the same time, provide the data for properly evaluating its environmental and economic impact.

ACKNOWLEDGEMENTS

R. C. Flegal, National Air Pollution Control Administration, guided the study and the U. S. Bureau of Mines, U. S. Geological Survey and the Utah Industrial Commission provided assistance and data exchange. Many coal companies were cooperative in lending maps, analyses and other data. Consultants C. P. Heiner, C. S. Westerberg and L. P. Pearce updated the literature and contacted producers, transporters and users of Utah coal.

Staff members of UGMS who worked on various aspects of the Utah coal project include R. L. Graham, K. C. Thomson, geologists; Fred May, palynologist; R. C. Holland, L. M. Trimble, M. R. Lindgren, R. D. Gray and Edward Dalton, geological field assistants; Steven Rasmussen and Greg McLaughlin, draftsmen. Saffet Doyuran organized and plotted the data on the quadrangle maps and Christine Landward typed the tables and manuscripts. The published version was handled by the editorial staff, Judy McClellan, Mary Horton, Linda Findlay, Judy Allen and Alayne Winegar, under the guidance of Ann Fadel, and the illustrations were supervised by Brent Jones.

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Compiled by H.H. Doelling from numerous sources

TOWNS AND CITIES (1960 Census)
- 0 - 1,000
- 1,000 - 5,000
- 5,000 - 10,000
- 10,000 - 25,000
- 25,000 - 50,000
- 50,000 - 100,000
- 100,000 and over

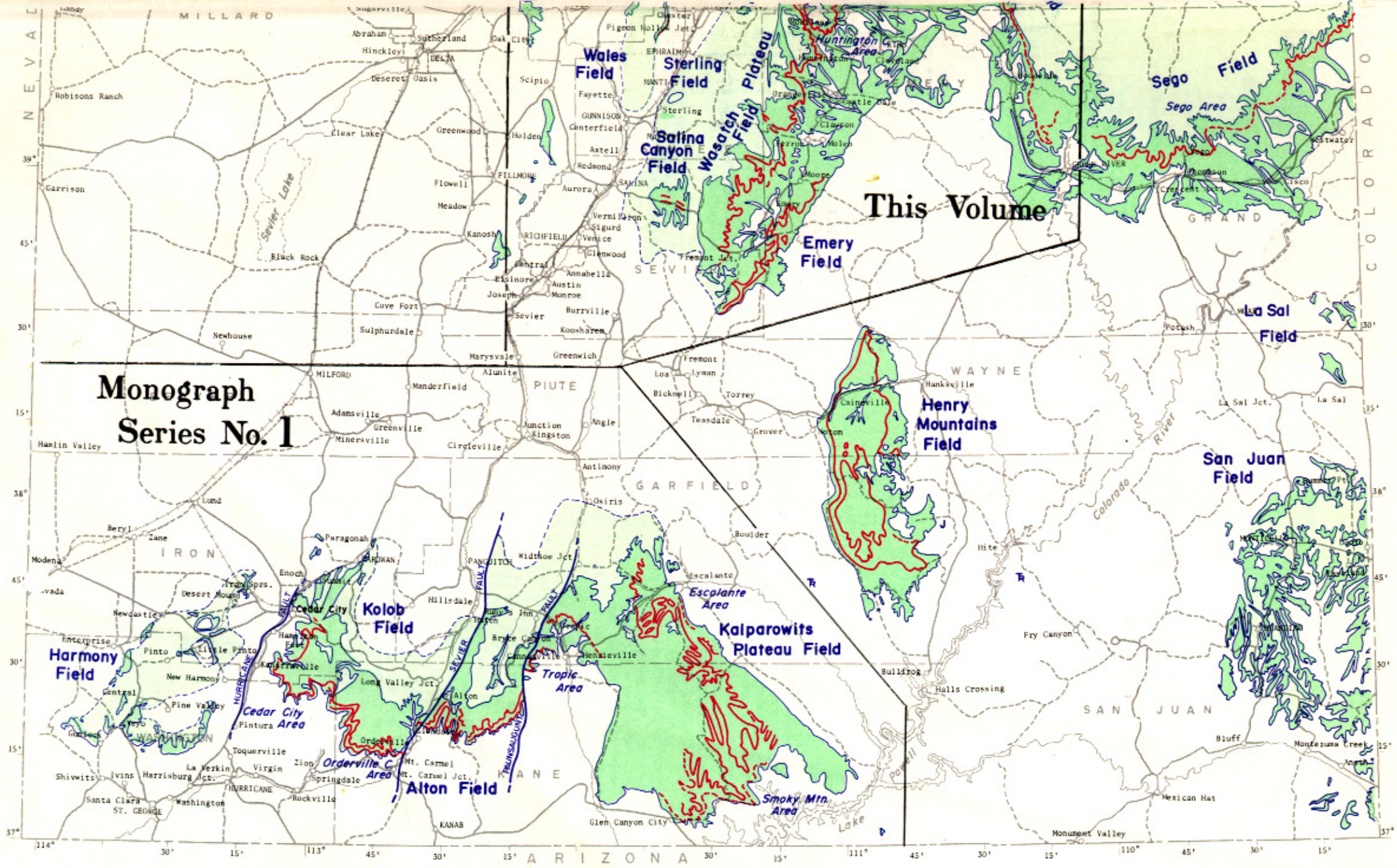
Paved roads
Important byways
Railroads

1970
- Deeply buried Cretaceous strata, probably coal bearing, or shallow where information is meager.
- Cretaceous outcrops
- Coal zones or important seams.
- Tertiary coal bearing rock, lignite or sub-bituminous
- Carboniferous coal bearing rock

M,P,T,J — Occurrence of reported non-economical coal seams by geologic age.

SCALE 1:1,500,000
0 10 20 30 40 50 Miles

Goose Creek – Grouse Creek Field
Lost Creek Field
Coalville Field
Henrys Fork Field
Tabby Mtn. Field
Vernal Field
Mt. Pleasant Field
Scofield Area
Book Cliffs
Castlegate Area
Sunnyside Area
Wasatch Plateau
Utah Lake
Green River
IDAHO
WYOMING
BOX ELDER
CACHE
RICH
WEBER
DAVIS
MORGAN
SUMMIT
DAGGET
DUCHESNE
UINTAH
TOOELE
UTAH
JUAB
SALT LAKE
WASATCH
CARBON
EVANSTON
Ogden
Logan
Brigham City
Clearfield
Layton
SALT LAKE CITY
S. Salt Lake
Murray
Midvale
Tooele
PROVO
Springville
Spanish Fork
Price
Vernal
Roosevelt
Duchesne
Fruitland
Heber City
Park City
Coalville
Evanston



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ABSTRACTS

SEVIER-SANPETE REGION

Four widely separated fields make up the Sevier-Sanpete region. Three are located on the west side of the Wasatch Plateau and the fourth on the east side of the Gunnison Plateau. The center of the region is about 100 miles south of Salt Lake City.

In 1970 none of the fields were active. Three had past production, the fourth was delineated as a result of drilling activity. Highlights of each field follow:

Coal Field	Host Formation	Past Production (tons)	Reserves x 10^6	Average Btu/lb	Sulfur Content (percent)
Mt. Pleasant	Blackhawk	–	249.1	12,890	0.8
Salina Canyon	Blackhawk	430,000	86.4	11,367	0.45
Sterling	Sixmile Canyon	60,000	2.0	11,767	0.9
Wales	North Horn	175,000	12.2	10,119	4.3

The Mt. Pleasant field was discovered by drilling Blackhawk Formation windows east of Mt. Pleasant in Sanpete County in the late 1920's and early 1940's. Several thick seams were discovered in the lower Blackhawk with quality comparable to the Wasatch Plateau coal field to the east. The drilling was to locate coking coal, but the samples underwent negative tests. No additional developmental work since has been undertaken. The thickest bed discovered was 5.7 feet, 1,000 to 1,100 feet below the surface.

Salina Canyon is cut in the southwest part of the Wasatch Plateau. The canyon exposes the upper Blackhawk Formation. Three coal zones have been mined. The upper two exposed along the canyon walls are limited in areal extent and contain thin coal seams. The third zone was discovered below the creek level and contains thick seams in the east part. Most production of the field came from this lower Ivie zone from a single shaft mine that operated from 1924 to 1933 and 1944 to 1953. The coal is comparable in quality to Wasatch Plateau coal field mines. An exceptional amount of resin occurs in the coal.

Sterling coal field also lies at the west edge of the Wasatch Plateau a few miles southeast of Manti. Six thin coal beds were mapped in the Sixmile Canyon Formation, 450 feet below the base of the Castlegate Sandstone which unconformably overlies it. Locally two of the beds coalesce to form a coal bed that was mined intermittently from 1888 to 1935. Outcrops and coal beds are limited in extent and the coal beds dip moderately to steeply.

Wales is one of the oldest coal fields in Utah. It is located on the east flank of the Gunnison Plateau. The first mine probably opened in 1855 and the last mine was abandoned in 1955. The coal beds are thin and badly split by shale and bone; they dip moderately to steeply. The length of outcrop is about 4½ miles and the coal is high in ash and sulfur.

WASATCH PLATEAU COAL FIELD

Coal was discovered in the Wasatch Plateau in 1874. The coal field, in parts of Carbon, Emery, Sanpete and Sevier counties, central Utah, is oriented approximately north-south. It has a length of about 90 miles, a width varying between 7 and 20 miles, and includes an area of 1,100 square miles.

Coal mining is concentrated in the north half of the field close to rail and highway connections. Several towns originated as a result of the enterprise, including Clearcreek, Mohrland, Hiawatha and Wattis. Since 1874 about 100 million tons of coal have been extracted. Of the many mines that have operated, eight are presently (1969) active. They produced 1,176,780 short tons of coal in 1969 and 1,402,061 tons in 1970. One mine is now active in the south half of the field.

All the coal lies in the Blackhawk Formation of Upper Cretaceous age. The outcrops are on the east-facing cliffs below the Wasatch Plateau and on the walls of canyons carved into the plateau. Twenty-two beds containing coal more than 4 feet thick have been named. All are in the lower one-third of the Blackhawk; the Hiawatha, Castlegate "A", Blind Canyon, Bear Canyon and Wattis beds are among the more important. The better, thicker beds are found in the north half of the field.

The Wasatch Plateau field coal is a high-volatile B bituminous product, often resinous, with the following characteristics, as-received: moisture 6.1 percent, volatile matter 43.4 percent, fixed carbon 47.4 percent, ash 6.7 percent, sulfur 0.6 percent and Btu/lb 12,589. Coal quality between seams in the same area is similar, but deteriorates slightly toward the south end of the field.

Original reserves amount to 6,230 million tons for the first three classes (measured, estimated and inferred) and 3,888 million tons for the potential reserve in areas thought to have coal seams 4 or more feet thick under less than 3,000 feet of cover.

The beds incline gently but are periodically cut by fault zones. The faults limit or impede mining for the most part; however, there is usually ample room between faults to mine profitably. The faults, subsurface water, variable seam thickness, undulating floor and ceiling, multiple coal seams and heavy overburden increase mining costs presently estimated to be about $5 or $6 per ton. The cost is expected to rise gradually as pollution control, safety and equipment costs rise.

In the future the Wasatch Plateau coal field, second in development and production in Utah, is expected to gradually supplant the Book Cliffs field as the most important because the easy-to-mine reserve in the Book Cliffs field is rapidly depleting. Markets have been mainly to the west, both for export to the Pacific states and for in-state use. Presently construction of a new power plant, which is expected to double field production by 1975, is underway at the mouth of Huntington Canyon.

BOOK CLIFFS COAL FIELD

The Book Cliffs coal field is the most important in the state of Utah with respect to present and past production. Coal production surpassed 208 million tons in the period between 1889 and 1969. In the last year 3,380,000 tons were extracted amounting to 72.3 percent of the state's total coal production.

The field extends from the North Gordon fault zone (8 miles east of Helper) eastward and southward along the Book Cliffs to Green River, a length of 70 miles. Cover increases rapidly behind the coal outcrops so that effective field width averages 4 miles making an area of 280 square miles. The field is conveniently subdivided into four areas: the Castlegate area takes in the west 14 miles of cliffs, the Soldier Canyon area covers the adjacent 13 miles, the Sunnyside area the next 22 miles and the southeast 21 miles from the Woodside area.

All the coal is contained in the Blackhawk Formation of Upper Cretaceous age ranging from 400 to 1,300 feet thick. The unit is thickest in the west part of the field. Some of the more important coal beds and zones include (ascending order) the Spring Canyon, Castlegate, Kenilworth, Gilson, Rock Canyon and Lower Sunnyside. The first three are important in the Castlegate area, the next two in the Soldier Canyon area and the last in the

Sunnyside area. The Lower Sunnyside bed is thick in the north end of the Woodside area as well. Coal beds in the remaining part of the Woodside area are too thin for commercial consideration. The strike of the beds is nearly parallel to the cliff face and the dip is to the north and east. The dips are described as gentle to moderate. The steepest (up to 15 degrees) occur in the Sunnyside area but for the most part average between 3 and 7 degrees. Few faults occur; the only cluster of significance is in the Sunnyside area where the strike changes. Displacements to 200 feet occur, generally with much space between them.

In 1969 eight mines were active in the field; all but one were in the Castlegate and Sunnyside areas. Both areas have thick seams and good coal. The Castlegate has had an additional advantage of being close to markets and on the major transportation routes. The Sunnyside owes its development to the metallurgical quality product found there. Much of the land (44 percent) is held for coal either as leases or as private property.

The rank of the coal is a high-volatile B bituminous. The ash content averages 6.9 percent and the sulfur content 0.85 percent. Sulfur is low in all areas except in the Sunnyside where locally the content has gone up to 3 percent. Part of the sulfur is pyritic and can be washed to metallurgical grade. Coal in the Sunnyside area is used for coking but must be blended with a percentage of medium- and low-volatile coal from other sources to achieve metallurgical standards. As-received Btu/lb for the field averages 12,762.

Original reserves for the Book Cliffs coal field in beds more than 4 feet thick and under less than 3,000 feet of cover amount to 3.7 billion tons. Recoverability on a field basis is one-third that amount. Minus the amount mined, 1.1 billion tons are still recoverable. Recoverability is generally higher on a seam basis but closely spaced seams, deep burning behind the outcrop and other geologic problems lower the overall rate.

The coal is exported to markets in the west states to steel plants (coke), steam generation plants, government installations, mines and smelters, cement plants, sugar factories and gypsum plants. It is assumed that these markets will be maintained, that production will fall slightly in the next 5 years but increase slightly thereafter. Other areas in Utah will be developed during this time to challenge the leading coal producing field of Utah.

EMERY COAL FIELD

The Emery coal field lies along the Emery-Sevier County line in central Utah, 35 miles east of Salina, 70 miles south of Price and 175 road miles south of Salt Lake City. The field is about 35 miles long and averages 6 miles wide for an effective area of 210 square miles.

The important coal beds occur within the Ferron Sandstone Member of the Mancos Shale. At least thirteen coal beds in four coal zones have been defined; about six achieve 4 feet thicknesses in the field. The most important A and C beds in the Lower coal zone and the I bed in the Upper coal zone are contained in highly lenticular strata and only closely spaced drilling can determine the true nature of the seams.

The beds strike northeasterly and dip gently 3 to 5 degrees westward. The only faulting of significance is the Joes Valley-Paradise fault zone, a graben feature 1 to 8 miles west of the outcrops. It is about 2 miles wide; the regional dip and strike resumes on the west side.

The Emery field averages a high-volatile C coal ranging from a subbituminous C to a high-volatile B bituminous coal. Sulfur content of all samples averages 1.0 percent with local highs of 4.7 percent and lows of 0.31 percent.

The first mine opened in 1881, but serious mining did not commence until 1930. Since then 1.6 million short tons of coal have been produced. At present the two operative mines produce between 57,000 and 140,000 tons annually. Measured and indicated reserves for the field total 757.6 million tons; inferred tonnage is 672.8 million tons.

Most future mining will continue underground although surface mining will be possible locally. Production is expected to increase slowly in the next 10 years depending on markets that are developed. Present markets include space-heating coal used in-state and coal for export. A new power plant could increase production substantially.

SEVIER-SANPETE REGION

by

H. H. Doelling[1]

INTRODUCTION

Location and Extent

Sevier and Sanpete counties lie at the heart of Utah. Within their borders four coal fields occur, all small in extent. Little is known about them, but at least two have the potential of increasing reserves with future exploration. The four coal fields include Wales, Mt. Pleasant, Sterling and Salina Canyon with an additional little known area of lignite, the Milburn field (Preface, figure 1a and figure 1). The Wasatch Plateau and Emery coal fields extend on the lands of Sevier and Sanpete counties; they are important enough to be discussed separately and this presentation excludes them.

The fields lie 85 to 135 miles south of Salt Lake City. The Wales field lies on the west side of Sanpete Valley along the east flank of the Gunnison Plateau. The coal outcrops trend north-south over a distance of 5½ miles. The beds dip so steeply and the overburden increases so rapidly that the field has only the width of a mile giving an effective area of 5½ square miles. Thin coal beds have been discovered elsewhere on the Gunnison Plateau and thick beds may exist outside of the area in question. They undoubtedly will be local in nature and will not constitute an important resource.

The Mt. Pleasant coal field is located on the west flank of the Wasatch Plateau opposite the Wales field. The upper part of the Blackhawk Formation is exposed and contains thin coal seams in a north-south band of outcrops about 10 miles long. Through drilling, thick coals are known to be present in the lower Blackhawk. The coals in this formation are believed continuous with those in the Wasatch Plateau field. The width of the field should average 3 miles and create a 30-square mile area. If mining under 2,000 to 3,000 feet of overburden were contemplated, the area could be vastly increased.

The Sterling field is limited to Sixmile Formation outcrops near the mouth and on both sides of Sixmile Canyon. Sterling is located at the south end of Sanpete Valley and the canyon extends easterly into the Wasatch Plateau. The total length of coal outcrop is about 2 miles and since the beds dip moderately to steeply, the effective area is less than 2 square miles.

Farthest south is the Salina Canyon field. Salina Canyon is a deep gorge which cuts into the south end of the Wasatch Plateau and intersects the top of the Blackhawk Formation. Some marginal coal beds crop out along the canyon walls and the drill has intersected thick beds in the lower part of the formation. The length of the field is about 10 miles and the width is about 4 miles creating a 40-square mile area. The Milburn lignite field is centered in secs. 7 and 8, T. 13 S., R. 5 E. in Dry Canyon east of Milburn. The extent of the field is unknown.

The Mt. Pleasant, Sterling and Salina coal fields are located on the west slope of the drainage divide. The omitted area to the west of the divide was not tested for coal although coal is likely present. If found, the coal would be buried 2,000 to 4,000 feet below the surface.

Topography and Drainage

All four fields are in rugged mountainous areas with steep-walled canyons. The Wales field is along the east side of the Gunnison Plateau and the principal drainages flow easterly into Sanpete Valley. The highest elevation on the plateau is about 8,900 feet and the principal drainages from south to north are: Rock Creek, Axehandle Canyon Creek, Peach Canyon Creek, Coal Canyon Creek and Wales Canyon Creek. These are tributaries to the San Pitch River which flows southerly in Sanpete Valley to

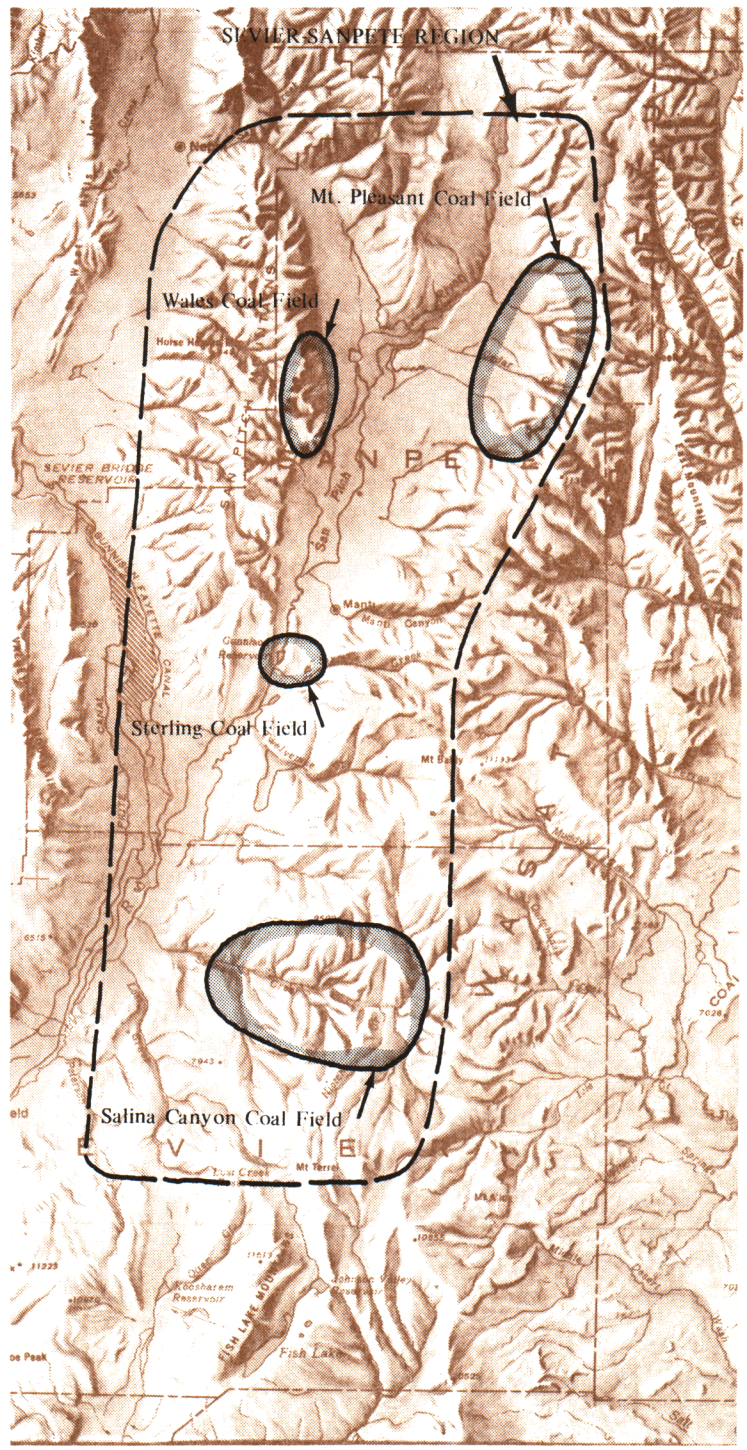


Figure 1. Relief map of central Utah showing the approximate location of the Sevier-Sanpete region.

[1]Economic geologist, Utah Geological and Mineralogical Survey.

join the Sevier River near Gunnison. The floor of Sanpete Valley is about 5,600 feet above sea level.

The west Wasatch Plateau is cut by west-flowing streams separated from each other by narrow knife-edge divides. The walls of these divides are steep and erosion has cut into the upper part of important coal-bearing units in the area of the Mt. Pleasant coal field. Elevations atop the Wasatch Plateau in this area rise to more than 10,000 feet. The town of Mt. Pleasant at the foot of the mountain is 5,800 feet above sea level. From south to north the principal drainages include Cedar Creek, Twin Creek, tributaries of Pleasant Creek, Birch Creek and Cottonwood Creek.

In the vicinity of Sterling, Sanpete Valley is divided into subvalleys and narrow ridges. The coal area lies where Sixmile Creek, the principal drainage, emerges into the easternmost valley. The town of Sterling is situated 5,500 feet above sea level and the mountains roundabout rise to about 8,800 feet (south of Rattlesnake Peak).

The mountains in the Salina Canyon field rise to more than 8,300 feet and the canyon floor rises from 5,900 to 7,100 feet above sea level. Principal drainages flowing into Salina Creek from the north are Taylor Flat Creek, Coal Hollow Creek and Water Hollow Creek. From the south and east they include Skumpah Canyon Creek, Meadow Creek, Niotche Creek and Browns Hole Creek.

Population, Industries and Transportation

The 1970 population for Sanpete County was 10,976 and for Sevier County 10,103. The people live in smaller towns, the more important of which are listed in table 1.

Table 1. Population of towns in the Sevier-Sanpete region, 1970.

Town	Population	County
Annabella	221	Sevier
Aurora	493	Sevier
Centerfield	419	Sanpete
Elsinore	357	Sevier
Ephraim	2,127	Sanpete
Fairview	696	Sanpete
Fayette	93	Sanpete
Fountain Green	467	Sanpete
Glenwood	212	Sevier
Gunnison	1,073	Sanpete
Joseph	125	Sevier
Koosharem	141	Sevier
Manti	1,803	Sanpete
Mayfield	267	Sanpete
Monroe	918	Sevier
Moroni	894	Sanpete
Mt. Pleasant	1,516	Sanpete
Redmond	409	Sevier
Richfield	4,471	Sevier
Salina	1,494	Sevier
Spring City	456	Sanpete
Sterling	144	Sanpete

Both counties' population has dropped slightly since 1960. The larger towns increased slightly at the expense of the smaller.

The principal industry is agriculture with the major output in cattle, turkeys and sheep. Forestry and lumbering is important followed by manufacturing and mining. Manufacturers are mainly involved in the processing of agricultural, lumbering and mining raw materials. Many people work for the government or are employed in retail trade and miscellaneous services. Snow College is a state-maintained school at Ephraim. At present the only coal-mining activity in the two counties is in Sevier County at the Southern Utah Fuel mine in the Wasatch Plateau. No mines are active in the four coal fields at present (1970). Sevier and Sanpete counties contain a stone and clay quarrying area which employs most of the mining personnel of the area.

Numerous highways serve the region; of most importance U. S. Highway 89 extends north-south along Sevier and Sanpete valleys. It joins with U. S. Highway 50-6 at Thistle to the north and continues to Provo and Salt Lake City. To the south it continues over Glen Canyon Dam into Arizona. Interstate Highway 70 follows Salina Canyon in extending from Denver, Colorado, to Los Angeles, California. It joins U. S. Highway 89 at Salina and is simultaneous with it to Sevier town in south Sevier County and then extends westward from 89 to U. S. Highway 91. Utah Highway 132 joins Nephi with Moroni and Mt. Pleasant; Utah Highway 28 joins Levan and Gunnison, Utah. Highway 63 joins Scipio and Salina and Utah Highway 4 connects Cove Fort with Sevier (future route of I-70). Two major routes link Sanpete Valley with Castle Valley; Utah Highway 31 links Fairview with Huntington and I-70 joins Emery with Salina. Several graded roads cross the Wasatch Plateau. A skyline drive follows the plateau crest.

The Marysvale branch of the Denver and Rio Grande Western Railway extends from the main line at Thistle southward through Sanpete and Sevier valleys. The Salt Lake-Los Angeles line of the Union Pacific Railroad lies about 25 to 30 miles east of the area. Scheduled bus lines serve the area, but air service is irregular. Most towns have cafes and motels.

Climate

The regional climate is a mid-latitude steppe which is modified locally by elevation. The lower parts of Sanpete and Sevier valleys receive less than 10 inches of precipitation annually. This amount increases with altitude; the top of Gunnison Plateau receives 25 inches and the higher parts of the Wasatch Plateau receive 40 inches annually (figure 2). Pashley (1956, p. 7) notes:

> Rainfall in the area is dominantly orographic and is fed by winds from the southwest. This results in the amount of rainfall increasing from west to east or from valley to crest. The summer season is typified by violent local showers that last an hour or two and are often accompanied by hail. When these storms are concentrated at the heads of the streams at the crest of the plateau they may be followed by flash floods which spread mud and boulders out over the alluvium of Sanpete Valley... During the winter snow accumulates on top of the plateau and supplies water to the streams during the spring. The last snow normally disappears from the crest by the middle of July.

Pashley's specific area of interest was the Wasatch Plateau. The snow usually melts from the lower Gunnison Plateau by April. Average summer and winter temperatures, also a function of elevation, are lower higher up. During summer the days are hot and dry with cool nights. In the valleys July daytime temperatures often reach the 90's and occasionally exceed 100° F. The diurnal range is about 30 degrees. In January the lower morning temperature normally dips into the low 20's or high teens and occasionally drops below zero. The temperatures on the plateau are usually 10 degrees cooler in the summer and 10 to 30 degrees colder in the wintertime.

HISTORICAL OUTLINE

Sanpete and Sevier valleys were settled by Mormon colonists under the leadership of Brigham Young between 1849 and 1875. The new settlers soon discovered coal in the nearby hills. Wales, along with Coalville in Summit County, has the distinction of being one of the first discovered districts. Clark (1914, p. 489) continues:

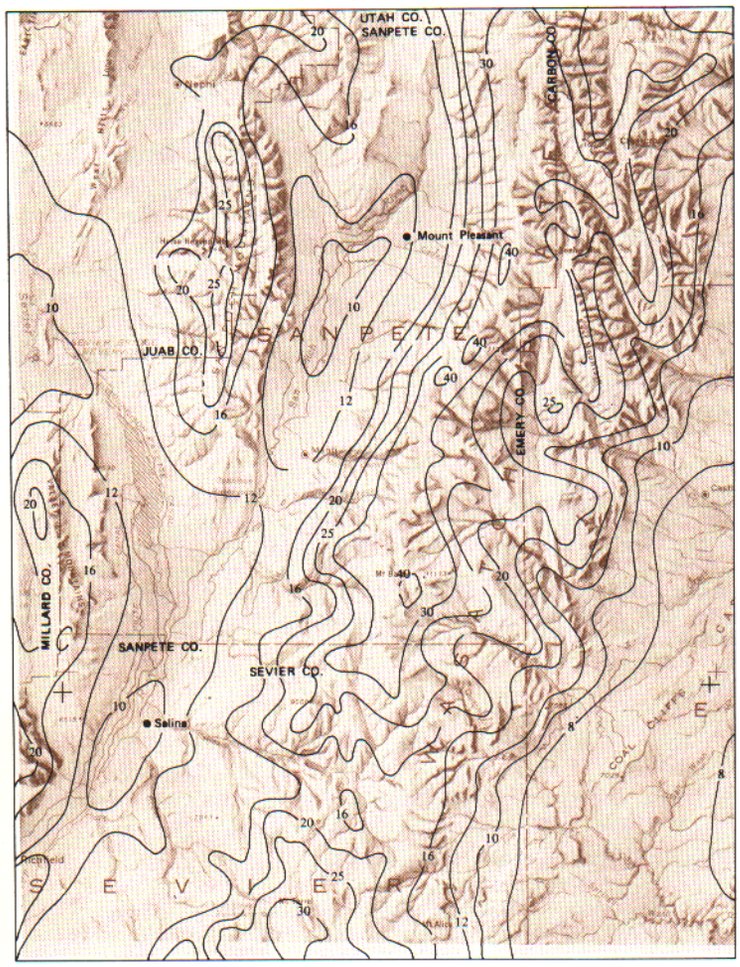


Figure 2. Rainfall map, Sevier-Sanpete region (isohyetals in inches).

Wales, however, claims the distinction of having produced the first coal mined in Utah. It is reported that J. E. Reese and John Price, who had been coal miners in Wales learned of the coal from an old Indian chief who called it "rock that would burn." These two men in 1857 founded the town of Wales, Utah, and were the pioneers in coal mining in the State. It was soon learned that this coal was a good blacksmithing coal, and in 1858 Reese and Price manufactured some coke, which they hauled by ox team to Salt Lake City. In 1873 the coal property passed into the hands of a Salt Lake company which in 1874 and 1875 built several coke ovens and manufactured coke, freighting it by team to York, the terminus of the Utah Central Railway, about 25 miles south of Provo. This company, after spending much money in experimental work, sold out to an English company, which in 1880 to 1882 built the first railroad to enter Sanpete Valley. This railroad connected the coal mines in Indian Pete Canyon via Wales, with Nephi, the terminus at that time of the Utah Central Railway. It is reported that the English company also spent much money in experimenting with different types of coke ovens and in the development of the coal, but finally abandoned the work through lack of funds.

Clark notes that the length of time the railroad operated is unknown. After a few years it was extended to Moroni and called the California Short Line and the spur to Wales was abandoned. Undoubtedly development of better Carbon County coal forced shutdown of all but local production. Richardson (1906, p. 28) adds that in 1862 this pioneer field of Utah was opened. Hileman, Collins and Wilson (1970, p. 44) report the field opened in 1855.

Coal in the other fields probably was discovered early also, but only at Sterling was significant production achieved prior to 1900. Hileman, Collins and Wilson (1970, p. 43) indicate the mine opened in 1888. Production was small at first and by the turn of the century about 3,000 tons annually were being produced, mostly for local consumption. The Sevier Valley branch (Marysvale branch) of the D & RGW Railroad, which started in Thistle in 1890, reached Manti in 1891 and Marysvale in 1896. Population of the area by 1900 reached about 30,000, about 10,000 more than inhabit the area today (1970). The railroad was extended to the mines in 1894. Richardson (1906, p. 283) termed it the south terminus of the Sanpete Valley Railway. He continues:

. . .the coal (was) worked in a slope until so much trouble was caused by water that the mine was abandoned and the present tunnel was made. The mouth of the tunnel is on the hillside along the east bank of Sixmile Creek. It was driven through buff sandstone and thin beds of shale until the coal was struck at a distance of about 2,000 feet.

Richardson further notes that the water was easily drained thereafter and that on August 17, 1905, the discharge at the tunnel mouth was 5.6 second-feet. Since that time the tunnel opening has provided a continuous source of water for irrigation.

Little activity with respect to coal is known to have occurred in Salina Canyon prior to 1900. Several small mines were opened thereafter and much prospecting took place especially in the upper seven miles of the canyon. Spieker and Baker (1928, p. 165) report that in 1922 and 1923 private corporations undertook drilling at three localities to determine the presence of valuable coal in the lower part of the Blackhawk Formation and that only the Wilson mine was operative in the canyon. The mine operated with hand-drawn cars and supplied users in the town of Salina. Other mines noted were the Kearns and Duggins mine (Coal Hollow) and Boston Acme mine. The Kearns and Duggins had been shut down since 1914 and Boston Acme was tunnels in the prospecting stage. By this time the competition with better, more easily mined coals in Carbon County forced the Wales and Sterling operations into intermittent and small operations. The maximum annual production at Wales probably never exceeded 10,000 tons and in 1903 Sterling produced 10,450 tons. The mines in Salina Canyon, as well, produced less than 1,000 tons in their best year prior to 1925.

Little is known about the early history pertaining to coal in the Mt. Pleasant field. Some of the thin beds of coal present in the upper Blackhawk Formation were prospected; other thin beds were prospected in overlying formations. One prospect was noted on a 2½-inch bed. From a few prospects in beds 8 to 18 inches thick, small quantities of coal for local consumption were produced. The next events of importance occurred in Salina Canyon. The largest mine to produce in this field constructed two shafts, beginning in 1924 and completed in 1926, to thicker lower beds in the Blackhawk. The shafts were sunk in bottom land which unfortunately allowed water from Salina Creek to enter the mine and create expensive pumping problems. At the same time the D & RGW Railroad constructed a branch line 18 miles from Salina to the mine site.

According to Pearce (1970c, p. 7):

The shaft was equipped with a headframe and automatic dumping equipment, a double drum hoist was installed on the surface so that loaded mine cars could be hoisted and the coal dumped automatically into bins while the empty mine car was descending. The mine equipment consisted of mine cars, track haulage, and an electric motor to transport the mine cars. The mine operated from 1926 to 1933, when it was forced to close down on account of the recession, the high mine costs due to having to pump 80 gallons per minute continuously to prevent flooding of the mine, and general adverse mining conditions. The removal of the bone and rock from the coal added to mine costs, and it was difficult to produce a clean coal for market. The principal source of the mine water was from Salina Creek.

The mine was closed down in 1933 and remained closed until 1944. As there was no production from the mine the railroad was abandoned and the track was taken up in 1942 for use elsewhere. In 1944, under new management, pumping of the water filled mine commenced and the mine and surface installations were rehabilitated. Production was achieved but the mine was plagued by high costs coupled with a shrinking coal market. The mine was forced to close permanently in December 1953. The property is now completely abandoned.

Meanwhile the recession caused the final abandonment of the mines at Sterling in 1935 and the shrinking coal market closed the last operation at Wales in 1955. From 1929 to 1931 several holes were drilled in the Mt. Pleasant field by private companies in hopes of finding thick coal beds. The operation encountered at least two minable coal beds. There was no follow-up, probably because of the recession. Holes also were drilled by the U. S. Bureau of Mines in 1941 and 1942 in an effort to find coal of coking quality. Six coal beds were encountered, three of minable thickness. The coke was of inferior quality and there was no

follow-up. Total coal produced from all four areas is estimated to be 665,000 tons. At present none of the fields is active. Clark (1914) mentions that local interest in the Wales coal never entirely died away; local prospectors still send in samples to be coked from that field.

GEOLOGIC SETTING

Stratigraphy

Sixteen consolidated units crop out in the vicinity of the coal fields ranging in age from Jurassic to Tertiary (figures 3 and 4). Six of these are known to contain coal, most of which is Cretaceous. A brief description of each unit is presented (figure 3) to aid in unit recognition and to provide a stratigraphic picture of formations shown on the geologic maps (figures 5 and 6). The area is structurally complex and locations of outcrops will be related to the particular coal fields and individually by formation.

Twelvemile Canyon Member of the Arapien Shale

The oldest beds exposed in the Sevier-Sanpete area are those of the Jurassic Arapien Shale. The lower Twelvemile Canyon Member consists of four different kinds of lithologic assemblages according to Spieker (1949, p. 16-17):

4. Dense, massive dark red shale locally containing thick beds of nearly pure rock salt.
3. Indistinctly bedded gray shale liberally and haphazardly punctuated by blotches of red and very gypsiferous.
2. Light gray shale, siltstone and sandstone, very evenly thin-bedded, locally containing thick beds of commercial gypsum.
1. Light gray limestone, massive to thinbedded, like the Twin Creek.

The Twelvemile Canyon Member was estimated to be 7,000 feet thick in the vicinity of Salina, but undoubtedly it thins in all directions from this location. It is best exposed in west-dipping beds on the west side of Sevier Valley. The unit is cut out by faults in the hills west of Sterling. Gypsum and salt are mined commercially in the Sevier-Sanpete area.

Twist Gulch Member of the Arapien Shale

The upper member of the Arapien is described by Spieker (1949, p. 16) as a thin-bedded dark red to chocolate siltstone, sandstone and shale with some massive layers and abundant interbedded layers and laminae of white to greenish white siltstone, brownish gray grit and sandstone and pure white medium- to fine-grained sandstone. The area of exposure follows that of the Twelvemile Canyon Member, but continues to appear at the foot of the east side of the Gunnison Plateau in discontinuous outcrops. The maximum thickness is estimated to be 3,000 feet. Like the lower member, the Twist Gulch is expected to thin as distance increases in all directions from the Salina area.

Morrison ? Formation

The Morrison ? Formation is not everywhere present in the area. In most areas the beds have been removed by pre-Indianola erosion. The only outcrops known near the coal fields are near the mouth of Salina Canyon. Spieker (1949, p. 19) poses the question:

> The stratigraphic relations of the formation are a source of much difficulty. In Salina Canyon excellent but very short exposures show gradation and apparent intertonguing with both the Arapien Shale and the Sanpete Formation. If the beds are really Morrison in age, the basal gradation is no problem, rather an interesting contribution to Morrison stratigraphy, but the upper one is most puzzling; the whole Lower Cretaceous should be missing and so far no one of several competent geologists has been able to recognize any sign of a break. . .

The Morrison ? consists of red, pink, lavender, ocher and gray shales, gray sandstone, gray, brown and red conglomerate and white freshwater limestones.

Indianola Group

The Indianola Group is subdivided into four formations (from oldest to youngest): Sanpete Formation, Allen Valley Shale, Funk Valley Formation and Sixmile Canyon Formation. In addition Hunt (1950, p. 54) added a formation above the normal Indianola (South Flat Formation). For the present the unit descriptions as presented in figure 3 are adequate, except where the presence of coal is involved. Except for Hunt's South Flat Formation all are best displayed in the vicinity of Sterling. North of Manti they no longer crop out adjacent to the Wasatch Plateau. Along the east margin of the Gunnison Plateau the Indianola cannot be differentiated. The South Flat is identifiable north of Wales. According to Taylor (1948, p. 14) the undifferentiated Indianola is described as:

> The undifferentiated group includes conglomerates which are white, gray, buff, and red. Characteristically the conglomerates include pebbles and cobbles, from one to ten inches in diameter, of pink, white, and green quartzites and dark gray limestone. . .Other than conglomerates there are fine- to coarse-grained red, white to gray, and buff, medium-bedded sandstones. Gray ochre, and orange shales are fairly common; and there is some limestone. All of these types cannot be observed in any one section of the area. The group commonly consists of sandstone interbedded with conglomerate.

None of the undifferentiated Indianola measured sections of the bibliography indicates coal. Coal is present, however, in the uppermost differentiated formations. The Sixmile Canyon Formation crops out at the mouth of the canyon with that name. The unit is apparently divisible into three parts:

3. Conglomerate and conglomeratic sandstone (about 425 feet thick).
2. Gray to cream colored and white mostly fine-grained sandstone; gray to white shale, carbonaceous shale and coal (about 300 feet thick).
1. Gray conglomeratic sandstone (about 2,000 feet thick).

The coal in unit two forms the basis of the Sterling coal field. At least six coal beds have been discovered.

The South Flat Formation is exposed only in the Gunnison Plateau from Wales northward. The South Flat also can be subdivided into three submembers:

3. Variegated sandstone, shale, clay and coal (about 1,350 feet thick).
2. Mostly massive conglomerate with subordinate sandstone (about 600 feet thick).
1. Sandstone and conglomerate with discontinuous coal (about 900 feet thick).

The coal beds in the South Flat Formation appear too thin to mine. The thickest coal bed measured 1½ feet thick.

Blackhawk Formation

The Blackhawk is undoubtedly the most important coal-bearing unit of the Sevier-Sanpete region; it forms the basis of the Mt. Pleasant and Salina Canyon fields. To the east it continues as the important coal-bearing unit of the Wasatch Plateau and Book Cliffs coal fields. In this region it is not exposed in its entirety and is present only in the Wasatch Plateau. To the west it is believed planed off by a pre-Price River erosional and orogenic interval. In Salina Canyon, the upper part of the Blackhawk, which forms the floor and walls of the canyon, consists of 800 to 900 feet of yellow-gray, brown or gray medium-grained sandstone, gray shale, carbonaceous shale and coal. Only the upper 550 feet are exposed and the coal beds at the surface are of marginal thickness. The drill has proven thick beds in the lower part of the unit that have been commercially mined.

Between Mt. Pleasant and Spring City the Blackhawk crops out in the canyons to the east. The lithology in this area is similar to that at Salina Canyon. Again only the upper 500 feet of the formation are exposed and coal beds are thin. Wells penetrated an additional 1,262 feet of the unit giving a total thickness of more than 1,750 feet; drill-hole data reveal thick coal seams lie near the

System	Series	Stratigraphic unit		Thickness (feet)	Description
TERTIARY	Oligocene	Gray Gulch Formation		0- 700+	Pyroclastics.
					Disconformity
	Eocene	Crazy Hollow Formation		0- 600	Siltstone, red, sandstone, white, pepper and salt, and red; local conglomerate.
					Disconformity
		Green River Formation		30-1,400+	Shale, gray to green, limestone, white to tan; some oolite, local sandstone and conglomerate.
		Colton Formation *Minor Coal*		0-1,600	Shale, varicolored to gray; sandstone, buff to brown, some local limestone.
	Paleocene	Flagstaff Limestone		50-1,500	Limestone, dark gray to tan, light gray and white, of varied lithology; shale, gray; some sandstone, silicic ash, and gypsum; local oil shale.
CRETACEOUS	Danian	North Horn Formation *COAL SEAMS*		500-3,000+	Shale; variegated red, gray, green; sandstone, buff to red; conglomerate; limestone; coal and lignite beds.
	Maestrichtian	Price River Formation including Castlegate Sandstone *Minor Coal*		200-2,000	Conglomerate, sandstone, little shale.
					Angular Unconformity
	Campanian	Blackhawk Formation *COAL SEAMS*		800-1,800	Sandstone, yellow gray to brown, irregularly bedded; shale, gray to black, carbonaceous coal beds.
	Santonian	Indianola Group	South Flat Formation *Minor Coal Seams*	0-2,850	Sandstone, conglomerate and limestone, brown, tan or buff, coal-bearing variegated beds.
	Coniacian		Sixmile Canyon Formation *COAL SEAMS*	2,800	Sandstone and conglomerate, gray to buff; coal.
			Funk Valley Formation	2,250	Sandstone, light buff to brown, locally conglomeratic, marine shale, gray.
	Turonian		Allen Valley Shale	600- 800	Shale, gray, marine.
	Cenomanian		Sanpete Formation	1,350	Sandstone, buff to gray and ocher; conglomerate; little shale.
JURASSIC	Upper	Morrison? Formation		0-2,000	Shale, variegated; sandstone gray to red; conglomerate, gray to red; local white limestone.
		Arapien Shale	Twist Gulch Member	3,000	Siltstone, dark red, thin-bedded to massive; sandstone, white to gray.
			Twelvemile Canyon Member	7,000+	Shale, gray and thin-bedded to massive, blotched gray, red and deep red, sandstone and grit, gray, yellow, brown, rock salt; gypsum; limestone, gray locally at base.

Figure 3. Generalized section of rock formations, Sevier-Sanpete region.

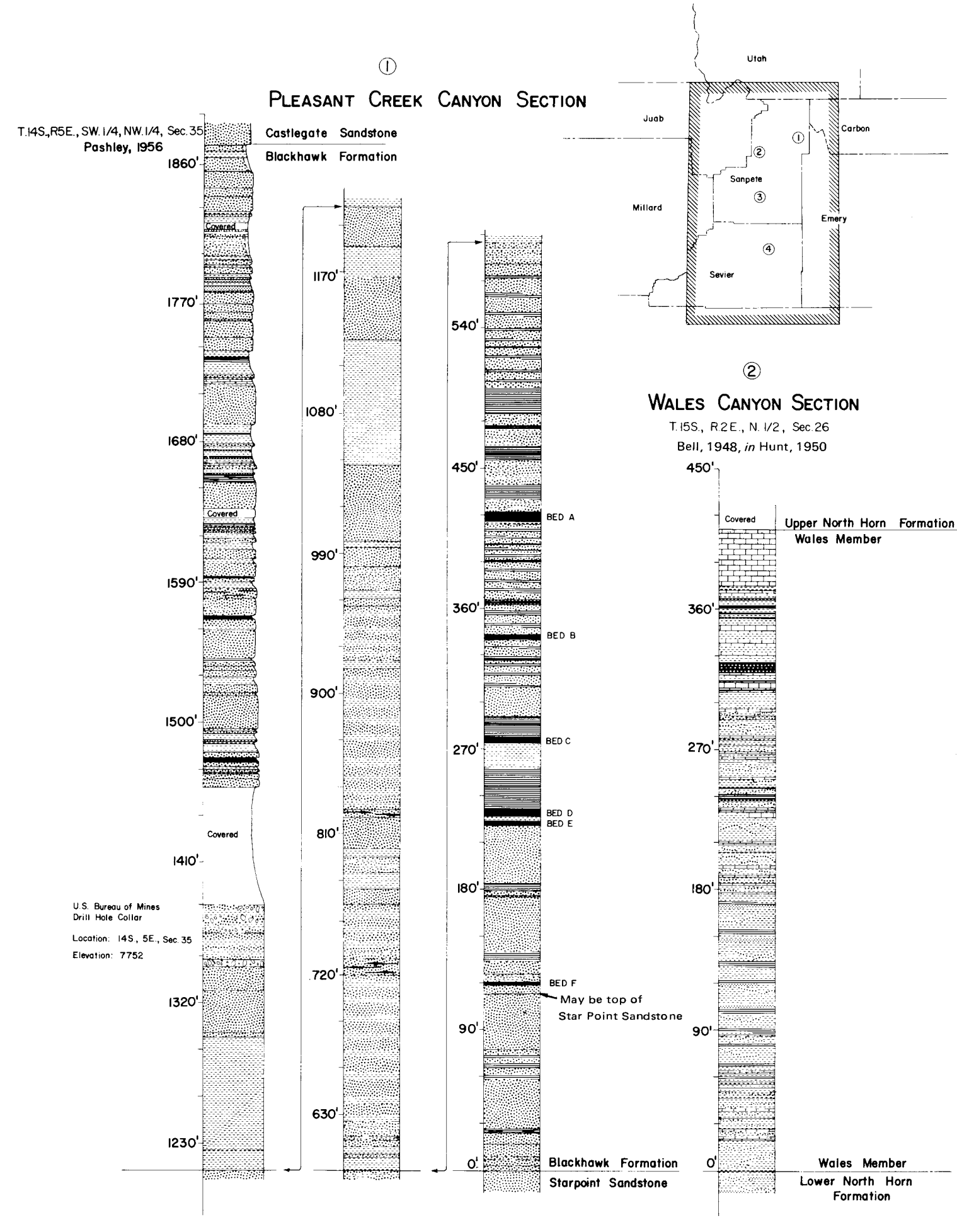


Figure 4. Sections of coal-bearing formations, Sevier-Sanpete region.

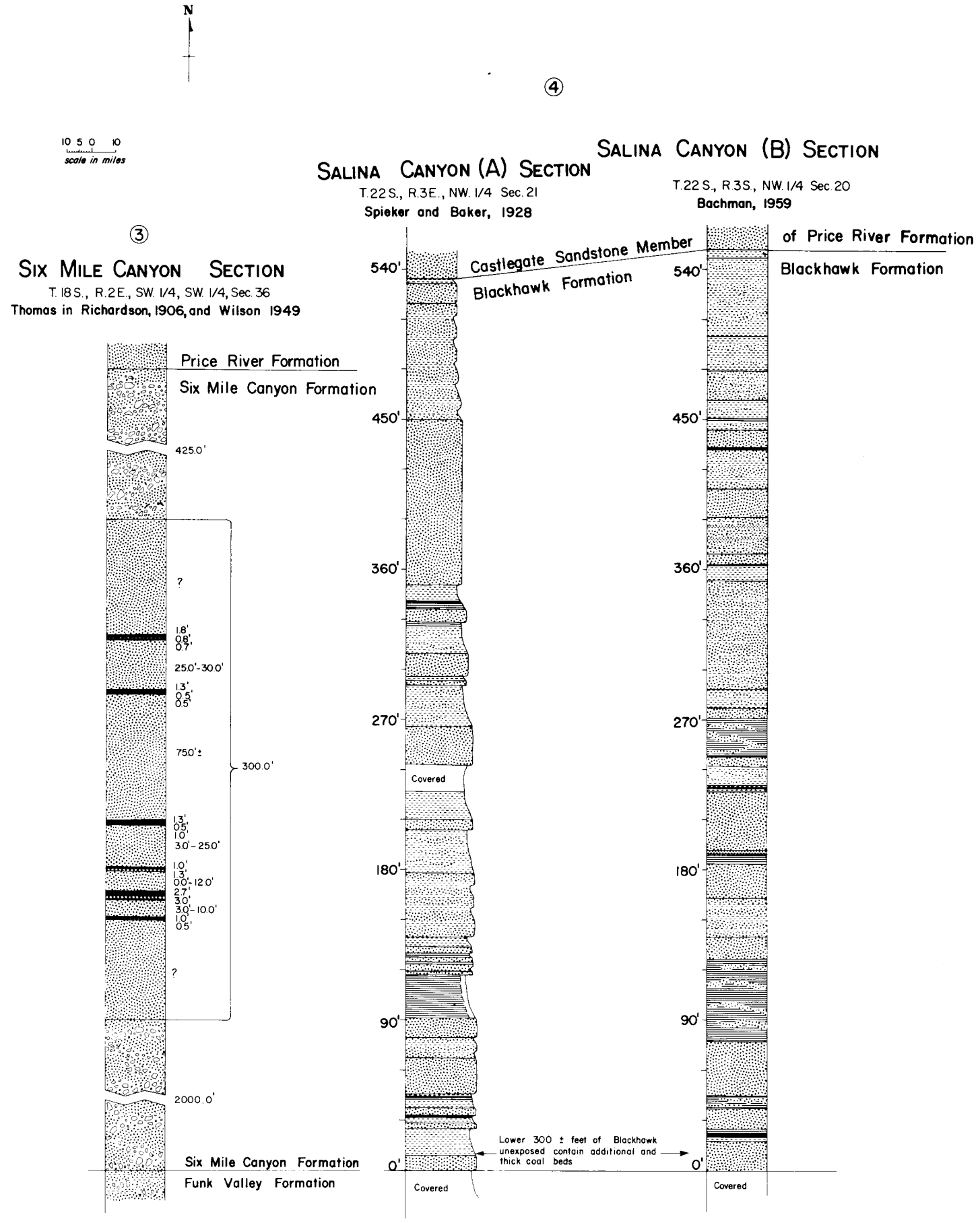
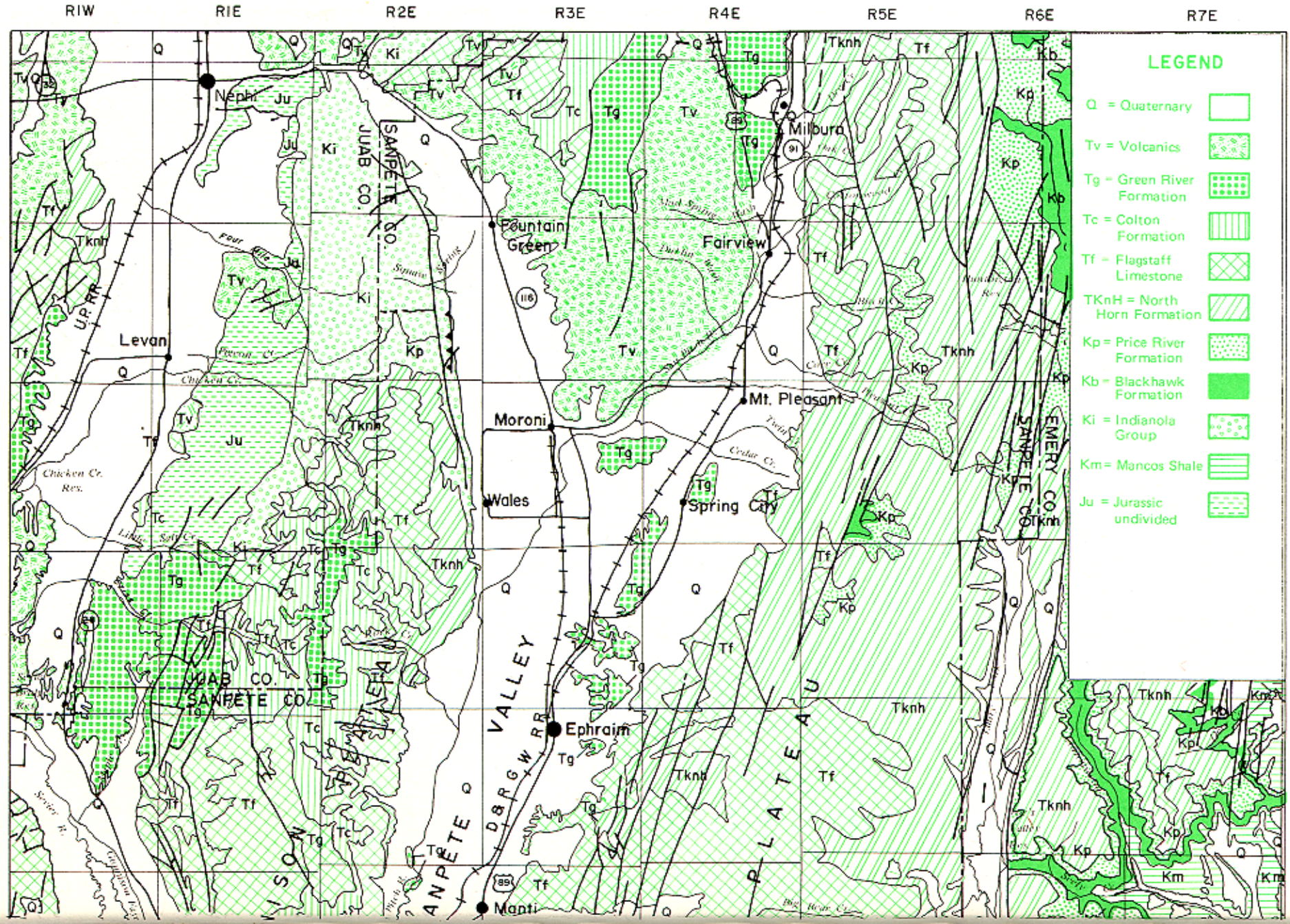


Figure 4. (continued)



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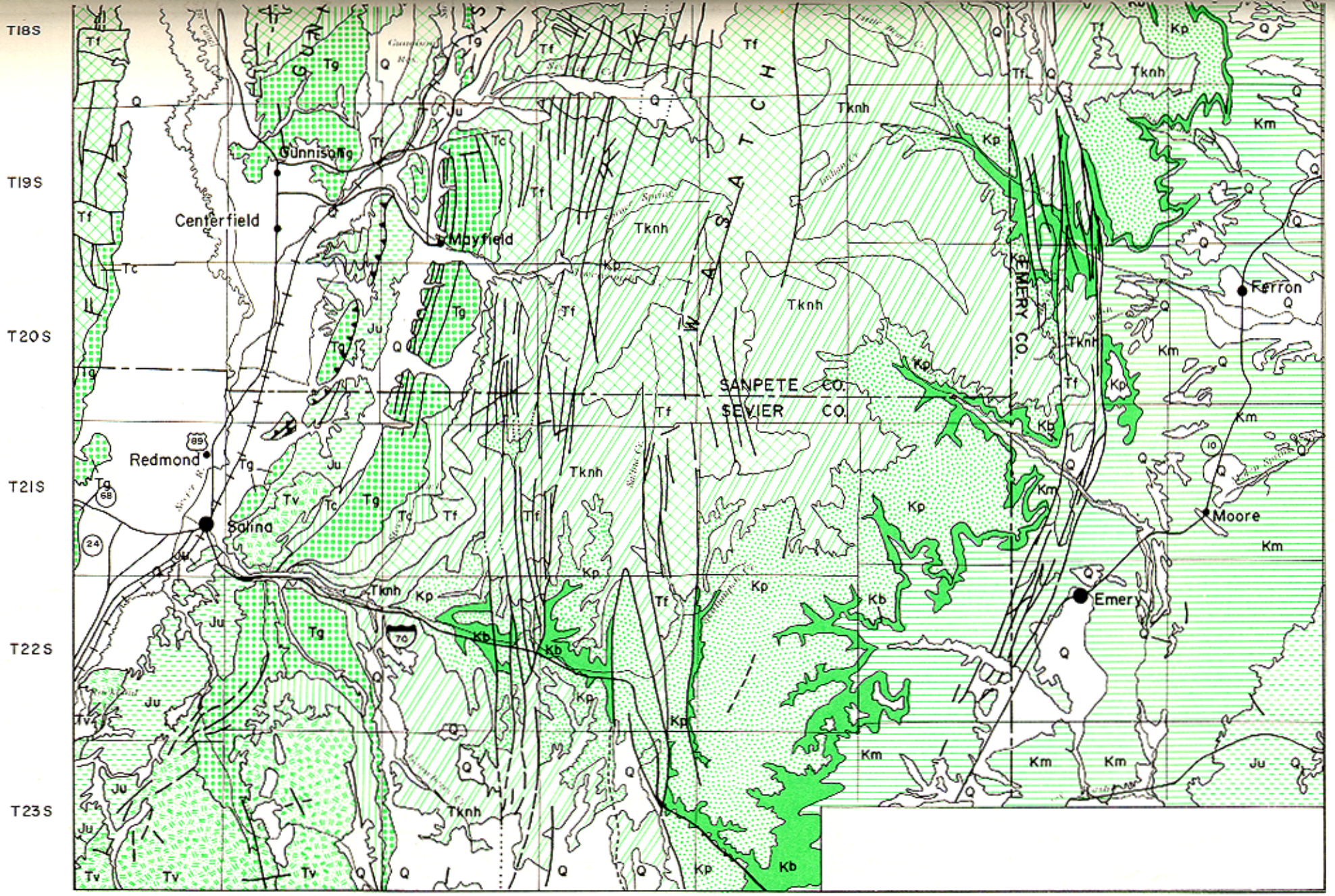
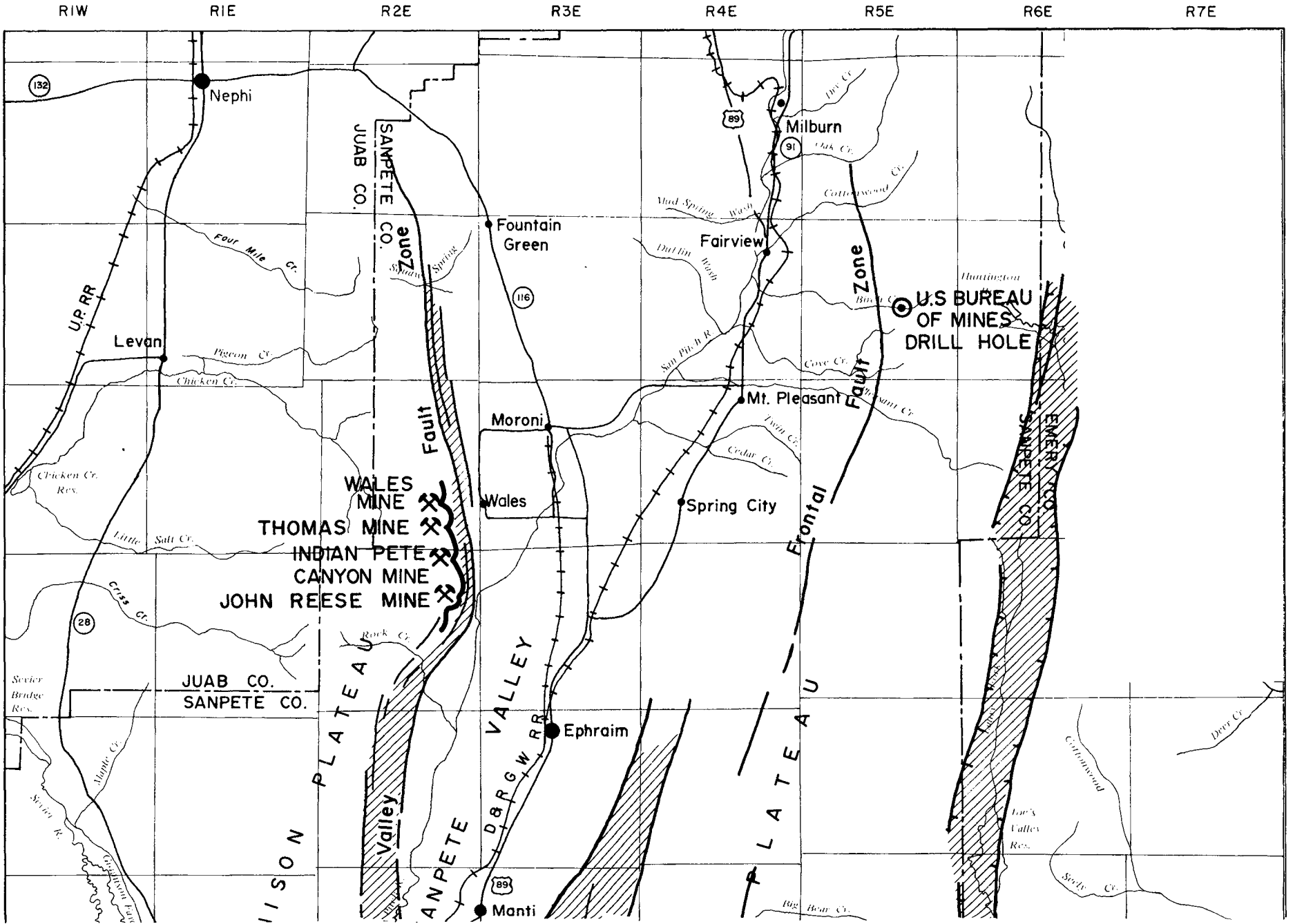


Figure 5. Generalized geology map, Sevier–Sanpete region.



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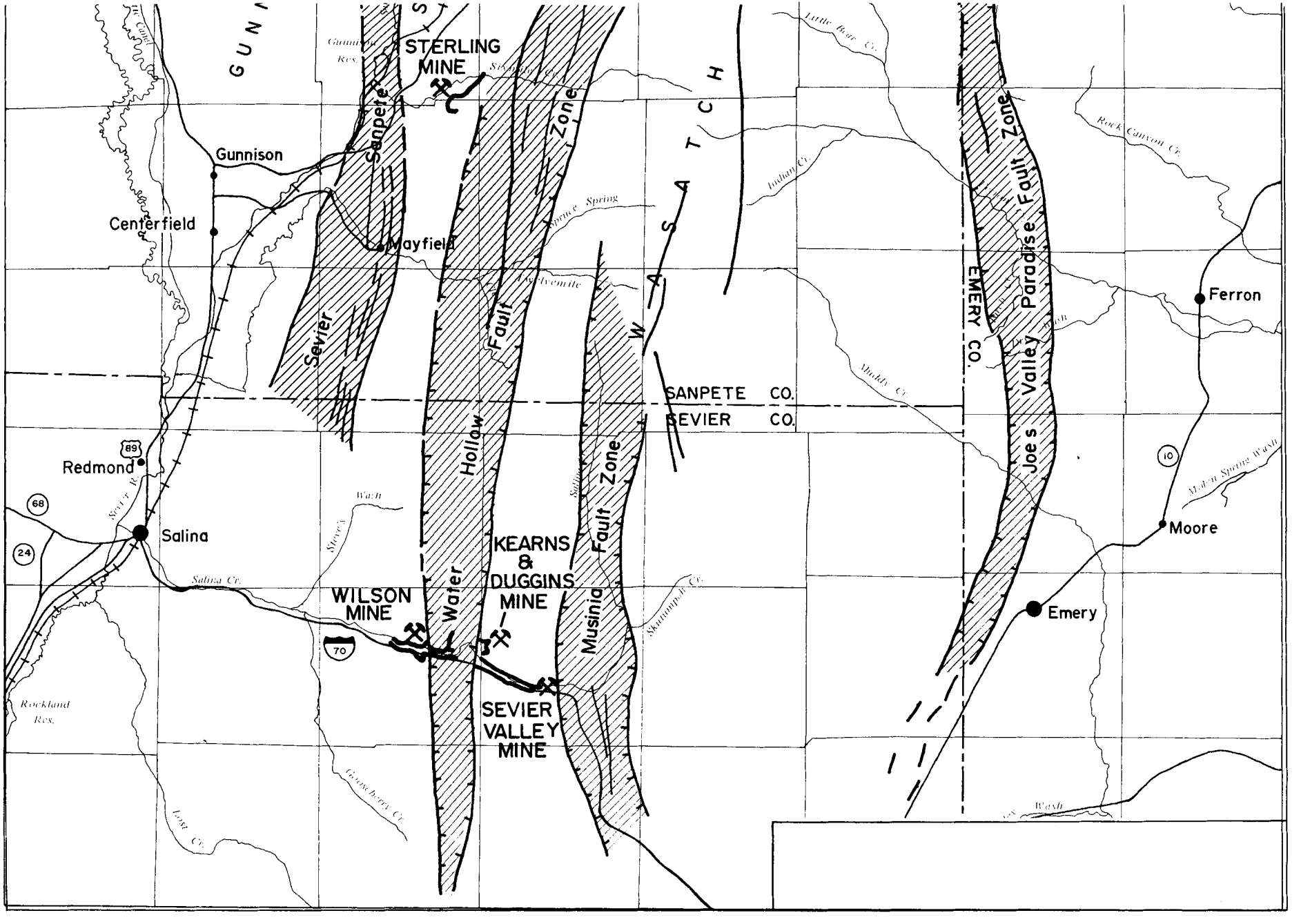


Figure 6. Generalized structure, mine and coal seam map, Sevier—Sanpete region.

base of the Blackhawk. These coals have not yet been commercially produced. The thickest coal bed discovered in the upper surface sections of the Blackhawk in the Mt. Pleasant field was 5.7 feet thick but split by 0.2 feet of shale and lime.

Price River Formation

The Price River Formation, including the Castlegate Sandstone, overlies all older beds unconformably. In the Wasatch Plateau coal field the Price River is a gray to white coarse-grained sometimes conglomeratic sandstone, the lower part of which forms a massive cliff. The upper part is ledge and slope forming with the more resistant strata interbedded with shale. Toward the west the clastics become more coarse so that conglomerates become a substantial part of the formation. The Castlegate remains identifiable throughout the entire Wasatch Plateau because of its massive nature. This is not possible in the Gunnison Plateau where the Price River is mostly conglomerate with subordinate medium- to coarse-grained sandstone lenses which weather to dark brown. The conglomeratic material of the Price River is mostly white, pink, and red quartzite and occasional black limestone, pebbles to cobbles. In the Mt. Pleasant, Sterling and Salina Canyon fields thin seams of coal occur in the Castlegate. The thickness of the formation is usually 1,000 to 2,000 feet thick, but in Salina Canyon it thins locally to 200 feet. The unit grades almost imperceptibly into the North Horn.

North Horn Formation

Normally the North Horn is made up of variegated shales with interbedded sandstone, conglomerate and freshwater limestone. Its thickness ranges from 500 feet in lower Salina Canyon to more than 3,000 feet in the Gunnison Plateau. According to Spieker (1949, p. 27) the age of the North Horn is well determined by vertebrate fauna. Remains of Cretaceous dinosaurs are located in the lower half or more of the unit and Paleocene mammalian fauna in the upper third. The North Horn displays an alternation between fluviatile and lacustrine conditions and locally drastic facies changes have been noted. Between Axehandle and Petes canyons along the east edge of the Gunnison Plateau the unit abruptly changes to massive conglomerate and sandstone with little shale.

In the Salina Canyon coal field the unit can be divided into (1) the lower two-thirds, lithologically similar to the Price River but with more shale and (2) the upper part consisting of white, red and brown shale and siltstone with thin beds of fine-grained sandstone and gray or white limestone. No coal is reported by investigators in this field.

In the Sterling area Wilson (1949, p. 29) notes that the most striking aspect of the formation is its reddish color which masks its other characteristics. He also does not report the presence of coal.

Near Mt. Pleasant Pashley (1956, p. 39) located a two-part division in the North Horn. He describes the lower part as gray, blue and red shale in thin, even and continuous beds interrupted by buff to gray limestone and brown to buff sandstone beds. The upper unit of the North Horn is mostly a cliff-forming massive brown sandstone. He reports the presence of thin and discontinuous coal beds in the upper North Horn. The North Horn forms the basis of the Milburn lignite field in Dry Creek Canyon east of Milburn (Pratt and Callaghan, 1970, p. 59) in beds up to 14 feet in thickness.

Hunt (1950, p. 74) recognized three units in Wales Canyon in the east Gunnison Plateau:

3. Upper member: mostly gray limestone and shale.
2. Wales coal member: coal-bearing sequence of limestone and shale, contains oil shale, thins to the north and south.
1. Lower member: variegated shale, conglomerate and sandstone.

The coal in the middle member forms the basis of the Wales coal field. The presence of thin coal beds in the North Horn of the Gunnison Plateau outside of the Wales field area is occasionally reported.

Flagstaff Limestone

Spieker (1949, p. 30) described the Flagstaff well:

> The Flagstaff Limestone is the most prominent formation in the area. It forms the great dip slopes on the outer flank of the Wasatch monocline as far south as Sixmile Canyon, and continues on southward in undiminished prominence but flanked by the lower and similar hogbacks of the Green River Formation. Along the high top of the Wasatch Plateau it makes for miles the sweeping lines of white cliffs that form an element unique in the scenery of the western United States. It caps the main frontal escarpment on the east side of the Gunnison Plateau as far north as Maple Canyon. . .The Flagstaff is not only prominent, but it is also useful, in its regional persistence and general consistency, as a marker unit, a steady and reliable guide running solidly and conservatively through the shambles of lithologic originality indulged by its fellow formations.

Lithologically the Flagstaff is dominated by freshwater limestone but it also contains some shale, sandstone, gypsum, volcanic ash, oil shale, bituminous and carbonaceous beds and even conglomerate. It grades downward into the North Horn and upward into the Colton Formation. Some of the limestones are quite pure and have been quarried commercially.

Colton Formation

The Colton Formation occurs only on the Gunnison Plateau where it consists of red and green-gray shale, gray and green sandstone and gray limestone. It is conformable with units above and below. The thickness of the Colton ranges up to 1,600 feet, but it is usually less than 800 feet thick.

Green River Formation

The Green River Formation is mainly exposed in Sanpete Valley along the flanks of Sevier Valley and in the Gunnison Plateau. In central Utah the formation consists mostly of freshwater limestone and shale. According to Spieker (1949, p. 35) the unit consists of two members: a lower blue-gray to light blue shale 100 to 400 feet thick and an overlying unit of cream to tan limestone of the same thickness. In the Uinta Basin the Green River contains oil shale, but little if any is known from central Utah. Along with the Flagstaff, the Green River Formation is important with respect to commercial carbonate rocks and numerous quarries have been opened in it.

Crazy Hollow and Gray Gulch Formations

These formations outcrop in scattered areas above the Green River Formation, especially near the mouth of Salina Canyon. Their descriptions in figure 3 are adequate and additional data are unimportant to the present report.

Unconsolidated Deposits

Throughout the Sevier-Sanpete region are numerous areas of alluvium, landslides, terrace and/or pediment gravels. The alluvium usually fills the bottoms of valleys and canyons; landslides are adjacent to steep cliffs or incompetent formations and the gravels have developed on shaley units.

Structure

The structure of the Sevier-Sanpete region is highly complex; beds are folded, faulted and locally removed by erosion. The area represents a transition between Colorado Plateaus and Great Basin lithologies. Mountain building involved the area and the area immediately to the west during Upper Cretaceous time; the area alternated in receiving sediment or having sediments removed by erosion.

Faults

Plentiful faults throughout the region are mostly high-angle faults trending parallel to the long dimensions of the plateaus. Occasionally some short faults lie perpendicular to the dominant trend. The Wasatch Plateau coal field immediately east of the region is similarly plagued with faults which occur in groups. They are from east to west: the North Gordon, Pleasant Valley and Joes Valley-Paradise fault zones. They are usually 2 to 3 miles wide with rocks between dropped as grabens and riven by paralleling subsidiary faults. Farther westward this type of fault zone continues. The first such zone is the Musinia graben which is best developed in the south and central part of the Wasatch Plateau. Its length is about 25 miles with maximum width of 3¼ miles just north of Salina Canyon. The fault zone extends from the headwaters of Twelvemile Creek southward and disappears in the volcanics of the Fish Lake Plateau. Several north-south faults exist on the Fish Lake Plateau near the headwaters of the Fremont River which may indicate an extension of the Musinia fault zone. The zone is 12 to 13 miles west of the Joes Valley-Paradise zone. The west marginal fault has its maximum displacement of 2,000 feet where it crosses Salina Canyon. The east marginal fault has a displacement of 1,250 feet where it crosses Spring Canyon and may reach a maximum of 2,500 feet a mile north of Skumpah Creek.

The next fault zone to the west is the Water Hollow graben. It is separated from the Musinia zone by less than 3 miles. The zone is much longer than its east neighbor but does not maintain its graben over the entire length. The length of the zone is at least 50 miles extending from the Fish Lake Plateau 12 miles south of Salina Canyon northward to where the faults intersect Sanpete Valley in the vicinity of Spring City. *En echelon* and slightly to the east, other faults continue northward and cut the coal beds in the vicinity of the Mt. Pleasant field. The west border fault at Salina Canyon has a displacement of 650 feet and increases in displacement toward the south. Evidence indicates that the displacement of the fault decreases northerly. The east fault has a displacement of 500 feet in Salina Canyon. One *en echelon* fault in the Mt. Pleasant area is a principal structural feature of that coal field and the upper part of the coal-bearing Blackhawk is exposed on the east upthrown block. This fault is called the Frontal Fault by Pashley (1956, p. 82, 83) who notes the feature is 12½ miles long and the stratigraphic throw is at least 1,328 feet along the South Fork of Cove Creek.

The next group of faults is not as clearly defined as the foregoing graben fault zones and is more complex. They parallel the east side of Sevier Valley and extend northward crossing the constriction at the mouth of Sixmile Canyon and crossing over to continue along the east flank of the Gunnison Plateau. This zone has normal faults and also a few thrust faults. The displacements along these faults range from a few feet to a thousand feet.

Folds

Westward across the Wasatch Plateau up to the Water Hollow fault zone and the Frontal Fault extension, the strata occur in typical plateau fashion. The strata are warped into swells and depressions which compensate each other to form an average horizontal surface. Dips are usually less than 10 degrees but locally may be as great as 15 degrees. This regimen is locally drastically changed immediately adjacent to the fault zones.

Between the Water Hollow-Frontal Fault zone and the valleys of the Sevier and San Pitch rivers, the strata are inclined to the west from 10 degrees to near verticality in what is known as the Wasatch monocline. The monocline extends from Milburn south beyond Salina Canyon where it becomes masked under volcanics. The feature is at least 60 miles long. The strata are dropped 6,000 to 7,000 feet along the monocline which strikes about N.20-30°E. The average inclination is between 25 and 45 degrees. At the base of the feature the rocks have been intensely deformed. According to Spieker (1949, p. 46):

> In this belt the strata approaching the base of the monocline suddenly plunge over to vertical and overturned attitudes and then in fairly short distances (generally less than half a mile) flatten out again. The folds commonly have the pattern of a tilted Z. They are cut by various faults of undoubtedly syngenetic origin.

The beds underneath Sevier and Sanpete valleys continue to be complexly folded and faulted. These conditions are reflected as the beds reappear on the east flank of the Gunnison Plateau. Basically the strata are nearly vertical along the edge, then gradually tilt westward until the beds nearly flatten out on the crest of the plateau. Westward and northward of Wales the structure becomes exceedingly complex; the strata become involved in a variety of folds but generally form an east-dipping sequence making a rough asymmetrical syncline of the plateau. The axis of this syncline follows the crest or is aligned in the east third of the physiographic feature.

Unconformities

In the normal sequence of deposition few unconformities occur within the region. This is illustrated by the stratigraphic relations diagram for central Utah (figure 7). In Salina Canyon the Morrison ? Formation apparently grades into the Sanpete Formation. If the formational correlations are correct there should be an unconformity because the whole Lower Cretaceous might be missing. The problem does not influence the coal geology and is presented only to make the reader aware of some of the complexities of the area.

An unconformity is generally recognized under the Price River. This unconformity is postulated to become angular along the Wasatch monocline, cutting out the coal-bearing Blackhawk Formation.

The next overall unconformities are above the Green River Formation and above the Crazy Hollow Formation. Again these do not affect coal-bearing strata. As one proceeds west from the crest of the Wasatch Plateau an orogenic belt is reached and in many local areas around the Sevier-Sanpete region beds have been tilted, planed off and younger sediments have covered the surface. Such local unconformities, if they influence the coal fields, are examined in the quadrangle reports.

GEOLOGIC AND TECTONIC HISTORY

At the end of Triassic and the beginning of Jurassic time central Utah was a desert on which a great dune field was accumulating sand. The Navajo Sandstone exposed to the east and south and at Thistle north of the region represents this deposit. Thereafter, subsidence increased and a Jurassic sea encroached from the north. The Sevier-Sanpete region of the sea became restricted and it is assumed that arid or semiarid conditions continued. Shales and evaporites were deposited in the form of the Arapien Shale, which near Salina may be 10,000 feet thick. The sea finally retreated and the restricted portion dried up. Fluvial conditions replaced the marine environment and the conglomerates, sandstone and shales of the Morrison ? Formation were deposited. The conglomerates were probably derived from highlands not far to the west and may mark a late Jurassic or early Cretaceous orogeny. According to present correlations little is known about what transpired between the deposition of Morrison ? conglomerates and the initial conglomerates of the Indianola Group. This includes all of Lower Cretaceous time and was probably a long period of stagnation, little deposition and little erosion. No unconformity is recognized regionally between the two units.

Intermittent orogenic pulses to the west or in the western part of the region were the rule during the Upper Cretaceous. The first produced the lower conglomerates of the Indianola Group, the second produced the upper conglomerates. These events transpired simultaneously with the encroachment of the Mancos sea from east to west. Eastward from the active area of the orogeny the clastics become finer and finer and intertongue with the shales deposited under marine conditions. On the Colorado Plateau, sand-

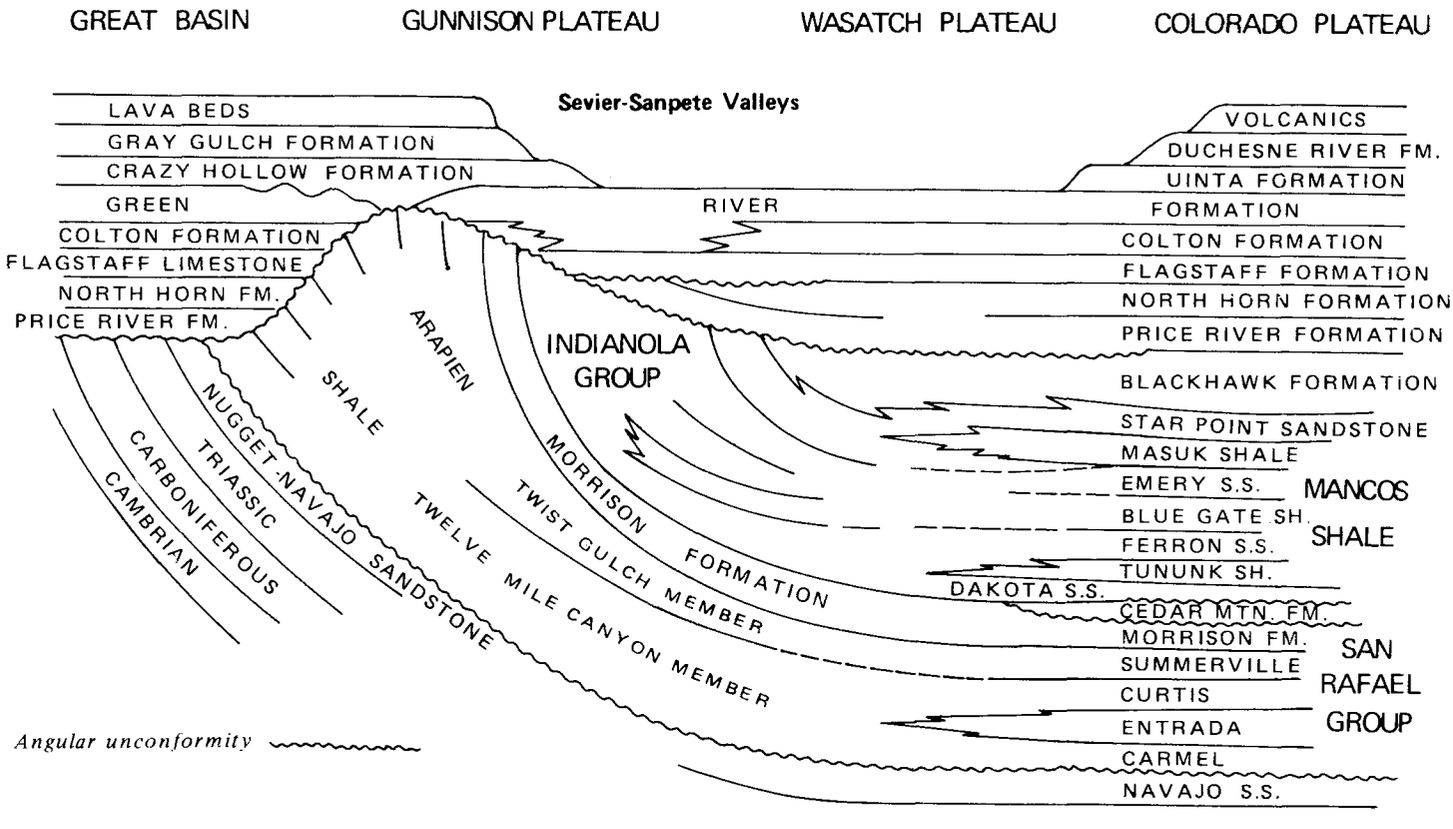


Figure 7. Stratigraphic diagram from Great Basin to Colorado Plateau through Sanpete County showing generalized regional correlations (after Spieker, 1949, figure 2).

stone tongues such as the Ferron and Emery attest to individual orogenic pulses. In the vicinity of Sterling the Allen Valley Shale and parts of the other formations which comprise the Indianola Group attest to the westernmost incursions of the Mancos sea. Lagoons formed behind the beaches; on the floodplains of sluggish streams coal forests developed. Such deposits make up the basis for the Emery coal field to the east and the Sterling coal field in this region (Sixmile Canyon Formation).

The mountain-building processes began to sweep eastward and folded the previously deposited rocks of the region. The products of this orogeny were swept eastward to deposit the upper Mancos members and the Star Point and Blackhawk formations. At the same time the Mancos sea began its spasmodic but steady retreat. As the sea retreated, lagoons developed behind the beaches and coal beds formed. This created the basis for the important Wasatch Plateau and Book Cliffs coal fields to the east and of the Mt. Pleasant and Salina coal fields in this region. Uplift proceeded at least into the area of the present Wasatch monocline and truncated the recently deposited Blackhawk at this point. Orogenic activity waned in the immediate area and conglomerates spread across the erosion-bevelled area from high areas to the north and west producing the Price River beds. The orogenic activity continued to subside and the Price River sediments gradually became finer and were replaced by the shales of the North Horn Formation. Swamps developed producing thin coal beds. Locally these beds became thick forming the basis of the Milburn lignite field and the Wales coal field. On occasion lacustrine conditions prevailed depositing limestone beds. A bed of coal in the Wales field is sandwiched between two limestone beds. These conditions marked the end of Cretaceous time. In early Tertiary time lacustrine conditions became more prevalent and widespread and the Flagstaff Limestone was deposited. Some mild tectonic activity occurred during the Paleocene. There is evidence for normal faulting near the mouth of Dry Canyon on the east front of the Gunnison Plateau south of Wales and arching in the Sixmile Canyon area.

After the deposition of the Flagstaff Spieker (1949, p. 79) notes several periods of faulting, thrusting and folding. Of most importance are the events which caused the flexing of the Wasatch monocline and the formation of the graben fault zones. Spieker believes the monocline was created between the late Eocene and the Miocene epochs of the Tertiary. Prior to this the area received sediments with the environments alternating between fluviatile and lacustrine (Green River and Colton). After Green River time the area fluctuated between subsidence and uplift and the final units were deposited. After deposition of the lake beds, arching took place at Salina Canyon. It may have been simultaneous with the formation of the Wasatch monocline. Bachman (1959, p. 49) believes that the tension produced during the flexing of the monocline produced the planes of weakness that determined the trend and gross structure of the Water Hollow fault zone. Faulting activity could have been prevalent at any time or even continuous from Oligocene to Pleistocene time. Since, the mid-Tertiary uplift and erosion have dominated to produce today's landscape.

Correlations with Surrounding Areas

The Sevier-Sanpete region is on the west edge of the coal-bearing provinces of Utah. To the north the geology is complex and full of facies changes. The changes that take place in the Cretaceous units are little known as they are mostly buried by Tertiary units or represented by conglomeratic units. The next coal field directly north is the Coalville field 90 miles away. The coal there is in the Frontier Formation which nearly correlates with the Indianola Group. The Coalville field is also on the west margin of Utah coal.

The Tabby Mountain coal field is located 50 to 60 miles northeast and contains coal in the Frontier and Mesaverde formations. Again the Frontier correlates with part of the Indianola and the Mesaverde with the Blackhawk. The Tabby Mountain field is located along the south flank of the Uinta Mountains in Duchesne County. It is directly north of the Wasatch Plateau and Book Cliffs coal fields and its geology is similar to theirs.

To the south the coal-bearing beds are covered by volcanics for almost 70 miles. When they emerge they have changed their character considerably and are known by an entirely different set of names. In the Kaiparowits Plateau the chief coal-bearing unit is the Straight Cliffs Formation which corresponds to part of the

Indianola. No coal bearers in the Kaiparowits are equivalent to the Blackhawk. In the Alton and Kolob fields the chief coal-bearing unit is the Dakota which would correspond to the very lowest part of the Indianola.

The most important correlation is the one with tne Wasatch Plateau to the east because of its proximity. The correlation is illustrated by the stratigraphic diagram from the Great Basin to the Colorado Plateau (figure 7). It shows that the Blackhawk and part of the upper Mancos are eliminated by a pre-Price River erosional interval in the west part of the area and that the sandstone members of the Mancos coarsen westward to form the Indianola Group.

Figure 8 illustrates correlations of Cretaceous formations around Utah.

COAL DEPOSITS

Status of Information

The mines of the Sevier-Sanpete region were among the first to open and produce coal. The resources, however, were not first-class deposits and after the initial sketchy accounts had been written, the areas were forgotten. E. M. Spieker, teaching at Ohio State University, sent many graduate students into the area to work out the geology of the area. Since that time much of the area has been geologically investigated, probably adequately with respect to the coal. Additional drill-hole data in the Mt. Pleasant and Salina Canyon coal fields are certainly needed as well as additional analytical data, since these two areas have the greatest potential.

In the References section all principal and supporting work thought applicable to the geology of the coal resources can be consulted if more detail is required.

Mines, Prospects and Production

The Wales field has the distinction of producing the first coal in Utah. Activity probably commenced in 1855. One hundred years later all mines had shut down and all activity had ceased in the entire Sevier-Sanpete region. Production through 1955 from four coal fields is tabulated below (table 2). For a list of mines see table 3.

Table 2. Production of coal through 1955 for the Sevier-Sanpete region.

Coal Field	Production (in tons)
Mt. Pleasant	Negligible
Salina Canyon	430,000
Sterling	60,000
Wales	175,000
	665,000

Land Ownership

The lands of the Sevier-Sanpete region are principally controlled by the National Forest Service, Bureau of Land Management, state of Utah or are owned privately. Forest lands are mostly located in higher elevated areas, principally the tops of the plateaus. The valleys and lower plateau tops are mostly privately owned and the BLM and state of Utah lands are mostly in the rough lands bordering plateau and valley. The Land Ownership Map (figure 9) shows the locations of these lands in more detail. Some privately owned land is probably held to mine coal, but none is currently being mined nor are there current leases or permits.

Quality of Coal

Each of the four coal fields is removed from the other by a considerable number of miles. The Mt. Pleasant and Salina Canyon fields are both in the Blackhawk Formation but it is doubtful that they are in the same beds considering their lenticular nature. Thus it would serve no purpose to average the analytical data to achieve a regional picture. The average proximate values for the four fields are therefore shown in comparison (table 4).

The number of analyses preclude the possibility that the calculations are representative of the field. Generally, however, they are close. All areas except Wales are low-sulfur fields. Additional quality data may be found in the quadrangle reports.

Reserves

Coal resources of the Sevier-Sanpete region are held in several formations and zones (table 5).

Some of the zones classified as major, such as at Wales and Sterling, would be carried as marginal in other fields. But, because they form the basis of these fields, they are classed as major coal zones. Of most importance are coal beds and zones in the Blackhawk Formation; the bulk of the reserve is contained here (table 6).

Table 3. Coal mines and prospects of the Sevier-Sanpete region.

Quadrangle	Location	Remarks
Salina Canyon		
Boston Acme No. 1 Sevier bed	NE.SW.18-22S-3E 4,304,940m.N. 446,370m.E.	Active 1923
Boston Acme No. 2 Upper Ivie bed	SE.NW.21-22S-3E 4,303,950m.N. 449,865m.E.	1925-?
Kearns and Duggins (Coal Hollow) Sevier bed	NW.18-22S-3E 4,306,025m.N. 445,750m.E.	Intermittently active 1910-1925
Sevier Valley Coal Co. prospects Sevier bed	20-22S-3E Several locations, south side of canyon	Prior to 1923
Sevier Valley mine Upper Ivie bed	NE.SE.20-22S-3E 4,303,525m.N. 448,780m.E.	1924-1933 1944-1953
Wilson mine Wilson bed	SW.SE.10-22S-2E 4,306,360m.N. 441,910m.E.	1911-1935
Sterling		
Jensen mine Sterling bed	SE.SE.35-18S-2E 4,338,890m.N. 443,495m.E.	Activity unknown
Morrison mine Sterling bed	SW.SW.36-18S-2E 4,339,120m.N. 443,700m.E.	1888-1902
Sterling mine (Thomas and Tuttle) Sterling bed	SW.SE.35-18S-2E 4,338,850m.N. 443,040m.E.	1902-1935?
Wales		
Coal Canyon mine	NE.NW.23-16S-2E 4,362,920m.N. 442,600m.E.	Activity unknown
Ephraim prospects	NW.23-16S-2E 4,362,240m.N. 442,265m.E.	Activity unknown
Indian Pete Canyon	NE.SE.2-16S-2E 4,366,960m.N. 443,290m.E.	Closed when rail- road was removed
John Reese mine	SE.NE.14-16S-2E 4,364,050m.N. 443,260m.E.	Activity unknown
Thomas mine (Edmunds, Old Canyon)	NW.NE.35-15S-2E 4,369,350m.N. 443,200m.E.	Activity unknown
Wales mine No. 1	NE.NW.26-15S-2E 4,370,750m.N. 442,430m.E.	1855-1912
Wales mine No. 2	SE.NW.26-15S-2E 4,370,510m.N. 442,430m.E.	

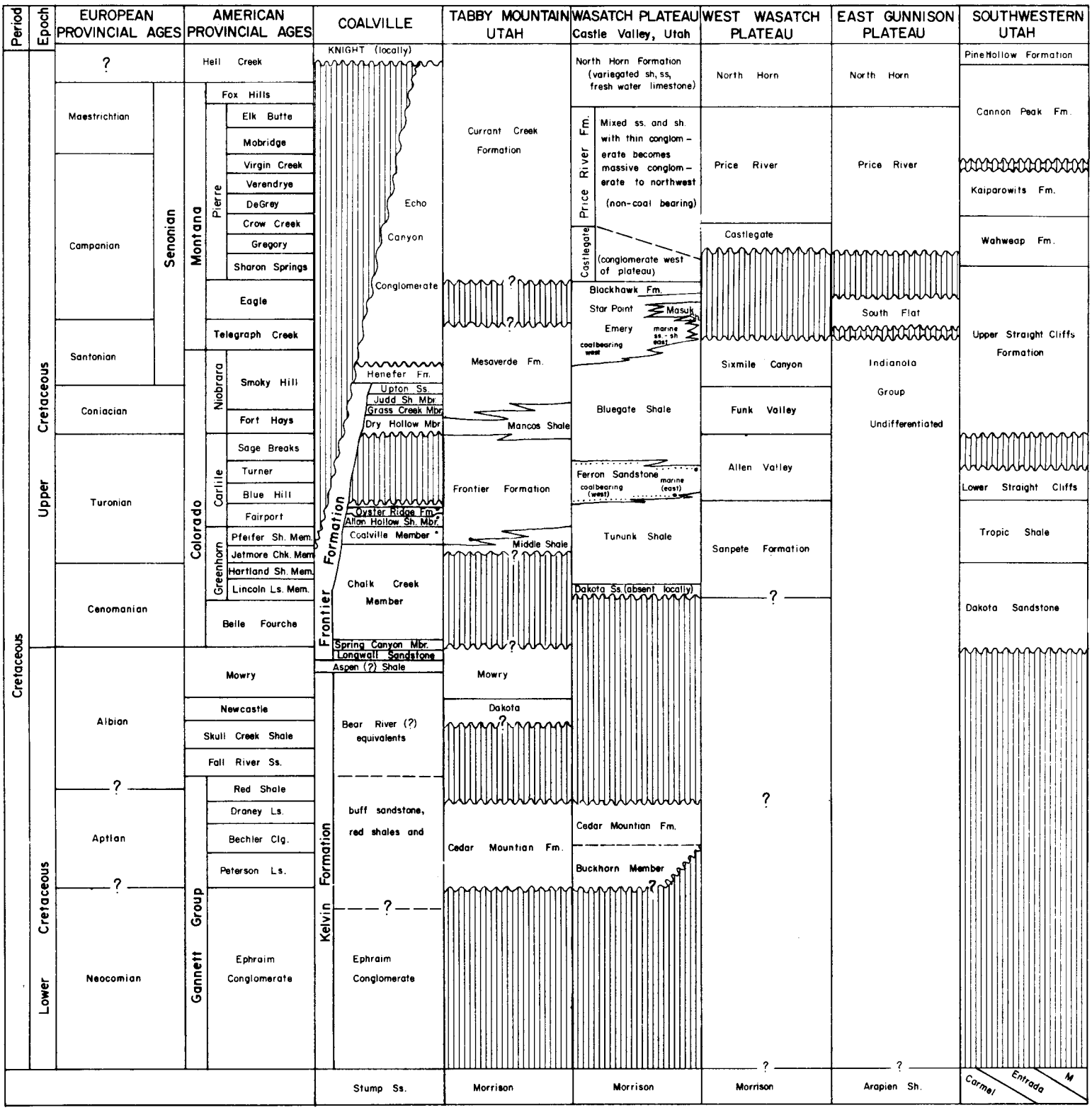


Figure 8. Correlation of Cretaceous formations around central Utah.

Table 4. Average proximate analyses of coal for the Sevier-Sanpete region.

	No. Samples	Percent Average	Percent Range
Moisture			
Mt. Pleasant	7	3.4	2.4 - 4.7
Salina Canyon	13	7.6	5.7 -14.9
Sterling	1	8.2	8.2
Wales	12	5.0	1.2 -14.2
Volatile matter			
Mt. Pleasant	7	42.9	41.8 -45.2
Salina Canyon	11	42.2	34.4 -45.6
Sterling	1	42.6	42.6
Wales	13	34.2	21.0 -43.2
Fixed carbon			
Mt. Pleasant	7	45.6	43.9 -48.9
Salina Canyon	11	42.2	36.3 -48.3
Sterling	1	43.2	43.2
Wales	13	46.4	24.6 -55.5
Ash			
Mt. Pleasant	7	8.1	5.1 -11.3
Salina Canyon	13	9.8	4.2 -13.2
Sterling	1	6.1	6.1
Wales	13	14.8	4.0 -29.2
Sulfur			
Mt. Pleasant	7	0.8	0.5 - 1.6
Salina Canyon	12	0.45	0.32- 0.60
Sterling	1	0.9	0.9
Wales	8	4.3	2.88- 6.79
Btu/lb			
Mt. Pleasant	7	12,890	12,440-13,290
Salina Canyon	11	11,367	9,690-12,080
Sterling	1	11,767	11,767
Wales	6	10,119	6,554-11,857

Table 5. Formations containing coal in the Sevier-Sanpete region.

Formation	Field	Zone	Classification
Colton Formation	Wales	–	Minor
North Horn	Wales	Wales	Major
	Milburn	–	Major
	Mt. Pleasant	–	Minor
Price River and Castlegate	Mt. Pleasant	–	Minor
	Sterling	–	Minor
	Salina Canyon	–	Minor
Blackhawk Formation	Mt. Pleasant	Six beds	Major
	Salina Canyon	Wilson	Marginal
		Sevier	Marginal
		Upper Ivie	Major
South Flat Formation	Gunnison Plateau	–	Minor
Sixmile Canyon Formation	Sterling	Sterling	Major

Table 6. Coal reserves in the Blackhawk Formation, Sevier-Sanpete region.

Field or quadrangle	Reserve tonnage
Milburn	?
Mt. Pleasant	249,100,000
Salina Canyon	86,370,000
Sterling	2,000,000
Wales	12,200,000
Total Coal	349,670,000

No examination has been made of the Milburn lignite field and the only account of the field is published in Pratt and Callaghan (1970, p. 59). The greatest potential for additional coal reserves is in the Blackhawk Formation of the Wasatch Plateau. Such possibility already has been contemplated to the west edge of the Wasatch Plateau coal field which nearly follows the Skyline Drive or the faults of the Musinia fault zone. A strong indication is that the coal beds thin westward but the findings in the Mt. Pleasant coal field confirm the possibility of thick coal in any of this west sector. This coal necessarily would be deep, but 70 square miles are available for prospecting in which the coal may be expected 1,500 to 3,000 feet below the surface. Areas included are between the Mt. Pleasant coal field and the Fish Lake Plateau. The thickest bed noted at Mt. Pleasant is 5.7 feet with another bed 5 feet thick. The Upper Ivie in Salina Canyon probably averages 5 feet. If a modest figure of 5 feet is employed over this part of the Wasatch Plateau, then a potential reserve of 390.2 million tons is deduced.

Coal Seams

As indicated in the section on reserves many coal seams have been discovered throughout the area, most of which are too thin to be of economic significance. The region is superimposed on the west edge of a huge area in Utah which was favorable to the formation of coal during the Cretaceous period. In this marginal area the beds of coal, even in the most favorable formations, are expected to be thin and often split. The extent of most of the beds is indeterminable because of deep cover which is characteristic of the region. At a few limited areas these beds outcrop or come near enough to the surface for easy exploration. These favorable but limited localities form the foundation for the coal fields noted in this report.

Milburn Lignite Field

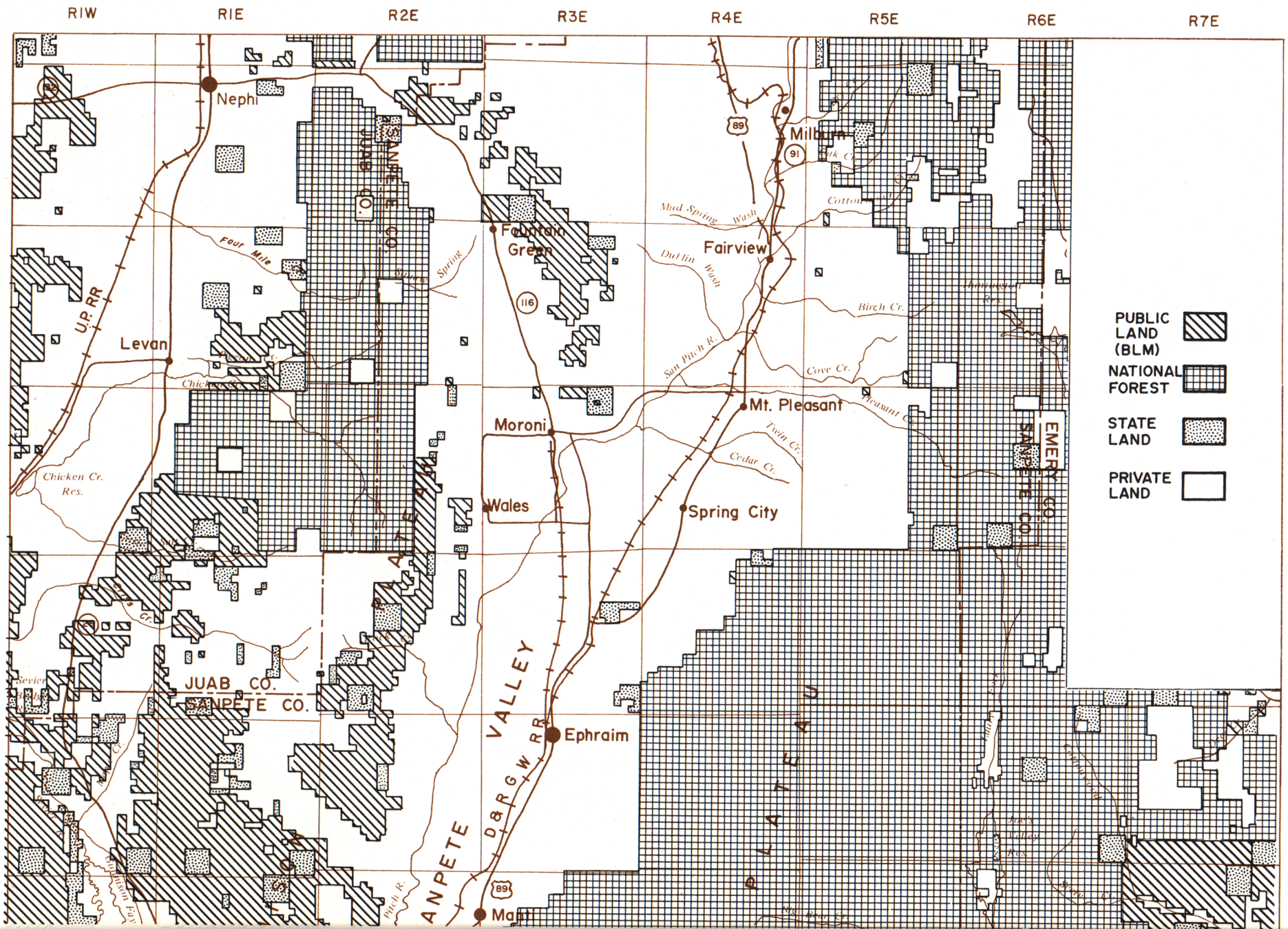
Lignite, consisting of dark gray to brownish black, earthy, friable, poorly bedded materials containing woody fragments, was prospected between 1955 and 1963, in secs. 7 and 8, T. 13 S., R. 5 E., in Dry Creek Canyon east of Milburn. Some of the lignite was subsequently mined, ground, and mixed with turkey feathers to produce a soil conditioner. The bed in a prospect pit is 1.1 feet thick and beds as thick as 14 feet have been found. The lignite beds occur in the North Horn Formation. An adit on the north side of the canyon in sec. 7 shows 1.6 feet of lignite containing clay partings and associated with limestone. . .(Pratt and Callaghan, 1970, p. 57).

Mt. Pleasant Coal Field

The North Horn, Price River (including the Castlegate) and Blackhawk all contain thin beds of coal. These beds are lenticular, often split and are often of poor quality. The better coals are subsurface, discovered by the drill, in the lower Blackhawk Formation. Six beds over 14 inches thick were discovered ranging up to 5.7 feet. They were located between 955 and 1,254 feet below the surface and two exceeded 4 feet thick; two others were between 3 and 4 feet.

Salina Canyon Coal Field

Thin seamlets of coal occur in the Castlegate Sandstone but the important beds are all in the Blackhawk Formation. The 850-foot unit has coal beds scattered throughout, but the best are near the bottom about 110 feet above the base. Three zones are of interest; the upper two, known as the Wilson and Sevier, are marginal in thickness and usually split. They crop out along the canyon walls and in total coal average 3 to 4 feet and range up to 6.5 feet. The areal extent of these zones is unknown but the effective length of outcrop extends 2 to 4 miles each. The Upper Ivie bed is well developed in the east part of the area and, in its west occurrences, thins and splits. Up to 11 feet of coal have been found, but in minable areas it averages closer to 5 feet. Except for one small exposure in the bed of Salina Creek, no surface exposures occur of this lower coal zone.



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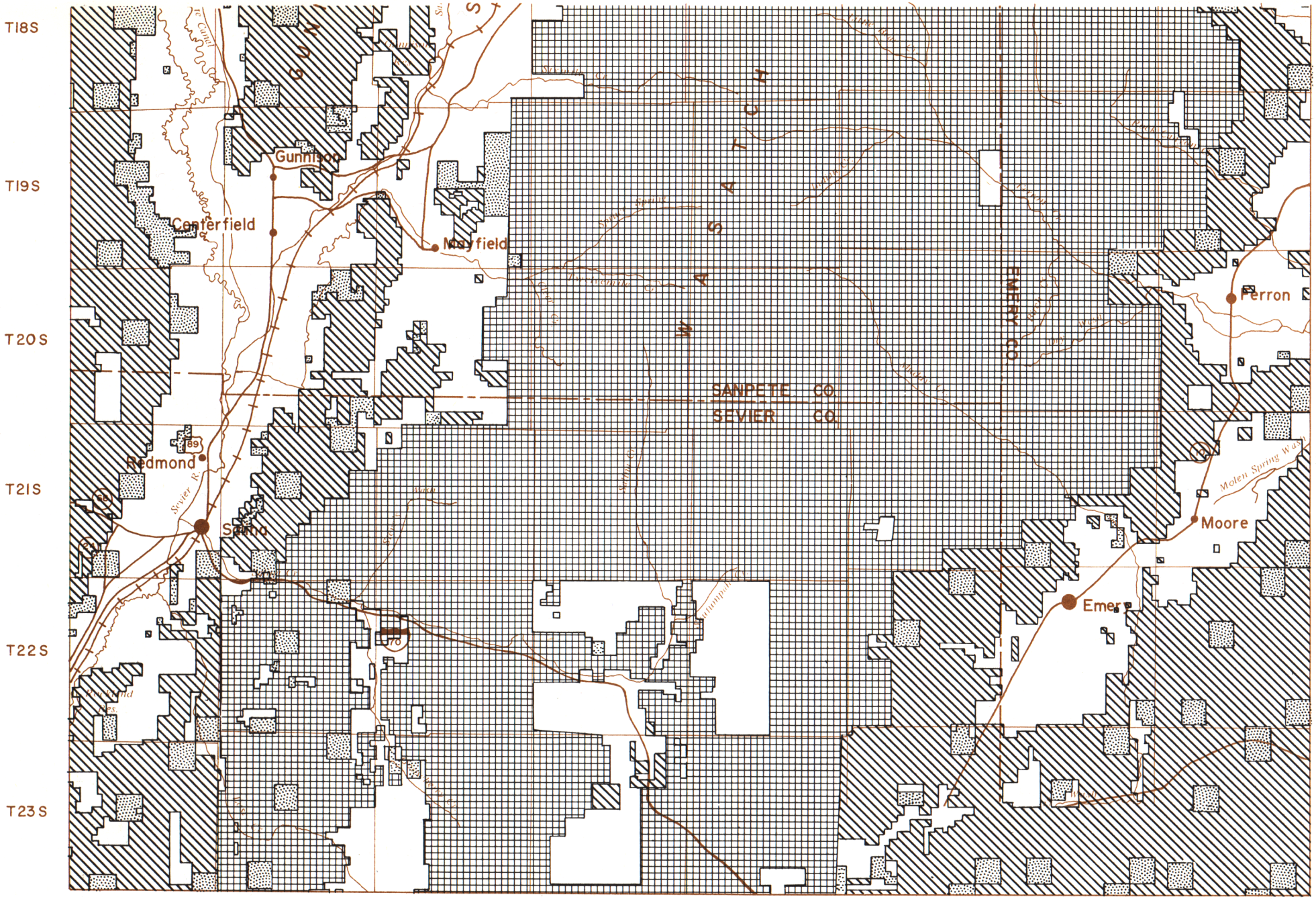


Figure 9. Land ownership map, Sevier–Sanpete region.

Sterling Coal Field

At Sterling thin beds of coal are present in the Castlegate but the important seams are in the Sixmile Canyon Formation. Six seams have been measured, all 1 to 3 feet thick. These coalesce locally to produce coal 4 feet or more thick. The coaley sequence is located about 450 feet below the base of the Castlegate Sandstone.

Wales Coal Field

The Gunnison Plateau contains beds of coal in the Colton, North Horn and South Flat formations. The beds in the first and last units are thin, lenticular and unimportant. The coal field is based on the Wales coal member, the middle unit of the North Horn Formation. The coal seams are exposed in a 5½-mile belt of outcrop and all sections are badly split. Total coal in any one section averages 3.7 feet and ranges up to 7.5 feet.

WATER RESOURCES

Water is in good supply in Sevier and Sanpete counties. Water rights cover all available supplies; mining and industrial operations should purchase suitable water rights. Present production of water from the groundwater reservoirs may be doubled without endangering the potential supply. An excellent summary of water resources is provided in Pratt and Callaghan (1970, p. 21-24). Unfortunately a similar work is not available for Sevier County but conditions of precipitation, geography, topography and land use are similar and the status should be the same.

ECONOMIC CONSIDERATIONS AND FORECAST

Coal from the Sevier-Sanpete region probably will not be mined in the near future on a large scale because of the (1) thin and badly split seams, (2) deep burial of much of the resource, (3) lenticular nature and limited area of individual coal bed development, (4) lower reserve-to-acres ratio and (5) proximity to better, more competitive sources of coal that have large reserves.

The coal, if washed and cleaned, is usually good quality and could be used as other Utah coal is used. The coal at Wales contains a high percentage of sulfur and none can be coked or blended to make coke.

It is predicted that none of the coal will be mined for at least 20 years and even then it is doubtful, except locally in emergencies or for unusual use such as for soil conditioners or for the resin content.

Abandoned Indian Pete Canyon mine, Wales coal field.

QUADRANGLE REPORTS

MT. PLEASANT–HUNTINGTON RESERVOIR QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Mt. Pleasant coal field is centered west of the town by that name and is made up of parts of the Mt. Pleasant and Huntington Reservoir quadrangles (figures 10 and 11). Other towns are Fairview to the northwest and Spring City to the southwest. All of the area is in northeast Sanpete County.

The surface is mountainous and covers the west side of the Wasatch Plateau from its crest to the east edge of Sanpete Valley. Skyline Drive, which follows the crest, is a graded road well above 10,000 feet along much of its course. It is a 6-mile drop to Sanpete Valley to the west which lies at 6,200 feet above sea level. The canyon and ridge country between expose the upper part of the coal measures.

Paved roads extend along the base of the plateau or lead to the canyon mouths. These join with U. S. Highway 89, 2 to 3 miles west. Dirt and jeep roads extend from the base of the plateau or from Skyline Drive to provide access to canyons and ridges. A branch line of the Denver and Rio Grande Western Railroad serves Fairview, Mt. Pleasant and Spring City.

STRATIGRAPHY

The stratigraphic sequence exposed on this composite quadrangle extends from the Blackhawk Formation of Upper Cretaceous age to the Flagstaff Limestone of Tertiary age. The Blackhawk is the coal-bearing unit and the basis for the Mt. Pleasant coal field. Its exposures are located along the upthrown block of a major north-south fault in the canyon bottoms. Upstream the unit is buried again by overlying units. Pashley (1956, p. 15) reports as to lithology and thickness:

> The sandstone of the Blackhawk ranges in color from brown to buff to gray. It consists mainly of medium- to fine-grained, semi-rounded clear quartz grains held together by a calcareous cement. Well preserved fossil leaves are found in some of these sandstones. The upper part of the Blackhawk Formation in many of the canyons between Spring City and Fairview consists dominantly of massive brown sandstone. . .
>
> The shales of the Blackhawk Formation are dominantly gray to black, commonly carbonaceous, and have a spar-like fracture. Some of the shale beds weather to a soft clay at the outcrop. All gradations between carbonaceous shale and nearly pure coal are represented in some beds. . .The author measured 491 feet of Blackhawk on the north wall of the South Fork of Cove Creek northeast of Mount Pleasant.

Sandstone and shale beds alternate and thin beds of conglomerate and coal also are occasionally present. Pashley reports a coal bed 2 feet thick exposed along the Straight Fork of Pleasant Creek road. It is the thickest surface exposure of coal in the field.

The U. S. Bureau of Mines drilled a well at the base of Pashley's measured section and penetrated 1,262 additional feet before the contact with the underlying Star Point Sandstone was reached. The Blackhawk then has a total thickness of 1,753 feet.

Pashley's measured section plus the log of the U. S. Bureau of Mines well gives an excellent description of the Blackhawk and they are repeated here for general information. An illustrated section also is given in the Stratigraphy section for the Sevier-Sanpete regional discussion (figure 4).

Section of Blackhawk Formation SW.NW.35-14S-5E, Sanpete County, Utah, measured by Pashley (1956):

Castlegate Sandstone Blackhawk Formation	Feet
105. Covered interval, slumped blocks of coarse-grained, gray sandstone present	4.0
104. Shale, dark gray to black, fissile, top covered	4.2
103. Sandstone, gray and buff, fine-grained, massive, partly covered	9.3
102. Sandstone, gray and brown, coarse- to medium-grained, composed of clear quartz grains and a few black grains, massive, forms a cliff	11.8
101. Sandstone, brown, medium-grained, middle is covered; becomes buff in color near top	6.8
100. Sandstone, gray, medium-grained, massive; lenses of coarse grains present, cross-bedded; upper part forms ledge projecting over lower part; becomes thin-bedded and brown in color in upper 4 feet	9.7
99. Shale, black, blocky fracture	1.8
98. Sandstone, brown, medium-grained, friable, forms ledge	1.7
97. Shale, black to gray, brown near base, blocky fracture, base covered	3.8
96. Covered interval	4.7
95. Sandstone, brown to buff, medium- to fine-grained	1.4
94. Covered interval	1.7
93. Sandstone, brown, ferruginous, medium-grained, massive, mostly covered	1.9
92. Covered interval, some blocks of brown, medium-grained sandstone float; some signs of coal and shale present	12.4
91. Shale, black, blocky fracture, top and bottom covered	3.0
90. Sandstone, brown, medium- to coarse-grained, very friable, forms thick rounded ledge, grades laterally into a gray shale	3.0
89. Shale, gray to black	1.6
88. Sandstone, gray with some brown staining, medium- to coarse-grained, massive, forms a ledge	4.4
87. Shale, dark-gray, hard, platy fracture, covered at base	2.4
86. Sandstone, brown, medium-grained, forms a ledge	1.3
85. Siltstone, gray, calcareous, thin-bedded, grades down into unit below	1.3
84. Shale, gray to black, fissile	2.3
83. Siltstone, gray, thin-bedded, contains leaves of several species (unidentified): grades up into a fine-grained sandstone	3.3
82. Shale, gray to black, grades up into unit 83	1.2
81. Sandstone, brown, coarse-grained in lower foot, medium-grained in middle, fine-grained above, forms a ledge	7.3
80. Sandstone, gray, coarse-grained, massive, composed of clear quartz grains and a few black, pink and white grains; becomes medium-grained and buff colored near top, forms a ledge	5.6
79. Sandstone, gray, fine-grained, beds 8 inches thick, fresh surface is gray on edges and brown in center; thin coal bed at base almost completely covered, underlain by 3-inch bed of coarse sandstone	5.4
78. Sandstone, brown, medium-grained, massive, forms ledge, calcareous cement, coarse-grained near top. Upper 3 feet covered	10.8
77. Sandstone, gray and buff, fine-grained, calcareous, individual beds are 10 inches thick	8.6
76. Shale, gray and brown, calcareous, weathers to clay at the outcrop, blocky fracture	4.0
75. Coal, fissile, low grade, argillaceous	1.0
74. Shale, gray to black, resembles coal, blocky fracture, poorly exposed	10.2
73. Siltstone, gray to buff, calcareous, forms a ledge	1.2
72. Shale, black, fissile	1.3
71. Limestone, gray, argillaceous, massive	2.8
70. Shale, gray, calcareous, blocky fracture	1.3
69. Sandstone, buff, fine-grained, massive, calcareous, well jointed; forms steep cliff over units below	25.0
68. Shale, like unit 66	5.7
67. Coal, thin seam between shales	0.7
66. Shale, black, blocky fracture, forms steep slope	5.9
65. Sandstone, brown, medium-grained, calcareous, massive, forms ledge	1.4
64. Shale, black, fissile	2.2
63. Siltstone, gray, calcareous, stained brown on surface	0.8
62. Shale, gray to black, stained brown by iron at the top, blocky fracture	3.3
61. Coal, fissile	0.7
60. Siltstone, gray to buff, calcareous	1.0

EXPLANATION (figures 11, 14, 18 and 21)

32 LO
Purple

Coal bed
Dashed where inferred or poorly exposed, dotted where burned. Thickness of coal in feet measured at triangles. Larger numbers refer to location of measured section shown on accompanying sheets.

Prospect

Coal mine

Purple

Burned zone
Area covered with natural clinker or red-burned sandstone.

DH

Coal drill hole

3

Strike and dip of beds

Apparent dip of beds

Syncline
Axis, dashed where approximately located or where ill defined.

Anticline
Axis, dashed where approximately located or where ill defined.

Monocline
Arrow points in direction of dip, dashed where approximately located or where ill defined.

Geologic unit contact
Dashed where location is approximate.

Horizontal strata

D
U

Fault
Dashed where inferred or ill defined.

Explanation For Measured Sections

22 Section numbers corresponds to map numbers on corresponding quadrangles

5.0' Thickness of unit in feet.

Top of unit below not found-thickness is a minimum

Sandstone

Siltstone

Limestone

Carbonaceous Shale

Gray Shale

Bone Shale

Coal

Shaley Sandstone or Sandy Shale

Natural Clinker

Ash

Carbonaceous Shale and Coal poorly exposed

Base of unit above not found-thickness is a minimum

0 5 10 15

Vertical scale in feet

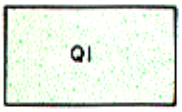
Complete thickness not shown

No horizontal scale intended.

EXPLANATION (continued)

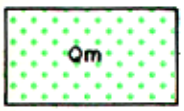
QUATERNARY

Alluvium
Stratified clay, silt, sand, gravel and some unsorted flood deposits.



Landslide Deposits
Mixed rubble and blocks of material slumped from formations at higher elevations.

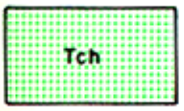
Gravel Deposits
Partly consolidated poorly sorted and stratified deposits of rock fragments of local origin, pediments or terrace, up to 75 feet thick.



Moraine
Glacial deposits, mostly unstratified up to 50 feet thick.

Gray Gulch Formation
Pyroclastics, 700± feet.

TERTIARY

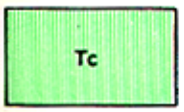


Crazy Hollow Formation
Siltstone, red, sandstone, white, pepper and salt, and red, local conglomerate. 0-600 feet.

-Disconformity-

Green River Formation
Shale, gray to green, limestone, white to tan, some oolite, local sandstone and conglomerate. 30-1,400+ feet.

-Disconformity-



Colton Formation
Shale, varicolored to gray; sandstone, buff to brown, some local limestone, 0-1,600 feet.

Flagstaff Limestone
Limestone, dark gray to tan, light gray and white, of varied lithology; shale, gray, some sandstone silicic ash, and gypsum; local oil shale. 50-1,500 feet.

TERTIARY

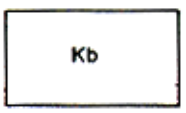
North Horn Formation
Shale, variegated red, gray, green, sandstone, buff to red; conglomerate; limestone, coal and lignite beds. 500-3,000+ feet.

CRETACEOUS

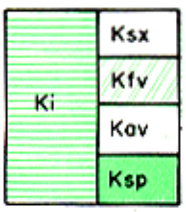
PRICE RIVER FORMATION

Castlegate Sandstone
Conglomerate, sandstone and a little shale, lower (Castlegate) part forms massive cliff. 200-2,000 feet.

-Angular Unconformity-

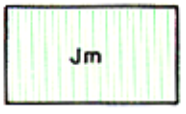


Blackhawk Formation
Sandstone, yellow gray to brown, irregularly bedded; shale, gray to black, carbonaceous, coal beds. 800-1,800 feet.



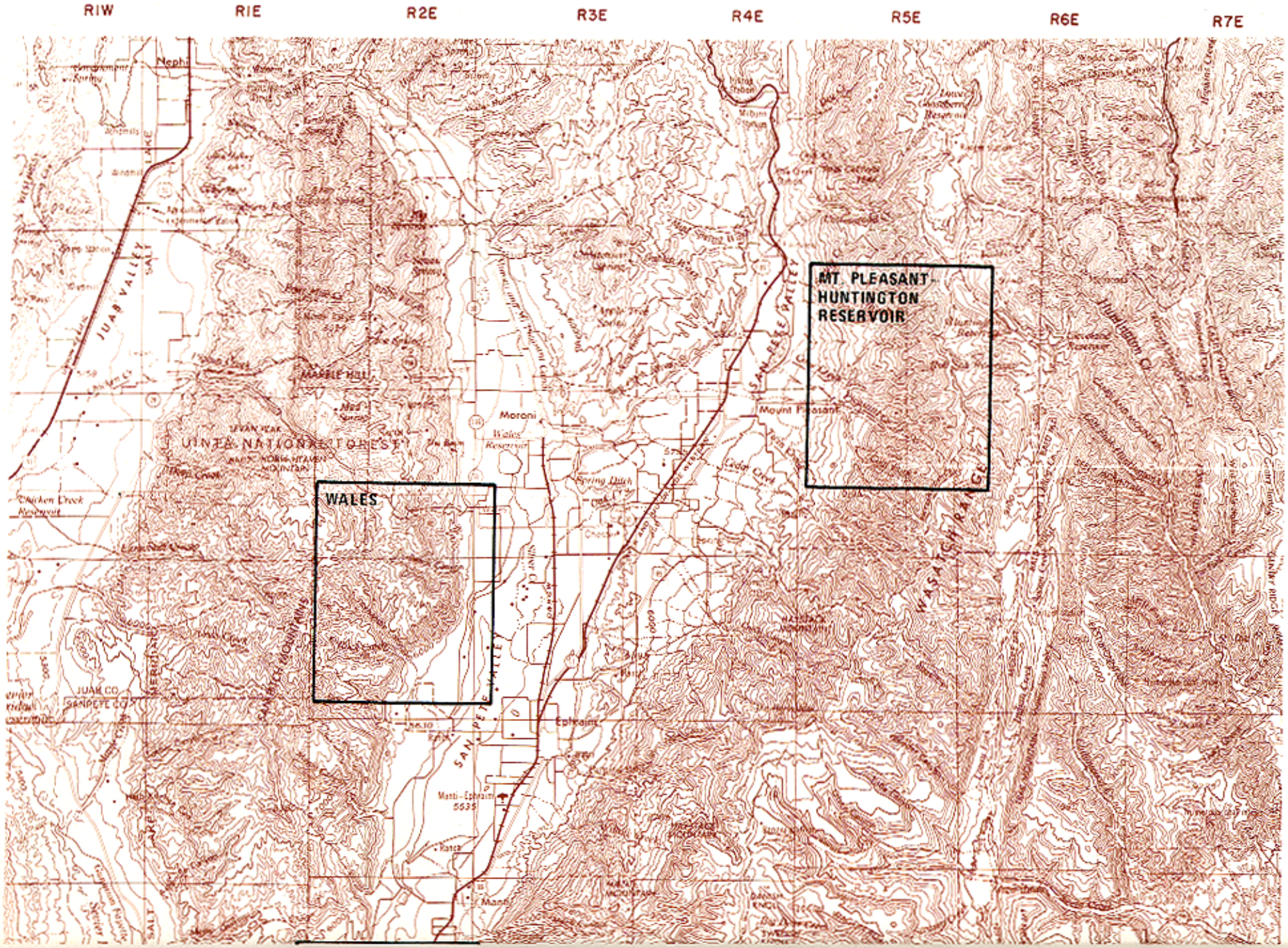
Indianola Group
Undifferentiated (Ki) conglomerate, multi-colored with fine- to coarse-grained, medium bedded red, yellow, white, gray sandstones and gray, orange shale.
Sixmile Canyon Fm. (Ksx) sandstone and conglomerate, gray to buff, coal beds. 2,800+ feet.
Funk Valley Fm. (Kfv) sandstone, light buff to brown, locally conglomeratic; marine shale, gray. 2,250 feet.
Allen Valley Shale (Kav) shale, gray marine. 600-800 feet.
Sanpete Fm. (Ksp) sandstone, buff to gray and ocher; conglomerate, little shale. 1,350 feet.

JURASSIC



Morrison? Formation
Shale, variegated; sandstone gray to red; conglomerate, gray to red; local white limestone. 0-2,000 feet.

Arapien Shale
Twist Gulch Member, siltstone, dark red, thin bedded to massive; sandstone, white to gray. 3,000 feet.
Twelvemile Canyon Member, shale, gray and thin bedded to massive, blotched gray, red and deep red, sandstone and grit, gray, yellow, brown; rock salt; gypsum; limestone, gray, locally at base. 7,000+ feet.



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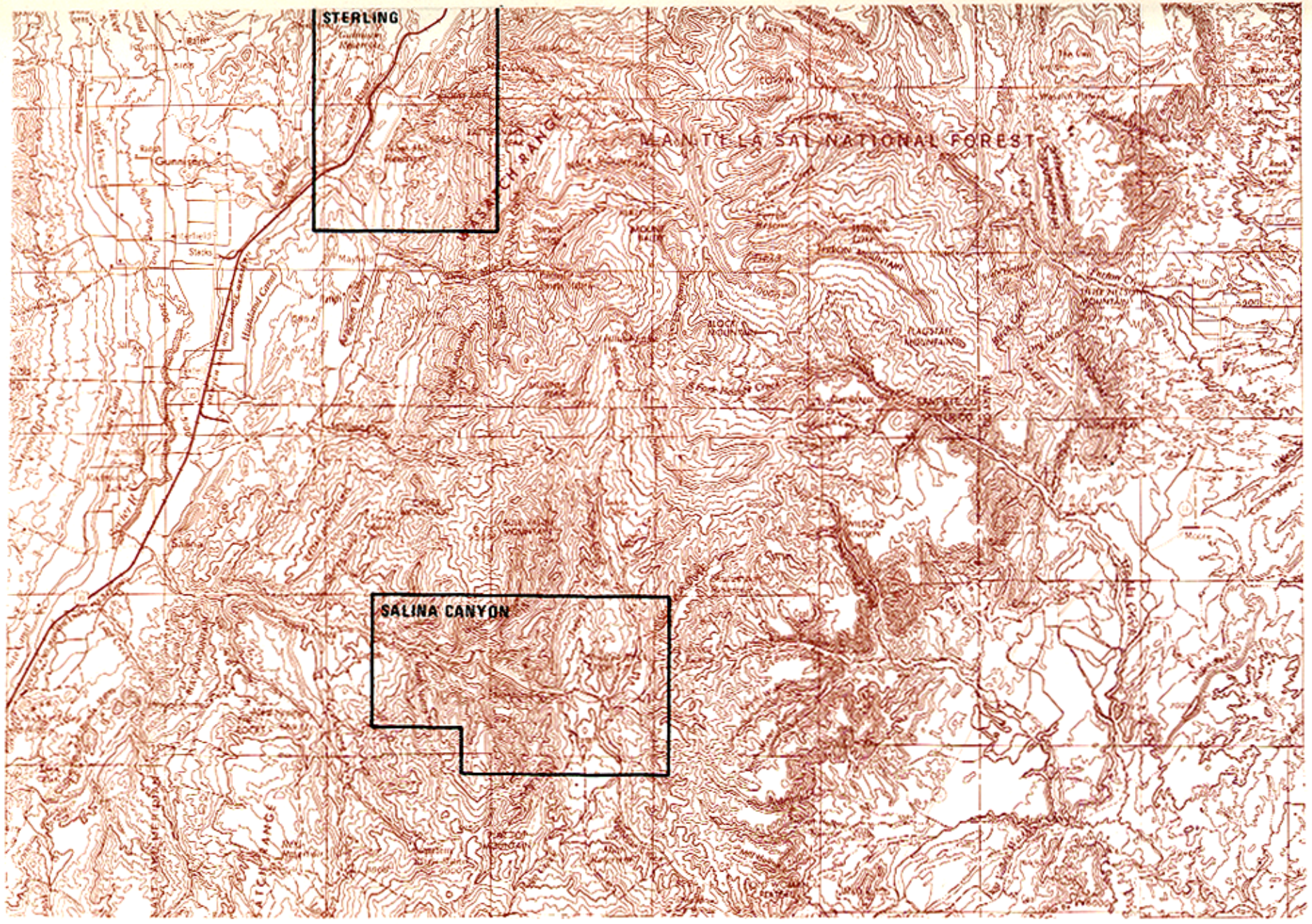
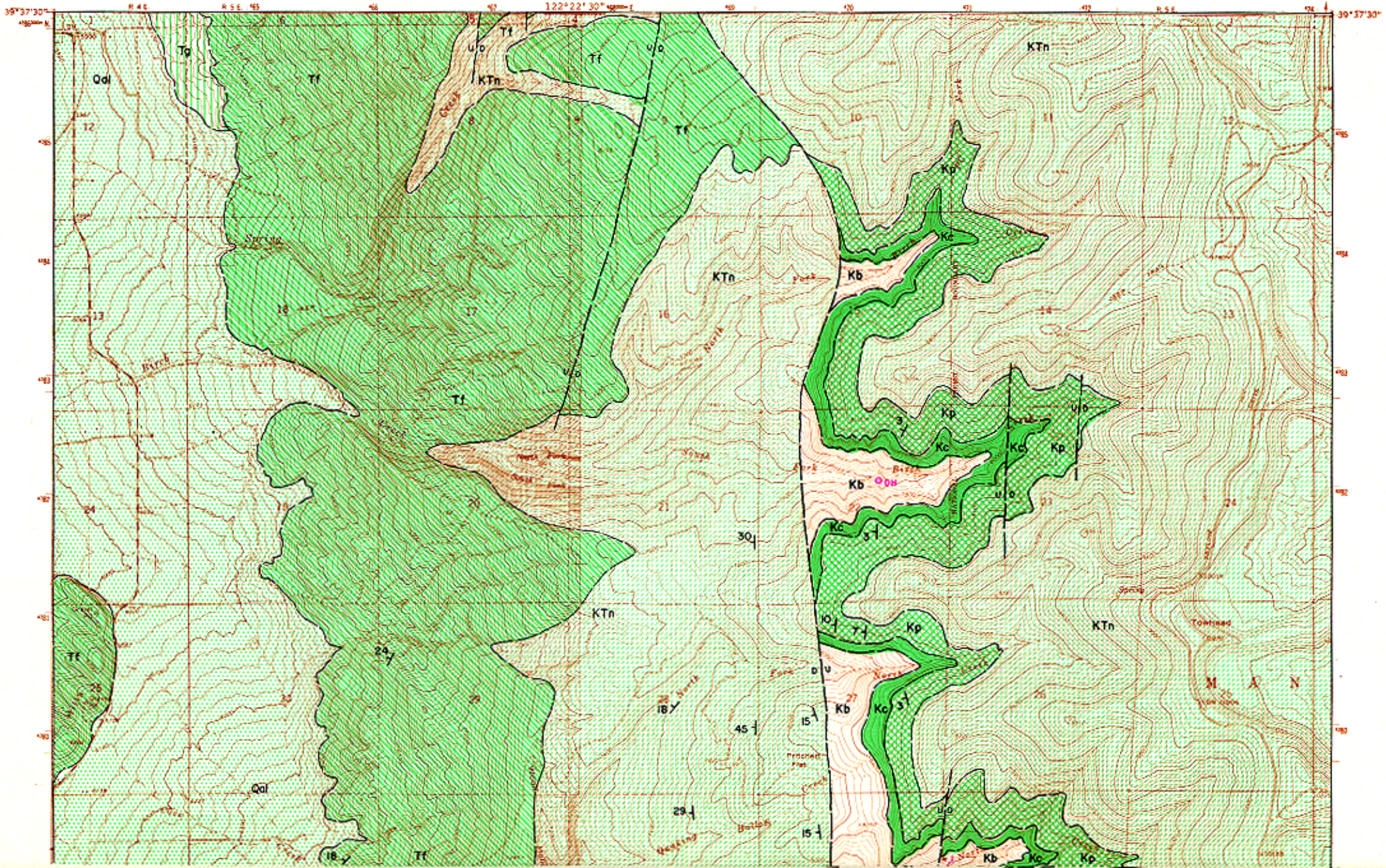


Figure 10. Topography, principal roads and quadrangle index map, Sevier–Sanpete region.

MT.-PLEASANT - HUNTINGTON RESERVOIR, UTAH



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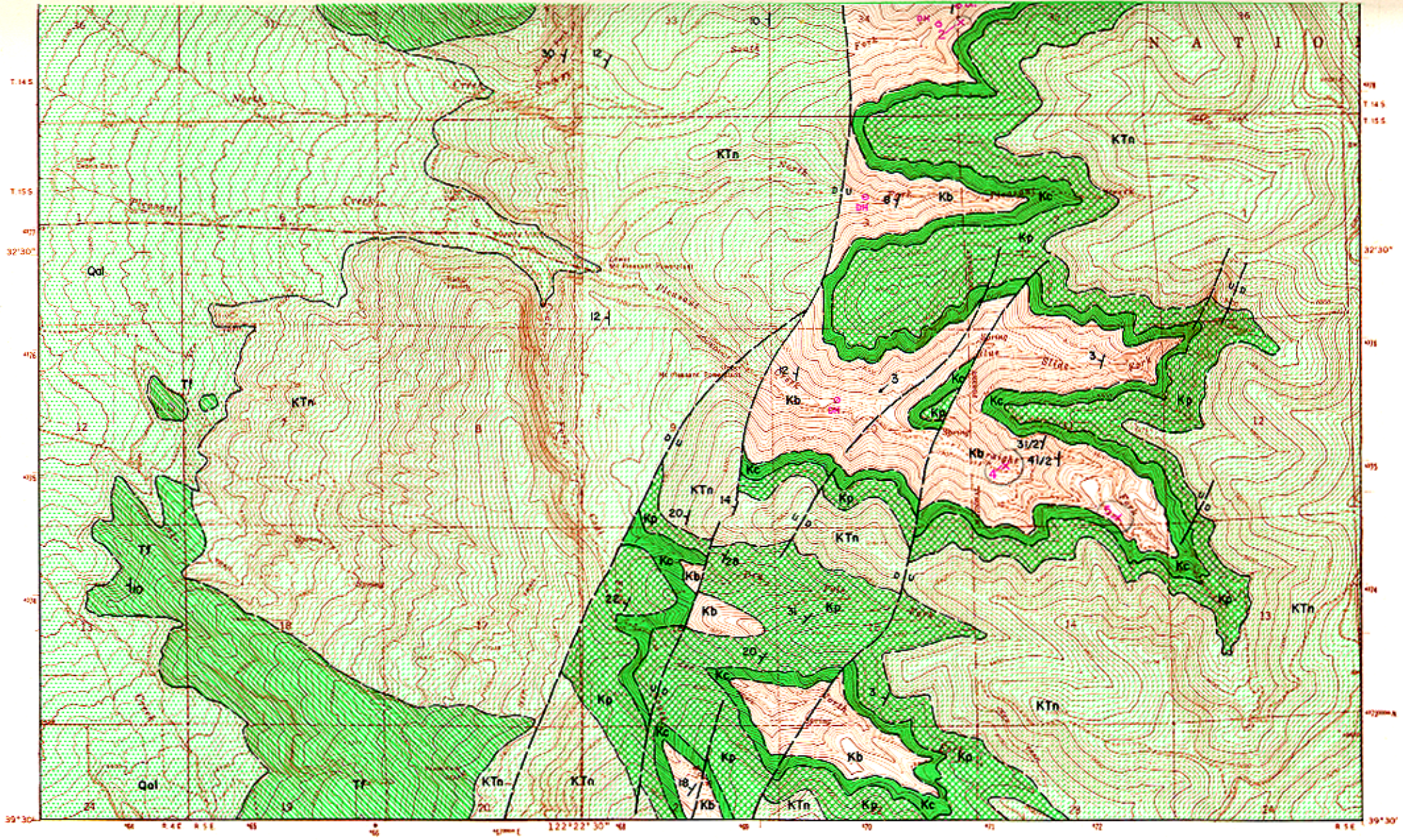


Figure 11. Coal and geology map, Mt. Pleasant—Huntington Reservoir quadrangle (explanation pages 22-23).

59. Shale, black, almost a coal, fissile, calcareous 2.4
58. Limestone, gray, iron staining present 0.8
57. Shale, black, argillaceous, blocky fracture 1.3
56. Sandstone, buff, fine-grained, calcareous, massive, forms ledge 2.2
55. Shale, black, argillaceous, blocky fracture 2.5
54. Sandstone, buff, fine-grained, calcareous, massive, forms ledge 0.8
53. Shale, gray to black, much brown iron staining, argillaceous, some coal present, blocky fracture, some iron-stone concretions present 5.4
52. Sandstone, buff, stained brown, medium-grained, massive, composed of clear quartz grains, calcareous, forms vertical cliff 17.0
51. Covered interval, covered by recent marl deposit, forms steep cliff below unit 52 . . . . . 6.0
50. Shale, gray, blocky fracture 3.9
49. Limestone, gray, massive, forms ledge 1.2
48. Shale, gray to black, some coal at the top, very fissile in upper foot, some orange resin present 1.1
47. Siltstone, buff to gray, calcareous, forms ledge 1.2
46. Shale, gray with brown iron stains, blocky fracture, calcareous, argillaceous 1.0
45. Sandstone, buff to gray, very fine-grained, calcareous, forms ledge over shale unit below 1.6
44. Shale, brown in lower foot, black above, almost a coal, blocky fracture 3.7
43. Sandstone, buff to gray, fine-grained, massive, calcareous, forms a ledge over unit 42 . . . . . 2.3
42. Shale, dark-gray, some brown iron staining, blocky fracture 2.3
41. Limestone, dark-gray, argillaceous 0.9
40. Shale, black, spar-like fracture 1.3
39. Sandstone, brown, fine-grained, calcareous, massive, forms ledge projecting over marl below 6.0
38. Covered interval, covered by marl deposit, probably a shale 2.8
37. Sandstone, buff, calcareous, fine-grained, forms step-like ledges 8.4
36. Coal, shaley 1.5
35. Sandstone, buff to gray, thin-bedded, fine-grained 2.1
34. Shale, gray to black, carbonaceous 4.3
33. Sandstone, brown to gray, contains thin lense of coal in middle, carbonaceous matter on bedding planes, calcareous 6.0
32. Shale, gray, weathers to clay 0.7
31. Sandstone, buff to brown, poorly sorted, medium and fine grains, massive 9.3
30. Shale, light gray, weathers to clay 0.3
29. Sandstone, light gray, fine-grained, thin-bedded, changes to limestone in upper 4 inches 0.8
28. Coal, thin-bedded, blocky fracture interbedded with gray shale, orange resin present 2.1
27. Sandstone, buff, fine-grained, layers of carbonaceous matter on bedding planes, massive, forms ledge over unit 26 . . . . . 6.3
26. Shale, gray, weathers to clay, some carbonaceous matter present 0.4
25. Sandstone, gray to buff, medium-grained, contains clear quartz grains, some grains stained by iron, massive, calcareous, forms a cliff 19.0
24. Shale, gray, carbonaceous, blocky fracture; 4-inch limestone bed present in middle of unit 2.2
23. Sandstone, brown to gray, fine-grained, massive, forms vertical cliff over unit 22 . . . . . 2.8
22. Sandstone, gray to brown, fine-grained, calcareous, forms slope under unit 23 . . . . . 2.6
21. Sandstone, buff to brown, medium-grained, massive, forms a ledge 3.9
20. Shale, gray to black, blocky fracture, contains coal fragments; base covered 4.7
19. Sandstone, gray to brown, medium-grained, inclusions of limonite present throughout 5.3
18. Sandstone, very fine-grained, forms step above unit 17 . . . . . 1.5
17. Sandstone, brown, medium- to coarse-grained, composed of angular clear quartz grains, some grains stained by iron, calcareous, massive, forms a cliff 22.5
16. Shale, carbonaceous, almost a coal, very fissile, weathers to clay 2.0
15. Sandstone, very fine-grained, calcareous 1.5
14. Shale, black, blocky fracture 4.0
13. Sandstone, gray to brown, fine-grained, massive, calcareous, forms a ledge 1.2
12. Shale, gray blocky fracture 0.8
11. Limestone, gray, argillaceous, forms thin ledge 0.7
10. Shale, gray to black, some brown iron staining, carbonaceous, blocky fracture; thin layer (4 inches) of brown sandstone 1 foot from top 5.9
9. Sandstone, gray, very fine-grained, fragments of carbonaceous matter present, massive, forms ledge, upper two feet covered 3.7
8. Coal and interbedded clay shale, orange resin present in coal 2.9
7. Sandstone, gray, very fine-grained, calcareous, thin-bedded, grades down into unit 2.8
6. Shale, black to gray, carbonaceous and arenaceous, blocky fracture, orange resin present 2.0
5. Sandstone, buff, fine-grained, calcareous, forms ledge 1.8
4. Shale, black, carbonaceous slightly arenaceous, spar-like fracture 1.0
3. Sandstone, brown, fine-grained, thin-bedded, forms small ledge 3.0
2. Sandstone, brown, medium- to fine-grained, composed of clear quartz grains, many grains stained by iron, calcareous; finer-grained at top, grades into 1-foot thick shale at the top 5.4
1. Covered interval, starting at the level of the creek 75.8

Total Blackhawk exposed 494.1

Creek level

Log of Hole 1-35 (location 1) drilled for Bureau of Mines 337 feet north and 30 feet east of west quarter corner of 35-14S-5E. Elevation 7,752 feet (War Minerals Report 151).

	Feet	
	Depth	Thickness
Boulders and sandy clay	0.0	18.0
Sand and clay	18.0	17.0
Boulders and sand	35.0	5.0
Soft sand	40.0	15.0
Broken sandstone and sand	55.0	27.0
Gray sandstone	82.0	3.0
Gray shale	85.0	72.0
Gray shale	157.0	13.0
Gray sandstone	170.0	25.0
Gray shale	195.0	20.0
Gray sandstone	215.0	40.0
Gray shale	255.0	80.0
Sandstone	335.0	49.0
Soft gray shale	384.0	4.0
Sandstone	388.0	12.0
Gray sandy shale	400.0	15.0
White clay	415.0	5.0
Dark gray sandstone	420.0	5.0
Gray sand shale	425.0	35.0
Soft gray shale	460.0	5.0
Gray sandy shale	465.0	90.0
Gray sandy shale	555.0	5.0
Coal stringers		
Fine gray sandstone	460.0	20.0
Gray shale	580.0	5.0
Brown sandy calcareous shale	585.0	10.0
Gray shale	595.0	10.0
Gray sandstone	605.0	10.0
Gray sandy calcareous shale	615.0	35.0
Gray sandy calcareous shale showing coal at 656 feet	650.0	10.0
Gray sandy calcareous shale	660.0	93.2
Gray sandy shale	753.2	9.5
Gray sandy shale, trace of coal	762.7	2.3
Gray sandstone	765.0	4.5
Hard gray shale	769.5	4.5
Gray sandstone	774.0	2.0
Hard gray shale	776.0	8.0
Laminated gray sandstone and shale	784.0	13.6
Laminated dark carbonaceous shale and sandstone	797.6	53.5
Coal	851.1	0.1
Laminated carbonaceous shale and sandstone	851.2	25.3
Coal	876.4	0.1
Carbonaceous shale	876.5	15.8
Coal	892.3	0.4
Sandy shale	892.6	7.4
Carbonaceous shale	900.0	1.2
Coal	901.2	0.3
Laminated carbonaceous shale and sandstone	901.5	11.5
Carbonaceous shale	913.0	4.0
Coal	917.0	0.7
Carbonaceous shale	917.7	4.3
Shaley sandstone	922.0	15.7
Carbonaceous shale	937.7	9.5
Sandy shale	947.2	7.3
Black draw slate	954.4	0.6
Coal with bone and shale splits	955.0	6.6
Calcareous shale	961.0	1.9
Carbonaceous shale and sandstone	962.9	12.5

Log of Hole 1-35 (continued).

Coal	975.3	0.2
Carbonaceous shale and sandstone	975.6	9.7
Coal	985.2	1.0
Carbonaceous shale and sandstone	986.2	23.9
Boney coal	1,010.1	0.8
Carbonaceous shale	1,010.9	1.2
Boney coal	1,012.0	0.5
Carbonaceous shale and sandstone	1,012.5	19.5
Coal	1,032.0	2.0
Carbonaceous shale	1,034.0	1.6
Carbonaceous shale and sandstone	1,035.6	12.6
Coal	1,048.2	0.1
Carbonaceous shale and sandstone	1,048.3	17.8
Sandstone	1,066.0	18.4
Coal	1,084.4	0.1
Carbonaceous shale	1,084.5	4.0
Coal	1,088.5	0.7
Carbonaceous shale	1,089.2	7.9
Coal	1,097.0	4.3
Dark shale and clay, highly fractured	1,101.3	15.7
Carbonaceous shale	1,117.0	12.0
Coal	1,129.0	0.1
Carbonaceous shale, fractured	1,129.1	13.9
Coal	1,143.0	5.0
Gray shale	1,148.0	3.0
Coal	1,151.0	3.0
Calcareous sandstone	1,154.0	37.0
Carbonaceous shale	1,191.0	5.0
Gray sandstone	1,196.0	3.0
Carbonaceous shale	1,199.0	1.0
Gray sandstone, medium- to coarse-grained	1,200.0	35.0
Carbonaceous shale	1,235.0	6.0
Light sandstone	1,241.0	8.0
Sandy shale	1,249.0	5.6
Coal	1,254.5	1.5
Soft brown sandstone	1,256.0	6.5
Hard gray sandstone (may be top of Star Point Sandstone)	1,262.5	35.8
Dark broken sandy carbonaceous shale	1,298.3	18.8
Light sandstone, fractured	1,317.0	32.0
Carbonaceous shale, coal flecks	1,349.0	3.0
Uncemented packed sand	1,352.0	7.0
Sandstone and packed sand	1,359.0	8.0
Gray sandstone	1,367.0	2.0
Sandstone and packed sand	1,369.0	4.0
Light-gray sandstone	1,373.0	3.0

The Price River Formation probably overlies the Blackhawk above a disconformity. The contact is poorly exposed but the supposition is believed valid because of evidence from surrounding areas. It is exposed everywhere above the Blackhawk initially as the Castlegate Sandstone. The unit is a massive, medium- to coarse-grained, cross-bedded sandstone and differs from the Blackhawk by the coarser grains and lighter color. The upper Price River is like the Castlegate in lithology but the sandstones are less massive, forming ledges rather than a shear cliff. In Pleasant Creek Canyon Price River totals 831 feet thick. A few conglomeratic beds and some very thin local beds of coal also occur.

North Horn Formation exposures cover much of the area, forming the crest of the plateau; they also lie below the Frontal fault. The North Horn is gradational with the Price River and represents an alternation of fluviatile and lacustrine conditions. The unit is entirely fluviatile north of Birch Creek and to the south the lower part is lacustrine. This lacustrine unit creates a gentle slope above the Price River and consists of thin, even and continuous beds of varicolored shale, buff to gray limestone and brown to buff sandstone. The fluviatile rocks are mostly brown resistant sandstone and make a high cliff at the top of the plateau. Occasional beds of shale lie between sandstone layers; some are carbonaceous and even coaley. About 5 or 6 miles northward is the Milburn field where lignite beds as thick as 14 feet have been found (Pratt and Callaghan, 1970, p. 59). The entire North Horn is about 1,400 feet thick.

All of the Flagstaff Limestone exposures are located on the west flank of the plateau along the Wasatch monocline. The unit is completely eroded from the crest in this area. The Flagstaff reflects lacustrine conditions and grades down and intertongues with the unit below. The Flagstaff consists mainly of freshwater limestone, but is interbedded with subordinate gray shale, sandstone, gypsum, oil shale, volcanic ash and conglomerate. The unit is easily recognized by its resistance to erosion and its light color. Some of the limestones are highly fossiliferous. The unit is incompletely exposed on the quadrangle and only the lower 300 to 400 feet are present.

Alluvium, which consists of interstratified clastics and clay to boulders derived from the consolidated units above, covers the foothills of the plateau adjacent to Sanpete Valley.

STRUCTURE

The inclinations of strata in this area may be grouped into two sections. The first is located west of the faulting and is grouped with the Wasatch monocline. The beds dip moderately to steeply to more than 45 degrees. The strike of the monocline is generally N 20°-30°E. East of the fault, inclinations are plateau-like, usually very moderate or gentle (3° to 5°) but occasionally up to 30 degrees along faults.

The major fault which divides the two structural divisions is termed the Frontal fault. It is uplifted to the east and has elevated the strata so that the coal-bearing beds have been exposed. The throw of the fault cannot be directly measured, but a minimum figure can be calculated on the basis of formation thicknesses. At least 1,328 feet of displacement exist along the fault.

In addition several minor faults parallel the Frontal fault on its east side. These all have their upthrown blocks to the east and are antithetic to the Wasatch monocline. The throw of some of these faults may be as much as 800 feet in places. East-west cross sections illustrating the structure are shown (figure 12): section A-A' extends from 26-14S-4E to 25-14S-5E and section B-B' extends from 12-15S-4E to 12-15S-5E.

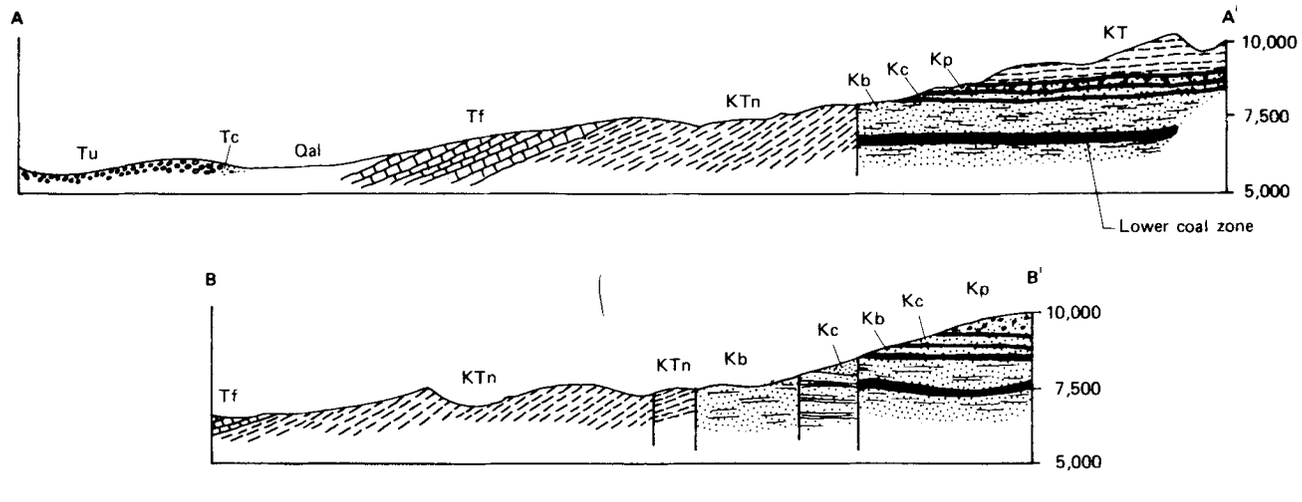


Figure 12. East-west structure sections, west Wasatch Plateau near Mt. Pleasant, Utah (after Pashley, 1956).

PROPERTY CONTROL

Practically all the land is private property or held by the National Forest Service. Small acreage is controlled by the Bureau of Land Management in the lower elevated parts and there is no state land. Private property constitutes 83 percent of the quadrangle and forest land constitutes 17 percent. Some of the private land still has the mineral rights reserved to the U. S. or state of Utah. There is no current leasing or permitting of lands on the quadrangle.

COAL

Surface Information

The North Horn, Price River and Blackhawk formations all expose thin coal beds in the area. At Cottonwood Creek, 2 miles north of the mapped area, a bed 6 to 8 inches thick in SE.NW.33-13S-5E is in the Price River Formation.

In Pleasant Creek in secs. 10 and 11-15S-5E, some mine developments or prospects are located in the Blackhawk in beds 8 to 12 inches thick. It is certain that other beds of this magnitude may be found on the quadrangle and in surrounding areas.

Subsurface Information

Several holes have been drilled in the Mt. Pleasant field to determine the presence of coal in the deeper unexposed part of the Blackhawk (figure 13). A summary of the locations of the holes is as follows (table 7).

Table 7. Location holes drilled in the Mt. Pleasant field.

Name	Location	Drilling Date
Wilson	SE.NW.10-15S-5E	1929-1931
Moreton No. 1	SE.NW.3-15S-5E	1929-1931
Moreton No. 2	NE.SE.34-14S-5E	1929-1931
Moreton No. 3	SE.NE.22-14S-5E	1929-1931
U. S. Bureau of Mines	SW.NW.35-14S-5E	1941-1942

The logs of the first four wells were unfortunately lost in the U. S. Geological Survey or Bureau of Mines archives in Washington D. C. Outside sources indicate that the Moreton wells encountered at least two minable coal beds. The log of the U. S. Bureau of Mines drill hole is given in the Stratigraphy section (p. 28).

Six beds of coal were penetrated as follows (table 8):

Table 8. Coal beds penetrated in the Mt. Pleasant field.

Bed	Thickness (ft)	Depth to top of bed	Altitude (ft)
A	5.7	955	6,797
Interval	71.0		
B	2.0	1,032	6,720
Interval	63.0		
C	3.5	1,097	6,655
Interval	42.0		
D	5.0	1,143	6,609
Interval	3.0		
E	3.0	1,151	6,601
Interval	100.0		
F	1.5	1,254	6,597

Of the six beds of coal only A, C and D are of minable thickness. Beds A and C are 136 feet apart and beds C and D are 42 feet apart. If D were mined it might be possible to extract coal from E at some localities depending on the thinning and thickening of the interval between the beds.

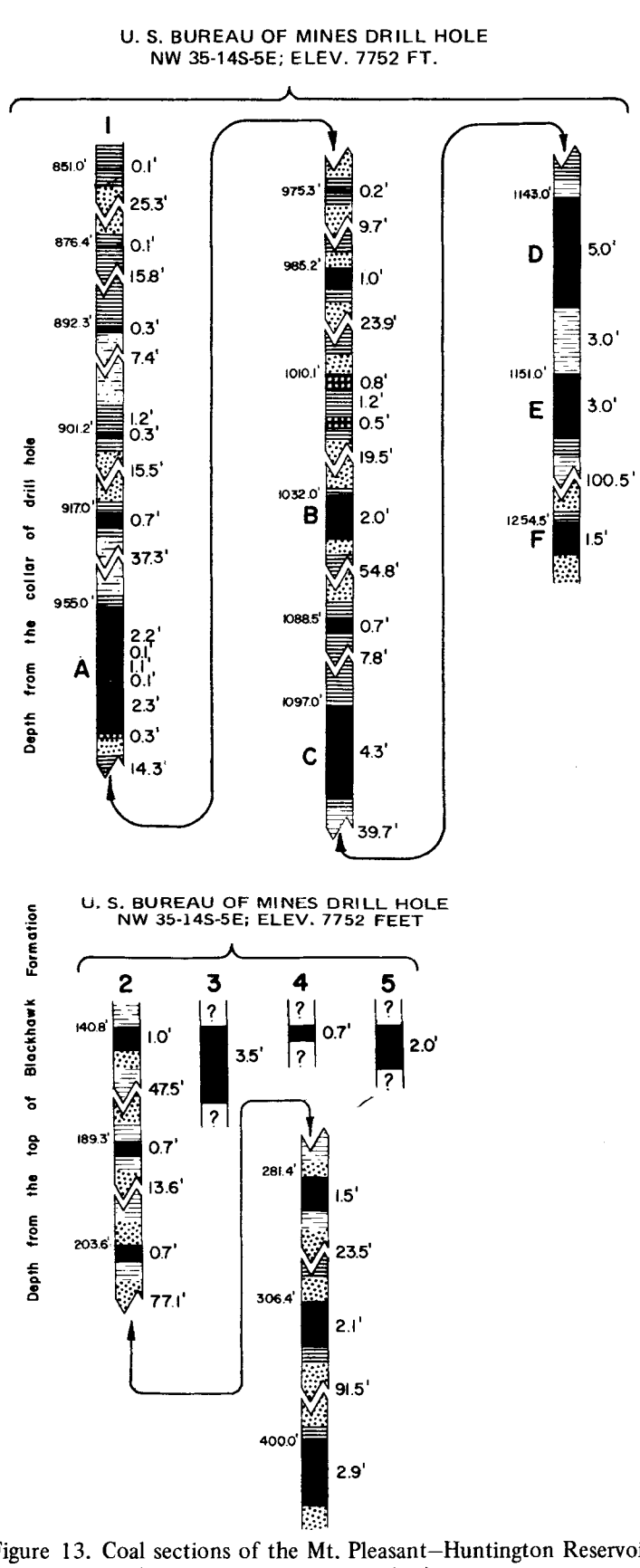


Figure 13. Coal sections of the Mt. Pleasant–Huntington Reservoir quadrangle (vertical scale 1 inch = 8 feet).

Any mining contemplated in the area would be deep. East of the Frontal fault, depth to the coal in the deep canyons is somewhat more than 1,000 feet. At the Castlegate-Price River the depth increases to 2,000 feet. The 3,000-foot limit can be expected at the middle of the North Horn. West of the fault the coal in the Blackhawk can be expected at depths below 2,500 feet, becoming deeper to the west.

Quality of Coal

Seven analyses are available from beds A to F and two analyses for bed C (table 9). The coal is rated as high-volatile A or B rank bituminous. The average proximate analysis is as follows (table 10):

Table 9. Coal analyses of the Sevier-Sanpete region.

No.	Mine or Prospect Coal Bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
				AN	M	VM	FC	Ash	S	H	C	N	O			AST	ADL	HGI		
									MT. PLEASANT–HUNTINGTON RESERVOIR QUADRANGLE											
1	U. S. Bureau of Mines Core bed A	SW.NW.35-14S-5E 4378890mN 470859mE	A	3.0	45.2	45.5	6.3		.6	5.8	72.9	1.6	12.8		13,150	–	1.0	–		30
			C	–	46.6	46.9	6.5		.6	5.7	75.2	1.7	10.3		13,560	–	–	–		
			D	–	49.9	50.1	–		.6	6.1	80.4	1.8	11.1		14,510	–	–	–		
2	U. S. Bureau of Mines Core bed B		A	3.7	42.3	48.9	5.1		.8	5.8	73.8	1.6	12.9		13,290	–	1.5	–		30
			C	–	43.9	50.8	5.3		.8	5.6	76.7	1.7	9.9		13,810	–	–	–		
			D	–	46.4	53.6	–		.9	5.9	81.0	1.8	10.4		14,590	–	–	–		
3	U. S. Bureau of Mines Core bed C		A	3.1	43.0	45.5	8.4		.8	5.8	71.5	1.5	12.0		12,840	–	1.0	–		32
			C	–	44.3	47.0	8.7		.8	5.6	73.7	1.6	9.6		13,250	–	–	–		
			D	–	48.5	51.5	–		.9	6.1	80.8	1.7	10.5		14,510	–	–	–		
4	U. S. Bureau of Mines Core bed C		A	3.7	43.0	45.8	7.5		.7	–	–	–	–		12,920	–	1.7	–		30
			C	–	44.6	47.6	7.8		.7	–	–	–	–		13,420	–	–	–		
			D	–	48.4	51.6	–		.7	–	–	–	–		14,560	–	–	–		
5	U. S. Bureau of Mines Core bed D		A	3.2	42.9	45.3	8.6		.6	5.7	71.6	1.4	12.1		12,890	–	–	–		30
			C	–	44.3	46.8	8.9		.6	5.5	74.0	1.5	9.5		13,310	–	–	–		
			D	–	48.6	51.4	–		.6	6.0	81.2	1.6	10.6		14,610	–	–	–		
6	U. S. Bureau of Mines Core bed E		A	4.7	42.2	43.9	9.2		.5	5.8	69.6	1.4	13.5		12,440	–	3.0	–		30
			C	–	44.3	46.1	9.6		.6	5.5	73.0	1.5	9.8		13,060	–	–	–		
			D	–	49.0	51.0	–		.6	6.1	80.8	1.6	10.9		14,450	–	–	–		
7	U. S. Bureau of Mines Core bed F		A	2.4	41.8	44.5	11.3		1.6	5.5	69.9	1.4	10.3		12,700	–	–	–		30
			C	–	42.9	45.5	11.6		1.7	5.4	71.7	1.4	8.2		13,010	–	–	–		
			D	–	48.5	51.5	–		1.9	6.1	81.1	1.6	9.3		14,720	–	–	–		
									SALINA CANYON QUADRANGLE											
1	Prospect Sevier bed	NW.20-22S-3E 4304000mN 447725mE	A	14.9	36.3	40.4	8.4		.4	–	–	–	–		9,690	2,200	11.2	–		14
			B	4.23	40.81	45.46	9.50		.46	–	–	–	–		10,910	–	–	–		
			C	–	42.6	47.5	9.9		.5	–	–	–	–		11,390	–	–	–		
			D	–	47.31	52.89	–		.53	–	–	–	–		12,646	–	–	–		
2	Prospect Sevier bed	NW.20-22S-3E 4303860mN 447690mE	A	10.0	37.6	48.3	4.2		0.49	–	–	–	–		11,856	–	7.2	–		34
			B	3.0	40.5	52.1	4.5		0.53	–	–	–	–		12,775	–	–	–		
			C	–	41.7	53.7	4.6		0.54	–	–	–	–		13,168	–	–	–		
			D	–	43.8	56.3	–		0.57	–	–	–	–		13,807	–	–	–		
3	Kearns & Duggins mine Sevier bed	NW.18-22S-3E 4306025mN 445750mE	A	6.4	45.1	36.3	12.2		.44	–	–	–	–		11,750	–	–	–		39
			B	3.4	46.5	37.5	12.6		.45	–	–	–	–		12,130	–	–	–		
			C	–	48.2	38.7	13.1		.47	–	–	–	–		12,550	–	–	–		
			D	–	55.4	44.6	–		.54	–	–	–	–		14,440	–	–	–		
4	Kearns & Duggins mine Sevier bed		A	5.9	45.5	37.8	10.8		.5	–	–	–	–		11,890	2,180	3.5	–		14
			B	2.50	47.10	39.17	11.23		.51	–	–	–	–		12,311	–	–	–		
			C	–	48.3	40.2	11.5		.5	–	–	–	–		12,630	–	–	–		
			D	–	54.59	45.41	–		.6	–	–	–	–		14,268	–	–	–		
5	Sevier Valley mine Upper Ivie bed	NE.SE.20-22S-3E 4303525mN 448780mE	A	6.2	42.6	38.8	12.5		.38	–	–	–	–		11,088	–	–	–		39
			B	1.5	44.7	40.7	13.1		.40	–	–	–	–		11,639	–	–	–		
			C	–	45.4	41.3	13.3		.41	–	–	–	–		11,815	–	–	–		
6	Sevier Valley mine Upper Ivie bed		A	10.7	34.4	44.8	10.1		–	–	–	–	–		10,803	–	–	–		39
			B	2.5	37.6	48.9	11.0		–	–	–	–	–		11,800	–	–	–		
			C	–	38.6	50.2	11.3		–	–	–	–	–		12,096	–	–	–		
7	Sevier Valley mine Upper Ivie bed		A	7.1	42.0	37.6	13.2		.38	–	–	–	–		10,493	–	–	–		39
			B	1.6	44.5	39.8	14.0		.40	–	–	–	–		11,108	–	–	–		
			C	–	45.3	40.5	14.3		.41	–	–	–	–		11,293	–	–	–		
8	Sevier Valley mine Upper Ivie bed		A	6.0	–	–	8.6		.32	–	–	–	–		–	–	–	–		41
9	Sevier Valley mine Upper Ivie bed		A	6.3	–	–	8.5		.57	–	–	–	–		–	–	–	–		41
10	Sevier Valley mine Upper Ivie bed		A	6.0	45.0	45.5	9.5		.5	–	–	–	–		12,080	–	–	–	T	2
			C	–	–	–	–		–	–	–	–	–		12,850	–	–	–		
11	Sevier Valley mine Upper Ivie bed		A	5.7	45.5	43.8	10.7		.4	–	–	–	–		11,820	–	–	–	T	2
			C	–	–	–	–		–	–	–	–	–		12,540	–	–	–		
12	Sevier Valley mine Upper Ivie bed		A	6.3	45.0	45.9	9.1		.6	5.3	71.4	1.3	12.3		12,030	–	–	–	T	2
			C	–	–	–	–		–	–	–	–	–		12,840	–	–	–		
13	Sevier Valley mine Upper Ivie bed		A	7.8	45.6	44.7	9.7		.4	–	–	–	–		11,540	–	–	–	T	2
			C	–	–	–	–		–	–	–	–	–		12,510	–	–	–		
									STERLING QUADRANGLE											
1	Morrison mine Sterling bed	SW.36-18S-2E 4339120mN 443700mE	A	8.07	42.59	43.20	6.14		.92	–	–	–	–		11,767	–	1.8	–		22
			C	–	46.33	46.99	6.68		1.00	–	–	–	–		12,800	–	–	–		
			D	–	49.65	50.35	–		1.07	–	–	–	–		13,714	–	–	–		
									WALES QUADRANGLE											
1	Indian Pete Canyon Wales coal zone	C.NW.NE.SE.2-16S-2E 4366960mN 433290mE	A	9.1	37.1	24.6	29.2		3.82	–	–	–	–		6,554	–	–	–		1
			C	–	40.8	27.1	32.1		4.20	–	–	–	–		7,210	–	–	–		

Table 9. (continued)

No.	Mine or Prospect-Coal Bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
2	Indian Pete Canyon Wales coal zone		A	2.41	32.41	45.99	19.19	3.71	–	–	–	–	11,201	–	.2	–		13
			C	–	33.21	47.13	19.66	3.80	–	–	–	–	11,479	–	–	–		
			D	–	41.34	58.66	–	4.73	–	–	–	–	14,287	–	–	–		
3	John Reese mine Wales coal zone	NE.NE.NW.23-16S-2E 4362920mN 442600mE	A	3.65	29.16	44.68	22.51	6.79	–	–	–	–	10,291	–	.1	–		13
			C	–	30.27	46.37	23.36	7.05	–	–	–	–	10,681	–	–	–		
			D	–	39.50	60.50	–	9.20	–	–	–	–	13,937	–	–	–		
4	Thomas mine Wales coal zone	NW.NE.35-15S-2E 4369350mN 443200mE	A	14.2	21.0	46.8	18.0	4.18	–	–	–	–	9,481	–	–	–		1
			C	–	24.5	54.5	21.0	4.87	–	–	–	–	11,050	–	–	–		
5	Thomas mine Wales coal zone		A	7.07	43.18	44.07	5.68	–	–	–	–	–	–	–	–	–		15
6	Thomas mine Wales coal zone		A	7.15	42.74	45.80	3.95	–	–	–	–	–	–	–	–	–		15
7	Thomas mine Wales coal zone		A	6.38	42.60	45.46	5.56	–	–	–	–	–	–	–	–	–		15
8	Thomas mine Wales coal zone		A	2.1	29.7	49.3	18.0	3.8	4.2	64.1	1.2	7.8	11,330	–	.5	–		30
			C	–	30.4	50.3	19.3	3.8	4.1	65.4	1.2	6.2	11,570	–	–	–		
			D	–	37.6	62.4	–	4.8	5.1	81.1	1.5	7.5	14,340	–	–	–		
9	Thomas mine Wales coal zone		A	2.70	35.7	45.87	15.73	4.63	–	–	–	–	11,857	2,130	.8	–		13
			C	–	36.69	47.14	16.17	4.76	–	–	–	–	12,184	–	–	–		
			D	–	43.77	56.23	–	5.68	–	–	–	–	14,535	–	–	–		
10	Wales mine Wales coal zone	NE.NW.26-15S-2E 4370750mN 442430mE	A	2.17	33.50	50.94	13.39	4.62	–	–	–	–	–	–	.8	–		22
			C	–	34.24	52.07	13.69	4.72	–	–	–	–	–	–	–	–		
			D	–	39.67	60.33	–	5.47	–	–	–	–	–	–	–	–		
11	Wales mine Wales coal zone		A	1.16	32.91	54.75	11.18	2.88	–	–	–	–	–	–	–	–		21
12	Wales mine Wales coal zone		A	–	33.70	55.54	11.50	–	–	–	–	–	–	–	–	–			21
13	Wales mine Wales coal zone		A	2.05	31.08	49.85	17.02	–	–	–	–	–	–	–	–	–			15

Table 10. Average proximate analyses of coal, Mt. Pleasant-Huntington Reservoir quadrangle.

	Percent	
	Average	Range
Moisture	3.4	2.4- 4.7
Volatile matter	42.9	41.8-45.2
Fixed carbon	45.6	43.9-48.9
Ash	8.1	5.1-11.3
Sulfur	0.8	0.5- 1.6
Btu/lb	12,890	12,440-13,290

Table 11. Analyses of sulfur content of beds C and A, Blackhawk Formation, Mt. Pleasant-Huntington Reservoir quadrangle.

Bed	Percent			
	Total Sulfur	Sulfate	Pyritic	Organic
Bed C	0.82	0.00	0.18	0.64
Bed A	0.58	0.00	0.06	0.52

Table 12. Calculated carbonization product yields from drill-core holes, Blackhawk Formation, Mt. Pleasant-Huntington Reservoir quadrangle, at 500° C.

Bed	Char	Water of decomposition	Tar plus light oil	Gas	Gas vol. scf/lb maf coal	Heating value of gas Btu/scf
A	68.7	5.0	20.6	4.6	0.901	815
B	71.6	4.7	18.7	4.3	0.891	826
C	69.9	4.8	20.0	4.6	0.894	815
D	69.8	4.7	20.1	4.3	0.876	830
E	69.5	4.9	20.0	4.8	0.907	802
F	70.2	4.2	20.7	3.9	0.845	849

Only bed F has sulfur exceeding 0.8 percent. Walker and Hartner (1966, p. 38) further investigated the sulfur (table 11).

Beds E and F have the highest ash content and Bed B produces the most Btu/lb. Coking tests made on samples from the beds showed that the resulting coke was softer, considerably weaker and more fingery than coke made from Sunnyside (Book Cliffs coal field) coal. Calculated carbonization product yields from the drill-hole cores (Gomez, Landers and Boyd, 1967, p. 11) are shown in table 12.

Mines and Development

Only a few prospects on thin coal beds have been developed on the Mt. Pleasant-Huntington Reservoir quadrangle. None is of importance and no production has been recorded. The only development has been the drilling of the aforementioned test holes.

Reserves

The effective area of the Mt. Pleasant coal field (thick coal with less than 3,000 feet of cover) probably extends an additional 3 to 4 miles south of the mapped area. Another window of the upper Blackhawk Formation crops out in the canyons that make up the headwaters of Cedar Creek. Drilling has proven the presence of at least two workable beds over a north-south distance of 6 miles and a width of 1½ miles. For an average of 10 feet for all the coal in the workable beds the following Class I and Class II reserves may be deduced (table 13):

Table 13. Class I and Class II coal reserves, Mt. Pleasant-Huntington Reservoir quadrangle.

Location	Acres	Avg. thickness (ft)	Tonnage
T.14S. R.5E.	3,360	10.0	58,500,000
T.15S. R.5E.	2,400	10.0	41,800,000
			100,300,000

Thick coal beds are known to exist to the east and it is only reasonable to assume the beds are continuous to provide an inferred (Class III) reserve. The nearest exposed coal to the east is about 6 miles distant from the drill-hole sites. The area here in-

cluded with the Mt. Pleasant field extends from the north map boundary southward to the south boundary of T. 15 S. between the Frontal fault to the assumed 3,000-foot overburden limit (table 14).

Table 14. Class III coal reserves, Mt. Pleasant-Huntington Reservoir quadrangle.

Location	Acres	Avg. thickness (ft)	Tonnage
T.14S. R.5E.	1,820	10.0	31,700,000
T.15S. R.5E.	6,720	10.0	117,100,000
			148,800,000

Total reserve, all classes: 249,100,000 short tons

PRINCIPAL WORK

Most of the geology was modified from Pashley (1956), Ohio State University, and most of the coal data were supplied by Duncan (1944), U. S. Bureau of Mines. Other helpful data were derived from the work of Pearce (1970c).

SALINA CANYON QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Salina Canyon coal field is located in Sevier County and is the southernmost field of the Sevier-Sanpete region (figures 10 and 14). The town of Salina is located 12 miles west of the mapped area. The area comprises parts of U. S. Geological Survey quadrangles Gooseberry Creek, Steves Mountain, Water Hollow Ridge and Yogo Creek and lies near the south end of the Wasatch Plateau.

The principal drainage is the west-flowing Salina Creek. Its canyon exposes the upper part of the Blackhawk coal measures. Along the course of the canyon in the mapped area the elevation rises from 5,900 to more than 7,100 feet. The tops of the ridges north and south of the canyon rise to a maximum of 8,500 feet.

Utah Highway 4 (formerly 10), which extends along Salina Canyon, is being replaced by Interstate Highway 70. To the west the highway reaches Salina and the Sevier Valley; to the east it leaves Salina Creek at its junction with Meadow Creek and follows Ivie Creek on the opposite side of the divide connecting with Price and Green River. Dirt forest roads provide access into the principal tributary canyons.

STRATIGRAPHY

Four mapped consolidated units are exposed on the composite map (figure 14). The oldest is the coal-bearing Blackhawk Formation which is mainly exposed in canyons and on canyon walls. Only the upper 550 feet of the 850-foot unit are represented at the surface. Essentially they consist of alternating cliffy sandstones and slope-forming shale. The sandstone is more abundant than the shale by a ratio of 3 to 2. There are also a few thin beds of coal.

Section of Blackhawk Formation measured on north side of Salina Canyon, NW.20-22S-3E., measured by Bachman (1959):

Castlegate Sandstone Blackhawk Formation	Feet
38. Shale, gray, brittle	5.0
37. Shale, dark gray, carbonaceous at the bottom, grading upward into gray shale, interbedded with buff and yellow, fine- to medium-grained sandstone. Sandstone in beds 1 to 4 feet thick	.47.0
36. Shale, gray, with thin beds of buff, fine-grained sandstone	.20.5
35. Sandstone, buff to gray, fine-grained, massive, weathers brown, contains several thin lenses of gray shale	.17.0
34. Shale, gray, dark gray and brown, contains thin lenses of buff, fine-grained sandstone and several beds of black, carbonaceous shale	.18.0
33. Sandstone, white, very fine-grained, small-scale cross-bedding, weathers buff with streaks of iron stain	.10.5
32. Shale, dark brown and black, carbonaceous, contains small lenses of coal	1.5
31. Sandstone, buff and gray, fine-grained, interbedded with gray and yellow shale	.23.0
30. Sandstone, buff, fine- to medium-grained, massive, cross-bedded, joints encrusted with calcite, weathers mottled brown	.17.5
29. Sandstone, buff to gray, fine-grained, thick-bedded, contains thin beds of dark gray shale and yellow-gray siltstone	.21.5
28. Sandstone, buff, fine-grained, massive, cross-bedded, joints encrusted with calcite, weathers brown	6.7
27. Coal, resinous, shaley	0.4
26. Shale, gray, sandy, grading upward into black, flaky shale	9.0
25. Sandstone, buff and gray, fine- to medium-grained, thin-bedded at base, becomes massive at top, weathers brown, contains lenses of gray shale and some thin beds of carbonaceous shale	.65.0
24. Shale, gray, interbedded with buff, fine-grained sandstone	.11.3
23. Sandstone, gray, fine-grained, flaggy, weathers brown	6.0
22. Shale, dark gray, carbonaceous, contains thin beds of buff, fine-grained sandstone, poorly exposed, coal bloom and blotches of red found in parts of this interval	.23.0
21. Sandstone, gray, fine- to medium-grained, thin-bedded, poorly cemented	5.0
20. Shale, gray, with thin beds of buff, fine-grained sandstone, and carbonaceous shale, traces of coal bloom	.11.5
19. Shale, dark gray, carbonaceous	1.0
18. Coal, resinous	0.3
17. Shale, gray, grading upward into black, carbonaceous shale	2.0
16. Sandstone, buff, fine-grained, massive, jointed, weathers dark brown, honeycomb weathering	.35.0
15. Siltstone, gray, soft, grading upward into fine-grained, gray sandstone	2.0
14. Shale, gray, brittle	1.0
13. Covered interval, trace of carbonaceous shale	5.0
12. Sandstone, buff and gray, lower part thin-bedded, becomes massive at top, calcite-encrusted joints, weathers brown	.21.0
11. Sandstone, gray to yellow, fine-grained, interbedded with buff, medium-grained sandstone and dark gray shale	.23.0
10. Sandstone, buff, fine-grained, massive, blocky on weathered surface, weathers dark brown	.13.0
9. Shale, gray to dark gray, carbonaceous, contains thin beds of fine-grained buff sandstone, traces of coal bloom	.49.0
8. Sandstone, buff, fine-grained, massive, jointed, weathers yellow with brown streaks, knobby surface	.32.5
7. Shale, gray to black, carbonaceous, interbedded with buff, fine-grained sandstone, poorly exposed	8.0
6. Sandstone, buff, fine-grained, massive, jointed, weathers dark brown, knobby	.12.0
5. Shale, dark gray, carbonaceous, grading upward into gray brittle shale	2.3
4. Coal, resinous, shaley	1.5
3. Shale, brown to black, carbonaceous	0.5
2. Shale, gray, sandy	2.5
1. Sandstone, buff and gray, fine-grained, hard, massive, weathers brown	.18.0
Total Blackhawk Formation exposed	.549.1

The sandstones are thin-bedded to massive, lenticular, fine- to medium-grained and gray, buff, yellow and brown in color. The shales are light gray, brown to black in color, often carbonaceous, clayey and brittle.

Castlegate Sandstone Blackhawk Formation	Feet
Shale, gray	2.5
Sandstone, cream-colored, fine-grained, massive	.12.0
Sandstone and gray shale, alternating in thin layers	.70.0
Sandstone, gray, weathering buff, medium-grained, cliff forming	.99.0
Shale, gray, partly concealed	9.5
Coal	0.8
Shale, gray, carbonaceous at top and containing thin lenses of coal	4.0
Sandstone, gray, weathering buff, medium-grained, massive	8.0
Shale, gray, carbonaceous at top, containing several thin bands of platy sandstone	.19.0
Sandstone, buff, medium-grained, massive	.14.0
Shale, gray	2.5
Sandstone, buff, fine-grained	3.0
Shale, gray, containing several thin beds of sandstone	.25.0
Sandstone, buff, medium-grained, massive, cliff forming	.23.0
Concealed	.16.0
Shale, gray	.17.0
Sandstone, gray, weathering buff, medium-grained, massive	6.0
Shale, gray, containing several thin beds of sandstone	.26.0
Sandstone, buff, fine-grained, with lenses of interbedded shale	.39.0
Shale, gray	6.0
Sandstone, buff, fine-grained, massive	4.0
Shale, black, carbonaceous, containing lenses of coal	2.5
Sandstone, gray-buff, and gray shale, interbedded	.11.0

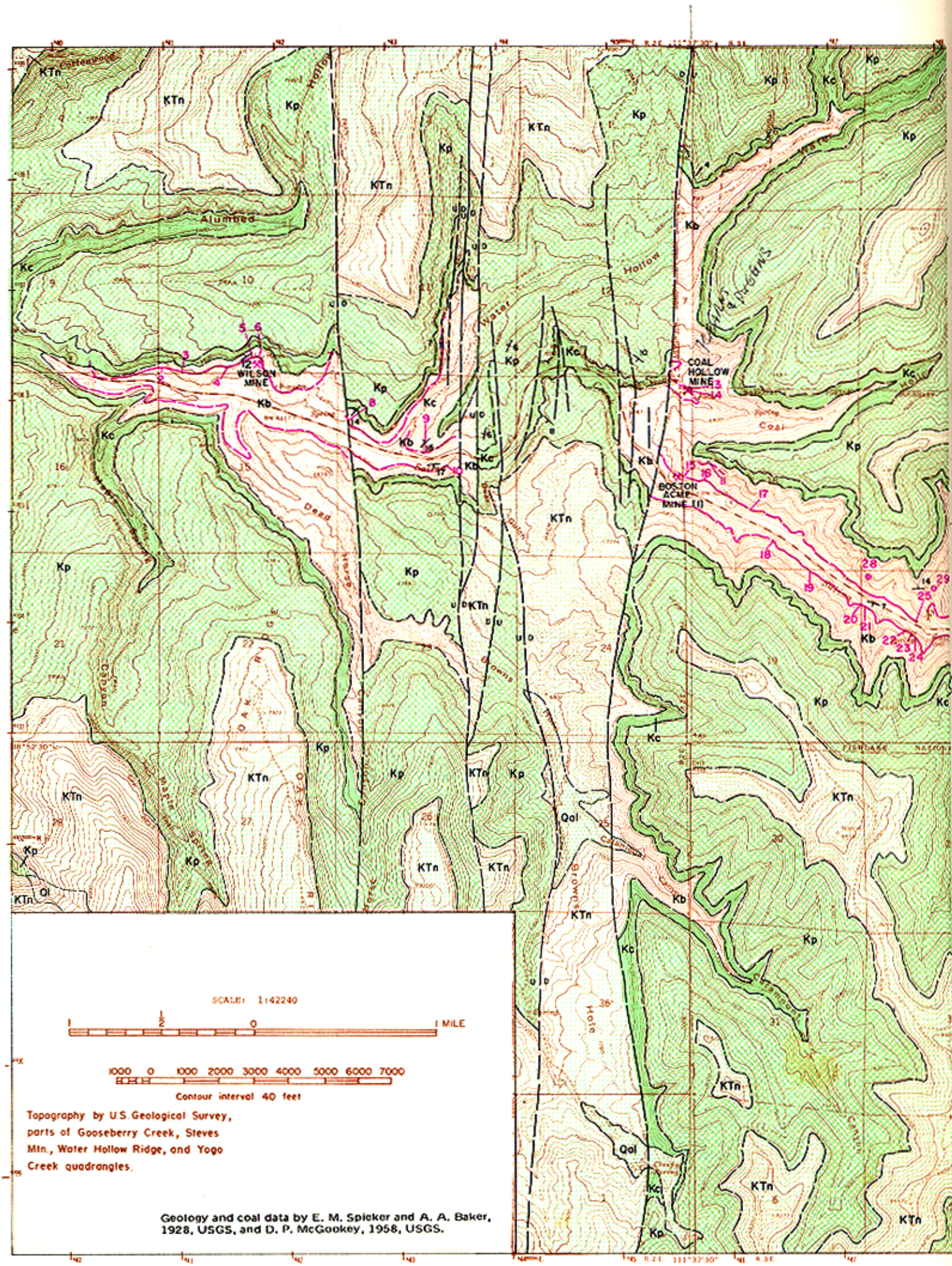
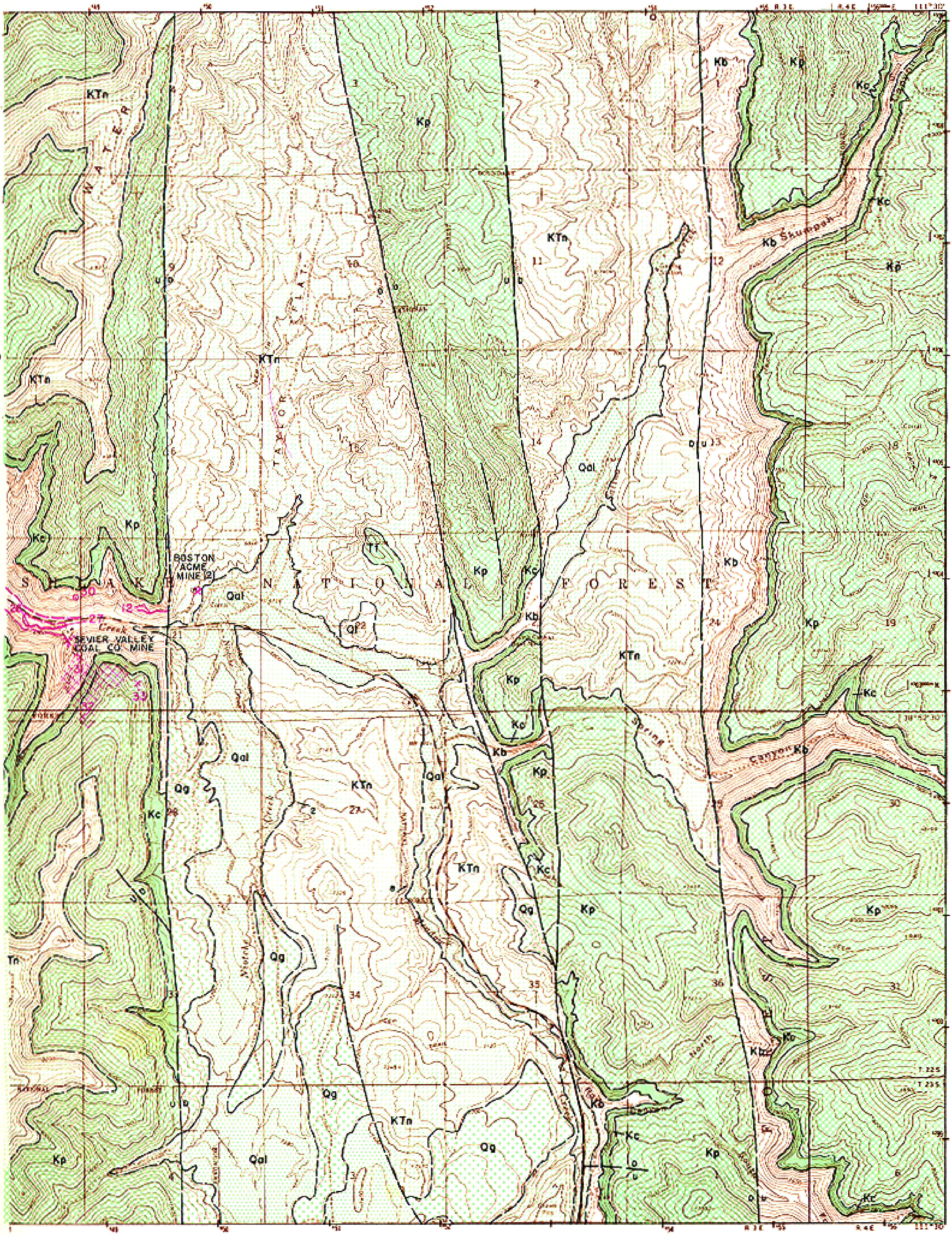


Figure 14. Coal and geology map, Salina Canyon quadrangle (explanation pages 22-23).


KTn
Kp
Kb
Kc
Qal
Qg
Tt
Skumpah
BOSTON ACME MINE (2)
SEVIER VALLEY COAL CO. MINE
NATIONAL FOREST
Spring
Canyon
Creek
TAYLOR FLAT
WATER
Notch

Concealed; slope shows evidence of carbonaceous shale	26.0
Sandstone, buff, fine-grained, massive	12.0
Sandstone, and shale, in thin-bedded alternation	12.0
Sandstone, gray, weathering buff, fine-grained, platy	22.0
Shale, gray	1.5
Coal, resinous	0.8
Shale, gray, carbonaceous at top	6.0
Sandstone, gray, fine-grained, massive	4.3
Shale, gray	0.1
Coal, resinous	1.6
Concealed, probably shale	3.0
Sandstone, buff, fine-grained, massive	3.0
Shale, gray	16.5
Sandstone, fine-grained, gray, massive	9.0
Concealed	
Total	537.7

Apparently the Price River Formation with its basal Castlegate Sandstone Member conformably overlies the Blackhawk. An unconformity is demonstrable in other areas of the region, Gunnison Plateau and north Wasatch Plateau, but it cannot be demonstrated in Salina Canyon. The Castlegate is composed of massive beds of medium- to coarse-grained sandstone with lenses of conglomerate. The resistant, cliffy Castlegate is easily differentiated from the Blackhawk by color. The overlying unit weathers to buff and light gray which contrasts with the browns of the Blackhawk. Occasionally some shales and even thin coal beds occur. Spieker and Baker (1928, p. 142) report:

> At the tunnel on the old railroad grade in Salina Canyon in SW.¼ sec. 9, T. 22 S., R. 2 E., the Castlegate Member contains a bed of alum-bearing sandstone. The top of the member passes beneath creek level not far west of the tunnel, and the tunnel is cut through a projecting point of the massive sandstone. The alum-bearing bed is about 50 feet beneath the top of the member, and it consists of fine-grained dark-gray nodular sandstone, apparently impregnated throughout with alum and containing thin layers of crystalline alum in the joint planes. It contains very thin seamlets of bright coal. It is best exposed in a cavelike hollow in the cliff, about 100 yards north of the tunnel. The bed is very lenticular and is probably not worthy of attention as a commercial source of alum.

The Price River Formation above the Castlegate is lithologically similar except for the presence of 25 percent shale. The Price River is also a resistant unit but breaks down into ledges rather than appearing as a single massive cliff. In the Salina Canyon area the Castlegate is 230 feet thick and the Price River is in excess of 700 feet.

The North Horn and Price River formations provide the upper surfaces of the Wasatch Plateau in this area. The North Horn grades down into the Price River and in most cases it is difficult to find a clearcut boundary. The North Horn characteristically contains bright variegated shales and the contact may be drawn below the first bed of such shale. The total thickness of the slope-forming North Horn in the Salina Canyon area is 700 to 1,000 feet. The lower part consists of about 500 feet of variegated shale, gray and cream sandstone and occasional conglomerate. The upper part consists of alternating shale, sandstone and limestone. Unconsolidated deposits of alluvium, assorted gravels and landslides are in valleys and canyons.

STRUCTURE

The most obvious structural feature of the Salina coal field is the faults of the Musinia and Water Hollow zones. All the faults trend north-south and many extend miles beyond the mapped area. The east group of faults (those east of the Sevier Valley coal mine) are a part of the Musinia fault zone. The rocks between the bounding faults have sunk into a graben and the middle faults produce a horst. The exact position of the faults often is obscured but the strata on each side of the faults attest to the displacements. The east Musinia fault places North Horn beds opposite the Blackhawk and near Skumpah Creek a maximum displacement of 2,500 feet has been measured. The horst in the center of the zone is structurally 500 to 600 feet lower than the area east of the east-bounding fault. The west Musinia fault also places North Horn against the Blackhawk at Salina Creek where the displacement is believed to be about 2,000 feet. The downfaulted block may be riven by additional unshown faults of lesser magnitude. The width of the graben is about 3 miles (figure 15).

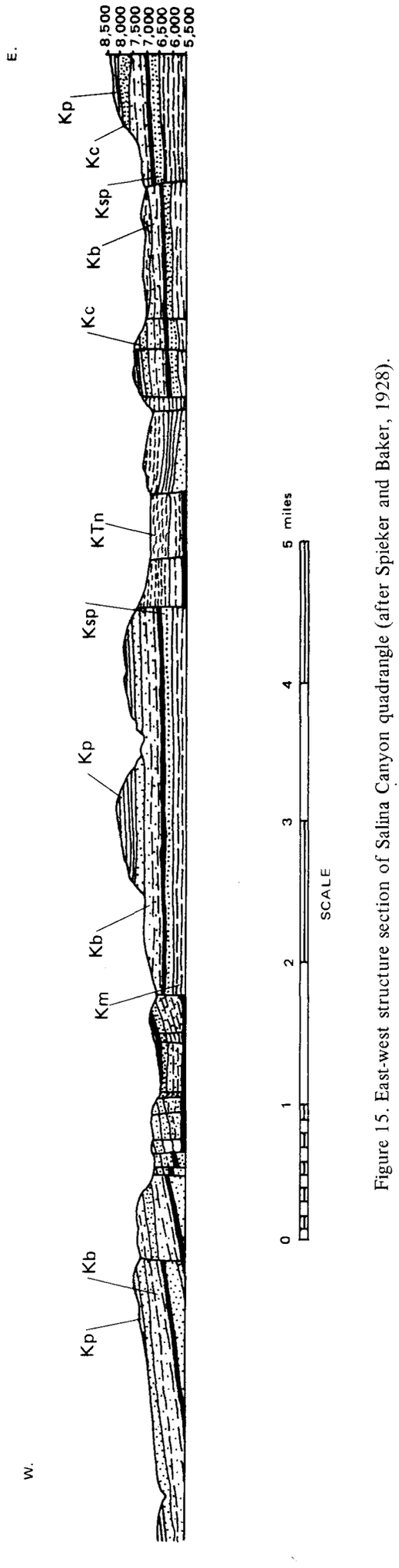


Figure 15. East-west structure section of Salina Canyon quadrangle (after Spieker and Baker, 1928).

About 3 miles west of the west boundary fault of the Musinia graben is the east boundary fault of the Water Hollow fault zone. It is similar to the Musinia structure with the rocks between the bounding faults sunken into a graben. The width of the Water Hollow zone at Salina Canyon is approximately 2 miles. The displacement of the east border fault is about 500 feet and the displacement of the west fault is about 650 feet. The central graben is riven by numerous paralleling faults some of which have not been mapped. All the faults are classified as high-angle faults.

The rocks are gently warped in the Salina Canyon area. Bachman (1959, p. 43) called the most conspicuous flexure the Salina Canyon arch which trends east-west and is superimposed over Salina Canyon from the Musinia graben westward. Although the feature is locally interrupted by faulting in the zones it can still, in most cases, be recognized. Dips to the north and south of the anticlinal feature are usually gentle (up to 7 degrees), but, locally other flexures, not of the areal magnitude of the first, bend the rocks more steeply. According to Bachman (p. 44):

> Several folds of minor order are seen in the Blackhawk Formation where it is exposed in Salina Canyon. One in the south bank of Salina Creek in the E ½, sec. 20, T. 22 S., R. 3 E., has resulted in the only exposure of the lowest coal bed known in Salina Canyon. . .Another fold is exposed in the cut on the north side of Utah Route 10 (I-70) in sec. 18, T. 22 S., R. 3 E. It is a small anticline exposed to a breadth of about 150 feet, whose limbs have a maximum dip of about 6 degrees. Poor exposures conceal the upward expression of both of these folds, but to all appearances they die out before reaching the base of the Castlegate Sandstone.

North, south and east of Salina Canyon the rocks are present in normal plateau fashion. West of the Water Hollow fault zone the rocks dip gently to moderately westward as a part of the Wasatch monocline.

PROPERTY CONTROL

The lands as shown on the mapped area (figure 9) are mostly under the control of the National Forest Service (61.7 percent) or privately owned (37.3 percent). The remaining 1 percent is divided between Bureau of Land Management and the state of Utah. The private lands are concentrated in the flatter areas around the Musinia graben.

Practically all of the land east of the Musinia fault zone is leased by J. H. Knight (1970) and is in reality a part of the Wasatch Plateau coal field. None of the land in the Salina Canyon coal field proper is under lease or is held for coal.

COAL

Surface Information

The following approximates the stratigraphic position of the coal beds between the Musinia and Water Hollow fault zones:

	Feet
Castlegate Sandstone	
Interval	±170
Wilson coal zone	
Interval	±215
Sevier coal zone	
Interval	±280
Upper Ivie coal zone	
Interval	±110
Star Point Sandstone	

The Wilson bed or zone is named for the old Wilson mine which was developed in it in 10-22S-2E. Twelve sections are available (figure 16), mostly on the west side of the Water Hollow fault zone. No individual bed of coal is 4 feet thick, but one bed at location 9 had 4.8 feet of coal with a ½-foot shale split. The average minable thickness in that area is about 3 feet.

The middle zone, the Sevier bed or zone, is similar to the Wilson bed. Again at localities 13 to 25 no single bed reaches a minimum of 4 feet in thickness; these localities are situated between the two fault zones. Locality 22 has the best showing, 6.2 feet of total coal split three times by 0.7 feet of shale.

The lower zone is the Upper Ivie bed which is correlated with the bed of the same name in the Wasatch Plateau coal field. Only two sections are available, both close to the abandoned Sevier Valley coal mine which operated in it. Location 26 had 6.2 feet of coal and location 27 had 10.8 feet of coal.

Subsurface Information

Spieker and Baker (1928, p. 155) note that private drilling was underway in the area between the fault zones, but the results were unavailable for their report. The following holes were drilled to the Upper Ivie bed in 1965 (table 15).

Table 15. Location of holes drilled in the Upper Ivie bed, Salina Canyon quadrangle.

Number	Location	Depth to coal bed (ft)	Thickness of coal (ft)
28	NW.NW.20-22S-3E	244	4.7
29	NE.NW.20-22S-3E	266	5.3 (split)
30	SE.NE.20-22S-3E	142	6.3 (split)

In addition three sections, localities 31, 32 and 33, come from the Sevier Valley mine. The total coal in these sections varies from 4.7 to 7.5 feet. To the east of the Musinia fault zone the Upper Ivie is known to average 9 feet thick (Wasatch Plateau coal field) at depths 750 to 900 feet below the surface. No coal sections are available west of the drill holes in section 20 but it is thought that the bed continues to thin westward.

Quality of Coal

Thirteen analyses are available for Salina Canyon coal field (table 9). A summary of proximate analyses from the Salina Canyon coal field is as follows (table 16):

Table 16. Average proximate analyses of coal, Salina Canyon quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	13	7.6	5.7 -14.9
Volatile matter	11	42.2	34.4 -45.6
Fixed carbon	11	42.2	36.3 -48.3
Ash	13	9.8	4.2 -13.2
Sulfur	12	0.45	0.32- 0.60
Btu/lb	11	11,367	9,690-12,080

Most of the samples were collected in the Sevier Valley mine and the Upper Ivie bed. Walker and Hartner (1966, p. 38) analyzed the sulfur in two of the Sevier Valley mine samples in more detail (table 17):

Table 17. Analyses of sulfur content of two Sevier Valley mine samples.

Mine	Bed	Percent			
		Sulfate	Pyritic	Organic	Total Sulfur
Sevier Valley	Upper Ivie	0.00	0.04	0.28	0.32
Sevier Valley	Upper Ivie	0.00	0.09	0.48	0.57

Spieker and Baker (1928) note that most of the coal beds are resinous, especially the upper beds. Buranek and Crawford (1952, p. 6-9) treat the subject in more detail and note that selected samples may contain up to 15 percent resin by volume and the average coal contains 8 percent.

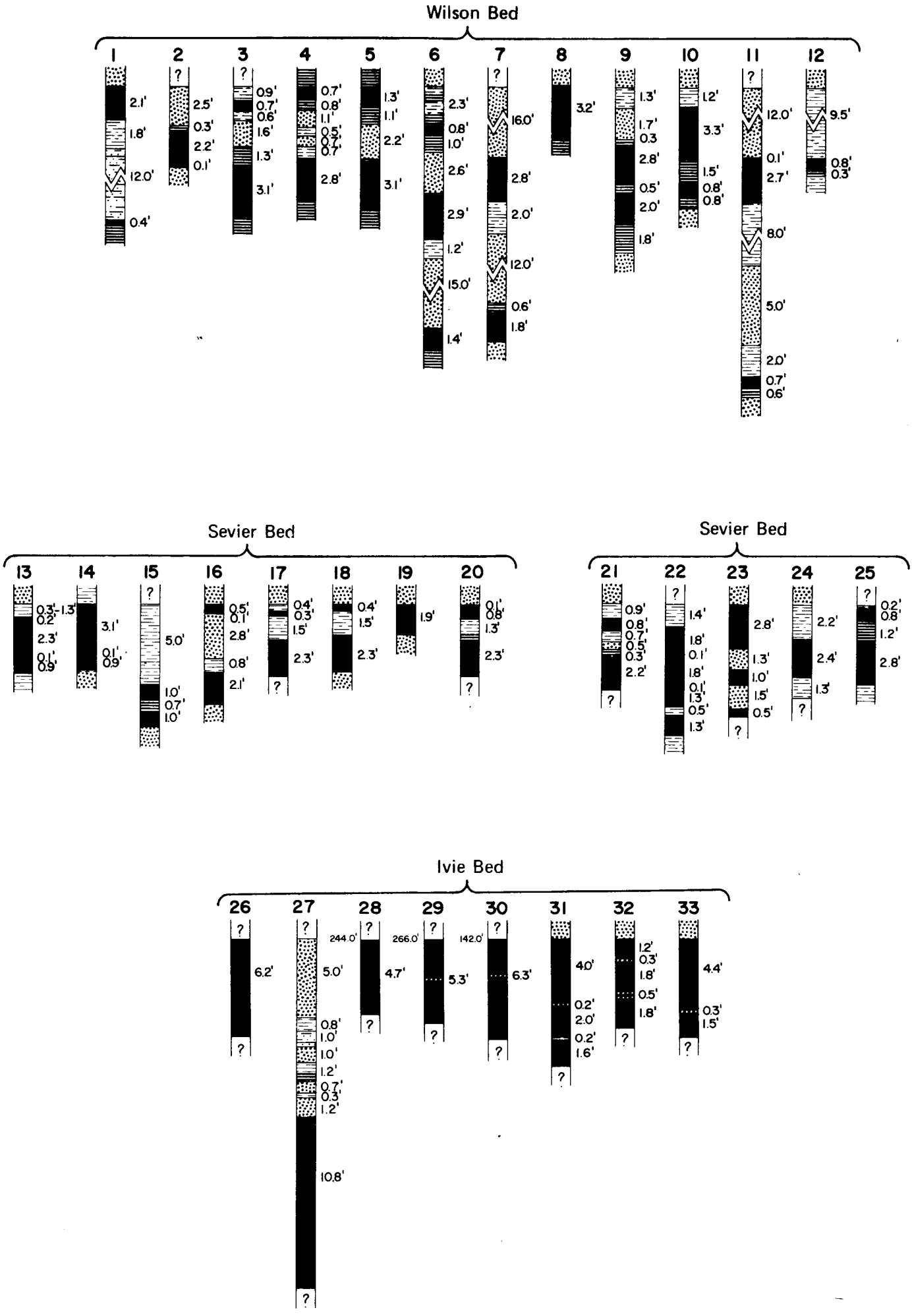


Figure 16. Coal sections of the Salina Canyon quadrangle (vertical scale: 1 inch = 8 feet).

Mines and Development

At least five mines and some additional prospects have operated in Salina Canyon. They are listed with pertinent information below (table 18):

Table 18. Mines and prospects, Salina Canyon quadrangle.

Mine	Location	Remarks
Boston Acme No. 1 Sevier bed	NE.SW.18-22S-3E 4,304,940m.N. 466,370m.E.	Active 1923
Boston Acme No. 2 Upper Ivie bed	SE.NW.21-22S-3E 4,303,950m.N. 449,865m.E.	1925-?
Kearns and Duggins mine (Coal Hollow) Sevier bed	NW.18-22S-3E 4,306,025m.N. 445,750m.E.	Intermittently active 1910-1925
Sevier Valley Coal Co. prospects Sevier bed	20-22S-3E several locations, south side of canyon.	Prior to 1923
Sevier Valley mine Upper Ivie bed	NE.SE.20-22S-3E 4,303,525m.N. 448,780m.E.	1924-1933 1944-1953
Wilson mine Wilson bed	SW.SE.10-22S-2E 4,306,360m.N. 441,910m.E.	1911-1935

The Boston Acme No. 1 group of mines was discussed by Spieker and Baker (1928, p. 166):

> A prospect tunnel on the Sevier bed has been driven by the Boston Acme Mining Co...This tunnel trends N.45°E and has been driven 182 feet in 1923. The coal bed is only 2 feet 3 inches thick as measured at the mouth of the mine, but between the coal and a good sandstone roof are 1 foot 6 inches of shale, 4 inches of coal and 5 inches of shale, and by mining out the overlying shale the tunnel was made high enough for work. A prospect pit has been dug on a higher coal, above the tunnel of the Boston Acme Co., but this coal is only 1 foot 5 inches thick.

The Boston Acme No. 2, a shaft mine, opened about 1925 with a 175-foot shaft sunk east of the west boundary fault of the Musinia zone and tunneled across the fault to the Upper Ivie bed. From available information the coal bed was 5½ feet thick. Shortly after the development of the tunnel the shaft caved; mining halted and the project was abandoned.

The Kearns and Duggins mine located in Coal Hollow operated in the Sevier bed. Spieker and Baker (1928, p. 166) report that the mine had not operated since their visit in 1914 and that the road had fallen into disrepair:

> The remains of coal bins and other equipment standing at the mine give evidence of considerable activity there in past years. The workings are fairly extensive. The main entry extends to the north and east nearly 350 feet from the mouth and large rooms have been mined out on each side of the entry. A crosscut from the main entry reaches the surface at the falls in Coal Creek. The mine was equipped with rails and steel cars for transporting the coal to the surface. The coal was hauled to Salina by wagon.

Spieker and Baker further report on the Sevier Valley Coal Co. prospects, all on the south side of Salina Canyon in sec. 20-22S-3E. Three tunnels, one 125 feet long, another 50 feet long and a third of unknown length were dug and the company proceeded to develop the coal field's most successful mine. It was opened by one shaft for haulage and another inclined for a manway and air return. Sinking operations, unfortunately in bottom land about 150 feet south of Salina Creek, began in 1924 and were completed in 1926. The D & RGW Railroad simultaneously constructed a branch line to the mine site from Salina, a distance of 18 miles. The shaft was equipped with a headframe and automatic dumping equipment; a double drum hoist was installed on the surface so that loaded mine cars could be hoisted and the coal dumped automatically into bins while the empty mine car was descending. The mine equipment consisted of mine cars, track haulage and an electric motor to transport the mine cars.

The mine operated from 1926 to 1933 when it was forced to close down because of the recession, resultant high mine costs from pumping 80 gpm continuously to prevent flooding of the mine and general adverse mining conditions. To remove bone and rock from the coal added to mine costs and it was difficult to produce a clear product for market. Nevertheless, during those years the mine produced approximately 230,000 tons of coal. The mine remained closed until 1944 during which time it filled with water. In the dawn of World War II the railroad tracks were lifted for use elsewhere. In 1944 Otto Reichert, Price, Utah, purchased the fee land on which the mine was located and leased adjoining government lands. By February of 1945 he had pumped the water from the mine and rehabilitated the surface installations. Even though plagued by high mine costs coupled with a shrinking coal market, he managed to produce about 189,000 tons of coal until December 1953. The property is now completely abandoned.

At the time of Spieker and Baker's visit in 1923 the Wilson mine was the only active mine. Presently two dumps high on the cliff above the highway mark the former operation. They report that hand-drawn cars transported the coal to the mine mouth which unloaded into a chute emptying into a bin along the road. It is estimated that 7,000 tons of coal were removed from the Wilson mine in which the coal was 3 feet thick.

Thus an estimated 430,000 tons of coal were removed from the coal beds of the Salina Canyon coal field.

Reserves

If only coal beds more than 4 feet thick are considered in a calculation of the reserve, then only the Upper Ivie bed may be considered important. Spieker and Baker (1928, p. 151-162) discussed all beds in some detail and assigned reserve figures (table 19):

Table 19. Reserves calculated by Spieker and Baker (1928) for the Salina Canyon quadrangle coal beds.

Wilson bed reserves Location:	Tons
Westernmost block of Water Hollow fault zone, ext. 2 miles north of Salina Canyon	3,000,000
Westernmost block of Water Hollow fault zone, ext. 1 mile south of Salina Canyon	2,300,000
9-22S-2E	2,300,000
10-22S-2E	2,900,000
15-22S-2E	2,000,000
16-22S-2E	2,300,000
	14,800,000

Sevier bed reserves
Locations included in calculation below:

T.22S. R.2E.
sec. 12, small strip in SE corner.
sec. 13, strip on east edge 0.1 to 0.3 miles wide.
sec. 14, strip on east edge about 0.4 miles wide.
T.22S. R.3E.
sec. 7 southern third.
secs. 18, 29 all.
sec. 17 western two-thirds.
sec. 20 NW; W 1/2 SW; NW.NE.

Average thickness – 2.5 feet
Area = 5.3 square miles or 3,392 acres
Tonnage 15,300,000 tons.

Spieker and Baker also estimated figures for the Ivie (?) bed which is probably the Upper Ivie for the area east of the Musinia fault zone: 123,550,000 tons for the west half of T. 22 S., R. 4 E. They inferred that thick coal lies in the Musinia graben at a depth no more than 2,300 feet beneath the surface. In the central horst, where the coal is expected to be less than 700 feet beneath the surface, they estimated 17,250,000 tons of coal. They were cautious west of the zone. They estimated that at least one square mile existed in which the coal averaged 6 feet thick and 7 million tons were assigned to it.

Pearce (1970) made another estimate of the reserves of the Salina Canyon field based on a lower thickness limit of 4 feet. Although the Wilson bed is more than 4 feet thick at one locality he assumes that this is a local occurrence and assigns no reserve. No reserve is assigned the Sevier bed as well. No coal sections for the Upper Ivie bed are available west of the 1965 drill holes and so the presence and/or workability of the coal bed cannot be predicted west of the center line of secs. 6, 7, 18, 19, 30 and 31, T. 22 S., R. 3 E. or about 2 miles west of the Musinia fault zone. The predictable area is 7,680 acres in which the coal averages 5 feet for 69.1 million tons of coal. Concerning the recoverable coal in the Musinia fault zone, Pearce contemplates the area is plagued by major and subsidary faults, attendant shear zones and a wide disparity in depths of up to 2,500 feet below the surface. In his opinion it would be misleading to estimate available coal in this area until it can be drilled and possible minable blocks delineated. The present author agrees except for the horst of Spieker and Baker. In addition Pearce also calculated reserves in the west two tiers of sections in T. 22 S. and T. 23 S., R. 4 E. and in the part of T. 22 S., R. 3 E. east of the east boundary fault of the Musinia fault zone (table 20).

Table 20. Reserves calculated by Pearce (1970) for Salina Canyon quadrangle (4-foot lower limit).

Location	Acres	Avg. thickness (ft)	Tonnage
T.22S. R.3E.			
secs. 1,12,13,24	1,280	too thin	–
secs. 25,36	640	9.0	10,368,000
T.22S. R.4E.			
secs. 5-8,17-20	5,120	too thin	–
secs. 29-32	2,560	9.0	41,472,000
T.23S. R.4E.			
secs. 5-8,17,18	3,840	8.0	55,396,000
			107,136,000

The above reserves belong to the Wasatch Plateau coal field but are presented here because part of the area is portrayed on the Salina Canyon map and also to illustrate the trend in the coal bed which crosses the boundary. In summary Pearce's figures for the Upper Ivie bed west of the Musinia graben are accepted and Spieker and Baker's figures for the Upper Ivie in the central horst of the graben appear acceptable for Class I, Class II and Class III (measured, indicated and inferred) reserves. Other areas must be regarded as potential (Class IV). The potential blocks of coal land are illustrated on figure 17 and the reserves are summarized below (table 21):

Table 21. Potential (Class IV) reserves for the Salina Canyon quadrangle.

Location	Acres	Avg. thickness (ft)	Tonnage
Area 1 (West of Musinia graben)	7,680	5.0	69,120,000
Area 2 (Horst in Musinia graben)	1,600	6.0	17,250,000
			86,370,000
Wasatch Plateau coal field Area 3			107,136,000
			193,506,000

PRINCIPAL WORK

Spieker and Baker (1928), U. S. Geological Survey geologists, investigated the geology and their work was supplemented by Baughman (1959) and Bachman (1959), Ohio State University. The coal data came mainly from Spieker and Baker supplemented by Pearce (1970b).

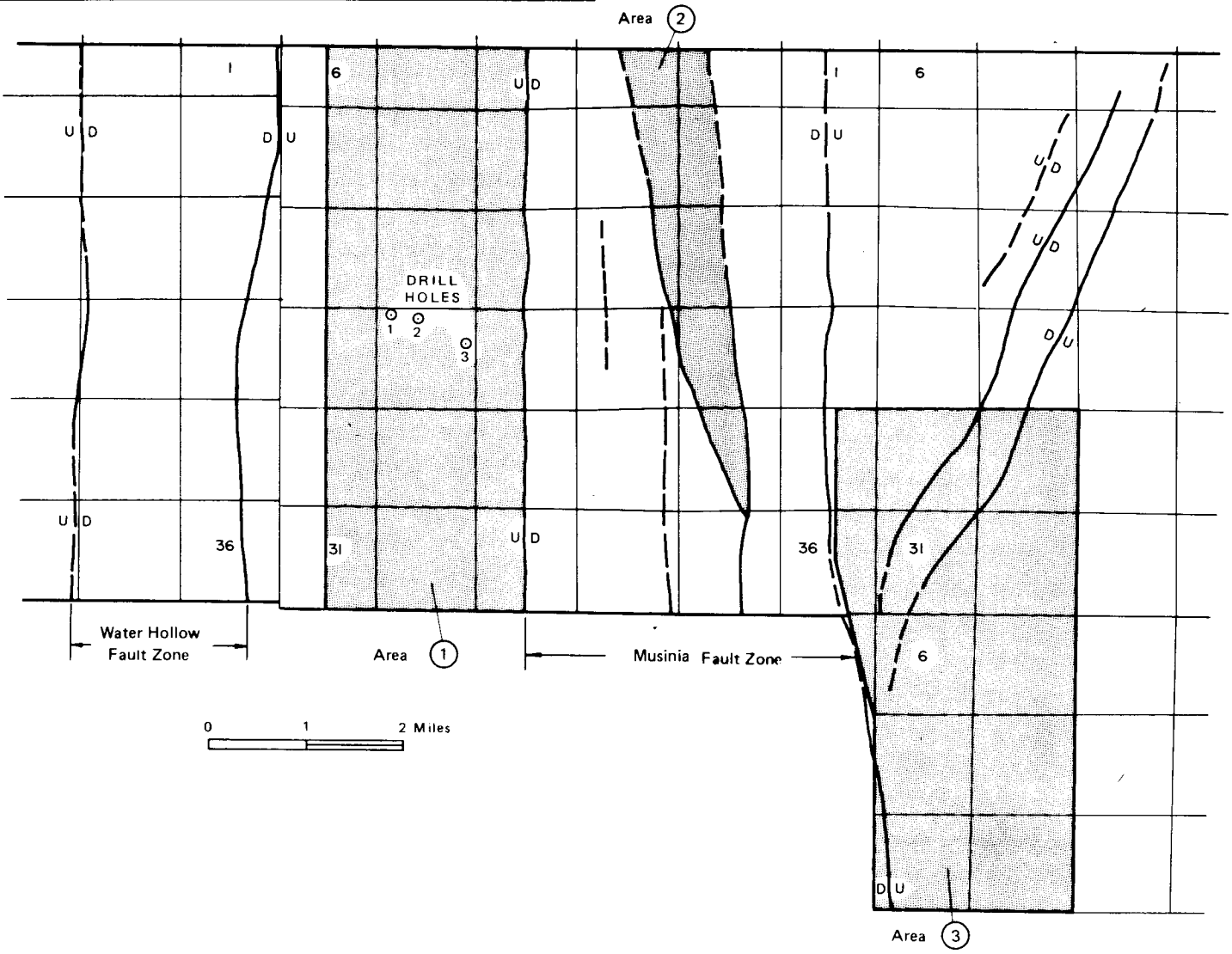


Figure 17. Faults and reserve map, Salina Canyon quadrangle.

STERLING QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Sterling quadrangle is located entirely within Sanpete County and includes the narrow area between Sanpete Valley to the north and Sevier Valley to the south (figures 10 and 18). Two towns are situated on the quadrangle area: Mayfield and Sterling, both small farming communities. The larger community of Gunnison lies 4 miles to the west and the larger community of Manti is located 2 miles north of the quadrangle.

The east part of the map is mountainous and represents the west part of the Wasatch Plateau. The relief in the vicinity of Sterling is 3,400 feet. The principal canyon cutting into the plateau is Sixmile Canyon around which the Sterling coal field is centered. To the west are a series of low ridges and narrow valleys. The relief here is about 600 to 900 feet. The San Pitch River flows through one of these narrow valleys southward. Sixmile and Twelvemile creeks are tributary to the San Pitch. Three large reservoirs on the quadrangle include the Gunnison Reservoir, Ninemile Reservoir and Palisade Lake. Elevations of the valley areas vary between 5,200 and 5,400 feet; the coal area ranges from 5,950 to 6,300 feet and the top of the plateau is almost 9,000 feet.

Sterling is served by U. S. Highway 89 and is joined to Mayfield by Utah Highway 137. A network of graded roads provides access to the ridge and valley area but access into the Wasatch Plateau is poor. A dirt road extends up Sixmile Canyon, however, to provide access to the coal field.

STRATIGRAPHY

Only the north two-thirds of the quadrangle are mapped geologically but almost the entire geologic column is represented. A thrust fault just east of the Gunnison Reservoir divides the west half of the mapped area from the east half. The sequence to the west is related to Gunnison Plateau geology in which the Indianola Group is undifferentiated. If the mapping is accurate, the column to the west starts with the oldest Arapien Shale against the thrust, then the Morrison ? Formation, thin and discontinuous occurrences of the Indianola Group, a thin exposure of the North Horn and the Flagstaff, Colton and Green River formations. The details of this part of the geology are unimportant to coal and are not further discussed.

The Sterling coal field lies on the east half of the mapped area (figure 18). Here the oldest rocks are the formations of the Indianola Group. The Sanpete Formation crops out in northeast-trending ridges northeast of Sterling. The ridges are surrounded by alluvium so that the true thickness cannot be ascertained but is estimated to be 1,350 feet thick. The Sanpete is mainly a buff to gray sandstone but also contains some shale and conglomerate. Between the Sanpete Ridge and the next ridge to the east is a narrow valley filled with alluvium beneath which the Allen Valley Shale occurs. The shale is a gray Mancos-like shale, 600 to 800 feet thick. The next ridge which flanks the lower part of the Wasatch monocline is composed of the remaining two formations in the Indianola Group. The first is the Funk Valley, mostly buff to brown sandstone with subordinate marine gray shale or conglomerate. The unit is about 2,250 feet thick and its exposures surround Palisade Lake, formerly called Funk Lake.

The Sixmile Canyon Formation is exposed on both sides of the lower part of Sixmile Canyon and is the upper and coal-bearing part of the Indianola Group in this area. The lower part of the unit consists of conglomerate and overlies the Funk Valley conformably. The attitude of the beds at the contact is slightly overturned and the truncated beds are unconformably overlain by the nearly horizontal Flagstaff Limestone. About a mile up the canyon the Sixmile is overlain in angular relationship by the massive sandstones of the Castlegate. The Sixmile in this area dips 20 to 40 degrees eastward. The lower conglomerate is about 2,000 feet thick and is followed by a middle coal-bearing member containing gray to cream colored and white fine-grained sandstone, gray to white shale, carbonaceous shale and coal that is 300 feet thick. The upper member consists of conglomeratic sandstone and conglomerate and 425 feet are exposed in Sixmile Canyon. At least six beds of coal have been located, but only one is thick enough to mine.

The Price River Formation, including the Castlegate Sandstone, is exposed in the east part of Sixmile Canyon. The Castlegate consists mainly of thick, massive, cliff-forming, fine- to medium-grained, white to gray sandstone with a minor quantity of conglomerate or coarse-grained sandstone. The Castlegate contains at least one lenticular carbonaceous bed consisting of very poor coal and carbonaceous shale 3 feet thick. The upper part of the Price River is lithologically similar to the Castlegate but the upper part is less massive and contains some reddish shale similar to that in the North Horn. The entire unit is 541 feet thick in Sixmile Canyon.

The North Horn Formation overlies the Price River in the east part of Sixmile Canyon and is conformable and gradational with it. The unit can be easily recognized even from a distance by its overall reddish color which overshadows the irregular bedding and varying lithology. The lower 600 feet of the unit consist of alternating variegated shale, fine-grained calcareous sandstone and thin conglomeratic beds. The upper part consists mainly of brilliantly colored alternating bands of red and purple shale. Dinosaur remains were discovered 300 feet above the base of the 900-foot formation, but no carbonaceous beds were reported.

The Flagstaff Limestone is the uppermost and youngest unit in the Sixmile Canyon area. It produces steep cliffs around the rim of the canyon. In the west part of the canyon the Flagstaff bends and dips westerly as part of the Wasatch monocline. The unit is 50 to 75 feet thick at its westernmost exposures, but thickens to more than 540 feet along the east map margin. It overlies all older units with an angular relationship. The upper part of the Flagstaff is everywhere removed by erosion and the thickness presented is, therefore, incomplete.

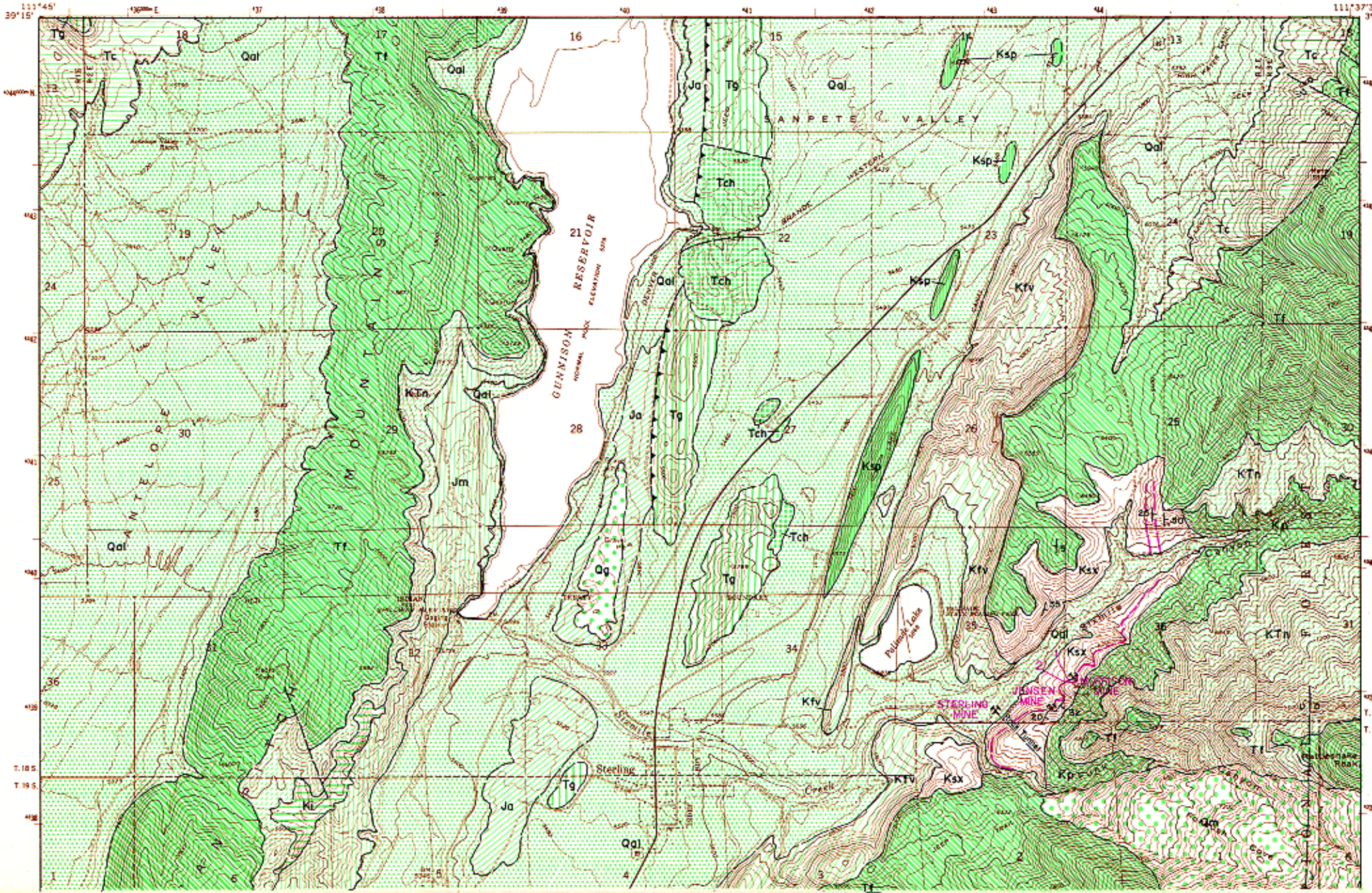
Still younger units are exposed away from the Sixmile Canyon area: the Colton, Green River and Crazy Hollow formations. Their outcrops are either along the edge of the Wasatch monocline or in the ridges west of Sterling. They are adequately described in figure 3.

STRUCTURE

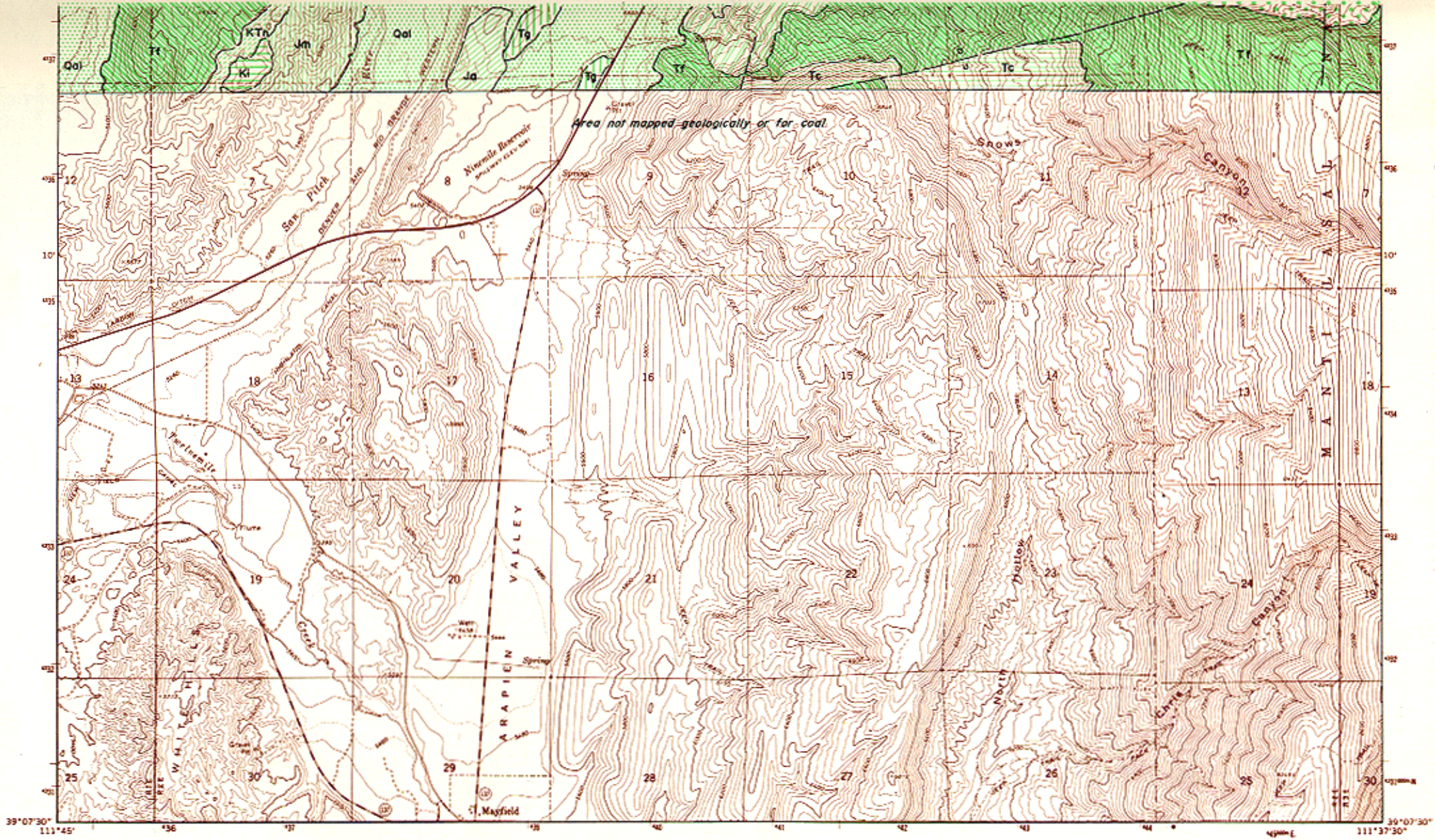
The structural relationships of the Sterling coal field were previously alluded to in the Sixmile Canyon Formation discussion in the Stratigraphy section. They are complex and have limited the size of the coal field. The geology illustrated on the map (figure 18) is general and probably several faults related to the steep folding are unmapped. The relationships are illustrated by the east-west cross section through Sixmile Canyon (figure 19).

The coal beds are located mainly along the south side of the canyon outcrops. The beds strike parallel to the canyon (northeast) and dip southeasterly 15 to 30 degrees. Coal outcrops on the north side, but it is limited areally and dips 25 to 50 degrees easterly.

STERLING, UTAH



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972



Topography by U.S. Geological Survey

SCALE 1:42240

1 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000

Contour interval 40 feet

Geology modified from E. M. Spieker, 1949, USGS; coal data by G. B. Richardson, 1906, USGS.

Figure 18. Coal and geology map, Sterling quadrangle (explanation pages 22-23).

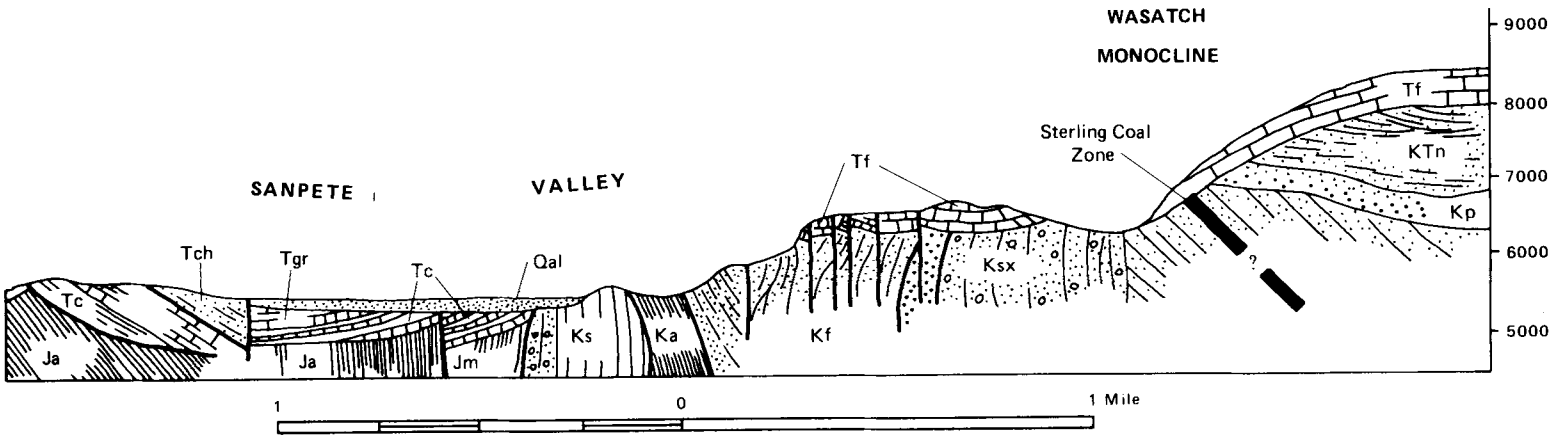


Figure 19. East-west cross section along Sixmile Canyon near Sterling quadrangle (after Spieker, 1949, p. 69).

PROPERTY CONTROL

Almost 60 percent of the land of the quadrangle are privately owned including all the coal lands. Bureau of Land Management property (20 percent) is located west and south of Sterling in scattered parcels. The National Forest Service (13 percent) controls the east map margin area and the state of Utah (7 percent) owns a few parcels south of Sterling. It is believed that no land is currently held for the purpose of mining the coal.

COAL

Surface Information

All the available coal data are from Richardson (1906, p. 283-284) and are presented on the coal section sheet (figure 20). Six seams or zones have been measured near the Morrison mine and each seam is separated from the next by 3 to 75 feet of sandstone. They are lenticular beds and at times split or coalesce. At one spot, beds 2 and 3 join at the expense of the intervening sandstone to produce a 4-foot coal bed, the thickest known in the field. According to Richardson (p. 284) the coal is lustrous black and much jointed in many directions and breaks easily into small pieces. The principal joints occur in two sets, east-west and north-south, and thin films of calcite occur along them. Small patches of resin are disseminated in the coal. Richardson notes that the best coal is confined to the area exploited and that it seems to be a local deposit. Thin beds have been located in the valleys immediately north and south of the known workings.

Subsurface Information

No drilling has taken place to prove the presence of coal. A rock tunnel (labelled the Sterling mine) through sandstone and shale intersected the bed near the level of the canyon floor 2,000 feet from the surface. Because of the steep dip and rapidly increasing overburden above the canyon floor, the coal is expected to reach great depth rapidly. Faults known to exist at the east have the downthrown blocks to the east.

Quality of Coal

The one available analysis (table 9) for the coal was derived from the number 2 bed (Sterling bed). The coal appears to be a high-volatile C bituminous coal with about 0.92 percent sulfur. Ash is low and moisture is 8 percent in the as-received sample. The coal will not coke.

Mines and Development

Three mines or prospects have been opened on the Sterling bed and all may be related in ownership (table 22).

Table 22. Mines and prospects, Sterling quadrangle.

Mine	Location	Remarks
Jensen mine Sterling bed	SE.SE.35-18S-2E 4,338,890mN 443,495mE	Activity unknown
Morrison mine Sterling bed	SW.SW.36-18S-2E 4,339,120mN 443,700mE	1888-1902
Sterling mine (Thomas and Tuttle mines) Sterling bed	SW.SE.35-18S-2E 4,338,850mN 443,040mE	1902-1935

Nothing is known about the Jensen mine. The Morrison mine commenced production about 1888 from openings on the hillside. Experiencing a water problem, the operators drove a tunnel in 1902 to the coal bed from the canyon floor level to drain the mine and to provide access to the coal. The tunnel, called the Sterling mine, is 2,000 feet long, 8 feet wide and 7 feet high near the outside opening. An 18-inch steel pipe is buried in the floor to conduct water. The tunnel has been maintained even after coal mining ceased to provide access to the source of water. Activity continued until about 1935 when the mine was finally shut down. According to Hileman, Collins and Wilson (1970, p. 43) the Sterling area produced about 60,000 tons of coal. At the time of greatest production the railroad extended to the mine mouth from Sterling. The water rights have been valuable and the Manti Water Board uses the drainage tunnel to increase irrigation supplies.

Reserves

Although six coal beds were counted in the vicinity of the Morrison mine in a 160-foot stratigraphic interval, only one bed 4 feet thick is locally minable. The thickness results from the disappearance of a sandstone tongue between two of the beds. The north-south extent of this thickened coal is not known but believed confined to parts of secs. 35 and 36, T. 18 S., R. 2 E. and to secs. 1 and 2, T. 19 S., R. 2 E. At various times (1927 to 1931) coal prospecting permits were granted in sec. 1, T. 19 S., R. 2 E. to individuals. The permits were subsequently relinquished and it is assumed that coal of economic importance was not found. The record indicates, however, that little if any exploratory work was done.

After examination of the outcrop and thicknesses at the surface it is assumed that little reserve in beds 4 feet thick exists. About 2 million tons might be assigned the coal field on an inferred basis. Part of this coal will be split by shale or bone. If thinner coal beds are considered, the reserve figure would increase by that amount.

PRINCIPAL WORK

Little work has been done on the Sterling coal field because of its minor potential. Richardson (1906) provided most of the coal data and the geology is a summary of work by Spieker (1949) and Wilson (1949). A reconnaissance visit was made by Utah Geological and Mineralogical Survey personnel for this presentation.

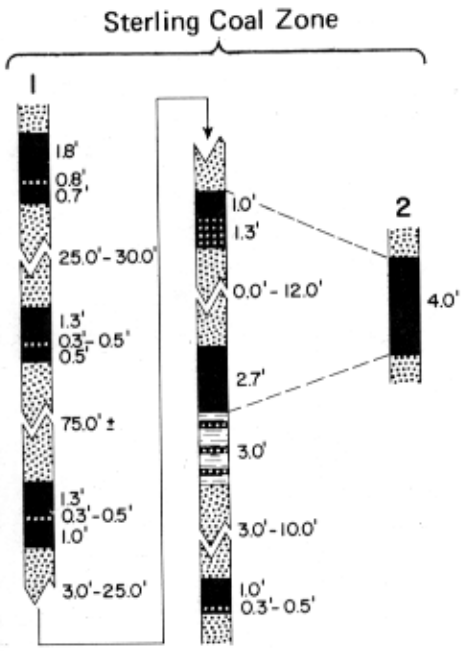
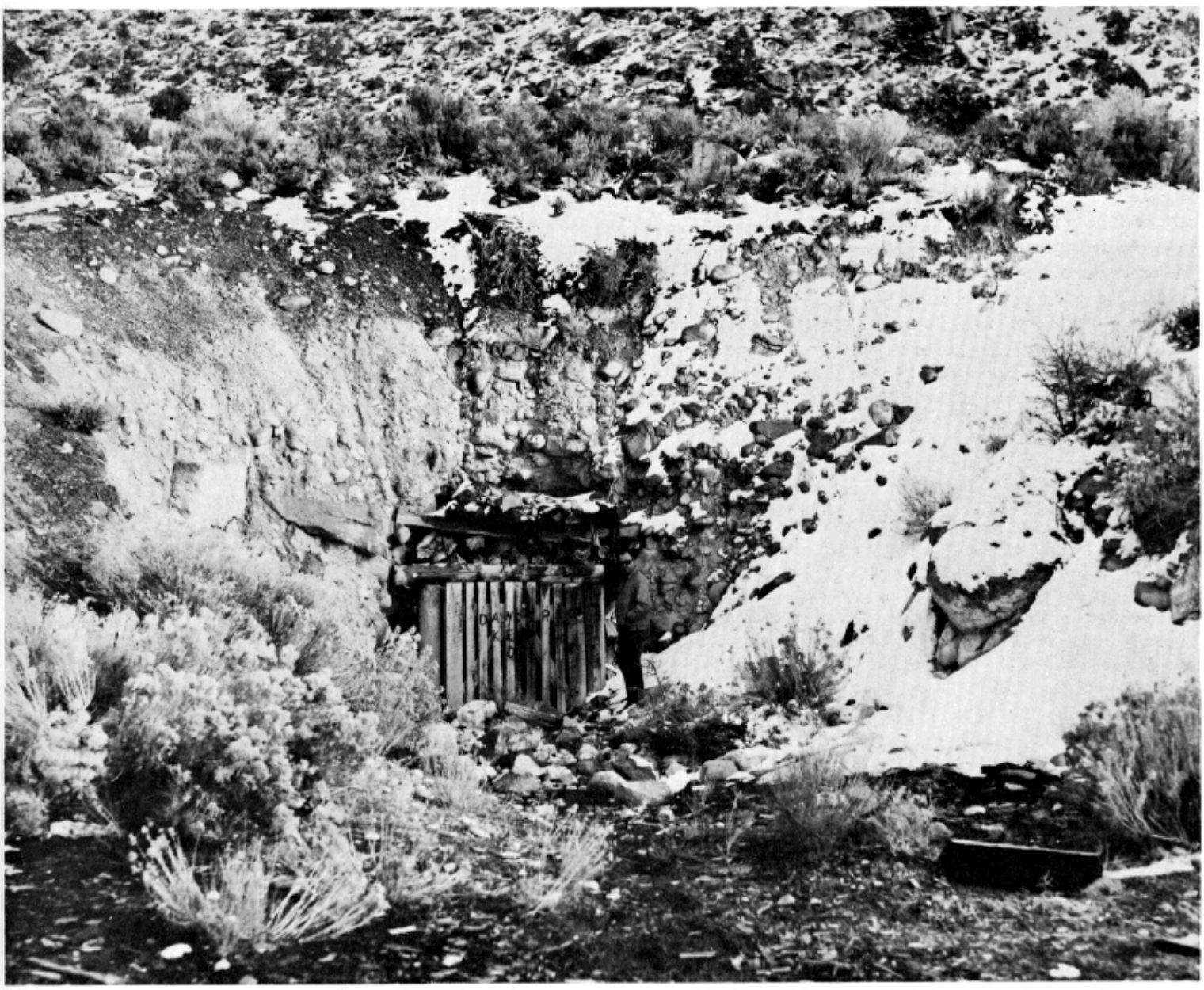


Figure 20. Coal sections of the Sterling quadrangle (vertical scale: 1 inch = 8 feet).

Coal from the Morrison mine was mined from three openings on this hillside (circled), about 1,500 feet east of rock tunnel opening (below). (Photo by C. S. Westerberg, 1970.)



Entrance to 2,000-foot rock tunnel driven about 1902 to coal bed, Morrison mine, Sterling quadrangle. It is maintained as an irrigation water source. An 18-inch steel pipeline is buried just below the surface.

Lower part of the Wales Member of the North Horn Formation in Wales Canyon. The slope is supported by resistant limestone beds in the middle of the unit; coal is sandwiched between the limestone beds.

Coal and shale sandwiched between limestone beds in Wales Canyon. Middle member of the North Horn Formation.

WALES QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Wales quadrangle is situated on the east flank of the Gunnison Plateau near the middle of its north-south dimension (figures 10 and 21). Wales village is found in the northeast map corner and lies opposite of Spring City in Sanpete Valley. Most of the quadrangle is in Sanpete County, but the northwest corner is a part of Juab County.

Sanpete Valley lies at elevations 5,400 to 5,800 feet above sea level. The initial cliffs of the Gunnison Plateau rise to more than 7,800 feet. Along the plateau divide the elevation exceeds 8,300 feet. Deep canyons have cut into the plateau front in which the coal is exposed.

A graded road parallels the plateau at its base and Utah Highway 117 serves Wales and connects the town with U. S. Highway 89 four miles to the east. Almost every ridge on the plateau top is served by a dirt road.

Some confusion exists in the names of many of the physical features of the quadrangle. Most of the names used in this report correspond to those portrayed on the geologic map. One exception is the Gunnison Plateau which appears on the map as the San Pitch Mountains. In earlier reports Wales Canyon was called New Canyon. The canyon immediately to the south is unnamed on the quadrangle but has been called Old Canyon, Boiler Canyon and Coal Canyon in previous reports. In this report Boiler Canyon is preferred.

The next canyon south is called Petes Canyon on the map, but has been called Peach Canyon and Indian Pete Canyon. Farther south both the canyon presently marked Coal Canyon and the smaller one immediately to the north have been termed Coal Canyon. The Left Hand Fork of Axehandle Canyon at times has been called the South Fork.

STRATIGRAPHY

Along the base of the plateau are steeply dipping exposures of the Jurassic Arapien Shale and the Indianola Group. The Arapien is represented by the Twist Gulch Member in incomplete exposures. At the base of the plateau in front of Dry Canyon, 956 feet of sandstone and shale of red and gray color are exposed. The sands are subangular and fine- to medium-grained. In the Wales area the unit is exposed in an irregular north-south belt which varies in width from a few feet to about 1,000 feet. The beds, in general, are overturned dipping east. The thickest section noted was at the Boiler Canyon mouth between Wales and Petes canyons where 1,264 feet were measured.

The Indianola Group is exposed in a paralleling band just west of the Arapien outcrops which it overlies. The Indianola cannot be differentiated into its member formations in the Gunnison Plateau. Multicolored conglomerates dominate the lithology with fine- to coarse-grained, medium-bedded, red, yellow and white to dark gray sandstone and gray and orange shales. The unit is probably incompletely exposed; the maximum thickness observed near Wales is about 1,000 feet. The exposed thickness of the unit between Axehandle Canyon and Rock Creek is 391 feet.

An angular unconformity occurs above the Indianola Group and adjacent to Wales Canyon it is covered by the Price River Formation. It thins in outcrop southward and pinches out in the vicinity of Boiler Canyon. It outcrops in isolated patches still farther south. The Price River consists mostly of coarse conglomerate with a well cemented sandstone matrix. Occasionally lenses of sandstone mar the continuity of the conglomerate.

The North Horn Formation is exposed along the plateau front and in the lower parts of the canyons. The unit is very diverse in the area and is composed of a variety of continental deposits ranging from extremely coarse clastics to lacustrine limestones.

In Wales Canyon the formation is well developed in the general facies that is common in the central Wasatch Plateau, and is about 2,500 feet thick. Here it contains a prominent limestone member with beds of coal and oil shale that is a most unusual occurrence; below the limestone are variegated shales and buff sandstone, with much red shale and conglomerate at the base, and above it gray shale and calcareous siltstone with some paler variegated beds. This facies continues southward to Coal Canyon (Boiler Canyon) but in the passage to Peach Canyon (Petes Canyon), barely a mile to the south, the whole formation changes abruptly to massive sandstone and conglomerate, with very little shale. This sandstone makes the main body of the bulky promontory known as Point of the Mountain (Big Mountain) and it continues some 5 miles southward past Axehandle Canyon into the Dry Canyon embayment, where shale reappears and the formation begins to take on a more nearly normal aspect. South of Dry Canyon the whole interval changes to gray shale and calcareous siltstone with very little pale colored beds (Spieker, 1949, p. 29).

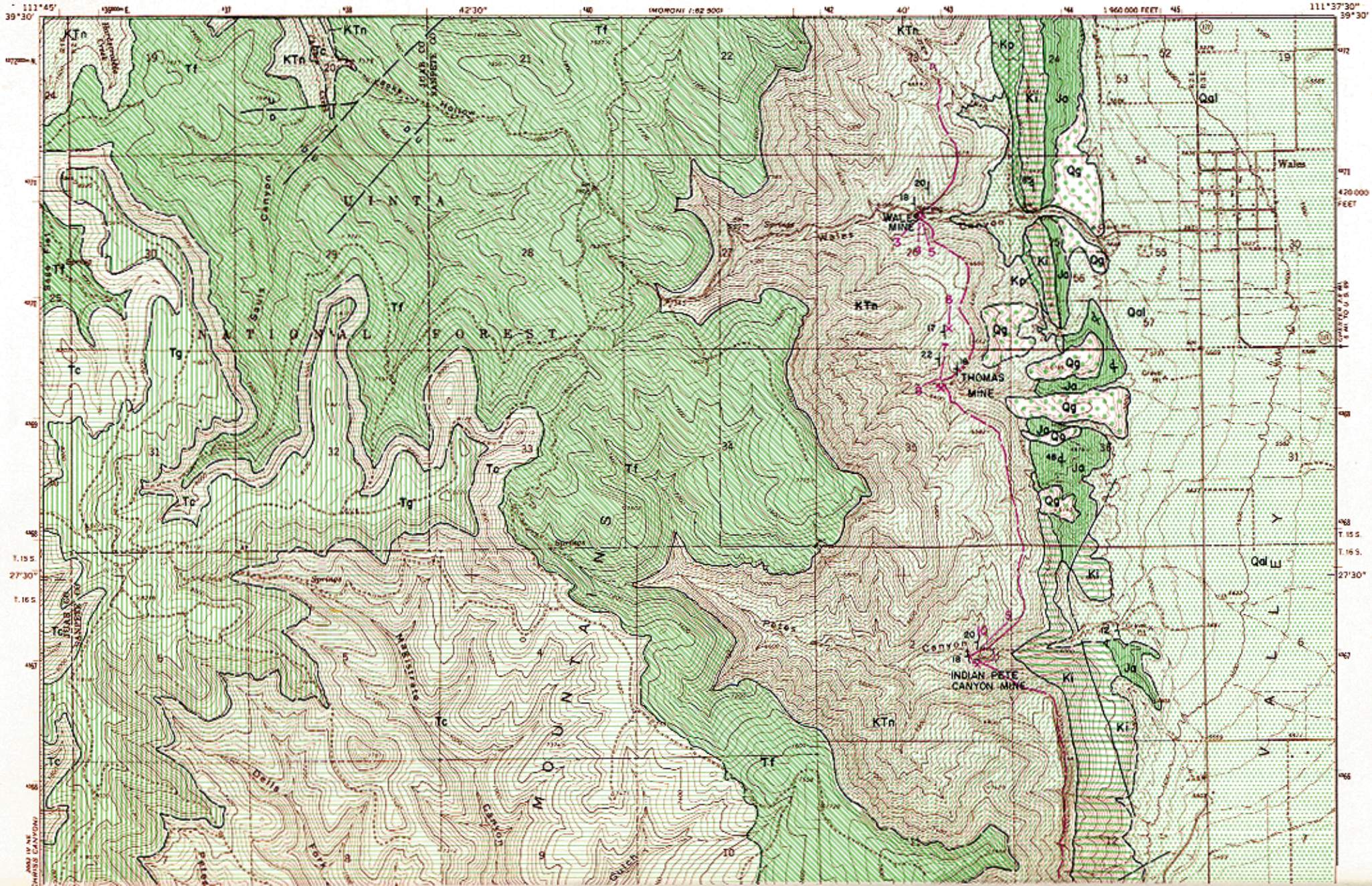
In Wales Canyon the North Horn is divisible into three members:

3. Upper Member: mostly gray limestone and shale, 1,647 feet.
2. Wales Coal Member: 323 feet.
1. Lower Member: variegated shale, conglomerate and sandstone, 1,195 feet.

Section of the Wales Coal Member, North Horn Formation in Wales Canyon on north side 26-15S-2E, by Hunt (1950).

North Horn Upper Member Wales Coal Member	Feet
94. Limestone, buff to dark gray, dense to finely crystalline sparingly fossiliferous. Limonite concentrations around many of the fossils. Massive- to medium-bedded. The top 15 feet are darker gray	36.0
93. Oil shale and limestone, like unit 85	8.1
92. Coal, very impure	1.0
91. Oil shale and limestone, like unit 85	3.6
90. Coal weathered, dull to bright. Contains two fossiliferous partings near the top	1.4
89. Oil shale and limestone, like unit 85	3.2
88. Coal, like unit 86. Contains a one-inch, brown clay shale parting	0.5
87. Oil shale and limestone, like unit 85	2.5
86. Coal, dull to bright, blocky, very impure	0.9
85. Oil shale, gray to dark gray, calcareous, fossiliferous. Interbedded with dark gray to buff, dense, to finely crystalline, fossiliferous limestone. The oil shale weathers bluish-gray at the surface	13.3
84. Limestone, dark gray to buff, dense. Interbedded with gray, silty, calcareous, fossiliferous shale. Top ledge of limestone weathers into chips	13.4
83. Limestone, dark gray to buff, dense, fossiliferous. Medium-bedded to shaley	1.2
82. Shale, light gray, silty, calcareous. Very fossiliferous, almost a marl in places	0.6
81. Coal, like unit 78	2.3
80. Shale, buff, silty	1.0
79. Limestone, dark gray, dense, fossiliferous	0.7
78. Coal, very impure, crumbles into a powder	1.5
77. Limestone, dark gray, dense, very fossiliferous. Contains dark gray fossiliferous, calcareous oil shale, light gray fossiliferous, marl	5.4
76. Coal, black, very impure. Overlain and underlain by a persistent, thin marly zone varying from one to two inches thick	0.3
75. Limestone, gray to buff, dense to finely crystalline. Thinly bedded to shaley. Fossiliferous	5.3
74. Marl, gray to white, some ferruginous staining, fossiliferous	0.4
73. Limestone, gray, dense, very fossiliferous, almost a coquina. Shaley at the base	1.3
72. Clay shale, gray, sandy, calcareous, grading upward into gray to buff, sandy, calcareous, shale. Fossiliferous near the top	10.0

WALES, UTAH



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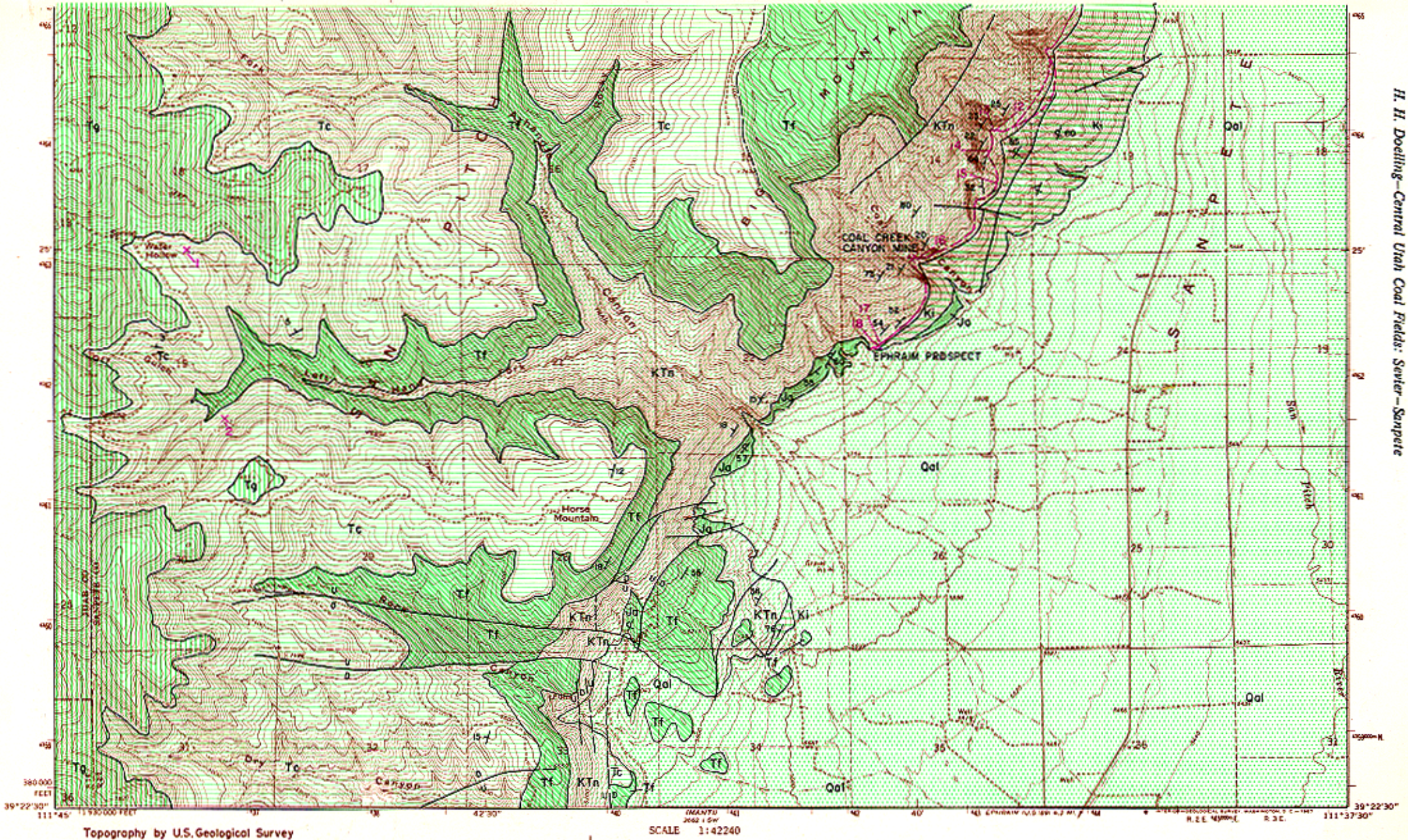

Figure 21. Coal and geology map, Wales quadrangle (explanation pages 22-23).

71. Limestone, gray to buff, dense, to finely crystalline. Sparingly fossiliferous. Some limonite staining 2.0
70. Shale, gray to buff, silty to sandy, calcareous, fossiliferous 2.9
69. Sandstone, gray to buff, fine- to medium-grained. Contains rounded to subangular quartz pebbles. Very shaley and friable in part 2.8
68. Shale, yellowish brown, silty to sandy, calcareous. Grades upward into gray, sandy, calcareous clay shale. Fossiliferous; some limonite staining 10.6
67. Limestone, buff, dense, argillaceous. Sparingly fossiliferous; some limonite staining 1.5
66. Shale, buff, sandy, calcareous, fossiliferous 1.5
65. Shale, gray to buff, sandy, calcareous, sparingly fossiliferous. Grading upward into gray to buff, sandy limestone. Some ferruginous stainings 3.1
64. Clay shale, gray, silty to sandy, calcareous, fossiliferous. Contains 3-inch gray, dense, fossiliferous limestone 4.1
63. Limestone, dark gray, dense to finely crystalline; fossiliferous 1.3
62. Shale, medium gray, sandy, calcareous; sparingly fossiliferous 2.0
61. Limestone, light brown to buff, sandy, finely crystalline. Becomes shaley toward top 1.5
60. Shale, gray, sandy, calcareous. Contains gray, sandy limestone 2.3
59. Clay shale, gray, sandy, calcareous, fossiliferous, becomes very carbonaceous in part. Contains a 5-inch fossiliferous zone near the top 9.5
58. Limestone, buff to gray, sandy, finely crystalline, fossiliferous. Becomes a calcareous sandstone in part 1.5
57. Clay shale, gray, sandy, calcareous, fossiliferous. Becoming buff, sandy shale at top 5.4
56. Coal, like unit 54. Has faint traces of blocky fracture 0.3
55. Clay shale, silty to sandy, calcareous, fossiliferous. Middle part is plastic clay with some limonite staining. Almost a lignite in upper 18 inches 3.4
54. Coal, very impure. Occasional small patches of anthraxylon, like unit 51 ..... 0.3
53. Shale, gray, silty to sandy, calcareous, fossiliferous. Some limonite staining. More clayey and carbonaceous near the top 2.3
52. Clay, gray to dark gray, sandy in part, somewhat plastic. Very carbonaceous, calcareous, fossiliferous 0.4
51. Coal, shaley, contains sandy and clayey material. Occasional tiny discontinuous streaks of anthraxylon 0.7
50. Shale, gray, silty to sandy, calcareous, fossiliferous. Becomes buff in upper part and is stained with limonite. The upper 3 inches are very carbonaceous 4.0
49. Limestone, medium gray, dense, argillaceous, very fossiliferous. Becomes shaley toward the top 1.2
48. Shale, light gray to white, calcareous, sandy. Very fossiliferous, almost a marl in many places 0.5
47. Shale, buff, silty to sandy, calcareous, fossiliferous. Becomes a shaley limestone at top 18.7
46. Limestone, dark gray, dense to finely crystalline, very fossiliferous. Upper part is shaley and more ferruginous 2.3
45. Shale, buff, sandy, fossiliferous, calcareous. Becomes dark gray upward and more fossiliferous. Stained with limonite 4.6
44. Limestone, gray, dense, fossiliferous, nodular. Concentrations of limonite around fossils 0.9
43. Shale, dark gray to buff, silty to sandy, calcareous, fossiliferous 8.0
42. Limestone, buff, dense, sparingly fossiliferous 1.3
41. Shale, buff to dark gray, silty to sandy, calcareous, slightly plastic 4.8
40. Limestone, gray, dense to finely crystalline. Very fossiliferous, concentrations of limonite around the fossils 1.0
39. Shale, buff, silty to sandy. Grades upward into dark gray, silty shale. Entire unit is very calcareous and fossiliferous 3.7
38. Limestone, gray, dense, very fossiliferous 1.3
37. Shale, buff to gray, silty to clayey, fossiliferous. Upper part is clayey and calcareous 4.6
36. Limestone, gray to buff, dense to finely crystalline. Very fossiliferous, some limonite staining 1.0
35. Shale, gray to buff, sandy to silty, calcareous. Alternates with dark gray, carbonaceous, fossiliferous shale 89.7
34. Limestone, dark gray, dense, fossiliferous. Contains a bed of nodular limestone; one inch 1.0
33. Shale, dark gray to buff, silty to sandy, calcareous. Contains several very fossiliferous zones, like unit 28 ..... 21.9
32. Shale, buff, sandy, calcareous. Sparingly fossiliferous 1.9
31. Clay shale, black, silty to sandy, slightly calcareous. Many carbonized plant fragments 0.5
30. Shale, like unit 28 ..... 1.6
29. Shale, dark gray, sandy, calcareous, fossiliferous. Becomes very carbonaceous at the top 3.2
28. Shale, buff, sandy, calcareous. Abundant white fragments of gastropods and pelecypods 1.4
27. Shale, dark gray, silty to sandy, carbonaceous. Alternates with gray to buff, sandy to silty, ferruginous shale 4.8
26. Shale, gray to buff, silty to sandy, stained with yellow-brown limonite. Middle part is a buff, fine- to medium-grained, calcareous, fossiliferous, sandstone 4.1
25. Shale, dark gray to black, very carbonaceous, calcareous, clayey to sandy. Slightly plastic. Very dark at the base and at the top 6.2
24. Limestone, buff, sandy. Some ferruginous staining; fossiliferous 1.5
23. Shale, green gray, silty to sandy, calcareous. Grades upward into dark gray, silty to sandy, slightly plastic shale. Fossiliferous 4.5
22. Shale, dark gray to buff, silty to sandy, calcareous; very sandy in places. Very fossiliferous. Some limonite staining 6.8
21. Limestone, dark gray to buff, argillaceous, dense, very fossiliferous 1.3
20. Shale, dark gray to buff, silty to sandy, calcareous, fossiliferous. Fossils occur as ferruginous molds and casts 3.5
19. Sandstone, gray to buff, medium-grained. Grades upward into gray, fine- to medium-grained, calcareous sandstone. Ferruginous cement 2.1
18. Shale, gray to greenish-gray, sandy. Grades upward into dark gray sandy, calcareous, fossiliferous shale 19.9

Total Wales Member 406.2

To the south of Wales Canyon the lower part of the unit either thins or was not developed. This southward exclusion of lower beds continues to the vicinity of Axehandle Canyon where the coal disappears. At the mouth of Axehandle Canyon the North Horn consists of a lower conglomerate with massive lenses of sandstone 279 feet thick and an upper sandstone and limestone unit with subordinate conglomerate 1,243 feet thick.

Near the mouth of Petes Canyon the following section was measured.

Section of North Horn Formation at mouth of Petes Canyon, secs. 1 and 2, 16S-2E, by Taylor (1948):

Flagstaff Limestone North Horn Formation	Feet
17. Shale, gray and variegated	215
16. Sandstone, tan, massive, forming cliffs, fine- to medium-grained, friable, interbedded with shale. Beds from 4 to 30 feet	390
15. Shale, variegated red, brown, gray, and black. Thin-bedded. Slope covered with algal limestone balls	515
14. Sandstone, ochre, thin- to medium-bedded, very shaley	18
13. Shale, light brown and tan	148
12. Sandstone, same as 9. Some shale, gray red. *Six thin beds of coal*, each averaging less than a foot in thickness	655
11. Covered interval, probably gray shale	45
10. Sandstone and conglomerate (same as 9 and 1, respectively)	3
9. Sandstone, mottled buff-brown, large-grained, friable	13
8. Covered interval	20
7. Sandstone, gray to buff, massive, medium- to large-grained. Weathers buff to brown	3
6. Covered interval	11
5. Same as 1	4
4. Covered interval	6
3. Same as 1	3
2. Covered interval	30
1. Conglomerate, reddish with some gray sandstone lenses. Pebbles average 1 to 2 inches, largely quartzites, limestone and sandstone	7
Alluvium	
Total	2,086

Richardson (1906, p. 282) measured a section of "Wasatch beds" which included the North Horn and perhaps part of the Flagstaff Formation at the Wales coal mine in Wales Canyon:

Generalized section of Wasatch beds in Gunnison Plateau, at Wales coal mine, by Richardson (1906):

	Feet
Fine-textured white limestone	+100
Talus	100
Gray limestone	10
Brown sandstone	10
Talus	150
Brown sandstone	5
Drab limestone	15
Brown sandstone	10
Drab limestone	5
Talus	100
White limestone	10
Drab shale	50
Buff limestone	15
Drab shale	50
Talus	150
Drab limestone	10
Drab shale, with streaks of purple shale	150
Brown sandstone	20
Drab shale, with a few thin beds of limestone	250
Brown sandstone	5
Drab shale	25
Brown sandstone	10
Buff shale	100
Gray limestone	25
Black limestone	5
Coal and bone	7
Black limestone	10
Dark shale	15
Brown sandstone	10
Drab shale	10
Gray limestone	5
Buff shale	40
Sandstone	10
Total	1,487

The Flagstaff Limestone overlies the North Horn at the top of the cliff that demarks the edge of the Gunnison Plateau. The unit is largely a freshwater dark gray limestone that weathers to cream or light gray and white. Occasionally a bed of sandstone or shale interrupts the otherwise pure limestone succession. The individual limestone beds are thick and the bedding appears even and regular. The unit is reasonably fossiliferous and freshwater mollusks are the most common varieties. The Flagstaff ranges from 300 to 450 feet in the area. In some parts of the Gunnison Plateau, the Flagstaff is more than 1,000 feet thick.

Overlying the Flagstaff atop the plateau and on the west third of the quadrangle is the Colton Formation. The Colton is about 800 feet thick and lithologically is divisible into three units:

	Feet
Upper unit: shale, red and gray, with a few thin beds of limestone. Many channel sands exposed	313
Middle unit: alternating beds of shale and limestone	311
Lower unit: sandstone, with a few relatively thin beds of shale and limestone	178
Total	802

At the head of the Left Hand Fork of Axehandle Canyon the middle unit contains a thin bed of coal; Clark (1914, plate XXIX) shows it as a prospect. A more detailed description is given in the section on coal.

The Green River Formation is exposed along the crest of the Gunnison Plateau and conformably overlies the Colton. The Green River of the Gunnison Plateau consists mostly of evenly bedded lacustrine limestone and shale. The limestones are gray to white but are yellow weathering. The shales are gray, hard and blocky. About 500 feet of the unit are exposed on the quadrangle.

STRUCTURE

A disturbed belt of rocks lies at the base of the Gunnison Plateau. The rocks are highly folded and some overturned; numerous faulted sections occur. To the west the beds dip westward, steeply at first and then gradually to gentler inclinations. Three cross sections illustrate the structure (figure 22).The first is across Coal Canyon, the second along Wales Canyon and the third is located about 1 mile north of the quadrangle. In the vicinity of the main coal zone the beds dip westerly from 17 to 25 degrees except locally where they are much steeper.

PROPERTY CONTROL

The lands of the Wales quadrangle are held as follows: private property 59.6 percent, Bureau of Land Management 19.0 percent, National Forest Service 16.5 percent and state of Utah 4.9 percent.

The coal is mainly on private land, but some is held by the Bureau of Land Management. Some of the coal rights on private property are reserved to the U. S. Most of the BLM and state land is along the precipitous east flank of the plateau; the forest land is all in the northwest corner of the quadrangle. The top of the Gunnison Plateau in other areas and all of Sanpete Valley is privately owned. No leases or permits for coal on the Wales quadrangle are currently (1970) in effect.

COAL

Surface Information

Eighteen coal sections were measured in the Colton and North Horn formations (figure 23). The two in the Colton are thin and noncommercial. The main Wales coal zone extends northward from sec. 23-16S-2E to sec. 3-15S-2E. From sec. 23-15S-2E northward the beds are reported to be too thin. Clark (1914) designated the coal in this area a coal zone rather than beds because coal is lenticular, interbedded with shale and bone and because it cannot be determined whether the coal occurs in one continuous bed or a succession of lenses. All of the sections show coal interbedded with shale and bone, which in former days, when the coal was mined, required considerable hand sorting to produce a marketable and burnable product. All the coal in the zone between Wales Canyon to south of Coal Canyon averages 3.7 feet thick and is split by an average of 1½ feet of shale and bone. More than half of the 5½-mile outcrop has coal exceeding 4 feet thick.

Subsurface Information

No drill-hole data are available for the quadrangle. The average 21-degree dip plus the effect of the rising surface to the west places the 3,000-foot coverline within an average of 1 mile west of the outcrops. From stratigraphic information the 3,000-foot limit might be expected near the base of the Colton. Dips become more gentle westward.

Quality of Coal

The average proximate analyses for the Wales coal field are as follows (table 23):

Table 23. Average proximate analyses of coal, Wales quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	12	5.0	1.2 -14.2
Volatile matter	13	34.2	21.0 -43.2
Fixed carbon	13	46.4	24.6 -55.5
Ash	13	14.8	4.0 -29.2
Sulfur	8	4.3	2.88- 6.79
Btu/lb	6	10,119	6,554-11,857

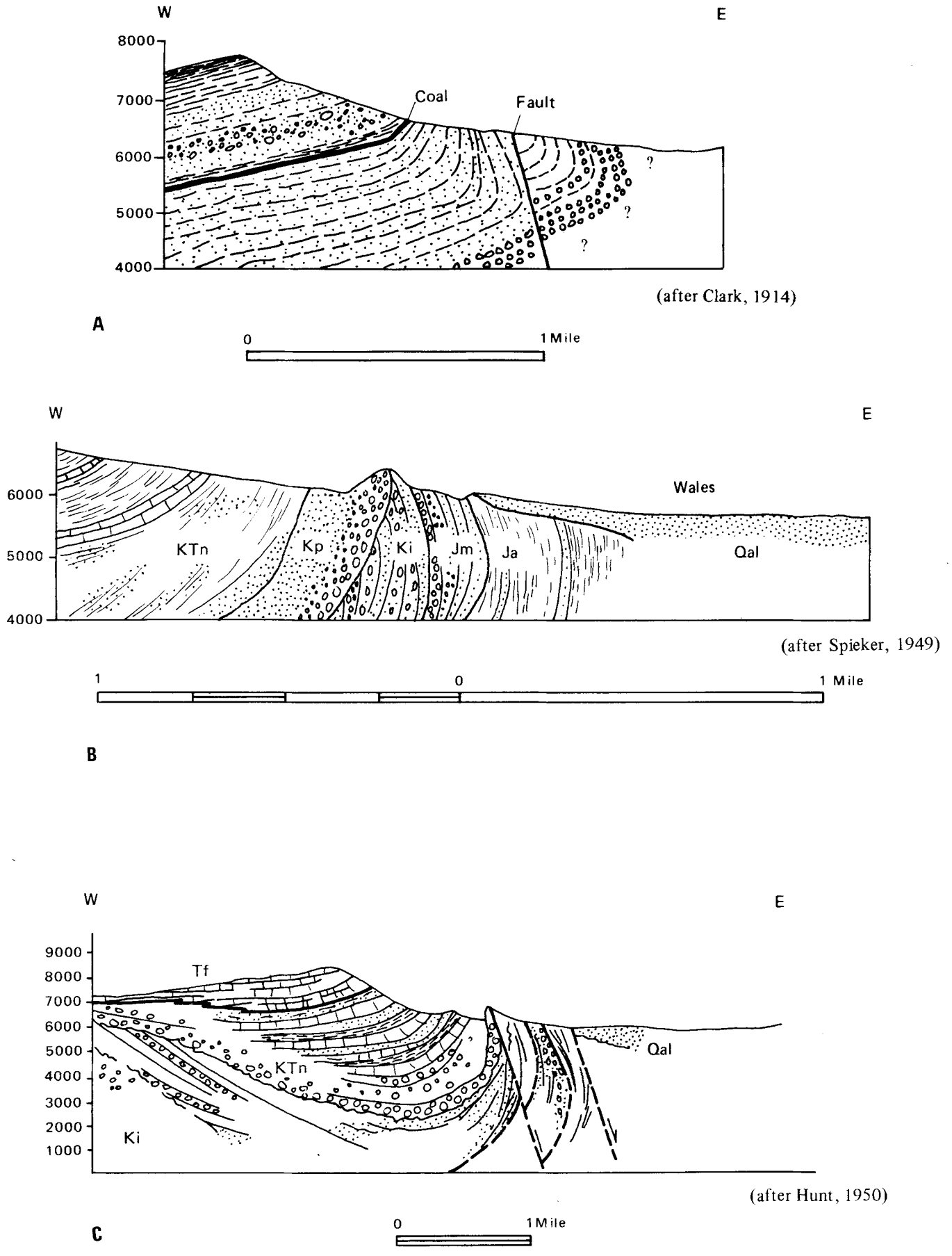

Figure 22. Cross sections (a) along Coal Canyon, (b) Gunnison Plateau Front at Wales and (c) 1 mile north of Wales quadrangle.

Thirteen coal analyses are available for Wales coal field (table 9). The coal is low in moisture and high in ash and sulfur. The high ash may be the result of coal degradation from bone which adhered to the coal sampled. The coal in itself is good quality if the foreign matter, except for the sulfur, could be inexpensively removed.

In 1857, a few years after the area was first mined, coke ovens were built at Wales. In crucible tests the coal afforded as high as 66 percent coke but in practice never exceeded 50 percent. In 1857 construction of coke ovens began and 18 or 19 structures were built. The effort was abandoned in 1877.

Gomez, Landers and Boyd (1967, p. 11) calculated carbonization product yields for the Thomas mine (table 24).

Table 24. Calculated carbonization product yields for the Thomas mine, Wales quadrangle, 500°C.

	Percent	
Char	79.2	wt. percent of maf coal
Water of decomposition	3.9	wt. percent of maf coal
Tar plus light oil	11.7	wt. percent of maf coal
Gas	5.2	wt. percent of maf coal
Gas vol.	.982	scf/lb maf coal
Heating value of gas	792	Btu/scf

Mines and Development

Interest in the coal at Wales began in 1855; between 1855 and 1955, when the last mine was shut down permanently, an estimated 175,000 tons had been produced (Hileman, Collins and Wilson, 1970, p. 44). Most of the activity was prior to 1900 (table 25).

Table 25. Mines and prospects, Wales quadrangle.

Mine	Location	Remarks
Coal Canyon mine	NE.NW.23-16S-2E 4,362,920mN 442,600mE	Activity unknown
Ephraim prospects	NW.23-16S-2E 4,362,240mN 442,265mE	Activity unknown
Indian Pete Canyon	NE.SE.2-16S-2E 4,366,960mN 443,290mE	Closed when railroad was removed
John Reese mine	SE.NE.14-16S-2E 4,364,050mN 443,260mE	Activity unknown
Thomas mine (Edmunds, Old Canyon)	NW.NE.35-15S-2E 4,369,350mN 443,200mE	Activity unknown
Wales mine No. 1	NE.NW.26-15S-2E 4,370,750mN 442,430mE	1855-1912
Wales mine No. 2	SE.NW.26-15S-2E 4,370,510mN 442,430mE	

Little activity has taken place in the Wales coal field since Clark (1914) made his investigations; his excerpts follow. Comments by the present author plus substitute locations or location numbers appear in parentheses so that the quadrangle map can be more effectively used:

At location 1 (Ephraim prospect) the coal bed had been faced up, but no development work has been undertaken. The coal here occurs in four benches (location 17). . .The upper bench is overlain by sandy shale and the lower bench is underlain by shale containing more or less carbonaceous matter that occurs as small lenses or as particles disseminated through the shale. . .

(Section 18 was measured near the Ephraim prospects but nothing is known about the mining activity.)

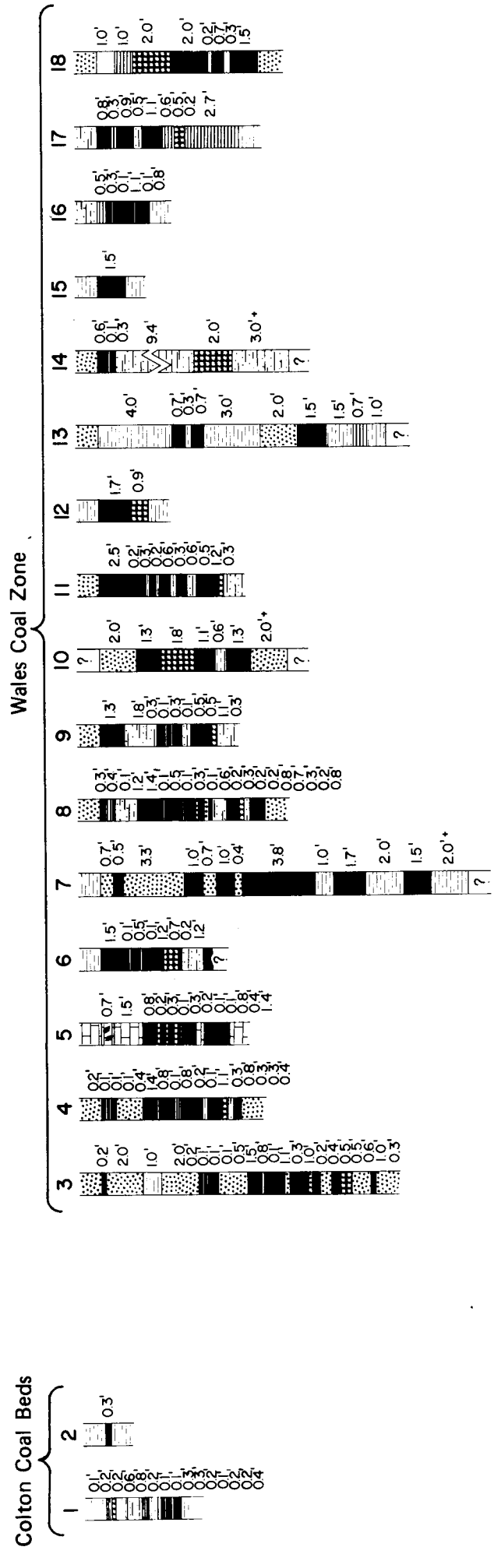

Figure 23. Coal sections of the Wales quadrangle (vertical scale: 1 inch = 8 feet).

Location 2 (Coal Creek Canyon mine) on the north side of the gulch, marks the mouth of an old drift prospect, which follows the strike of the coal bed for about 60 feet. The coal is here 2 feet 3 inches thick and contains only two 1-inch shale partings (location 16). It is underlain by shale and overlain by carbonaceous shale.

(Presently the mine is caved and water flows from a shale unit above.)

Location 5 (John Reese mine) marks the mouth of a mine in Coal Canyon which is operated during the winter by John Reese and others, the coal being hauled by wagon to supply the needs of near-by settlers. . .

(Localities 12 to 14 are measurements of the coal in the vicinity of the John Reese mine.)

At locations 6 and 7 in Indian Pete Canyon, in sec. 2, T. 16 S., R. 2 E., there are two abandoned mines, one on either side of the canyon. The bed in the vicinity is very irregular in thickness and character. . .The total thickness of the coal at location 6 (location 11), is 5 feet 2 inches, whereas at location 7 (location 9) it is only 3 feet 5 inches. The mine on the south side was one of the first coal mines opened in Utah and perhaps more has been removed from it than from any other mine in this area. The development was continued, it is reported, until the mine was flooded by water, when it was closed down and has never been reopened. Water almost completely filled the workings of the mine at the time of the writer's visit. . .The mine at location 7 (9) was opened some time after the one at location 6 (11) and the development has not been so extensive. . .

(Section 10 was measured in the north tunnel of Petes Canyon. The mine portal is still open and the tunnel is at least 200 feet long with several side branches.)

The mine at locations 8 and 9 (8 and 6) operated by H. R. Thomas, of Wales, is situated in sec. 35, T. 15 S., R. 2 E., in what is locally known as Old Canyon. The coal here mined is sold to the people of Wales and near-by small towns. The total production has been rather large for a local mine. Location 8 (8) marks the mouth of this mine and location 9 (6) the point in the mine at which (a) the sample for analysis was collected. . .The sections measured at locations 8 and 9 (8 and 6) show a great difference in the thickness of the coal, as well as in the thickness and arrangement of the coal benches and the partings between them. . .(Clark, p. 482, 483).

The section at locality 7 also was measured near the mine which is now abandoned and in disrepair. The remaining mines are those in Wales Canyon, localities 3 to 5. Clark reports two mines open on each side of the canyon. Both were abandoned and the north side tunnel was partly caved. He notes that nearly every mine has a good roof, either a sandy shale, calcareous sandstone or calcareous sandy shale. Richardson (1906, p. 283) reports that the Wales mine is opened on the outcrop and the workings extend 200 yards along strike. As such the mine closed sometime between 1905 and 1914.

Reserves

No previous workers have listed any reserves for the Wales coal field. The resources are small. In about 2.75 square miles the coal exceeds 4 feet thick and it is not too deep to mine. The available tonnage (Class I and II) reserve is therefore about 12.2 million tons.

PRINCIPAL WORK

Richardson (1906) and Clark (1914) provided most of the coal data. Hunt (1948 and 1950), Taylor (1948) and Thomson (1970) provided the geological information. The first two authors worked for the U. S. Geological Survey and Taylor and Hunt were sponsored by Ohio State University. Thomson (1970) provided a reconnaissance report specifically for this presentation.

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Entrance to old Wales coal mine, Wales Canyon. Ledge formers are limestones of the North Horn Formation.

Figure 1. Relief map of central Utah showing approximate location of the Wasatch Plateau coal field.

WASATCH PLATEAU COAL FIELD

by

H. H. Doelling[1]

INTRODUCTION

Location and Extent

The Wasatch Plateau coal field lies near the geographical center of Utah and embraces parts of Carbon, Emery, Sanpete, Sevier and Utah counties (Preface, figure 1a and figure 1). Width of the field ranges from 7 to 20 miles and length is about 90 miles, an area of about 1,100 square miles. The field is oriented nearly north-south with the north end slightly east of the middle. An erosional escarpment marks the east boundary; the west boundary roughly follows the drainage divide of the Wasatch Plateau. U. S. Highway 50-6 or the main line of the Denver and Rio Grande Western Railroad designates the north boundary. To the south the field thins and finally terminates against the volcanics of the Fish Lake Plateau. It is contiguous to the Book Cliffs coal field (northeast corner) and to the Mt. Pleasant and Salina Canyon coal fields on the west side of the drainage divide. The Emery coal field has its best development to the southeast. It is assumed that some of its coal extends under the Wasatch Plateau at great depth.

Topography and Drainage

The area is one of rugged topography (figure 2), mostly ledges and slopes. Deep canyons cut into the plateau from the east. The plateau edge is a steep cliff with a relief of about 1,000 feet. Coal measures are exposed in the canyon walls and along the cliffs. Exploitation usually has taken place in areas of good accessibility such as where tributary canyons V into the cliffs. Altitudes range from almost 7,000 feet to more than 10,000 feet above sea level. Coal outcrops mostly between 7,000 and 8,000 feet.

The major drainages of the Wasatch Plateau flow southeasterly toward the Colorado River: Gordon Creek, Huntington Creek, Cottonwood Creek, Rock Canyon Creek, Ferron Creek, Muddy Creek, Quitchupah Creek and Ivie Creek. An exception is Pleasant Valley Creek in the north part of the field which flows northerly and easterly and is a tributary of the Price River which eventually flows southeasterly into the Colorado River.

The plateau is mountainous. Faulting has created several depressed areas on the surface which have filled with water to form lakes—some developed and enlarged as reservoirs. Several large alpine meadow areas also are present.

Population, Industries and Transportation

Although the area covers sections of Sanpete, Sevier and Utah counties, it is economically tied to Carbon and Emery counties. An exception is the southernmost part where the major influence is Salina in Sevier County. Relatively few people live on the Wasatch Plateau itself. Those who mine the coal or graze sheep and cattle live in towns and villages below the cliffs. Of Emery County's population of 5,137 (1970), about 4,000 live below the cliffs in towns such as Emery, Ferron, Castle Dale, Orangeville and Huntington. In Carbon County the area is served by the Price-Helper area which has a population of about 11,000. The town of Salina in Sevier County lies about 20 miles west of the field with a population of 1,494 (1970). Nearby towns with 1960 and 1970 population figures are listed in table 1.

Table 1. Towns and population figures, Wasatch Plateau coal field.

Community	1960	1970	County
Carbonville	–	500	Carbon
Castle Dale	617	541	Emery
Castle Gate	321	205	Carbon
Clawson	100	100	Emery
Clearcreek	150	35	Carbon
Cleveland	261	244	Emery
Consumers	200	–	Carbon
Elmo	175	141	Emery
Emery	326	216	Emery
Ferron	386	663	Emery
Helper	2,459	1,964	Carbon
Hiawatha	439	166	Carbon
Kenilworth	879	500	Carbon
Mohrland	–	–	Emery
Molen	40	–	Emery
Moore	35	–	Emery
Mutual	213	–	Carbon
National	300	–	Carbon
Orangeville	571	511	Emery
Price	6,802	6,218	Carbon
Rains	100	–	Carbon
Royal	250	–	Carbon
Salina	1,618	1,494	Sevier
Scofield	158	71	Carbon
Soldier Summit	33	13	Wasatch
Wattis	200	–	Carbon
Wellington	1,066	922	Carbon
Total	18,390	14,504	

Since 1960 towns like Rains, Royal, Consumers, Mutual, National and Wattis have lost population; most have dissipated into ghost towns. The entire area has experienced a general decline in population.

People in the area are primarily engaged in mining (coal) or agriculture; they are employed also by governmental agencies or by service and sales companies. A smaller force works in transport companies and the tourist trade. Coal mining is the chief industry. Most of the miners reside in and around Price, Utah, a few in mining communities such as Hiawatha and Kenilworth. Helper originated as a transportation center where locomotives were maintained to transport coal westward over the plateau. Distribution of the work force is approximately as follows: government 30 percent, mining and construction 25 percent, farming and ranching 17 percent, trade 16 percent, services, banking and miscellaneous 10 percent, transportation 9 percent and manufacturing 2 percent. Seventy-five percent of the towns and villages owe their beginnings to the coal mining industry.

The Denver and Rio Grande Western Railroad serves the north part of the area. The main line extends from Denver to Salt Lake City and passes through Price and Helper. Three important spur lines crosscut the area: the first, the Utah Coal Route operated by the Utah Central Railroad, extends from Helper to Hiawatha and serves the Spring Canyon, Gordon Creek, Wattis and Hiawatha areas; the second stretches south from Colton along the Price River to Clearcreek in the Scofield quadrangle; the third runs south from Thistle (Spanish Fork Canyon) through the Sanpete and Sevier valleys on the west side of the Wasatch Plateau. It extends southward to Marysvale in Piute County through Salina. Originally built to remove metal ore from the Marysvale area, this line is now primarily an agricultural and an industrial products line. Coal mined in the Emery coal field and southern Wasatch Plateau has been moved intermittently by the line from Salina.

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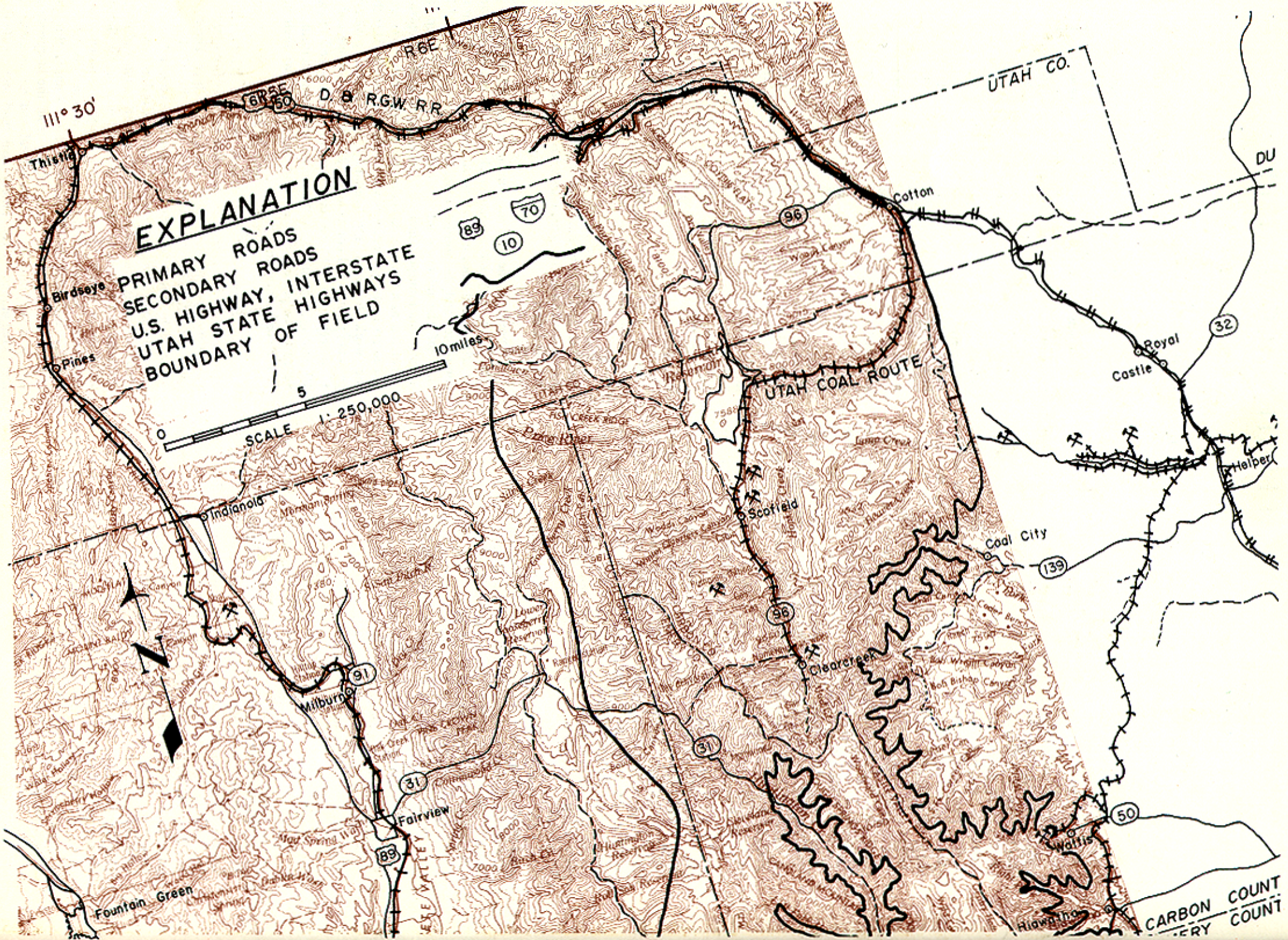

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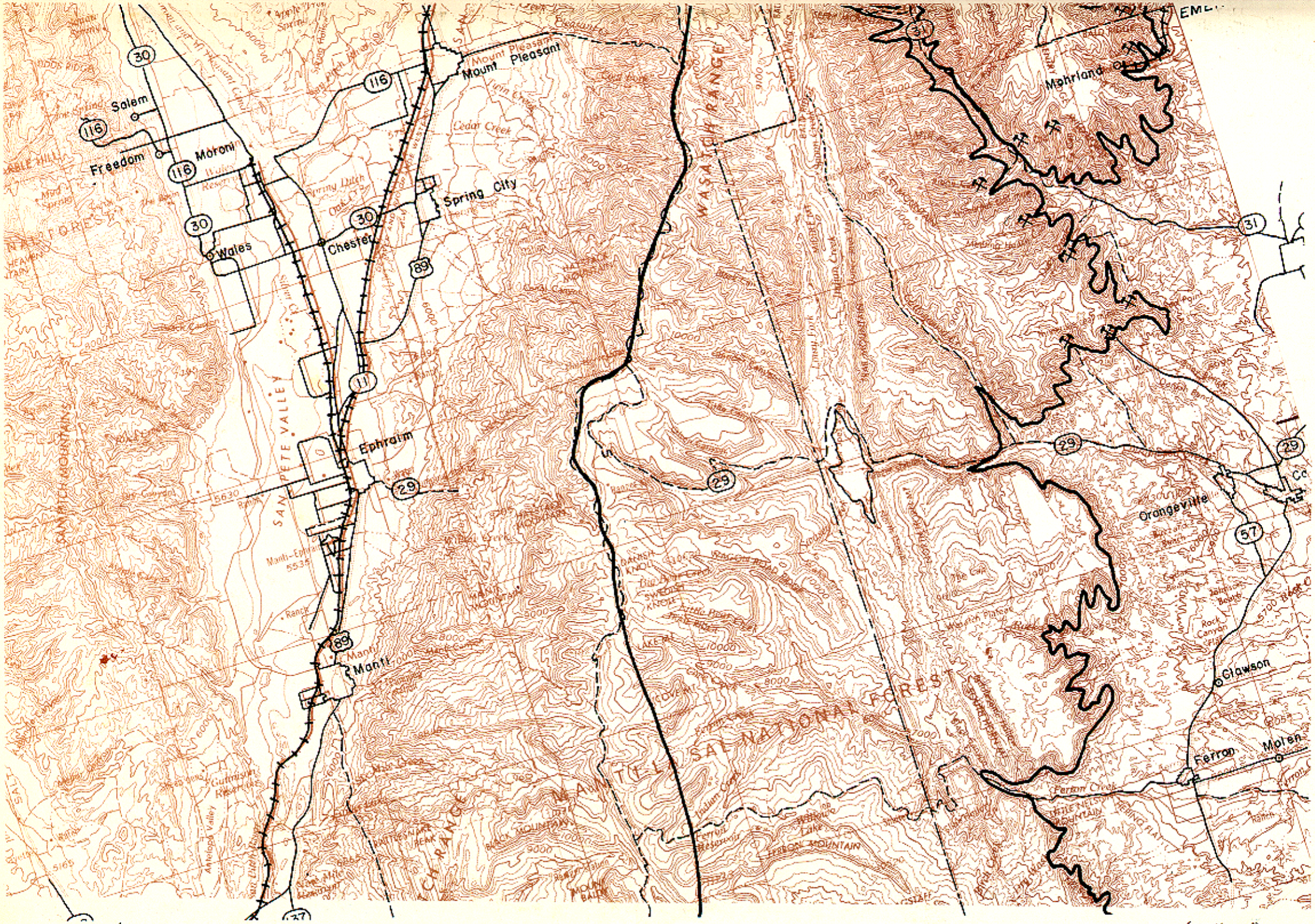
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Mount Pleasant
Ephraim
Manti
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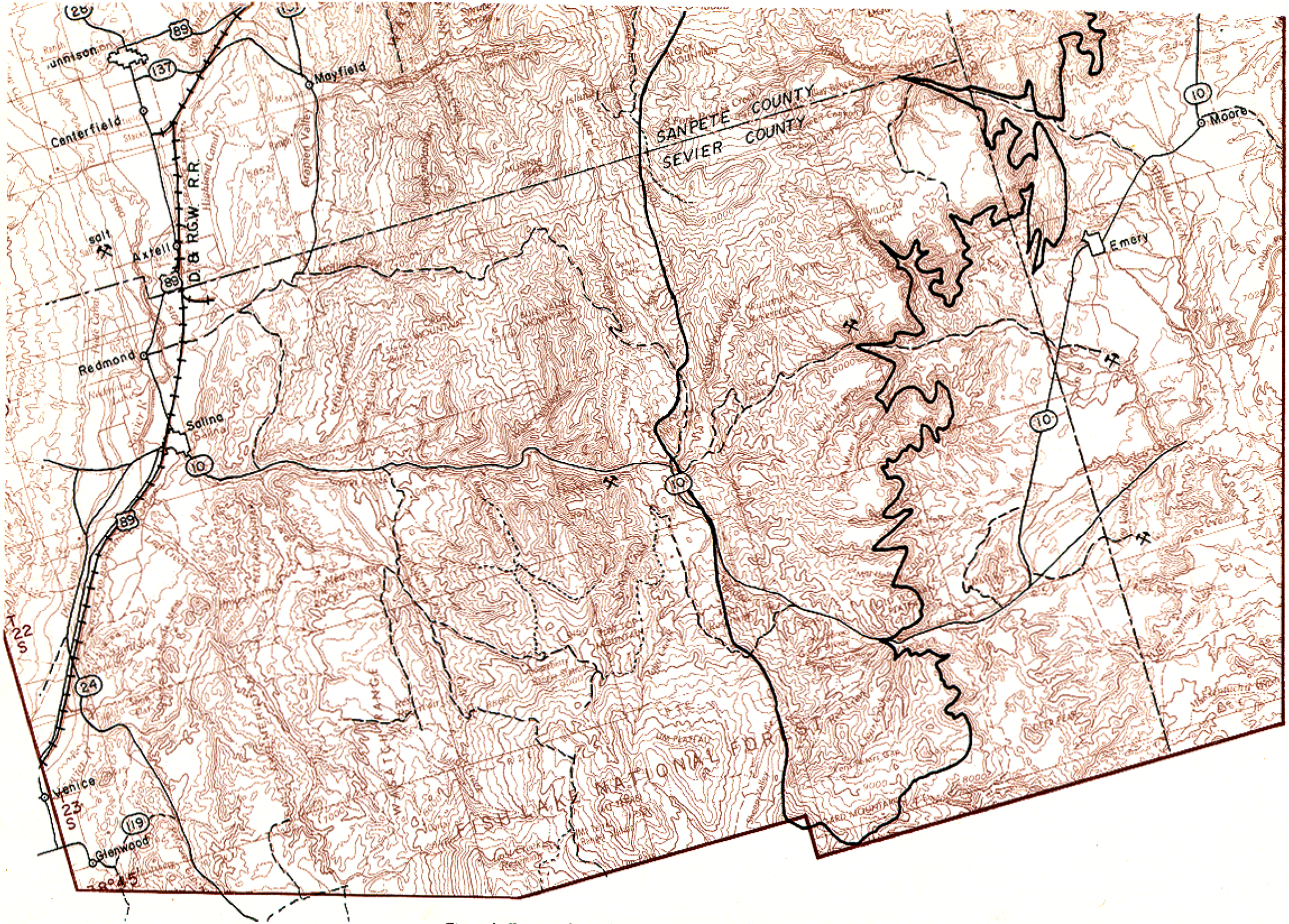


Figure 2. Topography and roads map, Wasatch Plateau coal field.

Major highways surround the plateau and secondary roads extend across it at intervals through the larger canyons (figure 2). U. S. Highway 6-50 forms part of the coal field's north boundary and joins Denver with Salt Lake City via Price. Utah Highway 10 parallels the plateau on the east from Price southerly to Fremont Junction and then crosses it through Ivie Creek and Salina canyons. Most of the towns in Emery County are on this highway. Interstate 70 was built recently across the San Rafael Swell and joins Utah Highway 10 along Ivie Creek; plans are to replace Highway 10 by Interstate 70 through Salina Canyon. U. S. Highway 89 parallels the D&RGW Marysvale tracks and the plateau on the west from Thistle through Salina to south Utah and Arizona. The better secondary roads crossing or approaching the Wasatch Plateau are Utah Highways 96, 50, 122, 31 and 29. Highway 96 extends south from Colton along the Price River to Clearcreek; Highways 50 and 122 join Wattis, Hiawatha and Mohrland with Utah Highway 10 eight miles south of Price; Highway 31 extends westward up Huntington Canyon from Huntington, crosses the plateau to Sanpete Valley at Fairview, and Highway 29 crosses the plateau through Straight Canyon and Joes Valley connecting Orangeville to Ephraim. A skyline drive is on top of the plateau.

Climate

The Wasatch Plateau climate varies with altitude from alpine to semiarid. Precipitation ranges from 8 inches along Utah Highway 10 to more than 40 inches on South Tent Mountain. In the area of the coal measures rainfall is between 15 and 25 inches (figure 3). Most comes during the winter as a result of cyclonic storms.

Occasional summer cloudbursts cause flash floods and damage to dirt roads. Temperatures on the plateau are cool in the winter and summer; summer frosts are common. Below the cliffs winters are cool and summers are hot. In the towns summertime temperatures are expected to reach into the 90's and wintertime nights down to zero. This is comparable to summer highs of 80° F on the plateau and -20° F on a winter morning.

HISTORICAL OUTLINE

The Corps of Topographical Engineers led by Captain J. W. Gunnison explored Castle Valley and discovered coal in 1853. During the 1870's most of the agricultural towns in Castle Valley were established. As early as 1855 attempts had been made, but colonization failed because of interference by Ute Indians.

At the same time coal was rediscovered on the Wasatch Plateau. According to Spieker (1931, p. 1):

> Coal was discovered in the Wasatch Plateau field in 1874 and mining was started in 1875, when the Fairview Coal and Coke Co. opened a mine in Huntington Canyon . . . in sec. 11, T. 14 S., R. 6 E., and established a settlement called Connellsville. In 1876 coal was being mined from 5 openings, 4 in Coal Canyon and one in Huntington Canyon near the mouth of Coal Canyon. A railroad was surveyed from Sanpete Valley to this place but was never built.

An article by J. H. Morton of Salt Lake City, appearing in the *Engineering and Mining Journal*, February 3, 1877, reads:

> About the first of this month I visited the coal mines situated on Huntington Creek, in Sanpete County [Emery County was created in 1880 from portions of Sanpete and Sevier counties], about one hundred miles southeast of this city. These mines were discovered in the summer of 1874 by some Mormon settlers, and are now the property of the Utah Coal Mining and Coke Company of Salt Lake City.
>
> The mines number seven in all, or rather that is the number actually opened and that I examined. . . The coal in Nos. 1, 2 and 6 contain considerable resin, which, though increasing the quantity of volatile matter, does not appear to interfere with the coking. This resinous coal makes a very excellent grade coal, burning bright and free, and leaving no clinker or any considerable ash. It makes a very fair gas coal and should supersede the Australian shale now used in this city. The coke, though inferior in hardness to Connellsville coke, is capable of sustaining the weight of any charge of ore in a blast furnace and is eagerly sought by the smelting men of Salt Lake. The company is now producing about 12½ tons coke daily, using ten ovens. The coal costs, delivered at the ovens, about $.70 per ton, the men working by the day at $3.50 for ten hours' work: the cost of producing 12½ tons of coke being the cost of working twenty men, including superintendent, fireman, carpenter, blacksmith, two teamsters, clerk, two men at the ovens and miners or laborers about the mines.

The costs to produce 12½ tons of coke plus the long haul by wagon to Springville put the enterprise out of business. Ruins of coke ovens remain in the vicinity of the mines.

The Utah or Mud Creek mine in Pleasant Valley opened in 1878 and failed after a zone of faults was intersected during the mining process. The Union Pacific and Winterquarters mines opened in 1884 near Pleasant Valley. Coke ovens were built but the product proved to be merely devolatilized lump coal and the process was abandoned. Faults also plagued these mines. All were reopened later. In 1899 the Clear Creek mine in the Scofield area opened and a long period of successful mining followed. According to Alexander (1963, p. 237):

> In 1882, the Denver & Rio Grande Western Railroad challenged Union Pacific by opening the vast coal deposits of Carbon County. [Carbon County was created from a part of Emery County in 1898.] By August 1882, as the road neared completion, Clearcreek became a coal mining boom town. D&RGW's coal subsidiary, the Utah Fuel Company, began immediately to obtain coal property . . . In 1900, the first year in which production topped 1 million tons, this company mined 90 percent of Utah's coal. Utah Fuel had replaced Union Pacific as Utah's chief coal supplier.

Hachman (1968, p. 23-24) reports:

> . . . The year 1900 is particularly significant in Utah coal history. That year's production for the State was 1,147,024 tons. . . This coal was valued at the mine at $1,447,750 or $1.26 per ton. Carbon County, then as today, was by far the largest producer, comprising 95 percent of Utah's total extraction. . . In 1900, almost 90 percent of the production, both mining and loading, were accomplished by hand, with the remainder shot-off-the-solid. . .

Much of the million tons produced from the Wasatch Plateau was mined from the adjoining Book Cliffs field. To 1910, however, most of the coal produced from the Wasatch Plateau was mined in the Scofield-Clearcreek area.

The Southern Utah Railroad built in 1909 joined Price with Hiawatha and Mohrland and the first important mines on the east-facing cliffs were opened. Later the Utah Railway (Utah Coal Route) was laid near Helper and the Southern Utah line was dismantled. Between 1910 and 1920 Utah coal production steadily increased and mechanical methods gradually replaced the pick and shovel.

Mines were developed gradually throughout the field but the larger ones undoubtedly were concentrated in the north end because of the presence of the railroad and nearness to market. They are listed along with locations and other data in the Mines, Prospects and Production section of this report. Through 1969, after 95 years of mining, almost 100 million tons of coal have been removed from the plateau. The production of the plateau gradually increased through 1920 followed by a lag until the end of World War II when the "golden age" of Utah coal was reached followed by another decline in 1957. During the 1960's renewed interest in coal caused a flurry of leasing activity on the plateau; present trends are discussed in the Economic Considerations and Forecast section of the report.

GEOLOGIC SETTING

Stratigraphy

Physiographically the maps cover the Wasatch Plateau proper and Castle Valley area below the cliffs. Older Cretaceous units, the Dakota and members of the Mancos Shale are exposed in Castle Valley and extend to the foot of the cliff (figure 4). The steeper parts of the cliff belong to the Mesaverde Group formations and the uppermost units on the plateau are the latest Cretaceous and Early Tertiary rocks. Figure 5 briefly describes the units.

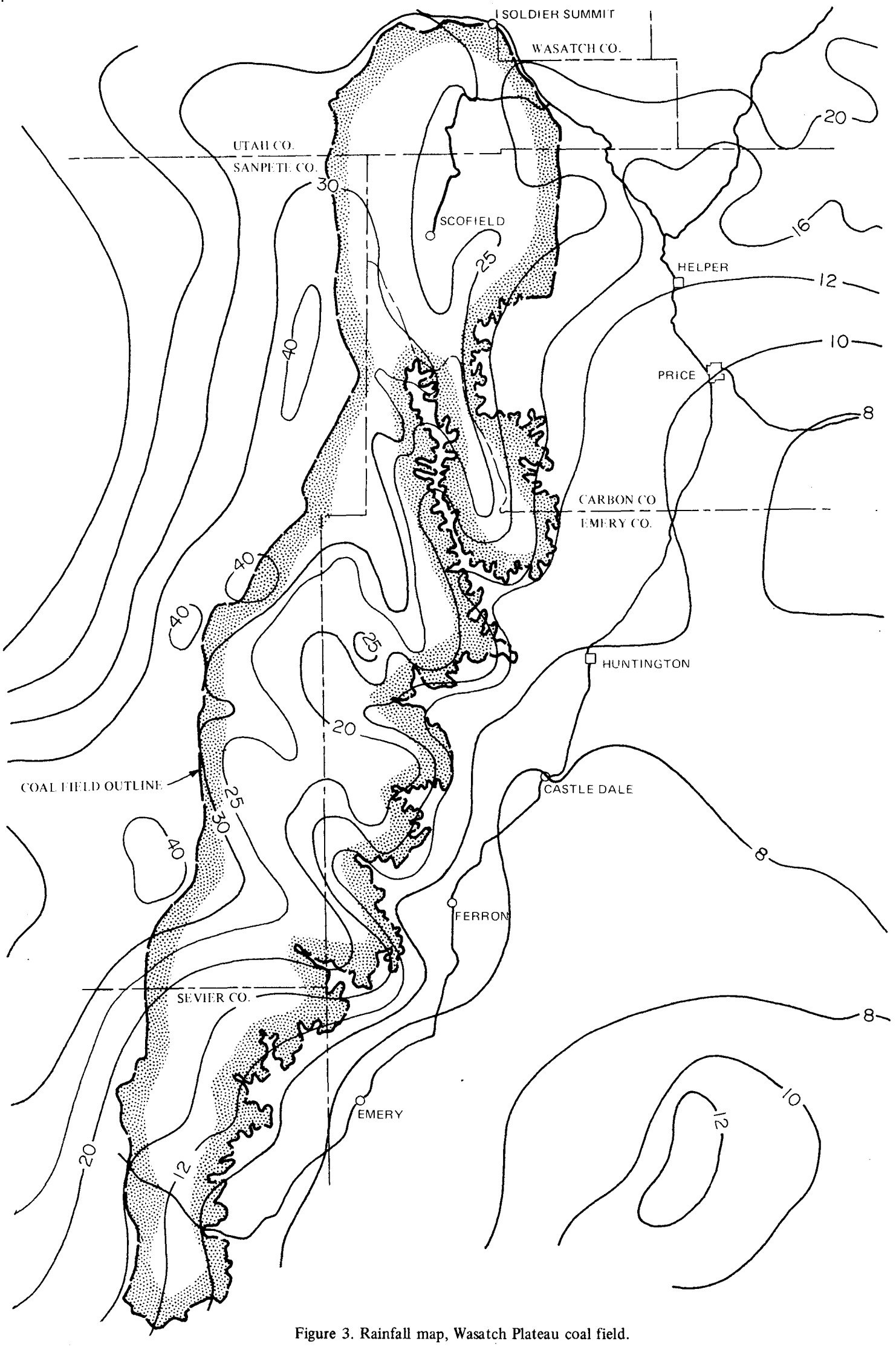
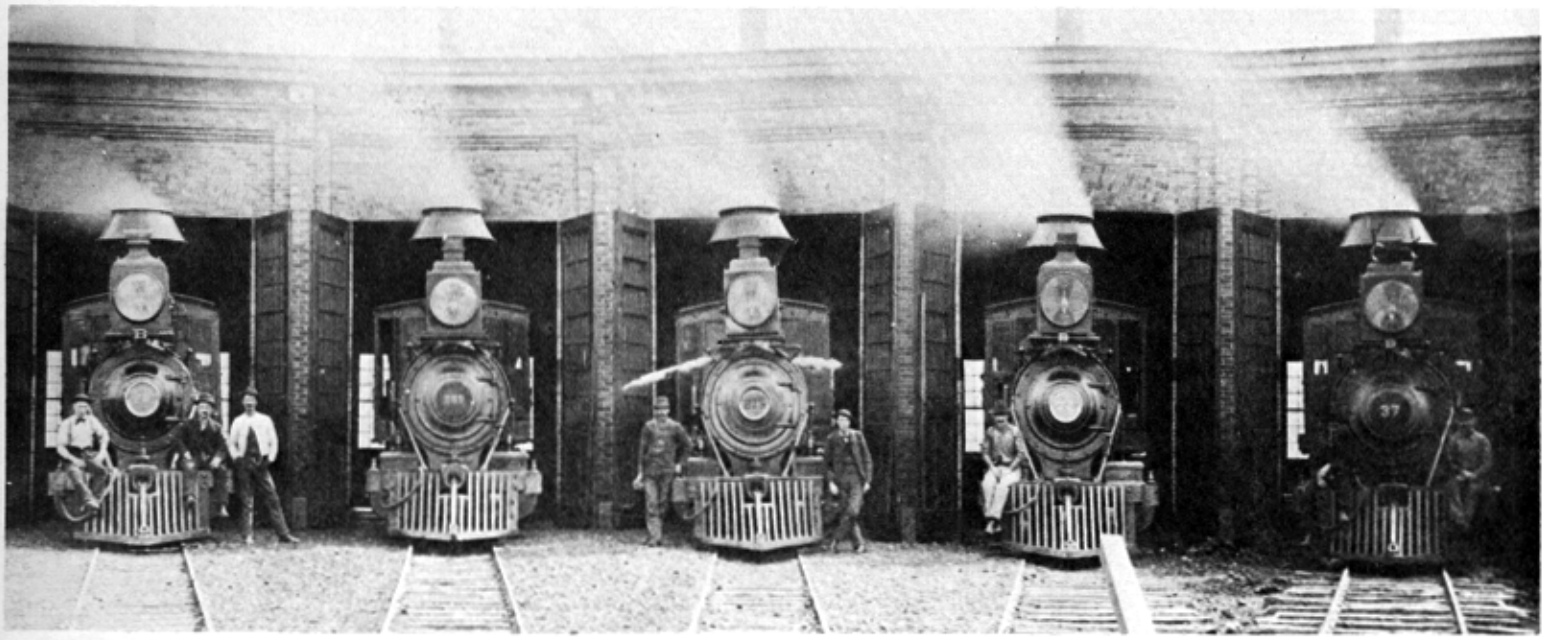
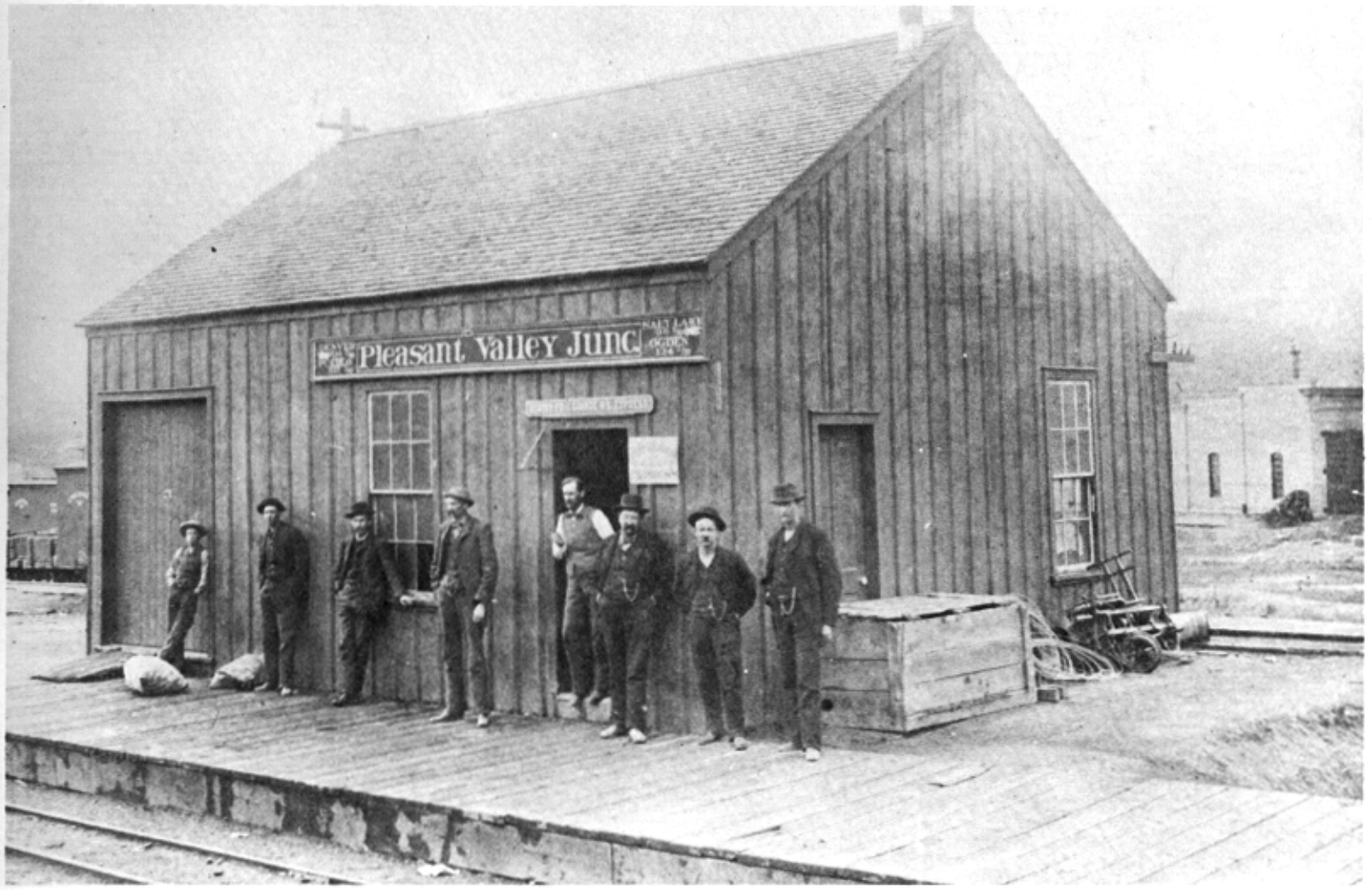


Figure 3. Rainfall map, Wasatch Plateau coal field.



Roundhouse picture of early locomotives that pulled coal up the grade from Helper to Soldier Summit, 1890 to 1910. Photo from Helper Mining Museum original.



Pleasant Valley Junction railroad station, early 1900's, probably located at the present town of Scofield. Photo from Helper Mining Museum original.

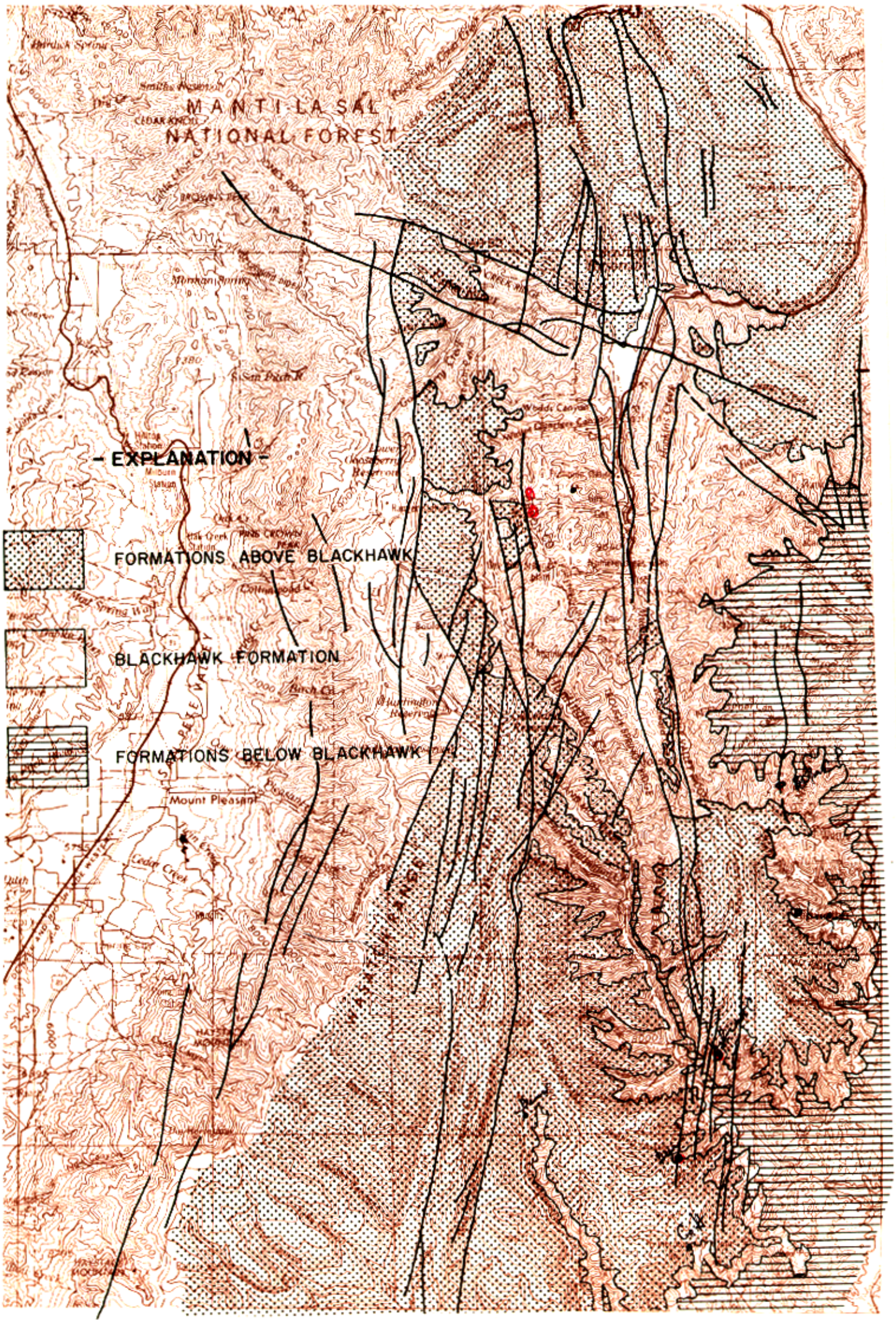


Figure 4. Generalized geology map, Wasatch Plateau coal field.

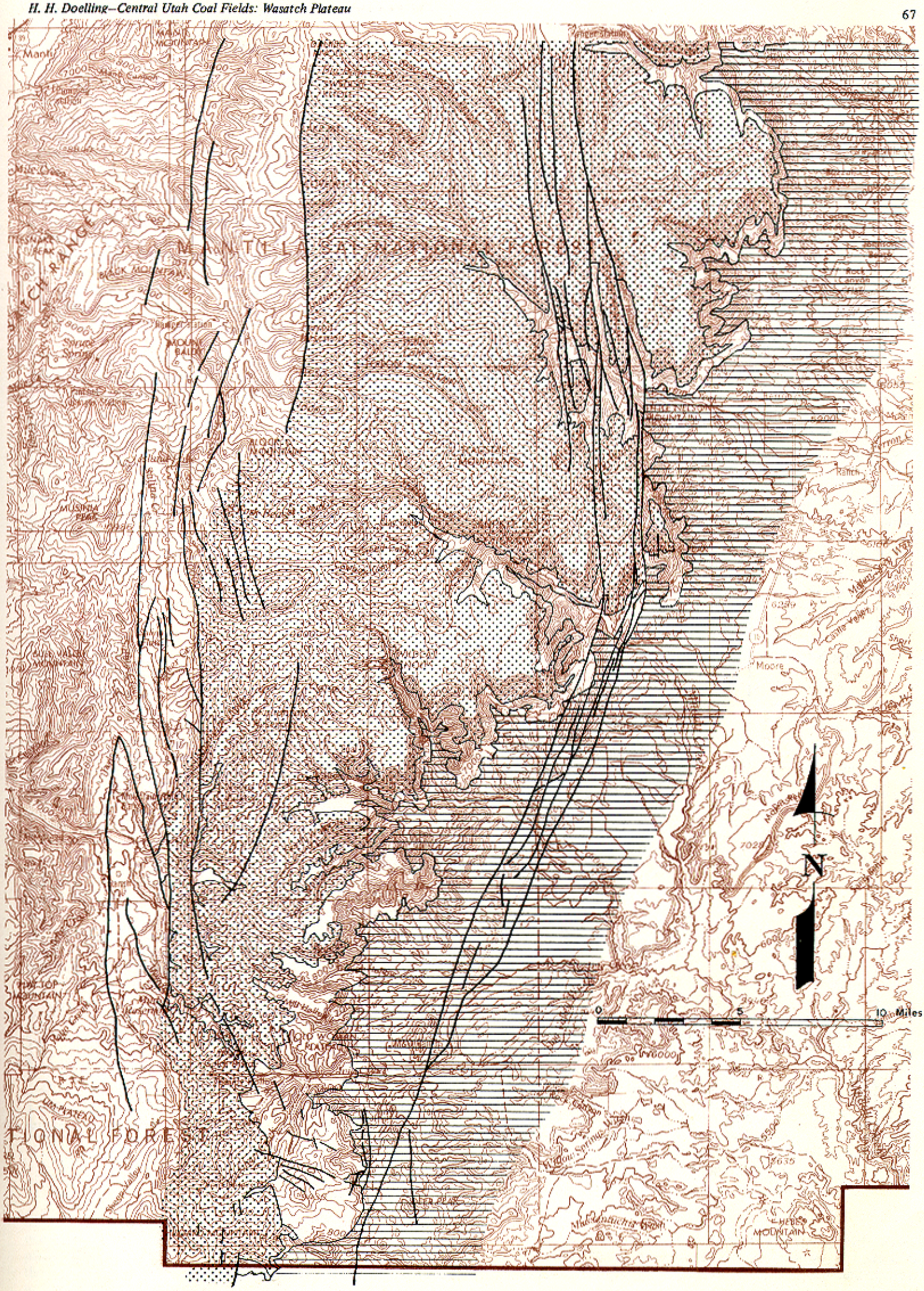


Figure 4. (continued)

System	Series	Stratigraphic Unit		Thickness (feet)	Description
TERTIARY	Eocene	Green River Formation		–	Chiefly greenish lacustrine shale and siltstone.
		Wasatch Group	Colton Formation	300-1,500	Varicolored shale with sandstone and limestone lenses, thickest to the north.
	Paleocene		Flagstaff Limestone	200-1,500	Dark yellow-gray to cream limestone, evenly bedded with minor amounts of sandstone, shale and volcanic ash, ledge former.
			North Horn Formation (Lower Wasatch)	500-2,500	Variegated shales with subordinate sandstone, conglomerate and freshwater limestone, thickens to north, slope former.
CRETACEOUS	?	Mesaverde Group	Price River Formation	600-1,000	Gray to white gritty sandstone interbedded with subordinate shale and conglomerate, ledge and slope former.
	Maestrichthian		Castlegate Sandstone	150- 500	White to gray, coarse-grained often conglomeratic sandstone, cliff former, weathers to shades of brown.
			Blackhawk Formation *MAJOR COAL SEAMS*	700-1,000	Yellow to gray, fine- to medium-grained sandstone, interbedded with subordinate gray and carbonaceous shale, several thick *coal* seams.
	Campanian		Star Point Sandstone	90-1,000	Yellow-gray massive cliff-forming sandstone, often in several tongues separated by Masuk Shale, thickens westward.
	Santonian	Mancos Shale	Masuk Shale	300-1,300	Yellow to blue-gray sandy shale, slope former, thick in north and central plateau area, thins southward.
			Emery Sandstone *COAL (?)*	50- 800	Yellow-gray friable sandstone tongue or tongues, cliff former, may contain *coal* (?) in south part of plateau if mapping is correct, thickens to west and south. *Coal* may be present in subsurface to west.
	Coniacian		Blue Gate Member	1,500-2,400	Pale blue-gray, nodular and irregularly bedded marine mudstone and siltstone with several arenaceous beds, weathers into low rolling hills and badlands, thickens northerly.
	Turonian		Ferron Sandstone Member *MAJOR COAL SEAMS*	50- 950	Alternating yellow-gray sandstone, sandy shale and gray shale with important *coal* beds of Emery coal field, resistant cliff former, thickens to the south.
	Cenomanian		Tununk Shale Member	400- 650	Blue-gray to black sandy marine slope forming mudstone.
	Albian	Dakota Sandstone *MINOR COAL*		0- 60	Variable assemblages of yellow-gray sandstone, conglomerate shale and *coal*. Beds lenticular and discontinuous.

Figure 5. Generalized section of rock formations, Wasatch Plateau coal field.

Dakota Sandstone

The Dakota is not the oldest Cretaceous unit of the area. The Lower Cretaceous Cedar Mountain Formation below it consists of gray to green nodular weathering clay shale or mudstone. The Dakota itself is mostly a yellow-gray sandstone, in places interbedded with subordinate sandy shale and conglomerate. Local unconformities are consistently found in it; sands are often cross-bedded suggesting reworked sand. Moderately resistant, the formation tends to form a dip slope and low cliff above the nodular shale below. Minor constituents of the formation include shale and coal. A thin coal bed of doubtful value is locally near the top of the unit. The Dakota is thin but has a highly variable thickness ranging up to 60 feet; in places it may be missing. The unit also varies lithologically; lenticular beds pinch in and out.

Tununk Shale

The lowest of five members, the Tununk Shale Member of the Mancos Shale, overlies the Dakota Sandstone. It is a nonresistant blue-gray to black shale, locally heavily charged with carbonaceous matter, 400 to 650 feet thick. The Tununk is locally gypsiferous and fossiliferous, is not a true shale but a mudstone and is in places silty. Outcrops form low slopes, rounded hills, badlands and steep slopes where capped by the resistant overlying Ferron Sandstone. The Tununk is mostly impermeable and resists the absorption of water so that little soil or vegetation occurs on it. Exceptions are where its surfaces are flat and alluvial debris has been deposited on it. The Tununk Shale represents the first deposit of the Cretaceous marine invasion that covered much of the North American continent.

Ferron Sandstone

This 50- to 950-foot member of the Mancos contains commercial coal beds in the south half of its 80-mile outcrop adjacent to the Wasatch Plateau. The unit consists of alternating cliffy sandstone and sequences of shaley sandstone, gray shale, carbonaceous shale and coal. It thickens from the Farnham anticline east of Wellington westerly and southerly. Near Paradise Lake it is at least 950 feet thick. Wells on the plateau have penetrated between 450 and 725 feet of strata. The coal in the Ferron is important from the town of Emery southward. Discussion of this coal is in the Emery coal field report.

Blue Gate Member

The Ferron Sandstone is overlain by a thick nodular and irregularly bedded mudstone and siltstone. The rock is blue-gray except where thin lenses of sandstone generally weather tan and brown. The Blue Gate is softer and has been stripped back from the top of much of the Ferron. Towards the base of the next cliff the Blue Gate is present as low rounded hills and badlands. Near Price it contains the yellow-gray sandstone beds of the Garley Canyon Sandstone Member of the Mancos, which is lenticular where exposed but undoubtedly is associated with a large body of sandstone to the west in the subsurface. Agricultural lands of Emery County are located in the "sag" between the Emery Sandstone hills and the cliffward-dipping Ferron. Enough sand and gravel in this sag have mixed with the otherwise impermeable Blue Gate to create good soil. Pure outcrops of Blue Gate like those of the Tununk support a minimum amount of vegetation. The Blue Gate ranges from 1,500 to 2,400 feet thick, increasing to the north.

Emery Sandstone

The Emery Member of the Mancos forms a step-like series of cliffs at the base of the Wasatch Plateau cliff. The unit splits into two tongues north of Emery with a medial marine shale and in places disappears completely. It ranges from 50 to 800 feet thick, the thickest sections to the south and west. The Emery is similar in appearance to other Cretaceous sandstone units except for a greater preponderance of sandy units and less carbonaceous units. According to Hale and Van de Graaff (1964, p. 129) the Emery is dominantly a marine sandstone facies along the east front of the plateau but thickens westward and changes rapidly to a coal-bearing facies beneath the plateau area. They also indicate that the facies of the area strike north-south. The farthest west exposures of the Emery are at the extreme south end of the field where a thick coal bed occurs in a sequence of sands not positively identified because of faulting and heavy cover.

Masuk Shale

The uppermost member of the Mancos Shale, the Masuk, represents the last marine invasion into the area. Its description is much like that of the Blue Gate although there is much more sand, especially towards the top. It ranges from 300 to 1,300 feet thick–1,000 to 1,100 feet thick in the north and central parts, thinning southerly to as little as 300 feet. In the subsurface to the west it changes facies and joins with the Emery and Star Point sandstones. The Masuk is a soft unit in its exposures but usually forms part of the cliffs rising to the top of the Wasatch Plateau.

Star Point Sandstone

The lowest of four formations comprising the Mesaverde Group of the Wasatch Plateau, the Star Point consists of several thick cliffy sandstone units separated by shale or by partings of thin-bedded sandstone. The unit ranges from 90 to 1,000 feet thick with the thicker sections to the west. In the southernmost part of the field it contains sandy shale; in the central and north parts it appears as a broad light colored band on the cliff (the steepest part). The Star Point is up to 1,000 feet thick in the Scofield area and nearly devoid of shale. In the Gordon Creek area the cliffy sand units were named in a classic section included below:

Section of Star Point Sandstone, sec. 16, T. 13 S., R. 8 E., by Spieker (1931, p. 22):

	Feet
Spring Canyon Tongue	
Sandstone, white, fine-grained, massive	20
Sandstone, buff, medium-grained, massive	80
Concealed (probably marine Mancos Shale)	80
Storrs Tongue: sandstone, locally white, normally buff, medium-grained	50
Concealed (probably marine Mancos Shale)	120
Panther Tongue: sandstone buff, fine- to medium-grained, massive, forming individual bench	23
Sandstone as above, forming bench	30
Sandstone, buff; weathers away readily, grading to shale in places	5
Sandstone, hard, buff, medium-grained	1
Shale, sandy, brown-gray	1
Shale, dark gray	25
Sandstone, hard, gray, weathers buff	5
Mancos Shale, Masuk Member	–
Total	440

Blackhawk Formation

The Blackhawk in the Mesaverde Group of the Wasatch Plateau contains important coal seams in the lower half of the formation. The 700- to 1,000-foot unit, less resistant than the units that contain it, consists of alternating slope- and cliff-forming units (figure 6). The cliff-forming sandstones are generally yellow-gray or white-gray on fresh surfaces and weather to shades of tan, yellow or brown. In places they are reddened by the natural burning of nearby coal seams. Sands are fine- to medium-grained and cemented by either calcite or silica. In a few places they are argillaceous. Iron colors the cement. Occasionally the iron has been leached by organic acids from covering swamps and the sandstone is white.

Slopes of the formation are made of various types of shale and coal. The shales, continental in origin, consist of three kinds: clay shale–soft, granular, gray to green in color and the most common; carbonaceous shale in various shades of brown and black; and smoke gray shale usually associated with the coal.

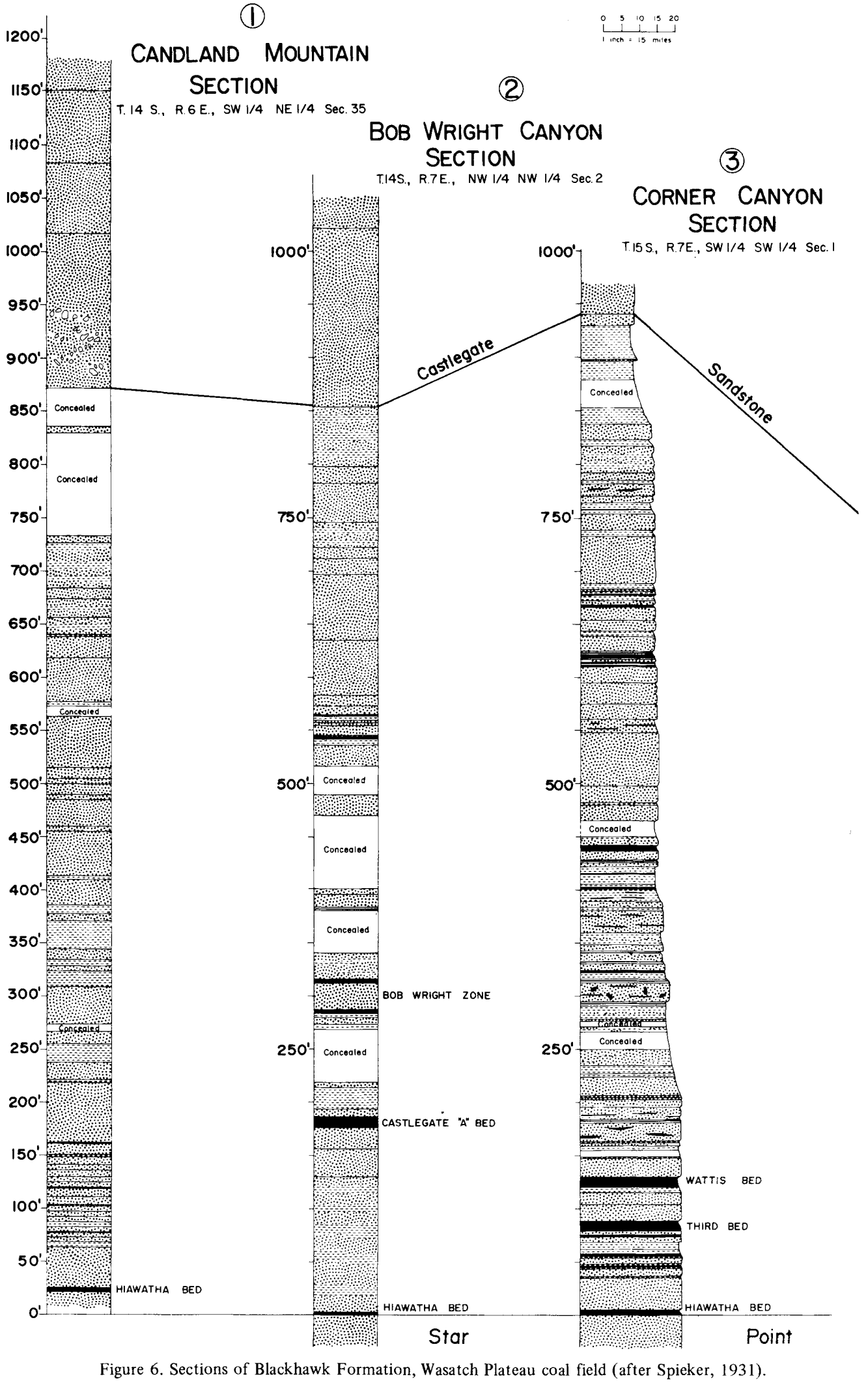
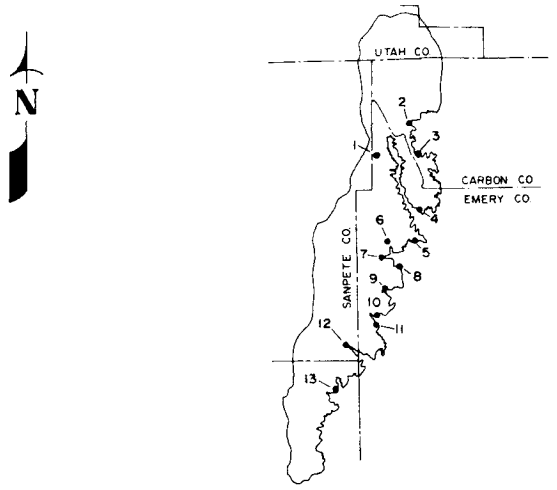


Figure 6. Sections of Blackhawk Formation, Wasatch Plateau coal field (after Spieker, 1931).



④

BEAR CANYON SECTION

T. 16 S., R. 7 E., NE 1/4 SW 1/4 Sec. 24

⑥

COTTONWOOD CANYON SECTION

T. 17 S., R. 6 E., SW 1/4 NE 1/4 Sec. 25

⑤

GRIMES WASH SECTION

T. 17 S., R. 7 E., SW 1/4 SW 1/4 Sec. 26

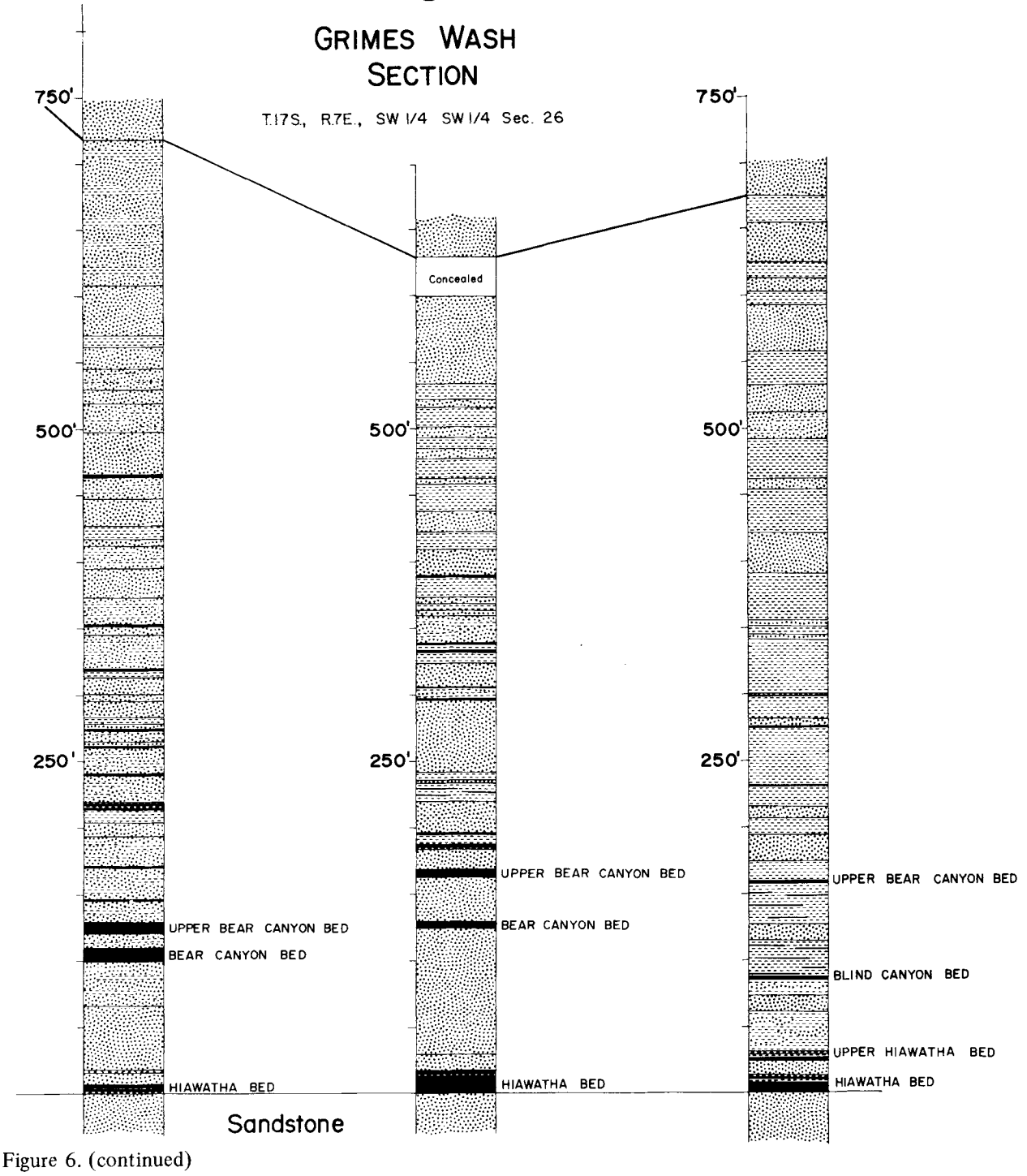
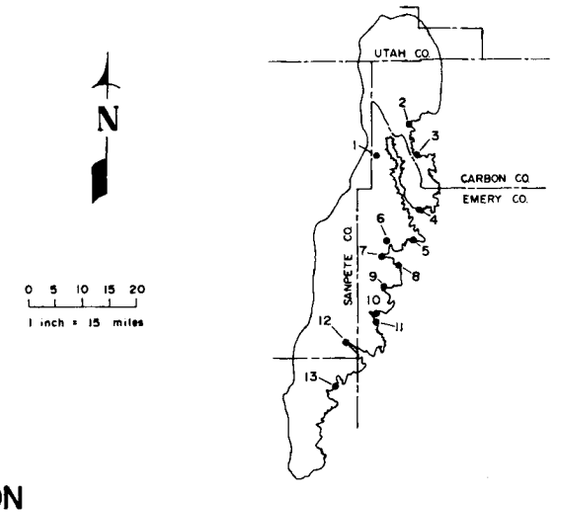


Figure 6. (continued)



⑦

STRAIGHT CANYON SECTION

18 S., R.6E., NE 1/4 NE 1/4 Sec.11

⑧

ORANGEVILLE CLIFF SECTION

T.18S., R.7E., NW 1/4 NW 1/4 Sec. 21

⑨

ROCK CANYON SECTION

T.19S., R.7E., NW 1/4 NW 1/4 Sec. 7

⑩

BIDDLECOME HOLLOW SECTION

T.19S., R.6E., SW 1/4 SE 1/4 Sec. 34

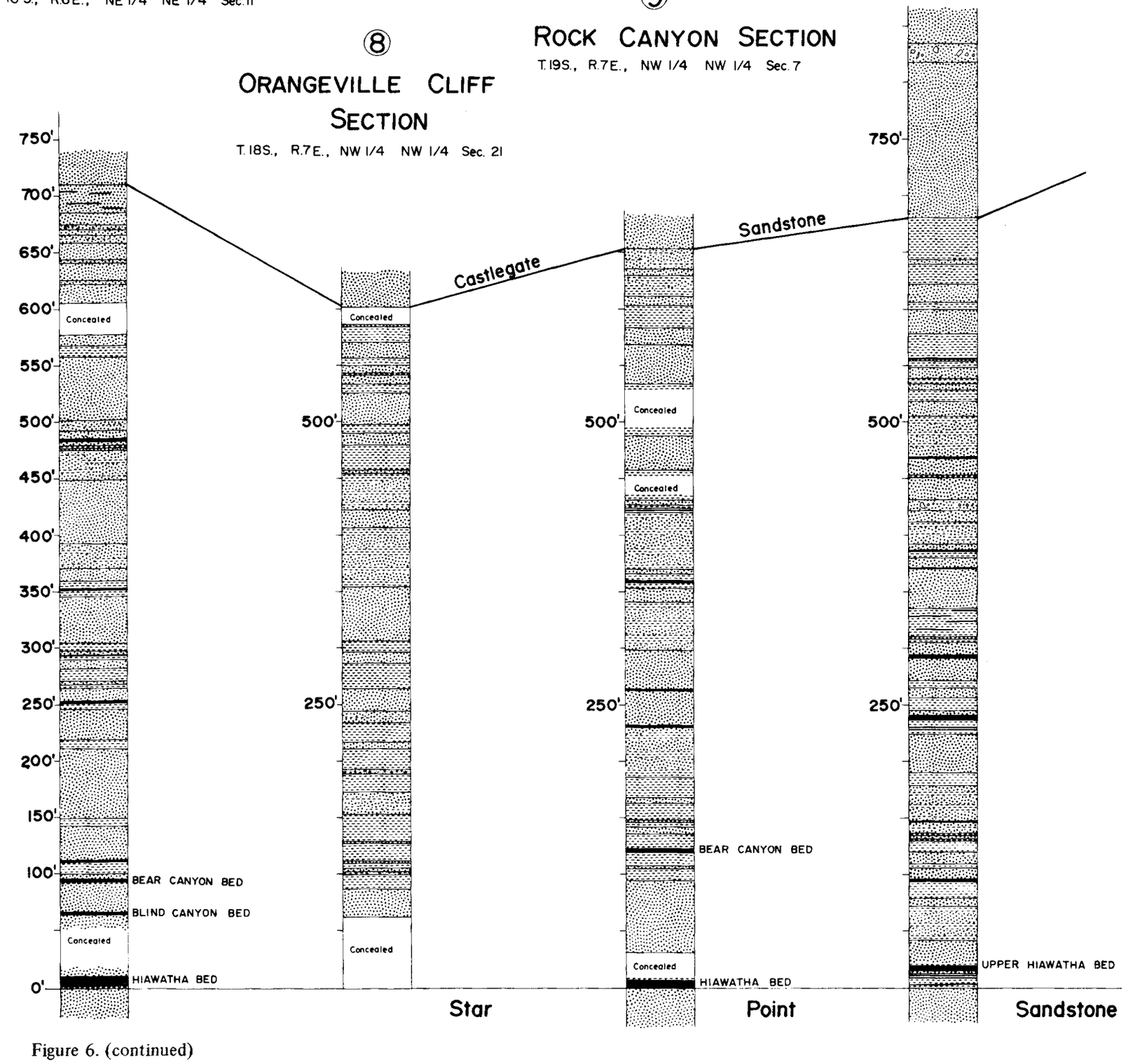


Figure 6. (continued)

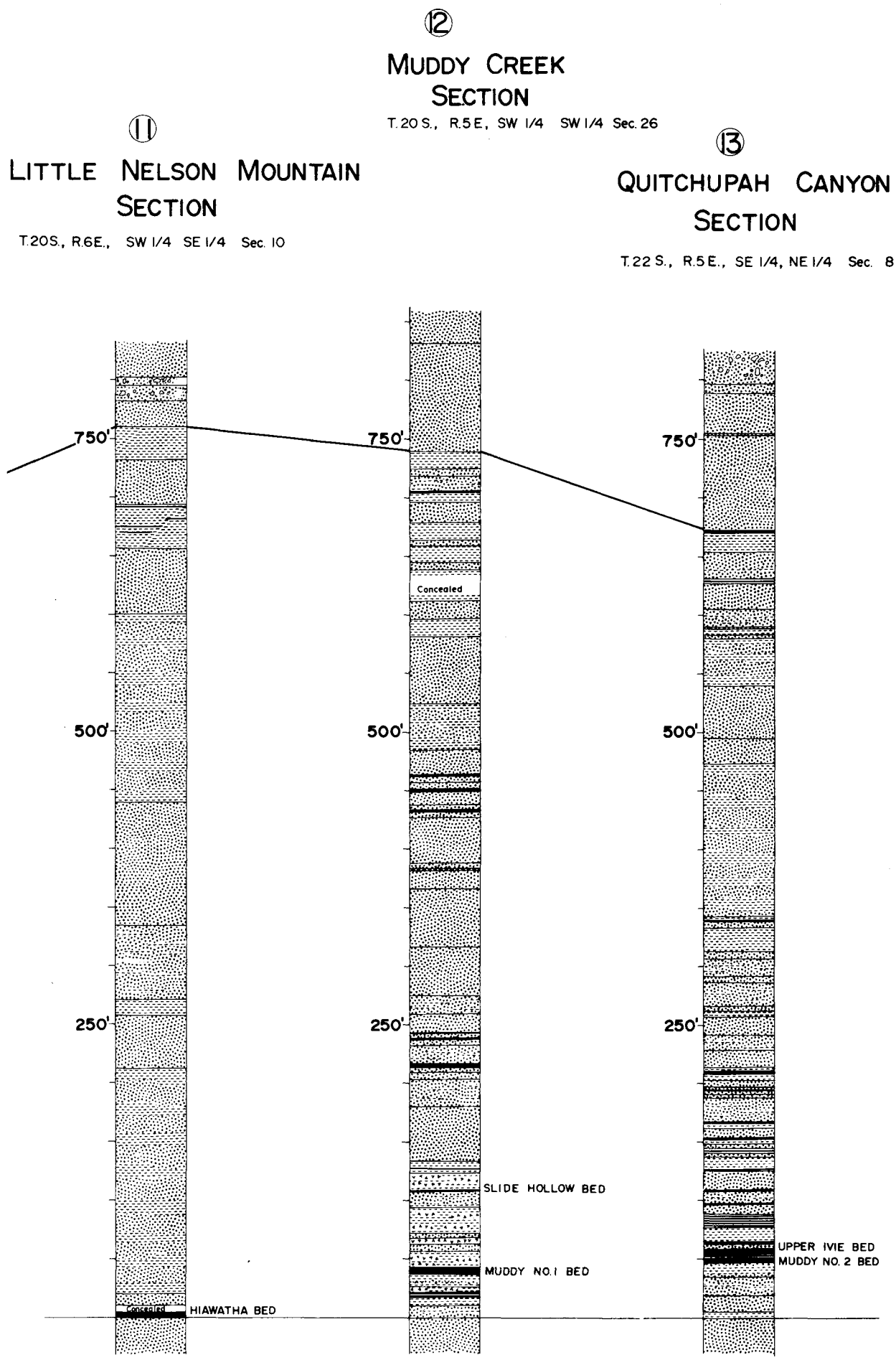


Figure 6. (continued)

Other strata include friable shaley sandstones, usually thin and platy, that are cemented loosely by calcium carbonate. In some places the rock grades into an impure limestone.

The proportion of shale to sandstone is greater in the north part of the field as compared to the south, but total change in character of the formation is slight. In a section measured by Spieker (1931, p. 30-33) the unit consists of one-third shale and two-thirds sandstone. Key beds are local in extent and each area has its own grouping. An exception is the Aberdeen Sandstone Member. It underlies the Castlegate "A" coal bed and can be traced from the Gordon Creek area southward to Gentry Ridge near Wattis.

The lower contact of the Blackhawk was defined by Spieker (1931, p. 35) as "the clear-cut upper surface of the Star Point Sandstone," but Young (1955, p. 183) redefined the base as the bottom of the Spring Canyon Tongue. Young's work concentrated on the Book Cliffs coal field to the east, but his reports add to the understanding of the Blackhawk in the Wasatch Plateau field. Excerpts from his report follow:

The redefined Blackhawk formation consists of some prominent littoral marine sandstone tongues and many lesser ones, all projecting eastward into the Mancos, where they lose their identity by grading into shale. Above each of them and below the next succeeding littoral marine sandstone, lagoonal deposits of sandstone, shale and coal were developed behind barrier bars, and where these deposits occur the underlying sandstone is almost everywhere white-capped. . .Division (of six members) is possible only where the basal littoral marine sandstones are developed at the extreme western end of the Book Cliffs at Storrs, Utah (simultaneously the northern end of the Wasatch Plateau field); only the basal sandstones of the Spring Canyon and Aberdeen members are present and between them is about 60 feet of coal-bearing rocks of the Spring Canyon Member. Above the basal sandstone of the Aberdeen Member are about 800 feet of undifferentiated coal measures of the Blackhawk, which are largely lagoonal but may include some inland floodplain deposits in the upper portion.

The commercial coal beds lie in the lower 250 to 350 feet of the formation; some thin units are in the upper part. Two of the more important coal beds are the Hiawatha and Castlegate "A" bed.

Castlegate Sandstone

The Castlegate Sandstone is generally carried as a member of the Price River Formation. It immediately overlies the Blackhawk. Along the cliffs it usually forms the uppermost part of the escarpment. The Castlegate varies from 150 to 500 feet thick. Massive, medium- to coarse-grained sandstone beds in places contain conglomerate with a matrix of grit. The cliffy units are occasionally broken by sandy, hard, gray shale and even thin (¼ inch) lenses of coal.

Price River Formation

The rocks above the Castlegate are less resistant, but like the Castlegate consist mainly of medium- to coarse-grained sandstone with occasional interbeds of gray to brown shale, some of which are carbonaceous. Individual beds are not as massive and are more friable, thus eroding more easily; hence the step-like outcrops. The unit ranges from 600 to 1,000 feet thick.

North Horn Formation

Because the North Horn Formation (Tw) is apparently gradational with the underlying Price River, the contact is difficult to discern. There are, however, differences in color and resistance to erosion. The North Horn forms slopes and rolling topography instead of steps and has a reddish color.

According to Spieker (1931, p. 46):

The Wasatch Formation (North Horn) contains a highly varied assemblage of rock types. The lower member (all of the North Horn) consists in the central part of the plateau predominantly of varicolored shale, in which the combinations of various shades of red, purple, chocolate-brown, green and gray are characteristic of the coloring of Wasatch rocks in the general region, but it contains many irregular beds of gray, brown and cream colored sandstone of various texture and thin beds of freshwater limestone, chiefly steel gray and cream colored but in places also white, tan and dark blue-gray. In the southwestern, central eastern and northern parts of the plateau the member contains more sandstone. Beds of conglomerate occur in the member irregularly both as to horizon and locality. . .

Fossils of Cretaceous age are in the lower part and of Tertiary age in the upper. The thickness ranges from 500 to 2,500 feet with the thickest sections to the north. The upper contact with the Flagstaff Limestone also is undefined.

Flagstaff Limestone

Even though the lower contact with the North Horn Formation is not sharp the Flagstaff is more resistant and easily recognized. It is a lacustrine limestone, fairly evenly bedded with a dark yellow-gray or cream color. Interbedded with the limestone are subordinate amounts of sandstone, shale and volcanic ash. The thickness of the unit ranges between 200 and 1,500 feet.

Colton Formation

Colton lithology is the same as the North Horn's except that its fossil content indicates a younger age. Outcrops are confined to the northernmost part of the Wasatch Plateau coal field notably along the White River (tributary to the Price River). The unit ranges from 300 to 1,500 feet thick.

Green River Formation

This formation overlies the Colton in the north part of the area. It is a deltaic complex of lenticular sandstone and greenish shales.

Igneous Rocks

Igneous dikes present in the north part of the field range from a few inches to 100 feet thick with most less than 10 feet thick. The fresh rock, a lamprophyre, is dark gray to black. These rocks cut the coal measures and metamorphose sedimentary rocks for short lateral distances. The coal itself has converted to a form of coke to a distance of mostly 2 feet, but as much as 10 feet. The coke is less porous and more solid than the artificial variety and contains a higher percentage of volatile hydrocarbons.

Surficial Deposits

Unconsolidated rock consists of three types. Larger stream channels and broad valleys contain alluvium that is coarse in the canyons but fine in the Castle Valley area. Long sloping plains which extend from the cliffs toward Castle Valley are covered by gravels, essentially remnants of an erosional surface. The gravel may be as much as 75 feet thick. The last group, landslides, are scattered at the base of the cliffs.

Structure

Spieker (1931, p. 52) describes the general structure of the Wasatch Plateau (figures 7 and 8):

The Wasatch Plateau lies between the simple dome-like uplift of the San Rafael Swell on the east and the highly faulted, structurally complex region of the Great Basin on the west. Occupying the transition ground between areas showing these different types of structure, it partakes of the nature of both. In the eastern part of the plateau the strata dips gently westward, in continuation of the dips of the west flank of the San Rafael Swell. . . The faults are of great importance in the coal field because of their effect on the coal beds and because of the mining problems they introduce. . .

Faults

Faults associated with the Wasatch Plateau cut and displace the coal (table 2). Basically they occur in north-south-trending

zones. They have been named by Spieker (1931, p. 54) and Spieker and Baker (1928, p. 145).

Table 2. Fault zones of the Wasatch Plateau coal field.

Fault	Miles			Feet
	Known length on plateau	Average width	Average distance from next zone east	Greatest displacement
Musinia	50	2	12	2,500
Joes Valley	75	2	5	2,500+
Pleasant Valley	35	4	6	1,500
North Gordon	22	4	–	800

Musinia Fault Zone

This zone marks the west boundary of the Wasatch Plateau coal field in the south. The Salina Canyon coal field lies west of the zone. It is best developed in the south part of the field and continues north of Block Mountain as a single possibly discontinuous fault. In the vicinity of Salina Canyon the zone is bounded by two major faults; the graben between them is faulted also. Here the displacement is near maximum; at Skumpah Creek it is estimated to be between 2,000 and 2,500 feet.

Joes Valley Fault Zone

The Joes Valley fault zone is the most extensive of the fault zones of the Wasatch Plateau field. Throughout its length of 75 miles in the plateau it is a graben in which the rocks have dropped 1,500 to 2,500 feet, and the dropped block is everywhere much shattered...The complexity of the internal faults of the zone is excellently shown on Ferron Creek, and a similar profusion of faults presumably exists in Joes Valley and in parts of the zone farther north, whose softer rocks form the surface and the exact nature of the faulting is not determinable.

The north end of the Joes Valley fault zone lies somewhere not far north of Cleveland Reservoir. The easternmost fault of the zone ... the Joes Valley fault, has caused a steep escarpment that is continuous from the north end of Candland Mountain to Ferron Canyon. Not far north of Ferron Canyon the displacement on the east side of the zone is taken up by a fault that branches from the Joes Valley fault and connects southward with the Paradise fault of southern Castle Valley. The westernmost fault of the zone is continuous from Miller Flat to the divide south of Ferron Canyon and there the displacement is taken up by an overlapping fault... that continues southward as far as Quitchupah Creek ...

The Paradise fault, the easternmost fault of the zone, borders Nelson Mountain on the west. Along this fault the Flagstaff Limestone... abuts against Mancos Shale, and the throw of the fault...in this part of the field is over 2,500 feet...

South of Nelson Mountain the fault continues in Mancos Shale and its trace may be followed fairly well because of exposures of the Emery Sandstone Member. The throw of the fault is about 2,000 feet at the crossing of Muddy Creek, causing the Emery Sandstone to abut against the upper part of the Blackhawk Formation...

South of Emery the faults of the Joes Valley zone, visible in the outcrop of the Emery Sandstone, gradually become less numerous. Near Saleratus Creek they begin to swing southwestward...toward Paradise Valley ... (Spieker, 1931, p. 57-58).

Stokes' Geologic Map of Utah (1963), SE quarter, shows that an alignment of faults along the Joes Valley zone extends from McGath Lake south of Boulder Mountain in Garfield County northward, west of Thousand Lake Mountain and past Cleveland Lake northward to the Strawberry Reservoir. At the north end of the field it fuses with the Pleasant Valley zone. The entire length of the zone may be as much as 160 miles. The zone roughly divides the coal field into two halves: the northeast part is east of the zone and the southwest part lies to the west.

Pleasant Valley Fault Zone

The Pleasant Valley fault zone divides the northeast half of the field. Although Joes Valley zone is the longest and most pronounced, the Pleasant Valley zone has caused the coal mining industry the greatest problems. Its south end is in Cottonwood Creek and north of the Price River it fuses with Joes Valley zone. The zone is 3 to 5 miles wide and represents a graben from Scofield northward. The major fault, the Pleasant Valley fault, appears continuous from the Scofield Reservoir to Tie Fork Canyon near Huntington Creek. Spieker (1931, p. 54) reported that the maximum displacement is almost 1,500 feet, but in most places it is much less. According to Taff (1906, p. 293): "The fault planes are nearly vertical and the throws or displacements vary from a few feet to nearly 100 feet."

North Gordon Fault Zone

Faults of this zone have diverse trends and displacements up to 800 feet. The easternmost fault with perhaps the greatest displacement is the east boundary of the field. Change in regional dip caused some of the faults; to the west the dip is west, but to the east it is north.

Folds

Except adjacent to the fault zones strata usually dip at slight angles to 5 or 6 degrees. Locally in and around faults they dip to 20 degrees. The dip is generally westerly over most of the field and northerly in the extreme north part. In places they appear horizontal. Some of the undulations and shallow anticlines and synclines have been tapped by gas wells. The intricate folds are illustrated in detail on the structure map of the north part of the field by Walton (1955, p. 406-07). The contours are mapped at the top of the Ferron Sandstone almost 4,800 feet below the surface but the map serves to illustrate the complexity of structure that is undoubtedly reflected to the surface.

Unconformities

No unconformities are shown on the Generalized Section of Rock Formations (figure 5). No doubt local unconformities exist, but a detailed description here is superfluous. The pronounced unconformity at the top of the Blackhawk, the Castlegate Sandstone, exhibits varied sediments deposited under different environmental conditions.

GEOLOGIC AND TECTONIC HISTORY

From late Triassic until late Cretaceous time the region gradually subsided. Rates of sedimentation fluctuated, but there were no long periods of nondeposition (except during the Lower Cretaceous) and no uplifts. During the latter part of this relatively quiet time events favorable to the accumulation of coal deposits took place. The deposition of the Dakota represents lagoonal, fluvial and perhaps beach and littoral environments in front of an advancing Mancos sea. Part of the Dakota may have been deposited in Lower Cretaceous time and was laid down in earliest Upper Cretaceous. The amount of Lower Cretaceous sedimentation was small.

The Mancos sea covered the area during its first westward transgression and deposited the Tununk Shale. The sea extended westward as far as Sanpete Valley. Most of the sediments originated to the landward side or from the west. In the west orogenic activity was gaining impetus and its spasmodic behavior caused the differences in the Wasatch Plateau Mancos members. When orogenic activity was high in the west the sandstone members were deposited and when it was low the sea encroached westward and deposited the marine shale. The first sandstone tongue to project eastward was the Ferron and according to Katich (1954, p. 48):

The sediments that constitute the Ferron Sandstone originated in valley-flat, swamp and littoral environments. At the time of deposition the regional relief must have been low, possibly near sea level. Rivers which originated in distant highlands became sluggish streams and lost themselves in broad swampy coastal plains. Low beach and dune barriers probably lay toward the sea. Parts of the coastal plain were covered by swamps in which localized coal beds were formed. Occasional rapid sinking of the marine basin permitted the sea to advance without materially altering the deposits over which it passed.

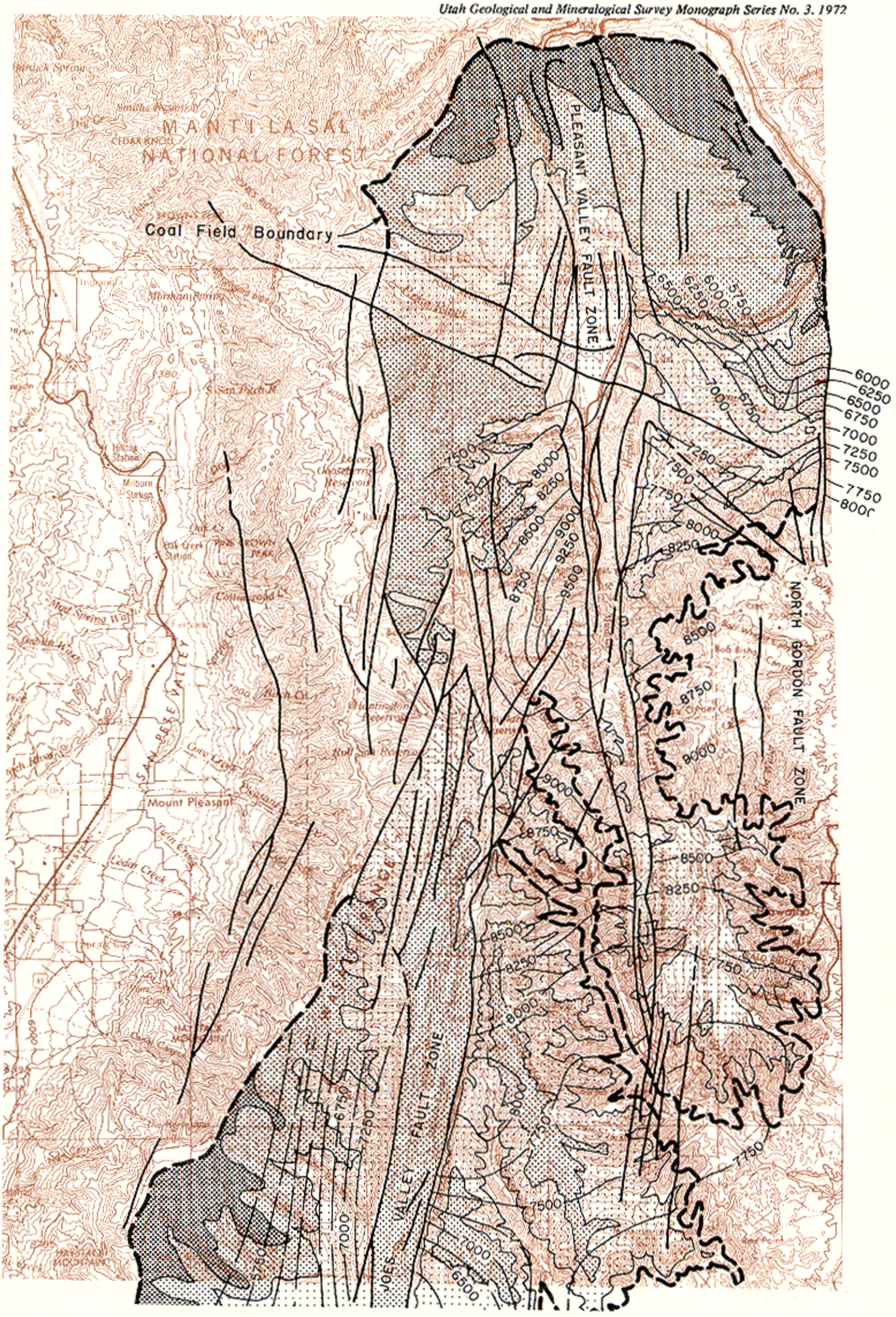


Figure 7. Generalized structure map, Wasatch Plateau coal field.

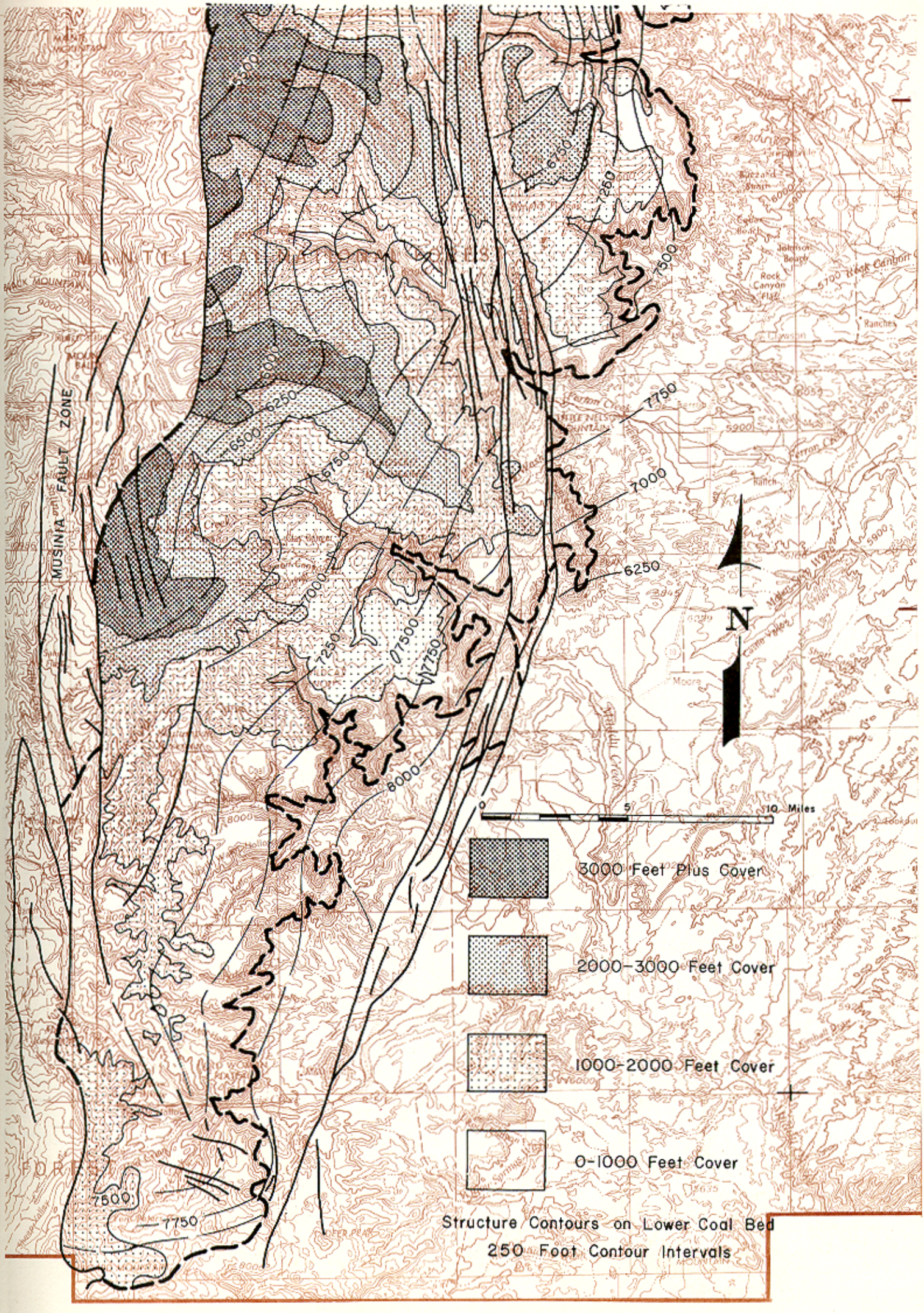


Figure 7. (continued)

R. 4 E.
R. 5 E.
R. 6 E.
R. 7 E.
R. 8 E.
T. 10 S.
T. 11 S.
T. 12 S.
T. 13 S.
TIE FORK SYNGLINE
WASATCH COUNTY
UTAH COUNTY
SOLDIER SUMMIT
SOUTH BOUNDARY UINTAH INDIAN RESERVATION
WESTERN SYNCLINE
MILL FORK SYNGLINE
PONDTOWN CREEK STRUCTURE
GRABEN
VALLEY
BEAVER CREEK
SANPETE COUNTY
CARBON COUNTY
COLTON
FISH CREEK
GOOSEBERRY RESERVOIR GRABEN
GOOSEBERRY RESERVOIR
SCOFIELD RESERVOIR
NORTHEAST SCOFIELD RESERVOIR STRUCTURE
PLEASANT VALLEY
FORGE
MT.
ELBOW AREA
ANTICLINE
CLEAR CREEK
FAIRVIEW
HIGHWAY
To Price

After Walton, 1955

Figure 8. Map showing geologic structure, Wasatch Plateau gas fields (contours on top of Ferron Sandstone).

The next transgression of the sea deposited the Blue Gate Shale Member. In the north part of Castle Valley the Garley Canyon Sandstone Tongue probably represents a weak orogenic pulse to the west of that region. Garley Canyon Sandstone is mainly littoral in origin. The following strong orogenic pulse deposited the Emery. Deposition did not extend as far east as that of the Ferron. In the Castle Valley area the Emery is mainly a littoral sand; westward in the subsurface, it reverts to a brackish water, coal-bearing unit, and finally to a continental floodplain deposit. With the last incursion of the sea the Masuk Shale was deposited. The sea retreated and the littoral sandstone tongues of the Star Point were laid down.

By Blackhawk time the main body of the sea had moved eastward. In the Book Cliffs coal field Young (1955, p. 183) notes six principal littoral sandstone tongues in the Blackhawk topped by lagoonal sands, shale and coal. Two are present in the Wasatch Plateau: the lower Spring Canyon (top of the Star Point) and the next to the lowest Aberdeen. The upper part of the Blackhawk in the Wasatch Plateau reverts to fluvial-type deposits indicating the eastward movement of the sea and perhaps the eastward movement of the orogenic pulses from the west.

A strong orogenic pulse followed and spread coarse sands and other clastics eastward (Castlegate Sandstone). No additional incursions of the sea followed and the environment became strictly continental. The Price River Formation and the North Horn were deposited in dominantly fluvial floodplain conditions. With time the source highlands to the west eroded and sediments became finer. Lakes developed on the floodplains as evidenced by freshwater limestone. This marked the end of the Cretaceous and the beginning of the Tertiary periods. Subsidence continued and possibly surpassed the rate of sedimentation; a large lake was created and limestone was deposited (Flagstaff). During the early Tertiary the area continued to receive sediments, lacustrine, fluvial and floodplain. Volcanic ash in some of the sediments indicates volcanic activity localized to the west.

Thereafter it is believed that uplift ensued and the area itself was taken up with orogeny. The activity has probably continued at a slow rate since Eocene time. Intermittent faulting since then has even displaced glacial deposits of Pleistocene age. The intrusion of dikes in the north part of the field probably occurred during middle to late Tertiary time. Erosion became prominent in Oligocene time and has continued to the present.

Correlation with Surrounding Areas

Investigators working in separate areas of the Cretaceous conclude that coal divisions are not restricted to fixed time-stratigraphic zones. Because of the transgression and regression of the Cretaceous (Mancos) sea, depositional facies differ from one area to another. The diagrammatic tentative correlations in figures 9 to 13 illustrate what happens between fields. Figure 14 shows the locations of correlations.

East Utah

Diagram A-A' (figure 9) correlates the coal-bearing formations and rocks containing them between Thistle (18 miles west of the north end of the Wasatch Plateau field) and Colorado. The source of sediments was to the west where the coarser deposits occur. The west to east sequence is simple: continental fluvial and floodplain deposits, lagoonal and paludal deposits (coal producers), littoral marine deposits (mostly beach and nearshore sands) and marine deposits (mostly shale). Note that the major coal producer in the Wasatch Plateau is the lower Blackhawk. To the east the unit thins, the lower part being replaced by the marine Mancos Shale. The lower coals are replaced by higher seams until finally near the Green River the entire Blackhawk disappears. Farther east the coal is found in the Price River.

Cross-section B-B' (figure 10) details essentially the same thing—particularly what happens to the Blackhawk to the northwest. A pre-Price River uplift truncates the west extension of the unit.

West Utah

Toward the west extensive facies changes predominate and formations are difficult to recognize. The west represents the source area. Cross-section C-C' (figure 11) indicates an uplift west of Sanpete Valley below the Price River. Essentially the west part of the Blackhawk has been removed by erosion and the westernmost exposures are on the west side of the Wasatch Plateau near Mt. Pleasant and Fairview. The Indianola Group and the Price River become formidable conglomerates in the vicinity of the uplift; these units are fully discussed in the Mt. Pleasant and Wales coal field sections.

Southwest Utah

Cross-section D-D' (figure 12) shows what happens to the rock units between the north Wasatch Plateau and the Kaiparowits coal field. Most of what is shown beneath the volcanics between the south Wasatch Plateau and the Kaiparowits is speculative, but the transition between the facies of many units takes place here. The fluctuating marine shoreline is well defined and according to the diagram the Blackhawk is correlated in part with the Kaiparowits Formation interval.

The sequence from the Wahweap to the Claron Formation of the Kaiparowits has little in common with the correlatives Blue Gate to Flagstaff in the Wasatch Plateau. The Straight Cliffs Formation matches well with part of the Ferron, the Tropic with the Tununk and the Dakota with the Dakota. Both the Claron and Flagstaff are limestones probably deposited in a continuous basin. The Claron, however, weathers to pink whereas the Flagstaff is gray or cream. The major difference between the two is that the Kaiparowits section represents mainly continental deposition and the Wasatch Plateau section represents alternating marine, littoral and lagoonal deposition.

Southeast Utah

Much of the Cretaceous has been removed from southeast Utah. In San Juan County remnants of Dakota and Mancos are found along the Colorado state line. In Wayne and Garfield counties a large remnant is preserved in the Henry Mountain Basin. Cross-section E to E' (figure 13) connects the central Wasatch Plateau with the Henry Mountains coal field. The same Mancos division exists but the lagoonal facies of the Blackhawk are probably eroded. The Mesaverde is barren in the Henry Mountains and represents the youngest strata left uneroded. Both the Emery and Ferron have thin lagoonal units with some commercial coal seams in the Henry Mountains field.

COAL DEPOSITS

Status of Information

Of the significant reports by the U. S. Geological Survey on the Wasatch Plateau coal field, those by Taff (1906 and 1907) on the Pleasant Valley area and by Spieker (1930 and 1931) were most important. Since Spieker published his monumental work in 1931, no additional comprehensive work has been done.

Spieker's work is excellent and covers all outcrop and stratigraphic information. Nevertheless his maps show only the Hiawatha or Castlegate "A" bed and detailed map work on the other seams would be helpful. A lack of subsurface data existed then as now. Little is known about the coal west of the surface exposures and present mines. Analytical data are adequate for the north part of the field, but to the south, where development has lagged, additional data are needed.

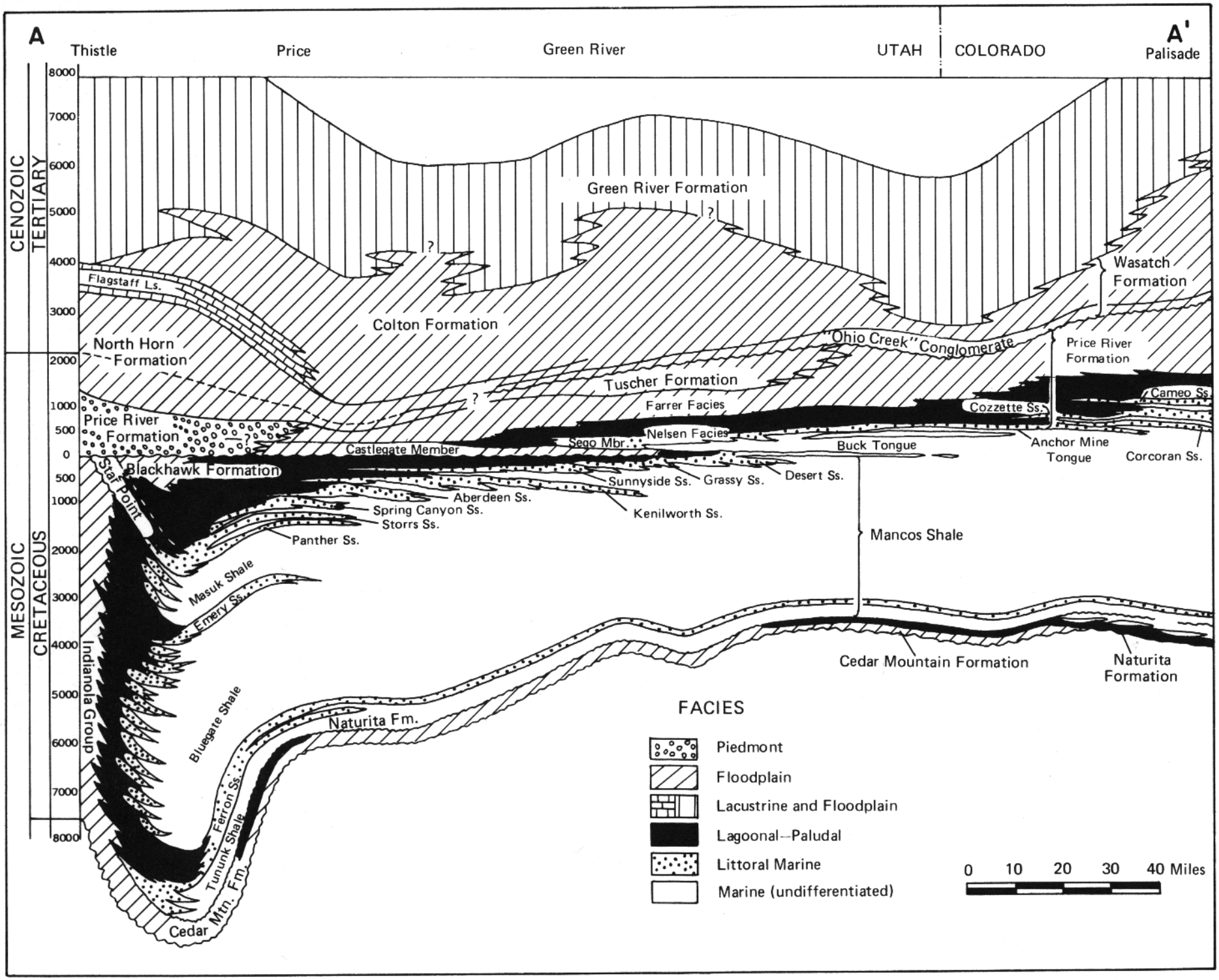


Figure 9. Stratigraphic correlation diagram of post-Jurassic rocks between Thistle, Utah, and Palisade, Colorado (after Young, 1966).

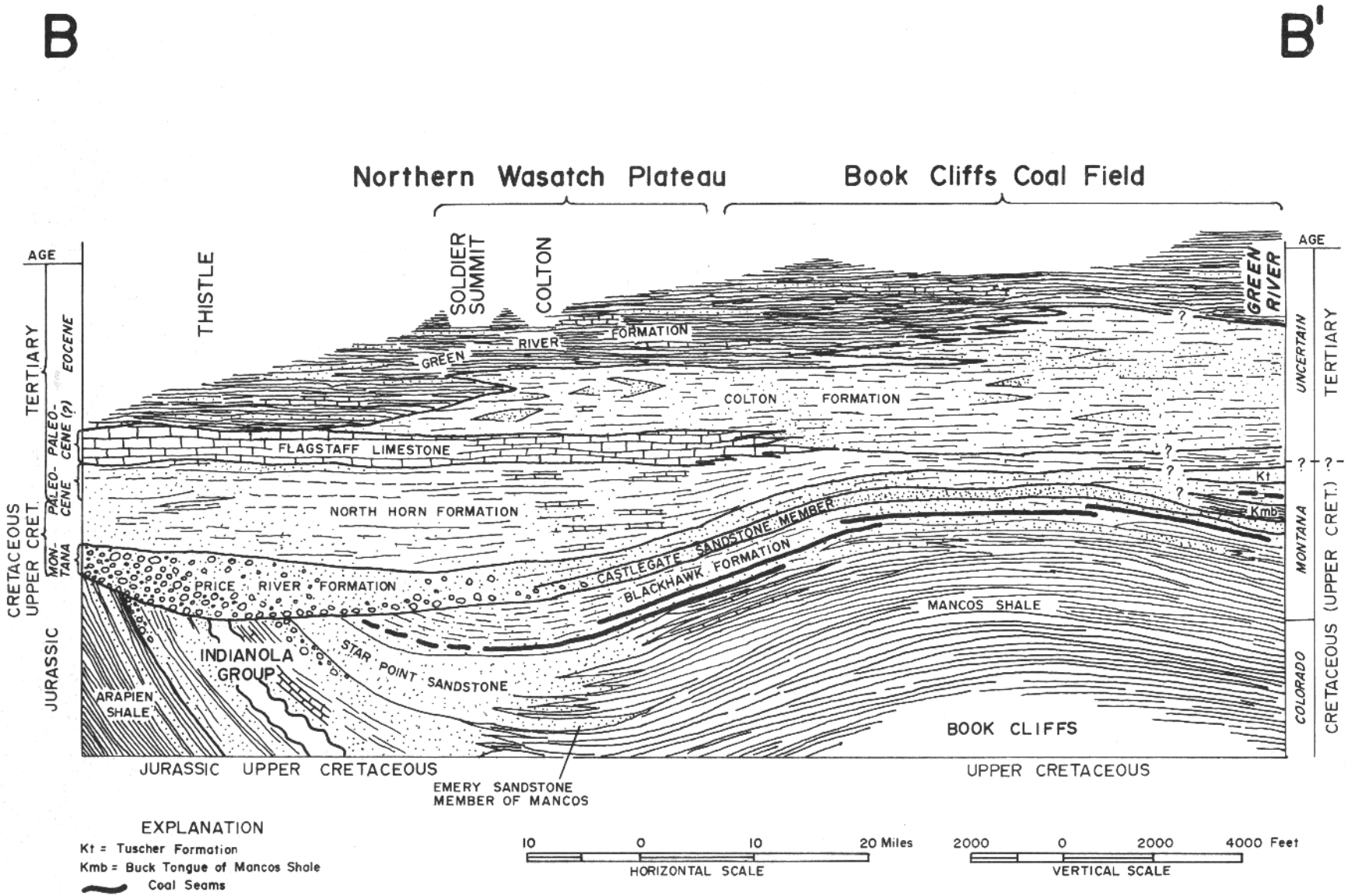


Figure 10. Stratigraphic diagram of post-Jurassic rocks through area north and east of Sanpete County (after Spieker, 1946, figure 18).

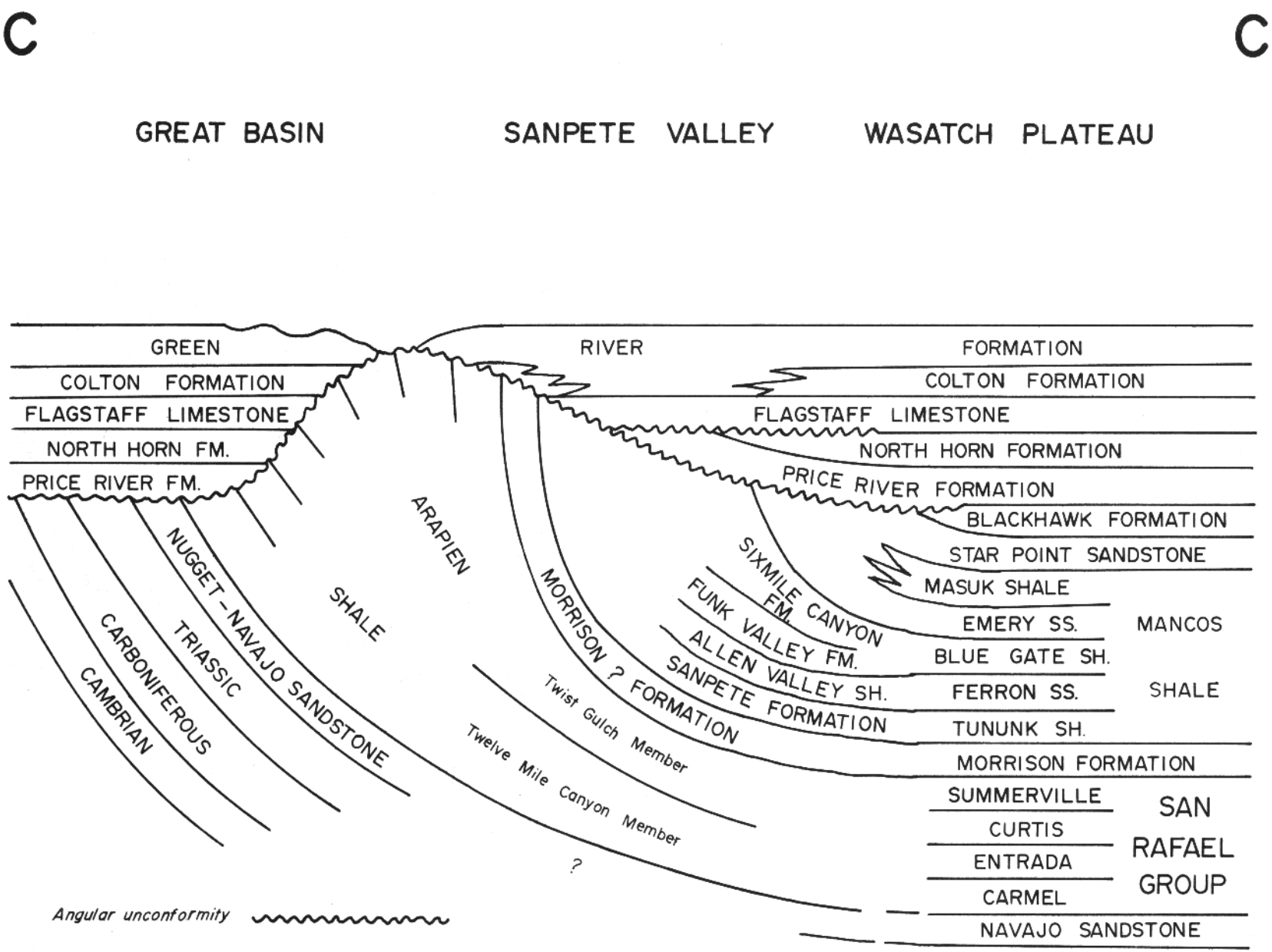


Figure 11. Stratigraphic diagram from Great Basin to Colorado Plateau showing generalized regional correlations (after Spieker, 1949, figure 2).

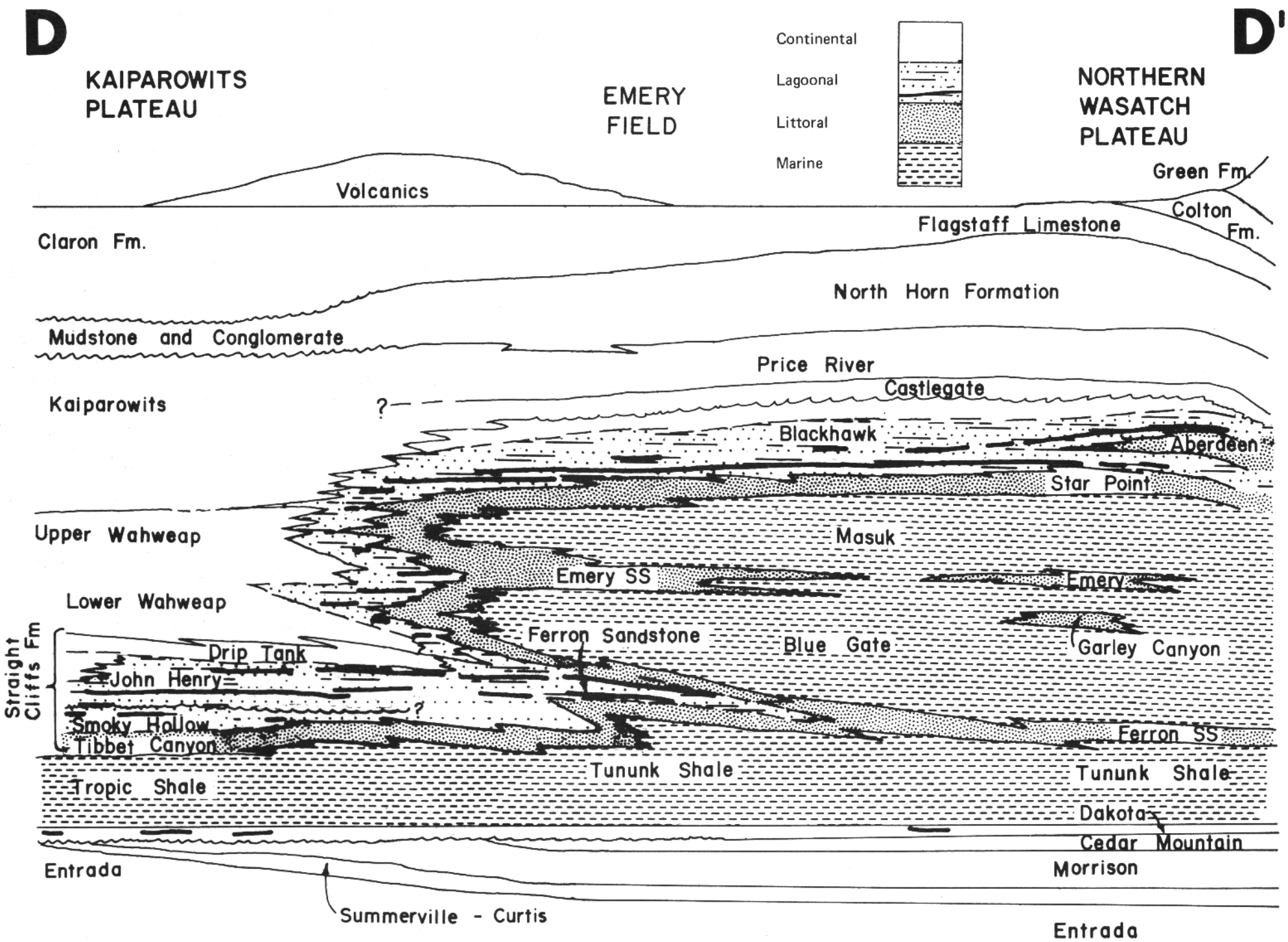


Figure 12. Stratigraphic correlation diagram from Kaiparowits Plateau to north Wasatch Plateau.

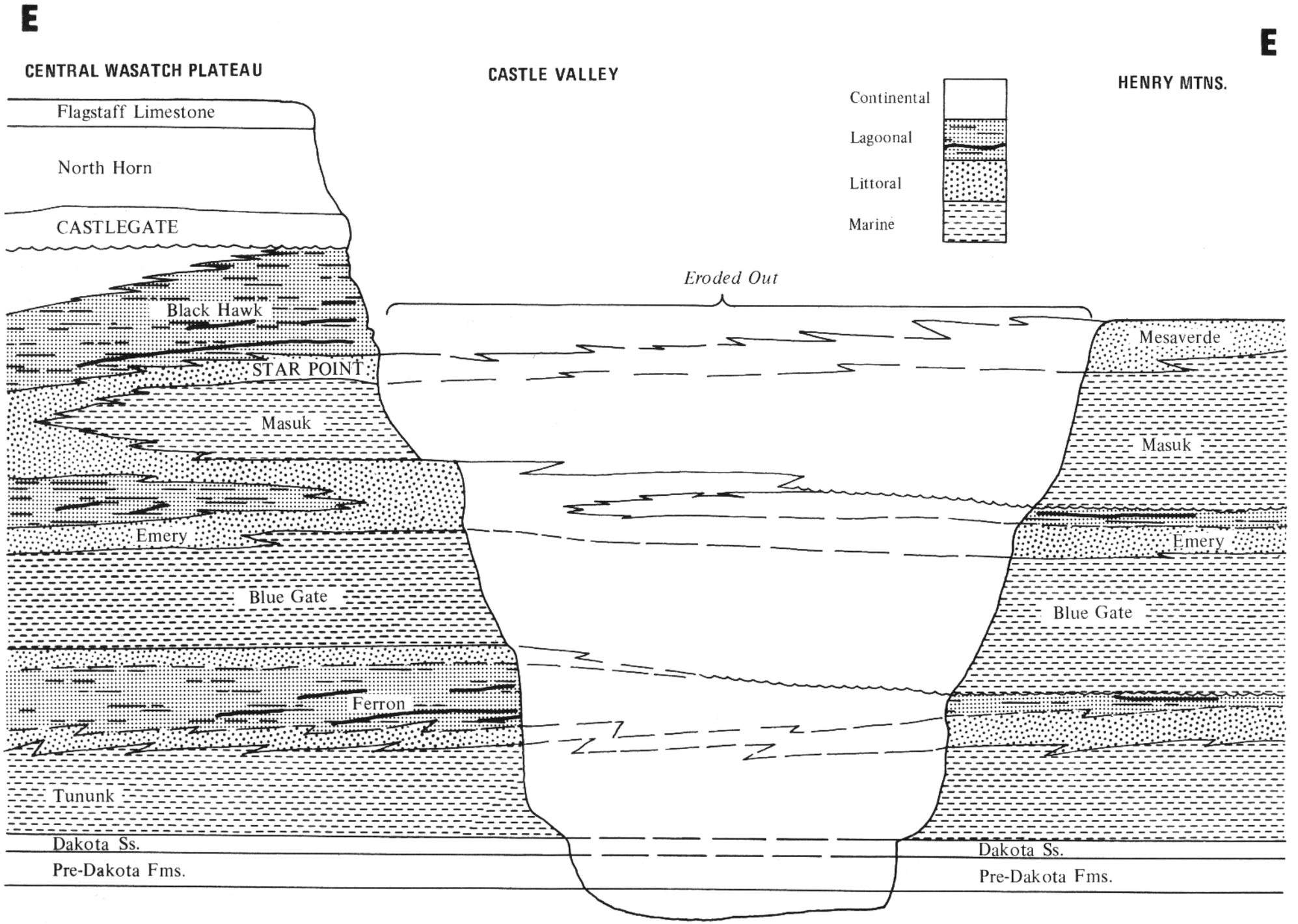


Figure 13. Stratigraphic correlation diagram from central Wasatch Plateau to the Henry Mountains.

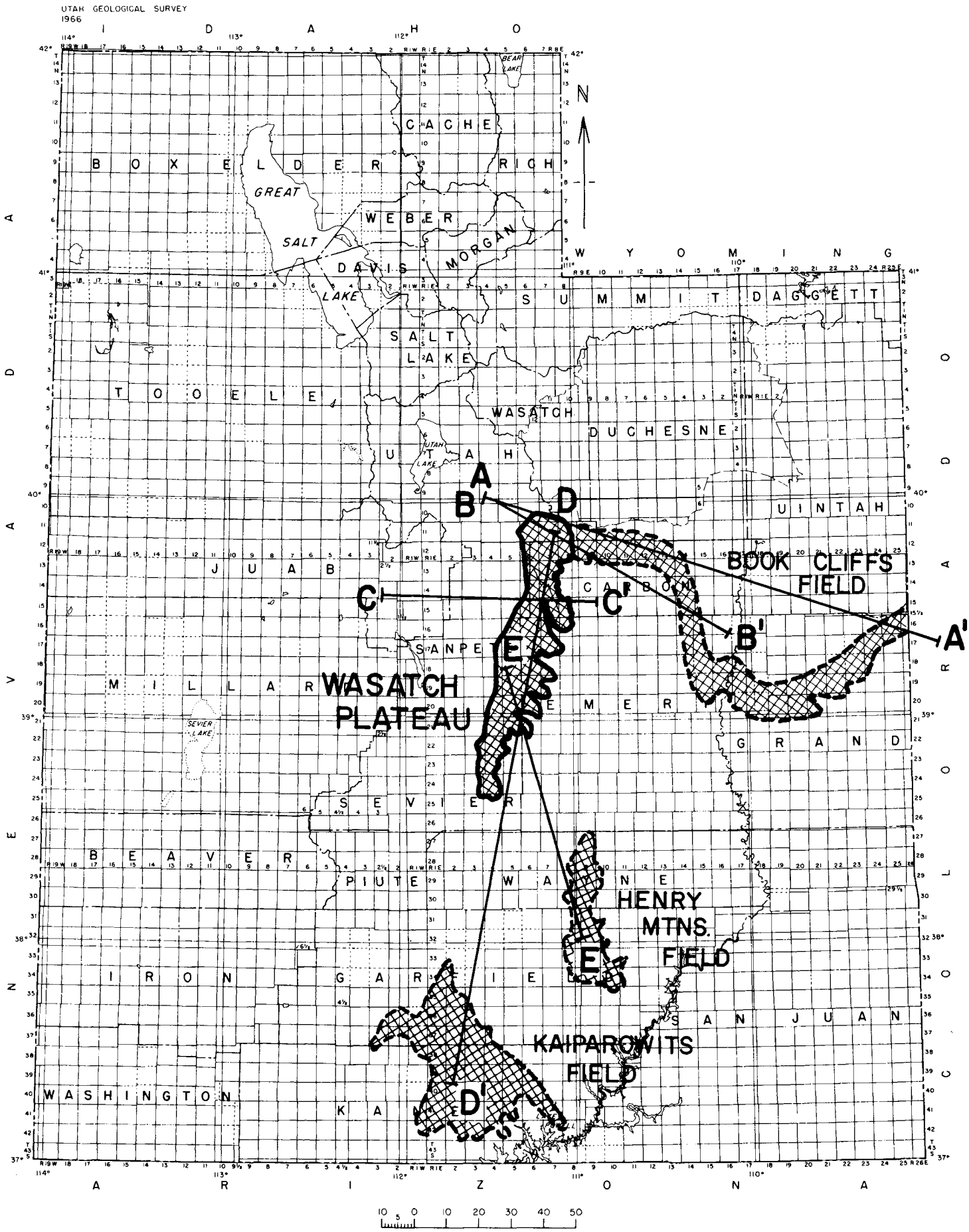


Figure 14. Index map of Utah showing locations of correlation diagrams, figures 9 to 13.

Principal and supporting works applicable to the geology of the coal resources are listed in the References section.

Mines, Prospects and Production

Mines and prospects have been opened in the Wasatch Plateau coal field since 1874. Most are in the north half of the field closer to markets and thicker seams (figure 15). Eighty percent of the production have come from two quadrangles: Hiawatha NE and Scofield NW. In 1969 and 1970 the following mines were active and producing coal:

Mine and quadrangle	Tons 1969	1970
Colombine mine (Scofield NW)	30,649	11,448
Co-op mine (Hiawatha NE)	44,000	21,556
Deseret-Beehive mine (Hiawatha SE)	104,675	96,190
Gordon Creek 1 and 2 (Scofield NE)	137,832	190,180
King mine (Hiawatha NE)	627,423	719,978
Larsen & Rigby mine (Scofield SW)	1,333	1,523
Southern Utah Fuel (Acord Lakes NW)	71,523	89,128
Wattis, Plateau Mng. (Scofield SE)	159,345	134,500
Deer Creek mine	–	137,858
	1,176,780	1,402,061

Table 3 lists mines according to quadrangle, location and period of activity. Estimated total production for the field is almost 100 million tons of coal. The production breakdown is given in the Reserves section.

Table 3. Mines and prospects, Wasatch Plateau coal field.

Mine or Prospect	Location	Remarks
Acord Lakes NE		
Link Canyon mine	SW.NW.26-21S-5E 4,312,300m.N. 471,300m.E.	Active 1940-1952
Acord Lakes NW		
Queatch-up-pah Creek mine (Queatchappel)	SE.SW.29-21S-5E 4,311,610m.N. 467,080m.E.	Intermittently active 1901-1920
Southern Utah Fuel (New Salina, Convulsion Canyon, Hanson)	NW.SE.NW.12-22S-4E 4,307,300m.N. 463,910m.E.	Active 1941-1970; (1970) active
Acord Lakes SW		
Knight mine (Ivie Creek)	SW.34-23S-4E 4,290,140m.N. 460,940m.E.	Active 1923 - ?
Castle Dale NW		
Axel Anderson mine (Rock Canyon, Clawson, Peterson)	NE.SE.NE.7-19S-7E 4,337,260m.N. 485,300m.E.	Active 1906-1932
Ferron mine	SE.19-19S-7E ≃4,333,085m.N. 484,075m.E.	Active 1901-1906
Killpack mine	SE.NW.5-19S-7E 4,338,790m.N. 486,000m.E.	
Castle Dale SW		
No mines		
Emery 3 NW		
A few small mines and several prospects have been opened mainly in Clear Creek Canyon and Red Canyon. The exact locations are unknown.		
Ferron Canyon		
Several prospect pits have been dug, locations unknown.		
Flagstaff Peak		
Ricci mine (Muddy Creek)	NE.NE.35-20S-5E 4,319,940m.N. 472,270m.E.	Active 1941-1953
Slide Hollow mine	4-20S-6E (exact location unknown)	Very old; presently abandoned
Hiawatha NE		
Bear Canyon mine	SW.SW.24-16S-7E 4,362,200m.N. 492,000m.E.	Intermittently active 1896-1906; active 1938-1957
Community mine	C.S.SW.NE.22-16S-7E 4,363,000m.N. 490,800m.E.	Active 1921

Table 3. (continued)

Mine or prospect	Location	Remarks
Co-op mine (Trail Gulch)	SE.SE.NE.22-16S-7E 4,363,000m.N. 491,040m.E.	Active 1938-1970; (1970) active
Hiawatha mine No. 1 No. 2	NE.SW.NW.29-15S-8E 4,371,425m.N. 495,175m.E. 4,371,520m.N. 495,175m.E.	Active 1905-1931
King mine (Blackhawk)	NE.NW.NW.NW.4-16S-8E 4,368,650m.N. 498,430m.E.	Active 1898-1970; (1970) active
Mohrland mine (King No. 2, Cedar Creek, Howard)	NE.NE.SE.SE.8-16S-8E 4,367,750m.N. 496,550m.E.	Active 1896-1938
Miller Canyon prospects	C.NW.32-15S-8E 4,369,900m.N. 495,350m.E.	Joins King mines in subsurface
Reichert mine	S.SE.NW.SE.20-16S-8E 4,362,600m.N. 496,000m.E.	Active 1940's
Sea Gull mine (Beehive)	34-16S-7E 4,359,400m.N. 489,400m.E.	Active 1943-1956
Tie Fork prospect	34-15S-7E	Activity unknown
Hiawatha NW		
Comfort mine (Smith) adit 1 adit 2	W.SE.SE.NW.28-16S-7E 4,361,400m.N. 487,190m.E. 4,361,490m.N. 487,480m.E.	Active 1936-1954
Helco mine (Black Magic, Rilda Canyon)	S.NW.NW.SW.28-16S-7E 4,361,050m.N. 487,100m.E.	Active 1938-1969
Tip Top mine (Sam & Jim's, Jim Peterson)	SW.NW.SE.NE.5-16S-7E 4,367,760m.N. 386,800m.E.	Active 1939-1956
Johnson mine	29-16S-7E 4,361,250m.N. 486,250m.E.	Active 1943-195?
Leamaster mine (Mill Fork)	SE.SW.16-16S-7E 4,363,830m.N. 487,910m.E.	Active 1943-1964
Rominger mine	SE.SW.SW.NW.28-16S-7E 4,361,380m.N. 487,080m.E.	Intermittently active 1938-1954
Hiawatha SE		
American mine (American Fuel)	10,11-17S-7E ≃4,356,250m.N. 490,150m.E.	Active 1937-1966
Anderson mine	N.SW.SW.26-17S-7E 4,351,280m.N. 490,300m.E.	Active in 1922
Deer Creek mine	NW.SW.NW.11-17S-7E 4,356,650m.N. 490,600m.E.	Intermittently active 1896-1916; active 1937-1956
Deseret mine (Beehive, Church, Otterson) No. 2	N.SE.NE.26-17S-7E 4,351,800m.N. 491,525m.E. 4,351,920m.N. 491,530m.E.	Active 1909-1970; (1970) active
Huntington mine (Meetinghouse, Harrison, Leonard, Community)	SW.SW.SE.NE.3-17S-7E 4,358,000m.N. 489,810m.E.	Active 1921-1952
Maple Creek mine	N.NE.14-17S-7E ≃4,355,000m.N. 491,600m.E.	May be prospect; active early 1940's
Paramount mine	SE.SE.SE.SW.2-17S-7E ≃4,357,400m.N. 490,850m.E.	Active 1948-1956
Stump Flat mine	24-17S-7E ≃4,352,450m.N. 492,400m.E.	Intermittently active 1938-1960
Wilburg mine (Fox, Straight Canyon, Castle Valley, Crow, Reed)	NE.NW.NW.NE.27-17S-7E 4,352,390m.N. 489,430m.E.	Intermittently active 1898-1936; active 1937-1967
Hiawatha SW		
Black Diamond mine (Fox)	SW.NE.NW.NW.12-18S-6E 4,347,220m.N. 482,520m.E.	Active 1898-195?
Cottonwood Canyon prospects	NW.SW.SE.25-17S-6E 4,351,350m.N. 483,710m.E.	Active 1946-1948
	SE.SE.NE.31-17S-7E 4,350,190m.N. 485,600m.E.	

(continued on page 90)

Figure 15. Mines and coal seams map, Wasatch Plateau coal field.

Figure 15. (continued)

Table 3. (continued)

Mine or prospect	Location	Remarks
Johnson mines (Twin City, Shumway, Cottonwood)	SW.SW.NE.11-18S-6E 4,351,900m.N. 483,575m.E. 4,351,990m.N. 481,600m.E.	Active 1909-1948
Oliphant mine	SW.NE.NE.NE.11-18S-6E 4,347,265m.N. 482,010m.E.	Active 1906-195?
Sitterud mine	Cottonwood Canyon, 10 miles NW of Orangeville, exact location unknown	Active 1946-1952
Straight Canyon prospect	NW.NE.11-18S-6E 4,347,300m.N. 481,720m.E.	Small hole by roadside
Trail Mountain mine	NW.SE.25-17S-6E	Active 1946-1967
No. 1	4,351,700m.N. 483,550m.E.	
No. 2	4,351,580m.N. 483,570m.E.	
No. 3	4,351,700m.N. 483,810m.E.	
Scofield NE		
Blue Blaze mines (McGowan, Consumers)	SE.SE.NE.SW.17-13S-8E 4,393,330m.N. 495,540m.E.	Active 1928-1952
Davis mine	17,18,20,21, or 28-13S-8E Exact location unknown	Active 1946
Gordon Creek mines	NW.NW.SW.SE.18-13S-8E 4,393,250m.N. 494,250m.E.	Active 1927-1930, 1941-1952, 1967-present (1970)
K. L. Storrs mine	NW.NE.NE.21-13S-8E ≃4,392,830m.N. 497,600m.E.	Active 1943
National mine	17-13S-8E ≃4,393,500m.N. 495,250m.E.	Active 1928-1938, 1950-1954
New Ewing mine	7, 18-13S-8E ≃4,394,590m.N. 494,270m.E.	No data
Success mine (Sheya)	NE.NE.20-13S-8E ≃4,392,700m.N. 496,100m.E.	Active 1945-1950
Sweet mine (Hudson)	C.E.SW.17-13S-8E ≃4,393,380m.N. 495,290m.E.	Active 1925-1940, intermittent until 1952
Western mine	Location unknown	Active 1948-1950
Scofield NW		
Amber mine	SE.SE.NW.3-14S-6E ≃4,386,160m.N. 480,050m.E.	Active 1877
Black Oaks mine	Location unknown	Active 1898
Blue Seal mine (Utah-Wyoming)	C.NW.NW.33-12S-7E 4,398,440m.N. 487,060m.E.	Intermittently active 1921-194?
Clear Creek mines	NW.SE.SW.NW.33-13S-7E	Active 1899-1967
No. 1	4,388,470m.N. 487,050m.E.	west of fault zone
(Pleasant Valley coal, Utah fuel,	NW.SE.SW.NW.33-13S-7E	West of fault zone
No. 2	4,388,470m.N. 487,050m.E.	
Independent Coal & Coke, North	SW.SW.SW.SW.SE.34-13S-7E	East of fault zone
No. 3	4,387,450m.N. 489,250m.E.	
American Coal)		
No. 4	SW.SE.SE.SE.SW.34-13S-7E 4,387,450m.N. 489,050m.E.	East of fault zone Bob Wright zone
Colombine mine (Standard-Colombine, McAlpine)	NW.NW.NW.SW.33-12S-7E 4,397,680m.N. 486,930m.E.	Presently active (1970)
Eagle mine (Jones)	SW.31-13S-7E ≃4,387,900m.N. 484,100m.E.	Intermittently active 1923-1941
Eccles Canyon mine	SE.SW.13-13S-6E 4,392,450m.N. 482,630m.E.	Intermittently active 1899-1952
Fish Creek mine (Wood Canyon)	31-12S-7E(?) ≃4,398,090m.N. 484,800m.E.	Active 1908-1910
Gibson mine	NE.NW.SW.NE.8-13S-7E 4,394,950m.N. 486,340m.E.	Opened in 1922, now abandoned

Table 3. (continued)

Mine or prospect	Location	Remarks
Jones mine	NW.SW.SW.33-12S-7E 4,397,410m.N. 486,880m.E.	Abandoned
Kimball mine	NW.NW.NW.SE.30-12S-7E 4,399,330m.N. 484,700m.E.	Active 1885-1900
Kinney mine (Monay)	NE.SW.SW.NW.33-12S-7E 4,398,090m.N. 487,050m.E.	Active 1920-1926, 1946-1956
Lewellyn mine	In Mud Creek	1897-1898
O'Conner (Black Diamond)	SW.SW.NE.32-13S-7E 4,388,440m.N. 486,270m.E.	Active 1956-1967
Scofield mine (Pleasant Valley, Union Pacific)	SW.SW.NW.NW.4-13S-7E 4,369,720m.N. 486,860m.E.	Intermittently active 1884-1936
Utah mine (Utah Central, Mud Creek)	SE.SE.NE.NE.17-13S-7E 4,393,520m.N. 486,820m.E.	Oldest mine, main activity 1910-1925
Utah Collieries (Smith & Nelson)	Unknown location	Active 1909-1910
Weeks mine	SE.NE.3-14S-6E ≃4,386,670m.N. 480,250m.E.	1877
Williams mine	4 miles up Mud Creek	1897
Winterquarters mines	1-13S-6E	Active 1878-1895
No. 1	≃4,396,400m.N. 482,800m.E.	
No. 2	SE.NW.SW.6-13S-7E 4,396,000m.N. 483,960m.E.	Active 1896-194?
No. 3	6-13S-7E	
No. 4	C.SE.NE.1-13S-6E 4,396,440m.N. 483,550m.E.	
No. 5	1-13S-6E	
(Smith, Cox & Smith)		
No. 6	SW.SW.NE.31-12S-7E ≃4,397,920m.N. 486,030m.E.	
Scofield SE		
Miller Creek Right Fork mine	NE.SE.19-15S-8E 4,372,700m.N. 494,875m.E.	Activity unknown
Wattis No. 1 mine	NE.NE.NE.17-15S-8E 4,374,100m.N. 496,500m.E.	Active 1917-1964
Wattis No. 2 mine (Plateau, Star Point)	NW.SE.16-15S-8E 4,374,300m.N. 497,640m.E.	Active 1966-1970
Scofield SW		
Arrowhead mine (Sanders)	NE.11-14S-6E 4,385,450m.N. 481,540m.E.	Active 1940's?
Bentley mine	NW.NW.SE.11-14S-6E 4,384,700m.N. 481,230m.E.	1874-1877
Colombo prospect	17,20,21-14S-7E ≃4,382,770m.N. 486,800m.E.	Activity unknown
Deseret mine	SW.SW.12-14S-6E ≃4,384,450m.N. 482,330m.E.	Active 1896-1910
Huntington mine (Fairview, Bell, New York, Tompkins, Connellsville)	SW.SW.SW.NE.11-14S-6E 4,385,110m.N. 481,320m.E.	Intermittently active 1875-194?
Fireside mine	NW.NW.NW.NW.9-14S-7E 4,385,250m.N. 486,060m.E.	Never produced
Larsen mine	NE.SE.SW.2-15S-6E 4,376,860m.N. 481,050m.E.	Active 1906-1915
Larsen & Rigby mine	NW.25-14S-6E ≃4,380,800m.N. 482,950m.E.	1937-1970? (1970) active

Table 3. (continued)

Mine or prospect	Location	Remarks
Loucks mine	NE.11-14S-6E ~4,385,350m.N. 481,400m.E.	Active 1874-1877
Soldier Summit SE		
Peoples Coal & Coke mine (Haley, Hales)	SW.11-12-7E 4,404,230m.N. 490,130m.E.	Active 1907-1909
Carbon Dale mine (Sunshine, Sunnybrook)	NW.13-12S-7E 4,403,250m.N. 491,860m.E.	Active 1900-1908

Land Ownership

The land and minerals of the Wasatch Plateau coal field are owned by governmental agencies, private companies and individuals. The National Forest Service is the largest land holder with about 55 percent. Private property controls 25 percent, the Bureau of Land Management, 15 percent and the state of Utah about 4 percent. The Land Ownership Map (figure 16) indicates that private property and the National Forest Service completely dominate the coal; only small parcels of coal land fall on BLM or state of Utah lands. Most of the private property is in the north part of the field where the more successful mines have been.

No coal prospecting permits exist for the Wasatch Plateau field; the coal land is either private property or leased. Acreages held by various companies and individuals in the quadrangle reports are listed in table 4. The figures may not be completely accurate, but show the activity as it exists (1970). Locations of these holdings are shown on the Leases and Permits Map for the Wasatch Plateau field (figure 17).

The total acreage held as coal land, about 152 square miles, is almost 14 percent of the field's land area.

Table 4. Coal land holdings in the Wasatch Plateau coal field.

Name	Leased acreage	Private acreage	Total
1. Christensen	80	–	80
2. Colombine coal	–	680	680
3. Colombo	1,909	–	1,909
4. Co-operative Security	4,245	1,360	5,605
5. Heiner and others	640	–	640
6. Helco	80	–	80
7. Huntington Corporation	7,070	6,000	13,070
8. Kearns Corporation	–	160	160
9. Kemmerer	–	2,320	2,320
10. Kingston	120	–	120
11. Knight	7,850	–	7,850
12. Larsen & Rigby	160	–	160
13. Leamaster	160	40	200
14. McKinnon	17,212	440	17,652
15. Nelson	–	80	80
16. North American	1,490	4,500	5,990
17. Paramount	613	1,600	2,213
18. Plateau	1,640	800	2,520
19. Presiding Bishopric LDS Church	760	–	760
20. Rilda Corporation	1,580	–	1,580
21. Robertson	40	–	40
22. Sanders	160	–	160
23. Sentry Royalty (Peabody)	880	–	880
24. Southern Utah Fuel	2,283	80	2,363
25. Swisher Coal	560	480	1,040
26. Sunnybrook Coal & Coke	–	800	800
27. Union Pacific Coal and others	–	1,000?	1,000?
28. United States Fuel	5,040	13,560	18,600
29. Wasatch Coal	280	640	920
30. Western Coal	260	–	260
31. Unassigned	–	7,560	7,560
Total	55,112	42,180	97,292

Quality of Coal

More than 800 analyses show little difference in quality between coal seams and fairly constant coal throughout the field (table 5). A slight deterioration to the south is evident, but fewer analyses with more taken at abandoned mines or at weathered outcrops are available.

Table 5. Coal quality data, Wasatch Plateau coal field.

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES AN	M	VM	FC	Ash	ULTIMATE ANALYSES S	H	C	N	O	Btu/lb	OTHER TESTS AST	ADL	HGI	Kind of Sample	Ref. Source
	ACORD LAKES NE QUADRANGLE																		
1	Link Canyon mine Upper Hiawatha bed	SW.NW.26–21S–5E 4312300mN 471300mE	A	12.9			5.5	.45	–			–							73
2	Link Canyon mine		A	8.8	–	–	5.4	.41	–	–	–	–	–	–	–				73
3	Link Canyon mine		A	7.4	38.6	46.1	8.3	.4	–	–	–	–	11,770	–	–	–	T		2
			C	–	41.5	49.6	8.9	–	–	–	–	–	12,710	–					
4	Link Canyon mine		A	7.0	37.8	45.3	10.0	.4	–	–	–	–	11,570	–	–	–	T		2
			C	–	40.6	48.7	10.7	–	–	–	–	–	12,450	–		–			
5	Link Canyon mine		A	7.1	37.5	45.8	9.8	.4	–	–	–	–	11,590	–	–	–	T		2
			C	–	40.3	49.2	10.5	–	–	–	–	–	12,480	–	–	–			
6	Link Canyon mine		A	7.3	38.3	46.4	8.3	.4	–	–	–	–	11,730	–	–	–	T		2
			C	–	41.2	49.9	8.9	–	–	–	–	–	12,650	–	–	–			
7	Link Canyon mine		A	7.5	38.3	46.3	8.4	.5	–	–	–	–	11,710	–	–	–	T		2
			C	–	41.2	49.8	9.0	–	–	–	–	–	12,660	–	–	–			
	ACORD LAKES NW QUADRANGLE																		
1	Southern Utah Fuel mine Upper Ivie bed	NW.SE.NW.12–22S–4E 4307300mN 463910mE	A	5.6	37.9	50.4	6.1	.4	–	–	–	–	12,260	–	.9	–			53
			C	–	40.1	53.5	6.4	.4	–	–	–	–	12,990	–	–	–			
			D	–	42.9	57.1	–	.5	–	–	–	–	13,880	–	–	–			
2	Southern Utah Fuel mine		A	8.6	–		6.7	.37	–	–	–	–	–	–	–	–			73
3	Southern Utah Fuel mine		A	8.5	37.2	48.1	6.7	.3	–	–	–	–	11,760	–	–	–	T		2
			C	–	40.4	52.3	7.3		–	–	–	–	12,860	–	–	–			
4	Southern Utah Fuel mine		A	8.2	36.2	48.8	7.1	.5	–	–	–	–	11,810	–	–		T		2
			C	–	39.3	53.0	7.7	–	–	–	–	–	12,860		–	–			
5	Southern Utah Fuel mine		A	8.8	36.7	48.3	6.0	.5	–	–	–	–	11,840	–	–		T		2
			C	–	40.3	53.1	6.6	–	–	–	–	–	12,980	–	–	–			

(continued on page 96)

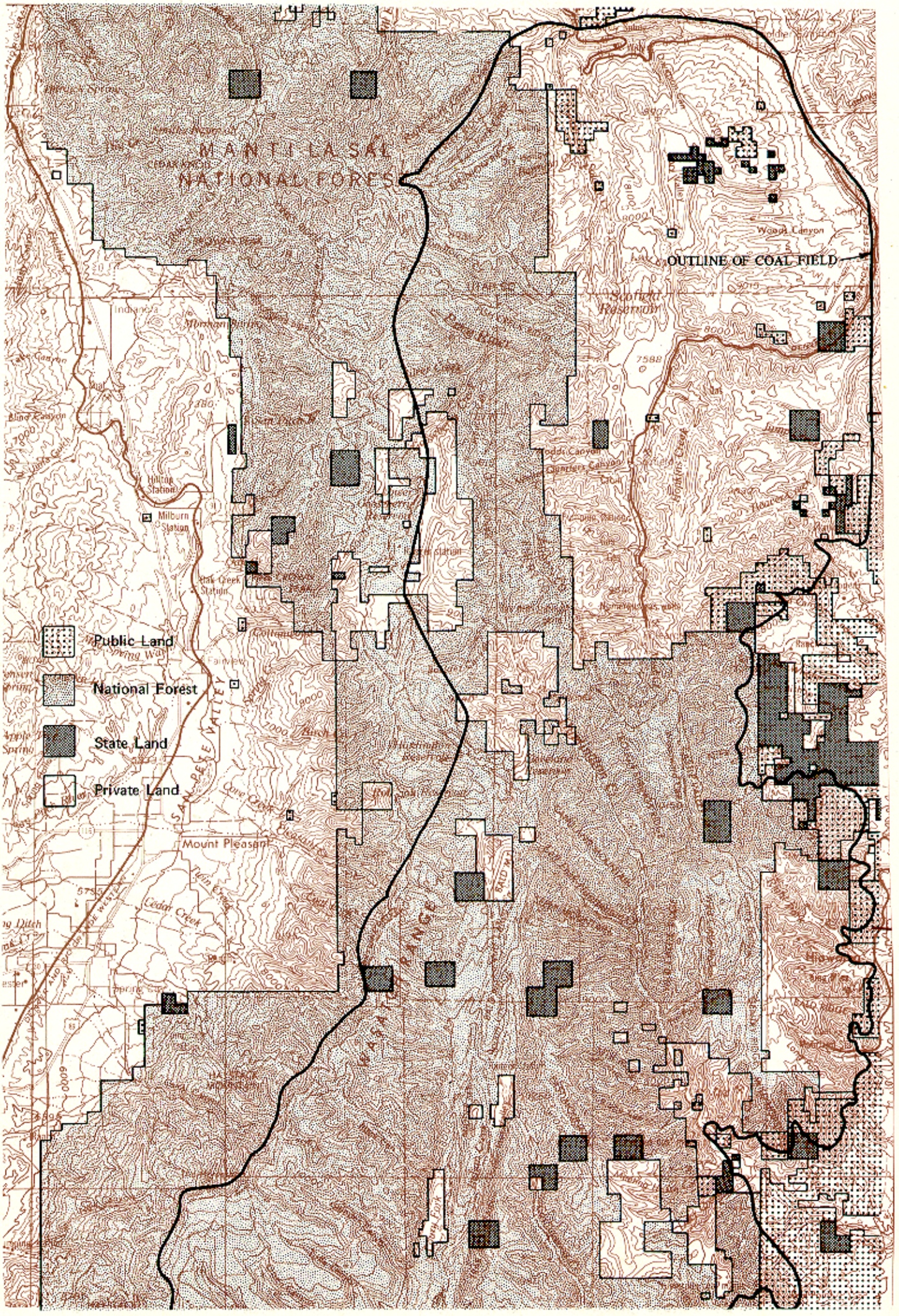


Figure 16. Land ownership map, Wasatch Plateau coal field.

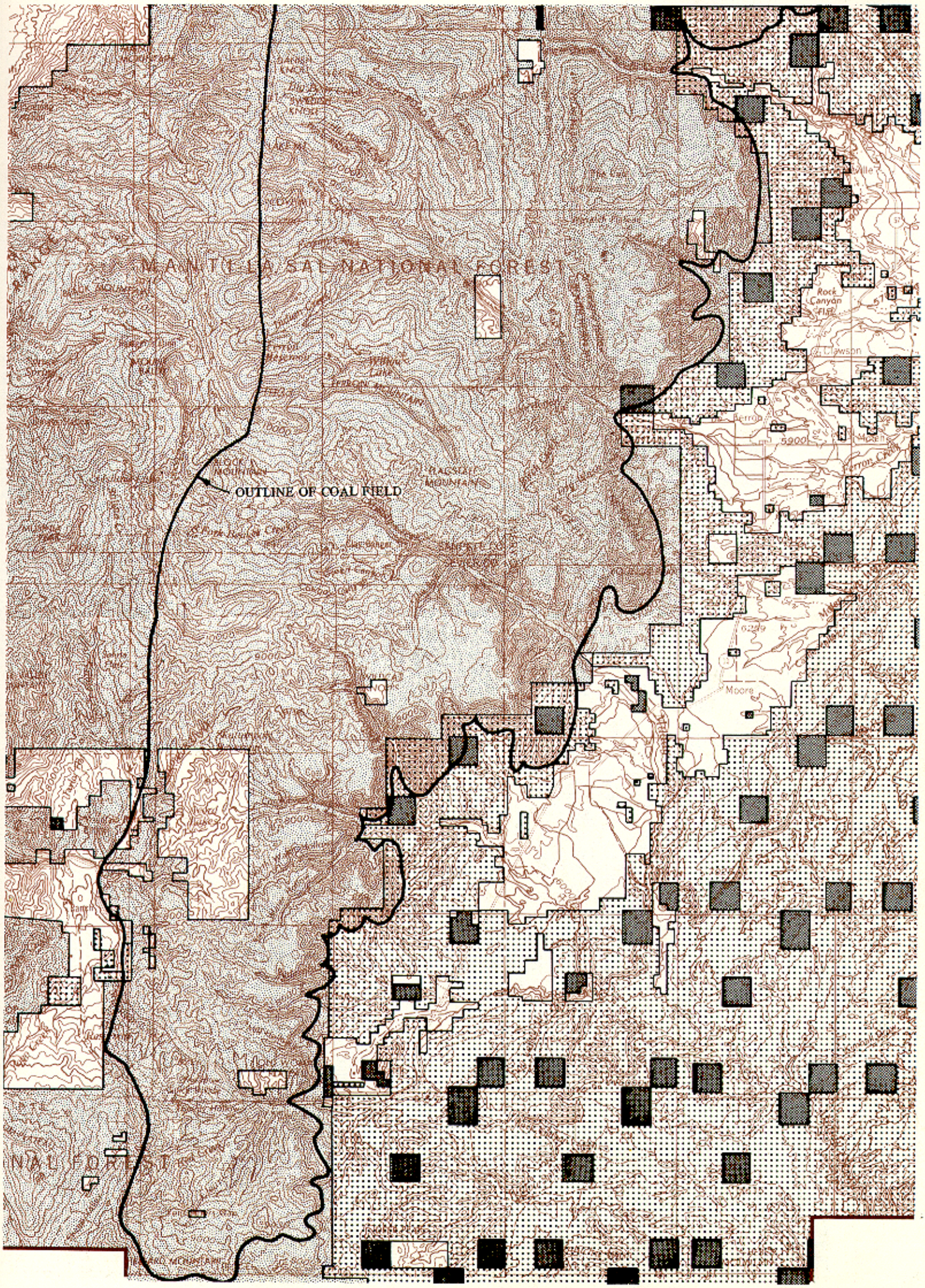


Figure 16. (continued)

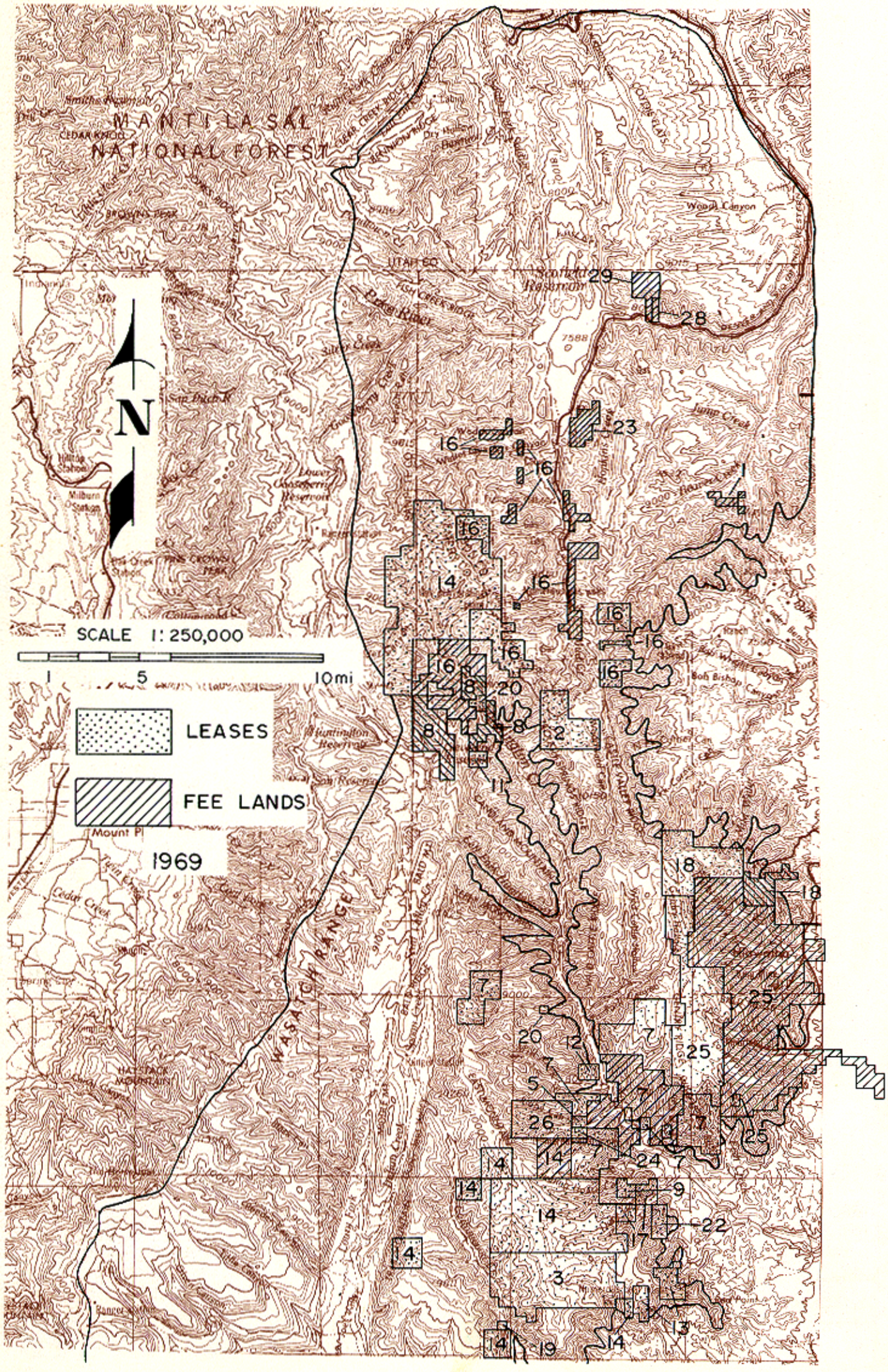


Figure 17. Leases and permits map, Wasatch Plateau coal field.

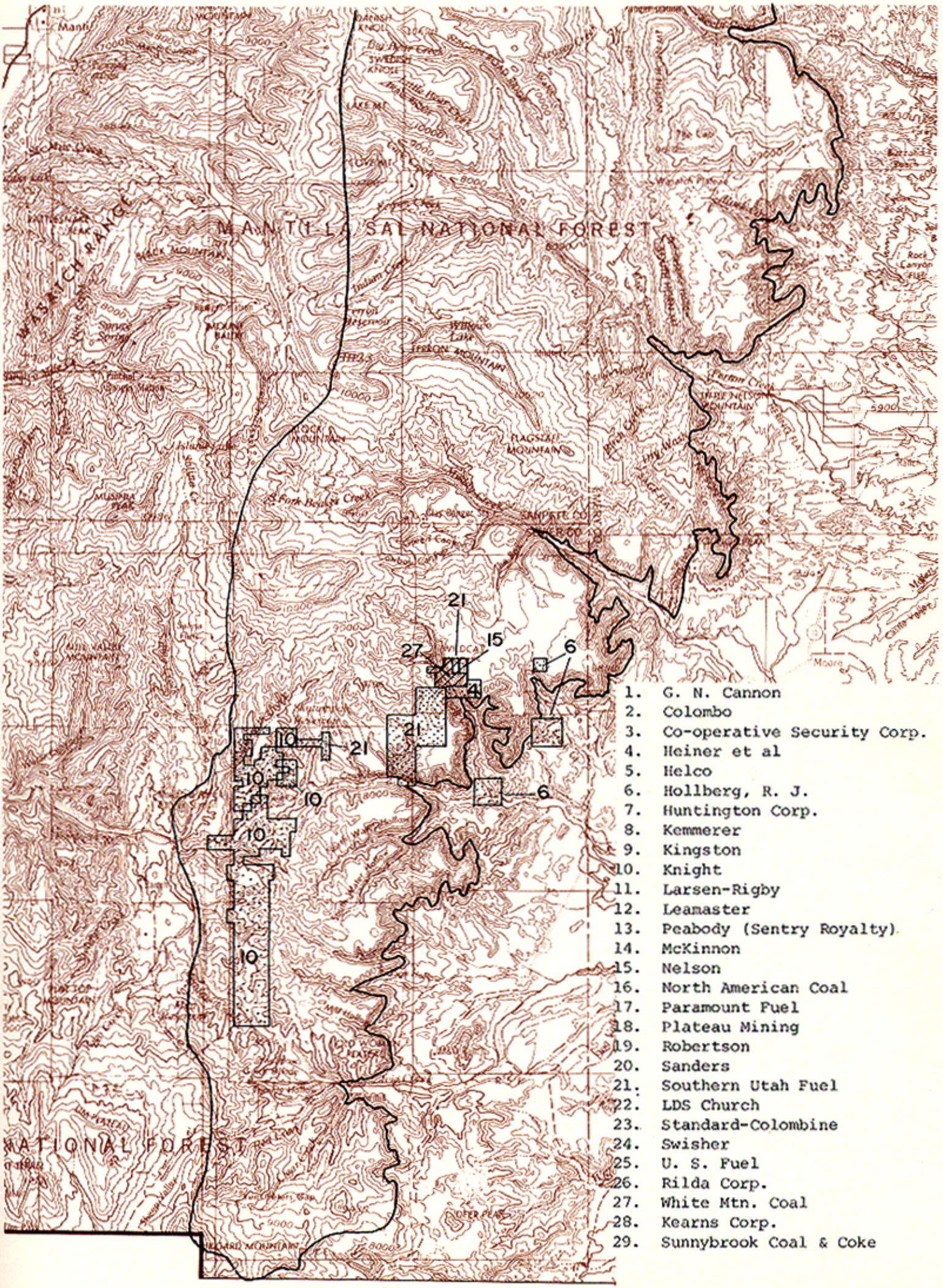


Figure 17. (continued)

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
6	Southern Utah Fuel mine		A	10.4	37.7	46.4	5.9	.5	–	–	–	–	11,530	–	–	–	T	2
			C	–	41.9	51.6	6.5	–	–	–	–	–	12,870	–	–	–		
7	Southern Utah Fuel mine		A	8.7	38.3	46.1	6.6	.5	–	–	–	–	11,790	–	–	–	T	7
			C	–	42.1	50.7	7.2	–	–	–	–	–	12,920	–	–	–		
8	Southern Utah Fuel mine		A	8.6	39.0	45.5	6.6	.5	–	–	–	–	11,780	–	–	–	T	7
			C	–	42.8	50.0	7.2	–	–	–	–	–	12,890	–	–	–		
9	Southern Utah Fuel mine		A	8.8	39.4	45.5	6.1	.5	–	–	–	–	11,900	–	–	–	T	7
			C	–	43.3	50.0	6.7	–	–	–	–	–	13,040	–	–	–		
10	Southern Utah Fuel mine		A	9.5	40.6	43.3	7.1	.6	–	–	–	–	11,390	–	–	–	T	7
			C	–	44.6	47.6	7.8	–	–	–	–	–	12,590	–	–	–		
11	Southern Utah Fuel mine		A	9.5	38.9	45.4	6.7	.5	–	–	–	–	11,740	–	–	–	T	9
			C	–	42.7	49.9	7.4	–	–	–	–	–	12,970	–	–	–		
12	Southern Utah Fuel mine		A	9.3	39.7	45.1	6.3	.4	–	–	–	–	11,670	–	–	–		13
			C	–	43.6	49.5	6.9	–	–	–	–	–	12,850	–	–	–		
	CASTLE DALE NW QUADRANGLE																	
1	Axel Anderson mine	NE.SE.NE.7–19S–7E	A	6.4	41.0	47.0	6.3	.8	–	–	–	–	12,200	–	1.4	–		56
	Hiawatha bed	4337260mN 485300mE	C	–	44.0	49.5	6.7	.8	–	–	–	–	13,110	–	–	–		
			D	–	46.6	53.1	–	.9	–	–	–	–	14,010	–	–	–		
2	Killpack mine	SE.NW.5–19S–7E	A	6.8	41.0	47.0	5.2	.6	–	–	–	–	12,490	–	2.2	–		56
	Hiawatha bed	4338790mN 486000mE	C	–	44.0	50.4	5.6	.6	–	–	–	–	13,400	–	–	–		
			D	–	46.6	53.4	–	.7	–	–	–	–	14,200	–	–	–		
3	Killpack mine		A	9.8	34.4	54.4	1.4	.9	–	–	–	–	12,400	–	3.2	–		56
			C	–	38.1	60.4	1.5	1.0	–	–	–	–	13,740	–	–	–		
			D	–	38.7	61.3	–	1.0	–	–	–	–	13,960	–	–	–		
	EMERY 3 NW QUADRANGLE																	
1	Outcrop	NW.9–25S–5E	A	11.9	36.4	42.7	9.0	0.53	–	–	–	–	–	–	–	–		21
	Lower zone, Ferron	4278500mN 467290mE	C	–	41.3	48.5	10.2	0.60	–	–	–	–	9,830	–	–	–		
2	Emery Prospect	10–24S–4E	A	12.9	37.2	43.9	6.0	.6	–	–	–	–	10,600	2,240	5.6	–		29
	Ivie bed (Blackhawk)	4287720mN 460750mE	C	–	42.7	50.4	6.9	.7	–	–	–	–	12,170	–	–	–		
3	Emery prospect	3–24S–4E?	A	13.9	35.2	43.6	7.3	.6	–	–	–	–	10,540	2,340	6.7	–		29
	Ivie bed		B	7.63	37.72	46.82	7.83	.66	–	–	–	–	11,300	–	–	–		
			C	–	40.8	50.7	8.5	.7	–	–	–	–	12,240	–	–	–		
			D	–	44.62	55.38	–	.79	–	–	–	–	13,367	–	–	–		
	FLAGSTAFF PEAK QUADRANGLE																	
1	Ricci mine	NE.NE.35–20S–5E	A	8.4	39.1	45.2	7.3	0.47	–	–	–	–	11,922	–	–	–		32
	Muddy no. 1 bed	4319940mN 472270mE	D	–	46.3	53.7	–	0.60	5.6	79.5	1.3	13.0	14,040	–	–	–		73
	HIAWATHA NE QUADRANGLE																	
1	Bear Canyon mine	SW.SW.24–16S–7E	A	5.0	45.2	45.9	3.9	.6	6.0	77.9	1.5	9.9	13,470	–	–	–	T	4
	Hiawatha bed	4362200mN 492000mE	C	–	47.6	48.3	4.1	–	–	–	–	–	14,170	–	–	–		
2	Bear Canyon mine		A	5.1	44.8	45.8	4.5	.4	–	–	–	–	13,340	–	–	–	T	4
	Hiawatha bed		C	–	47.1	48.2	4.7	–	–	–	–	–	14,060	–	–	–		
3	Bear Canyon mine		A	5.2	44.4	45.7	4.9	.5	–	–	–	–	13,180	–	–	52	T	4
	Hiawatha bed		C	–	46.7	48.1	5.2	–	–	–	–	–	13,910	–	–	–		
4	Bear Canyon mine		A	5.0	45.4	43.5	6.1	.7	–	–	–	–	12,980	–	–	–	T	4
	Hiawatha bed		C	–	47.8	45.8	6.4	–	–	–	–	–	13,650	–	–	–		
5	Bear Canyon mine		A	5.6	44.1	45.8	4.5	.6	–	–	–	–	13,150	2,130	4.4	–		29
			C	–	46.7	48.5	4.8	.6	–	–	–	–	13,930	–	–	–		
6	Bear Canyon mine		A	7.6	42.6	44.7	5.1	.5	–	–	–	–	12,900	2,040	5.2	–		29
			C	–	46.2	48.3	5.5	.5	–	–	–	–	13,970	–	–	–		
7	Bear Canyon mine		A	8.1	42.3	44.5	5.1	.5	–	–	–	–	12,800	2,040	5.7	–		29
			C	–	46.1	48.4	5.5	.6	–	–	–	–	13,930	–	–	–		
8	Bear Canyon mine		A	6.4	41.7	48.1	3.8	.6	–	–	–	–	12,920	2,060	3.1	–		29
			C	–	44.5	51.5	4.0	.6	–	–	–	–	13,800	–	–	–		
9	Bear Canyon mine		A	10.9	37.4	45.9	5.8	.6	–	–	–	–	10,840	2,510	8.6	–		29
	Bear Canyon bed		C	–	42.0	51.5	6.5	.7	–	–	–	–	12,160	–	–	–		
10	Bear Canyon mine		A	5.8	44.5	45.9	3.8	.5	6.3	74.1	1.4	13.9	13,320	–	2.7	–		53
	Bear Canyon bed		C	–	47.2	48.7	4.1	.5	6.0	78.6	1.5	9.3	14,140	–	–	–		
			D	–	49.2	50.8	–	.5	6.3	81.9	1.5	9.8	14,740	–	–	–		
11	Bear Canyon mine		A	4.6	45.7	45.4	4.3	.6	6.4	74.2	1.4	13.1	13,530	–	1.5	–		53
	Bear Canyon bed		C	–	47.9	47.6	4.5	.6	6.2	77.8	1.5	9.4	14,190	–	–	–		
			D	–	50.1	49.9	–	.6	6.5	81.4	1.6	9.9	14,860	–	–	–		
12	Bear Canyon mine		A	4.5	46.0	44.9	4.6	.5	6.3	74.1	1.4	13.1	13,530	–	1.3	–		53
	Bear Canyon bed		C	–	48.1	47.1	4.8	.5	6.1	77.6	1.5	9.5	14,160	–	–	–		
			D	–	50.5	49.5	–	.6	6.4	81.5	1.6	9.9	14,870	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
13	Bear Canyon mine Bear Canyon bed		A C D	4.5 – –	44.9 47.0 49.4	46.0 48.1 50.6	4.6 4.9 –	.5 .5 .5	6.2 6.0 6.3	74.4 77.8 81.8	1.4 1.5 1.5	12.9 9.3 9.9	13,480 14,110 14,830	– – –	1.0 – –	– – –		53
14	Bear Canyon mine Bear Canyon bed		A	5.8	44.5	45.9	3.8	.5	6.3	74.1	1.4	13.9	13,381	–	–	–		74
15	Co-op mine Hiawatha bed	SE.SE.NE.22–16S–7E 4363000mN 491040mE	A	5.2	–	–	4.8	.36	–	–	–	–	–	–	–	–		73
16	Co-op mine		A C	4.5 –	47.4 –	41.3 –	6.8 –	– –	– –	– –	– –	– –	12,690 13,390	– –	– –	– –		80
17	Co-op mine		A C	4.68 –	46.9 –	41.1 –	7.3 –	– –	– –	– –	– –	– –	12,820 13,550	– –	– –	– –		80
18	Co-op mine		A C	5.3 –	45.2 –	38.3 –	11.2 –	– –	– –	– –	– –	– –	12,190 12,880	– –	– –	– –		80
19	Co-op mine		A B C	3.65 2.4 –	44.95 45.8 46.7	43.9 44.1 45.5	7.6 7.7 7.8	– – –	– – –	– – –	– – –	– – –	13,180 13,462 13,700	– – –	– – –	– – –		80
20	Co-op mine		A B C	7.3 2.1 –	36.98 39.0 39.9	47.1 49.7 50.8	8.7 9.2 9.4	– – –	– – –	– – –	– – –	– – –	12,182 12,857 13,136	– – –	– – –	– – –		80
21	Co-op mine		A B C	6.7 2.96 –	41.4 43.6 44.95	43.9 45.7 47.0	7.5 7.8 8.0	– – –	– – –	– – –	– – –	– – –	12,581 13,086 13,485	– – –	– – –	– – –		80
22	Co-op mine Hiawatha bed		A C	4.9 –	44.8 47.2	45.8 48.2	4.4 4.6	.3 –	– –	– –	– –	– –	13,410 14,110	– –	– –	– –	T	4
23	Co-op mine Hiawatha bed		A C	5.3 –	43.1 45.4	46.8 49.3	5.0 5.3	.3 –	– –	– –	– –	– –	13,180 13,910	– –	– –	47 –	T	4
24	Co-op mine Hiawatha bed		A C	6.5 –	42.9 45.6	44.7 47.6	6.4 6.8	.4 –	– –	– –	– –	– –	12,650 13,530	– –	– –	– –	T	4
25	Co-op mine Hiawatha bed		A C	5.0 –	41.5 43.7	48.0 50.5	5.5 5.8	.5 –	– –	– –	– –	– –	13,050 13,740	– –	– –	– –	T	5
26	Co-op mine Hiawatha bed		A C	5.4 –	41.9 44.1	47.2 49.7	5.9 6.2	.5 –	– –	– –	– –	– –	12,970 13,710	– –	– –	48 –	T	5
27	Co-op mine Hiawatha bed		A C	5.2 –	42.6 44.8	45.9 48.3	6.6 6.9	.4 –	– –	– –	– –	– –	12,750 13,450	– –	– –	– –	T	5
28	Co-op mine Hiawatha bed		A C	4.6 –	44.8 47.2	44.8 47.2	5.3 5.6	.5 –	– –	– –	– –	– –	13,360 14,000	– –	– –	– –	T	7
29	Co-op mine Hiawatha bed		A C	3.7 –	44.0 45.8	45.0 46.9	7.0 7.3	.4 –	– –	– –	– –	– –	13,180 13,690	– –	– –	– –	D	7
30	Co-op mine Hiawatha bed		A C	4.7 –	44.0 46.3	44.2 46.5	6.8 7.2	.9 –	– –	– –	– –	– –	13,090 13,730	– –	– –	47 –	T	7
31	Co-op mine Hiawatha bed		A C	5.7 –	43.5 46.3	44.0 46.8	6.5 6.9	.5 –	– –	– –	– –	– –	12,980 13,770	– –	– –	– –	T	7
32	Co-op mine Hiawatha bed		A C	5.4 –	43.4 45.7	45.7 48.1	5.9 6.2	.5 –	– –	– –	– –	– –	13,100 13,850	– –	– –	– –	T	9
33	Co-op mine Hiawatha bed		A C	6.7 –	43.3 46.5	43.2 46.4	6.6 7.1	.6 –	– –	– –	– –	– –	12,780 13,700	– –	– –	– –	T	9
34	Co-op mine Hiawatha bed		A C	8.6 –	42.5 46.7	42.0 46.1	6.6 7.2	.6 –	– –	– –	– –	– –	12,430 13,600	– –	– –	– –	T	9
35	Co-op mine Hiawatha bed		A C	4.7 –	45.5 47.9	44.1 46.4	5.4 5.7	.5 –	– –	– –	– –	– –	13,410 14,070	– –	– –	– –	T	11
36	Co-op mine Hiawatha bed		A C	4.3 –	46.4 48.3	42.1 43.8	7.6 7.9	.6 –	– –	– –	– –	– –	13,070 13,650	– –	– –	– –	T	11
37	Co-op mine Hiawatha bed		A C	5.9 –	44.7 47.5	40.4 43.0	8.9 9.5	.6 –	– –	– –	– –	– –	12,570 13,360	– –	– –	– –	T	11
38	Co-op mine		A D	7.8 –	43.7 51.5	41.2 48.5	7.3 –	– .6	– 6.3	– 80.4	– 1.5	– 11.2	– 14,610	– –	– –	– –		43
39	Hiawatha mine Book Cliff bed	NE.SW.NW.29–15S–8E	A C D	4.26 – –	43.29 45.09 –	46.37 48.30 –	6.35 6.61 –	.63 – –	– – –	– – –	– – –	– – –	12,881 13,454 14,406	– – –	– – –	– – –		55
40	Hiawatha mine		A C D	5.13 – –	42.91 45.17 –	46.51 48.96 –	5.58 5.87 –	.65 – –	– – –	– – –	– – –	– – –	12,959 13,660 14,512	– – –	– – –	– – –		52
41	Hiawatha No. 1 mine Hiawatha bed	NE.SW.NW.29–15S–8E 4371425mN 495175mE	A C D	7.57 – –	39.10 42.30 44.99	47.80 51.72 55.01	5.53 5.98 –	.71 .77 .82	– – –	– – –	– – –	– – –	– – –	2,430 – –	4.3 – –	– – –		27
42	Hiawatha No. 1 mine Hiawatha bed		A C D	7.36 – –	39.67 42.82 45.72	47.09 50.83 54.28	5.88 6.35 –	.66 .71 .75	– – –	– – –	– – –	– – –	– – –	– – –	3.9 – –	– – –		27

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES AN	M	VM	FC	Ash	ULTIMATE ANALYSES S	H	C	N	O	Btu/lb	OTHER TESTS AST	ADL	HGI	Kind of Sample	Ref. Source
43	Hiawatha No. 1 mine Hiawatha bed		A	7.49	39.72	47.17	5.62	.64	6.09	69.12	1.35	17.18	12,512	–	4.1	–		27
			C	–	42.94	50.98	6.08	.69	5.69	74.72	1.46	11.36	13,534	–	–	–		
			D	–	45.72	54.28	–	.73	6.06	79.55	1.55	12.11	14,409	–	–	–		
44	Hiawatha No. 1 mine Hiawatha bed		A	6.1	40.6	47.2	6.1	.7	–	–	–	–	12,570	2,620	2.3	–		29
45	Hiawatha No. 1 mine		A	6.7	41.8	43.6	7.9	.7	–	–	–	–	12,270	2,340	2.9	–		29
46	Hiawatha No. 1 mine		A	5.8	42.4	45.7	6.1	.7	–	–	–	–	12,550	2,340	2.1	–		29
47	Hiawatha No. 1 mine		A	6.2	40.7	44.3	8.8	.7	–	–	–	–	12,210	2,340	2.3	–		29
48	Hiawatha No. 1 mine		A	7.4	39.7	47.0	5.9	.7	–	–	–	–	–	2,140	3.9	–		27
49	Hiawatha No. 1 mine		A	6.4	41.4	44.7	7.5	.7	5.9	69.4	1.4	15.1	12,410	–	2.4	–		29
			C	–	44.2	47.8	8.0	.8	5.6	74.1	1.5	10.0	13,250	–	–	–		
			D	–	48.1	51.9	–	.9	6.0	80.6	1.7	10.8	14,400	–	–	–		
50	Hiawatha No. 1 mine		A	7.5	39.7	47.2	5.6	.6	6.1	69.1	1.4	17.2	12,520	–	4.1	–		29
			C	–	42.9	51.0	6.1	.7	5.7	74.7	1.5	11.3	13,530	–	–	–		
			D	–	45.7	54.3	–	.7	6.1	79.6	1.6	12.0	14,410	–	–	–		
51	Hiawatha No. 2 mine Hiawatha bed	NE.SW.NW.29–15S–8E 4371520mN 495175mE	A	5.7	40.8	46.5	7.0	.6	6.0	69.5	1.4	11.5	12,650	–	2.4	–		27
			C	–	43.2	49.4	7.4	.6	5.7	73.6	1.5	11.2	13,410	–	–	–		
			D	–	46.7	53.3	–	.6	6.1	79.5	1.6	12.2	14,470	–	–	–		
52	Hiawatha No. 2 mine Hiawatha bed		A	5.84	40.10	46.31	7.75	.53	–	–	–	–	–	2,200	2.6	–		27
			C	–	42.59	49.18	8.23	.56	–	–	–	–	–	–	–	–		
			D	–	46.41	53.59	–	.61	–	–	–	–	–	–	–	–		
53	Hiawatha No. 2 mine Hiawatha bed		A	5.41	41.25	46.94	6.40	.58	–	–	–	–	–	2,220	2.2	–		27
			C	–	43.61	49.62	6.77	.61	–	–	–	–	–	–	–	–		
			D	–	46.78	53.22	–	.65	–	–	–	–	–	–	–	–		
54	Hiawatha No. 2 mine Hiawatha bed		A	6.3	42.3	44.7	6.7	.6	–	–	–	–	12,400	2,340	3.7	–		29
55	Hiawatha No. 2 mine		A	5.5	41.3	45.7	7.5	.6	–	–	–	–	12,390	2,390	3.3	–		29
56	Hiawatha No. 2 mine		A	5.3	42.8	44.6	7.3	.7	–	–	–	–	12,390	2,560	3.0	–		29
57	Hiawatha No. 2 mine		A	5.6	40.0	46.8	7.6	.8	–	–	–	–	12,370	2,390	3.5	–		29
58	Hiawatha No. 2 mine		A	5.8	41.6	45.3	7.3	.7	5.8	69.0	1.4	15.8	12,400	–	3.4	–		29
			C	–	44.2	48.1	7.7	.7	5.5	73.3	1.5	11.3	13,160	–	–	–		
			D	–	47.9	52.1	–	.8	6.0	79.4	1.7	12.1	14,260	–	–	–		
59	King mine Hiawatha bed	NE.NW.NW.NW.4–16S–8E 4368650mN 498430mE	A	4.8	44.7	44.6	5.8	.5	–	–	–	–	12,990	–	–	–	D	81
			C	–	47.0	46.9	6.1	–	–	–	–	–	13,650	–	–	–		
60	King mine		A	6.4	43.2	45.5	5.4	.5	–	–	–	–	12,820	–	–	–	D	81
			C	–	45.9	48.4	5.7	–	–	–	–	–	13,700	–	–	–		
61	King mine		A	5.9	43.3	44.8	5.8	.5	–	–	–	–	12,850	–	–	–	D	81
			C	–	46.1	47.7	6.2	–	–	–	–	–	13,660	–	–	–		
					42.64	44.77	5.78											
62	King mine		A	6.7	42.4	44.8	5.8	.5	–	–	–	–	12,690	–	–	–		15
			C	–	45.6	48.2	6.2	–	–	–	–	–	13,610	–	–	–		
63	King mine		A	5.9	42.6	45.5	5.9	.6	–	–	–	–	12,780	–	–	–	T	10
			C	–	45.3	48.4	6.3	–	–	–	–	–	13,580	–	–	–		
64	King mine		A	5.9	42.8	45.2	6.0	.6	–	–	–	–	12,860	–	–	–	T	10
			C	–	45.5	48.1	6.4	–	–	–	–	–	13,670	–	–	–		
65	King mine		A	4.5	42.4	46.1	6.6	.5	–	–	–	–	12,970	–	–	–	D	10
			C	–	44.6	48.5	6.9	–	–	–	–		13,580	–	–	–		
66	King mine		A	5.5	41.7	45.8	7.5	.6	–	–	–	–	12,590	–	–	–	T	10
			C	–	43.9	48.2	7.9	–	–	–	–	–	13,330	–	–	–		
67	King mine		A	5.5	43.0	47.2	4.8	.6	–	–	–	–	13,180	–	–	–	D	10
			C	–	45.3	49.7	5.0	–	–	–	–	–	13,940	–	–	–		
68	King mine		A	5.5	43.4	45.5	6.1	.6	–	–	–	–	12,900	–	–	–	T	10
			C	–	45.7	47.9	6.4	–	–	–	–	–	13,650	–	–	–		
69	King mine		A	4.3	43.3	46.6	6.1	.5	–	–	–	–	13,060	–	–	–	D	10
			C	–	45.1	48.5	6.4	–	–	–	–	–	13,650	–	–	–		
70	King mine		A	7.0	42.5	44.7	5.8	.6	–	–	–	–	12,740	–	–	–	T	10
			C	–	45.7	48.1	6.2	–	–	–	–	–	13,700	–	–	–		
71	King mine		A	5.6	42.7	46.7	4.6	.6	–	–	–	–	13,100	–	–	–	D	10
			C	–	45.4	49.7	4.9	–	–	–	–	–	13,880	–	–	–		
72	King mine		A	6.2	42.9	46.3	4.8	.6	–	–	–	–	12,920	–	–	–	T	10
			C	–	45.6	49.3	5.1	–	–	–	–	–	13,770	–	–	–		
73	King mine Hiawatha bed		A	7.2	40.5	47.3	5.2	.5	–	–	–	–	12,630	–	–	–	T	16
			C	–	43.5	50.9	5.6	–	–	–	–	–	13,610	–	–	–		
74	King mine Hiawatha bed		A	6.0	42.4	46.7	5.0	.5	–	–	–	–	12,920	–	–	–	D	16
			C	–	45.1	49.6	5.3	–	–	–	–	–	13,760	–	–	–		
75	King mine Hiawatha bed		A	7.1	41.4	47.2	4.5	.5	–	–	–	–	12,800	–	–	–	T	16
			C	–	44.5	50.7	4.8	–	–	–	–	–	13,770	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
76	King mine Hiawatha bed		A C	7.3 –	42.6 45.9	45.5 49.1	4.6 5.0	.5 –	– –	– –	– –	– –	12,810 13,810	– –	– –	– –	T	16
77	King mine Hiawatha bed		A C	6.2 –	42.7 45.5	46.1 49.1	5.1 5.4	.5 –	– –	– –	– –	– –	12,880 13,740	– –	– –	– –	T	16
78	King mine Hiawatha bed		A C	7.0 –	43.0 46.2	45.8 49.2	4.3 4.6	.5 –	– –	– –	– –	– –	12,920 13,890	– –	– –	– –	T	16
79	King mine Hiawatha bed		A C	6.1 –	43.1 45.9	45.6 48.6	5.2 5.5	.5 –	– –	– –	– –	– –	12,920 13,770	– –	– –	– –	D	16
80	King mine Hiawatha bed		A C	6.1 –	42.5 45.3	46.2 49.2	5.2 5.5	.5 –	– –	– –	– –	– –	12,930 13,770	– –	– –	– –	D	16
81	King mine Hiawatha bed		A C	7.0 –	42.7 45.9	45.8 49.3	4.5 4.8	.5 –	– –	– –	– –	– –	12,860 13,830	– –	– –	– –	T	16
82	King mine Hiawatha bed		A C	6.7 –	43.0 46.1	45.4 48.7	4.9 5.2	.4 –	– –	– –	– –	– –	12,870 13,800	– –	– –	– –	D	16
83	King mine Hiawatha bed		A C	5.6 –	44.3 46.9	46.8 49.6	3.3 3.5	.5 –	– –	– –	– –	– –	13,250 14,040	– –	– –	– –	T	16
84	King mine		A C	6.4 –	42.0 44.9	46.0 49.1	5.6 6.0	.5 –	– –	– –	– –	– –	12,860 13,730	– –	– –	– –	T	13
85	King mine		A C	7.0 –	42.0 45.2	45.0 48.4	6.0 6.4	.5 –	– –	– –	– –	– –	12,710 13,680	– –	– –	– –	D	13
86	King mine		A C	6.7 –	42.2 45.2	45.3 48.5	5.9 6.3	.6 –	– –	– –	– –	– –	12,760 13,670	– –	– –	– –	T	13
87	King mine		A C	6.9 –	42.8 46.0	44.7 48.0	5.6 6.0	.6 –	– –	– –	– –	– –	12,820 13,770	– –	– –	– –	T	13
88	King mine		A C	6.2 –	42.8 45.6	45.7 48.7	5.3 5.7	.6 –	– –	– –	– –	– –	12,960 13,810	– –	– –	– –	T	13
89	King mine		A C	4.5 –	42.4 44.4	45.8 48.0	7.3 7.6	.6 –	– –	– –	– –	– –	12,830 13,440	– –	– –	– –	D	13
90	King mine		A C	4.7 –	43.4 45.5	45.9 48.2	6.0 6.3	.6 –	– –	– –	– –	– –	13,030 13,680	– –	– –	– –	D	13
91	King mine		A C	7.3 –	42.3 45.6	45.5 49.1	4.9 5.3	.6 –	– –	– –	– –	– –	12,810 13,820	– –	– –	– –	T	13
92	King mine		A C	5.8 –	42.9 45.5	44.8 47.5	6.6 7.0	.5 –	– –	– –	– –	– –	12,740 13,520	– –	– –	– –	D	13
93	King mine		A C	5.7 –	42.6 45.2	47.4 50.2	4.3 4.6	.7 –	– –	– –	– –	– –	13,090 13,880	– –	– –	– –	T	13
94	King mine		A C	4.4 –	43.1 45.1	46.9 49.1	5.5 5.8	.5 –	– –	– –	– –	– –	13,070 13,680	– –	– –	– –	D	11
95	King mine		A C	6.1 –	42.4 45.2	45.7 48.7	5.7 6.1	.5 –	– –	– –	– –	– –	12,800 13,650	– –	– –	– –	D	11
96	King mine		A C	3.8 –	43.1 44.8	47.7 49.6	5.4 5.6	.6 –	– –	– –	– –	– –	13,270 13,790	– –	– –	– –	D	11
97	King mine		A C	5.4 –	42.9 45.4	44.6 47.2	7.0 7.4	.6 –	– –	– –	– –	– –	12,730 13,470	– –	– –	– –	D	12
98	King mine		A C	4.4 –	43.4 45.4	45.6 47.7	6.6 6.9	.6 –	– –	– –	– –	– –	13,030 13,630	– –	– –	– –	D	12
99	King mine Hiawatha bed		A C	4.5 –	42.8 44.8	47.4 49.6	5.3 5.6	.5 –	– –	– –	– –	– –	13,090 13,710	– –	– –	– –	D	8
100	King mine Hiawatha bed		A C	5.3 –	42.2 44.6	46.9 49.5	5.6 5.9	.5 –	– –	– –	– –	– –	12,960 13,690	– –	– –	– –	D	8
101	King mine Hiawatha bed		A C	4.8 –	42.7 44.9	47.6 50.0	4.9 5.1	.5 –	– –	– –	– –	– –	13,180 13,840	– –	– –	– –	D	8
102	King mine Hiawatha bed		A C	4.9 –	42.6 44.8	47.5 49.9	5.0 5.3	.6 –	– –	– –	– –	– –	13,060 13,730	– –	– –	– –	D	8
103	King mine Hiawatha bed		A C	4.6 –	42.5 44.6	47.3 49.6	5.5 5.8	.6 –	– –	– –	– –	– –	13,050 13,680	– –	– –	– –	D	8
104	King mine Hiawatha bed		A C	5.2 –	42.6 44.9	47.0 49.6	5.2 5.5	.5 –	– –	– –	– –	– –	13,040 13,750	– –	– –	– –	D	8
105	King mine Hiawatha bed		A C	5.0 –	42.8 45.0	46.7 49.2	5.5 5.8	.6 –	– –	– –	– –	– –	13,020 13,710	– –	– –	– –	D	8
106	King mine Hiawatha bed		A C	5.3 –	42.2 44.6	46.3 48.9	6.2 6.5	.5 –	– –	– –	– –	– –	12,930 13,650	– –	– –	– –	D	9
107	King mine Hiawatha bed		A C	5.0 –	42.7 44.9	45.7 48.1	6.7 7.0	.5 –	– –	– –	– –	– –	12,890 13,570	– –	– –	– –	D	9
108	King mine Hiawatha bed		A C	4.8 –	42.6 44.7	46.9 49.3	5.7 6.0	.6 –	– –	– –	– –	– –	13,040 13,700	– –	– –	– –	D	9

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
109	King mine Hiawatha bed		A C	6.4 –	42.1 45.0	45.5 48.6	6.0 6.4	.5 –	– –	– –	– –	– –	12,810 13,690	– –	– –	– –	D	9
110	King mine Hiawatha bed		A C	6.0 –	42.7 45.4	45.5 48.4	5.8 6.2	.6 –	– –	– –	– –	– –	12,900 13,720	– –	– –	– –	D	9
111	King mine		A C	5.3 –	42.1 44.5	45.9 48.5	6.6 7.0	.8 –	– –	– –	– –	– –	12,810 13,530	– –	– –	– –	T	2
112	King mine		A C	5.8 –	42.1 44.7	45.7 48.5	6.4 6.8	.7 –	– –	– –	– –	– –	12,810 13,590	– –	– –	– –	T	2
113	King mine		A C	5.1 –	42.5 44.8	45.2 47.6	7.2 7.6	.6 –	– –	– –	– –	– –	12,770 13,460	– –	– –	– –	T	2
114	King mine		A C	5.2 –	42.2 44.5	45.0 47.5	7.6 8.0	.6 –	– –	– –	– –	– –	12,600 13,290	– –	– –	– –	D	2
115	King mine		A C	5.2 –	42.4 44.7	45.7 48.2	6.7 7.1	.8 –	– –	– –	– –	– –	12,730 13,430	– –	– –	– –	T	2
116	King mine		A C	4.8 –	42.4 44.5	46.0 48.3	6.9 7.2	.5 –	– –	– –	– –	– –	12,840 13,480	– –	– –	– –	D	2
117	King mine		A C	3.6 –	43.1 44.7	45.6 47.3	7.7 8.0	.6 –	– –	– –	– –	– –	12,850 13,330	– –	– –	– –	D	2
118	King mine		A C	4.9 –	41.7 43.9	46.9 49.3	6.5 6.8	.6 –	– –	– –	– –	– –	12,840 13,510	– –	– –	– –	T	2
119	King mine Hiawatha bed		A	7.54	43.03	43.40	6.03	.63	–	–	–	–	12,483	–	4.4	–		28
120	King mine Hiawatha bed		A	7.48	41.90	45.07	5.55	.60	–	–	–	–	12,560	–	4.1	–		28
121	King mine Hiawatha bed		A	6.45	42.14	43.96	7.45	.95	–	–	–	–	12,407	–	2.2	–		28
122	King mine Hiawatha bed		A	7.09	42.12	45.73	5.06	.70	–	–	–	–	12,584	–	3.4	–		28
123	King mine Hiawatha bed		A	6.63	43.39	44.30	5.68	.76	–	–	–	–	12,677	–	3.0	–		28
124	King mine Hiawatha bed		A	7.41	40.96	46.87	4.76	.72	–	–	–	–	12,577	–	3.7	–		28
125	King mine Hiawatha bed		A	7.46	43.04	43.80	5.70	.63	–	–	–	–	12,521	–	4.0	–		28
126	King mine Hiawatha bed		A C D	7.18 – –	42.16 45.42 48.47	44.81 48.28 51.53	5.85 6.30 –	.68 .73 .78	5.71 5.29 5.65	69.85 75.26 80.32	1.43 1.54 1.64	16.48 10.88 11.61	12,537 13,507 14,414	– –	3.5 –	– –		28
127	King mine Hiawatha bed		A C D	7.61 – –	41.73 45.17 48.56	44.21 47.85 51.44	6.45 6.98 –	.71 .77 .83	– – –	– – –	– – –	– – –	12,310 13,325 14,324	– –	3.5 –	– –		28
128	King mine Hiawatha bed		A C	4.2 –	42.2 44.1	46.1 48.1	7.5 7.8	.6 –	– –	– –	– –	– –	12,770 13,330	– –	– –	– –	D	3
129	King mine Hiawatha bed		A C	5.4 –	42.2 44.6	45.6 48.2	6.8 7.2	.6 –	– –	– –	– –	– –	12,750 13,480	– –	– –	– –	D	3
130	King mine Hiawatha bed		A C	5.2 –	41.2 43.5	46.5 49.0	7.1 7.5	.8 –	– –	– –	– –	– –	12,650 13,340	– –	– –	– –		54
131	King mine Hiawatha bed		A C	4.9 –	42.1 44.3	45.7 48.1	7.2 7.6	.7 –	– –	– –	– –	– –	12,650 13,300	– –	– –	– –		54
132	King mine Hiawatha bed		A C	5.1 –	42.0 44.3	45.6 48.1	7.2 7.6	.6 –	– –	– –	– –	– –	12,640 13,320	– –	– –	– –		54
133	King mine Hiawatha bed		A C	4.8 –	42.3 44.4	45.4 47.7	7.5 7.9	.6 –	– –	– –	– –	– –	12,760 13,400	– –	– –	– –		54
134	King mine Hiawatha bed		A C	6.6 –	40.9 43.8	45.7 48.9	6.8 7.3	.7 –	– –	– –	– –	– –	12,500 13,380	– –	– –	– –		54
135	King mine Hiawatha bed		A C	4.8 –	42.0 44.1	46.4 48.7	6.9 7.2	.7 –	– –	– –	– –	– –	12,680 13,320	– –	– –	– –		54
136	King mine Hiawatha bed		A C	5.8 –	42.1 44.7	46.1 48.9	6.0 6.4	.6 –	– –	– –	– –	– –	12,710 13,490	– –	– –	– –		54
137	King mine Hiawatha bed		A C	4.6 –	43.4 45.5	44.7 46.9	7.3 7.6	.6 –	– –	– –	– –	– –	12,680 13,290	– –	– –	– –		54
138	King mine Hiawatha bed		A C	4.9 –	42.4 44.6	46.0 48.4	6.6 7.0	.6 –	– –	– –	– –	– –	12,710 13,370	– –	– –	– –		54
139	King mine		A C	4.57 –	44.61 46.76	44.72 46.88	6.07 6.36	.61 –	– –	– –	– –	– –	12,985 13,607	– –	– –	– –		52
140	King mine Hiawatha bed		A C	3.8 –	42.9 44.6	45.9 47.7	7.4 7.7	.6 –	– –	– –	– –	– –	12,900 13,410	– –	– –	– –	D	4

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
141	King mine Hiawatha bed		A C	5.9 –	41.8 44.4	44.9 47.7	7.4 7.9	.6 –	– –	– –	– –	– –	12,620 13,410	– –	– –	– –	D	4
142	King mine Hiawatha bed		A C	3.6 –	41.8 43.4	48.9 50.7	5.7 5.9	.5 –	– –	– –	– –	– –	13,130 13,620	– –	– –	– –	D	5
143	King mine Hiawatha bed		A C	4.2 –	42.8 44.7	46.8 48.9	6.1 6.4	.5 –	– –	– –	– –	– –	13,000 13,570	– –	– –	– –	D	5
144	King mine Hiawatha bed		A C	4.4 –	42.0 43.9	47.4 49.6	6.2 6.5	.5 –	– –	– –	– –	– –	12,960 13,560	– –	– –	– –	D	5
145	King Mine Hiawatha bed		A C	5.4 –	42.2 44.6	46.6 49.3	5.8 6.1	.6 –	– –	– –	– –	– –	12,990 13,730	– –	– –	– –		7
146	King mine		A	6.6	42.6	43.8	7.0	.9	–	–	–	–	12,350	2,130	2.0	–		29
147	King mine		A	5.6	42.2	45.6	6.6	.6	–	–	–	–	12,680	2,130	1.8	–		29
148	King mine Hiawatha bed		A	5.8	42.7	45.2	6.3	.9	–	–	–	–	12,630	2,060	1.6	–		29
149	King mine		A C D	5.9 – –	41.9 44.5 47.9	45.5 48.4 52.1	6.7 7.1 –	.9 .9 1.0	6.1 5.7 6.2	70.0 74.4 80.2	1.3 1.4 1.5	15.0 10.5 11.1	12,570 13,360 14,380	– – –	1.9 – –	– – –		29
150	King mine		A	7.5	43.0	43.5	6.0	–	–	–	–	–	12,480	2,100	4.4	–		28
151	King mine		A	7.5	41.9	45.0	5.6	.6	–	–	–	–	12,560	2,050	4.1	–		28
152	King mine		A	6.6	42.1	43.8	7.5	1.0	–	–	–	–	12,410	2,050	2.2	–		28
153	King mine		A	7.1	42.1	45.7	5.1	.7	–	–	–	–	12,580	2,040	3.4	–		28
154	King mine		A	6.6	43.4	44.3	5.7	.8	–	–	–	–	12,680	–	3.0	–		28
155	King mine		A	7.4	41.0	46.8	4.8	.7	–	–	–	–	12,580	2,430	3.7	–		28
156	King mine		A	7.5	43.0	43.8	5.7	.6	–	–	–	–	12,520	–	4.0	–		28
157	King mine		A C D	7.2 – –	42.2 45.4 48.5	44.7 48.3 51.5	5.9 6.3 –	.7 .7 .8	5.7 5.3 5.7	69.9 75.3 80.3	1.4 1.5 1.6	16.4 10.9 11.6	12,540 13,510 14,420	– – –	3.5 – –	– – –		28
158	King mine		A C	7.6 –	41.7 45.2	44.2 47.8	6.5 7.0	.7 .8	– –	– –	– –	– –	12,310 13,330	2,090 –	3.5 –	– –		28
159	King mine		A	6.0	40.6	46.2	7.2	1.1	–	–	–	–	12,590	2,130	2.2	–		29
160	King mine Hiawatha bed		A B C D	7.2 3.8 – –	42.2 43.7 45.4 48.5	44.8 46.5 48.3 51.5	5.8 6.1 6.3 –	.68 .70 1.73 1.78	5.71 5.52 5.29 5.65	69.85 72.41 75.26 80.32	1.43 1.48 1.54 1.64	14.68 13.83 10.88 11.61	12,540 13,000 13,510 14,410	– – – –	3.5 – – –	– – – –		20
161	King mine Hiawatha bed		A B C D	7.6 4.3 – –	41.7 43.2 45.2 48.6	44.2 45.8 47.9 51.4	6.5 6.7 7.0 –	.71 .74 .77 .83	– – – –	– – – –	– – – –	– – – –	12,310 12,750 13,330 14,320	– – – –	3.5 – – –	– – – –		20
162	King mine Hiawatha bed		A B C D	7.5 3.6 – –	43.0 44.8 46.5 49.6	43.8 45.6 47.3 50.4	5.7 5.9 6.2 –	.63 .66 .68 .72	– – – –	– – – –	– – – –	– – – –	12,520 13,040 13,530 14,420	– – – –	4.0 – – –	– – – –		20
163	King mine		A B C D	7.4 3.9 – –	41.0 42.5 44.2 46.6	46.9 48.7 50.6 53.4	4.8 4.9 5.1 –	.72 .75 .78 .82	– – – –	– – – –	– – – –	– – – –	12,580 13,060 13,580 14,320	– – – –	3.7 – – –	– – – –		20
164	King mine		A B C D	6.6 8.7 – –	43.4 44.7 46.5 49.5	44.3 45.7 47.5 50.5	5.7 5.9 6.1 –	.76 .78 .81 .86	– – – –	– – – –	– – – –	– – – –	12,680 13,070 13,580 14,460	– – – –	3.0 – – –	– – – –		20
165	King mine Hiawatha bed		A B C D	7.5 3.3 – –	43.0 45.0 46.5 49.8	43.4 45.4 47.0 50.2	6.0 6.3 6.5 –	.63 .66 .68 .73	– – – –	– – – –	– – – –	– – – –	12,480 13,055 13,500 14,440	– – – –	4.4 – – –	– – – –		20
166	King mine Hiawatha bed		A B C D	7.5 3.5 – –	41.9 43.7 45.3 48.2	45.1 47.0 48.7 51.8	5.6 5.8 6.0 –	.60 .63 .65 .69	– – – –	– – – –	– – – –	– – – –	12,560 13,100 13,580 14,440	– – – –	4.1 – – –	– – – –		20
167	King mine Hiawatha bed		A B C D	6.5 4.4 – –	42.2 43.1 45.0 49.0	44.0 44.9 47.0 51.1	7.5 7.97 8.0 –	.95 – 1.02 1.11	– – – –	– – – –	– – – –	– – – –	12,410 12,680 13,260 14,410	– – – –	2.2 – – –	– – – –		20
168	King mine Hiawatha bed		A B C D	7.1 3.8 – –	42.1 43.6 45.3 48.0	45.7 47.4 49.2 52.1	5.1 5.2 5.5 –	.70 .72 .75 .79	– – – –	– – – –	– – – –	– – – –	12,580 13,030 13,540 14,320	– – – –	3.4 – – –	– – – –		20
169	King mine Hiawatha bed		A C	5.6 –	41.5 44.0	47.7 50.5	5.2 5.5	.6 –	– –	– –	– –	– –	13,020 13,800	– –	– –	– –		6
170	King mine Hiawatha bed		A C	5.6 –	41.0 43.4	48.0 50.8	5.5 5.8	.6 –	– –	– –	– –	– –	13,010 13,780	– –	– –	– –		6

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
171	King mine Hiawatha bed		A	5.7	41.8	46.8	5.8	.7	–	–	–	–	12,980	–	–	–		6
			C	–	44.3	49.6	6.1	–	–	–	–	–	13,770	–	–	–		
172	King mine Hiawatha bed		A	5.7	42.5	45.9	5.8	.6	–	–	–	–	12,950	–	–	–		6
			C	–	45.1	48.7	6.2	–	–	–	–	–	13,730	–	–	–		
173	King mine Hiawatha bed		A	5.0	43.3	45.7	6.0	.6	–	–	–	–	12,990	–	–	–		6
			C	–	45.6	48.1	6.3	–	–	–	–	–	13,670	–	–	–		
174	King mine Hiawatha bed		A	3.1	44.2	46.9	5.8	.5	–	–	–	–	13,270	–	–	–		6
			C	–	45.6	48.4	6.0	–	–	–	–	–	13,690	–	–	–		
175	King mine Hiawatha bed		A	5.8	42.7	45.4	6.1	.7	–	–	–	–	12,890	–	–	50		6
			C	–	45.3	48.2	6.5	–	–	–	–	–	13,670	–	–	–		
176	King mine Hiawatha bed		A	5.2	42.8	46.5	5.5	.6	–	–	–	–	13,020	–	–	–		6
			C	–	45.1	49.1	5.8	–	–	–	–	–	13,730	–	–	–		
177	King mine Hiawatha bed		A	2.1	44.5	47.8	5.6	.7	–	–	–	–	13,490	–	–	–		6
			C	–	45.5	48.8	5.7	–	–	–	–	–	13,770	–	–	–		
178	King mine Hiawatha bed		A	5.0	43.2	46.6	5.2	.5	6.0	72.4	1.5	14.4	13,035	–	–	–		74
179	King mine Hiawatha bed		A	5.4	–	–	6.3	.58	–	–	–	–	–	–	–	–		73
180	King mine		A	6.0	43.0	45.1	5.9	.6	–	–	–	–	12,820	–	–	–		14
			C	–	45.7	48.0	6.3	–	–	–	–	–	13,660	–	–	–		
181	King mine		A	4.7	43.9	45.7	5.6	.5	–	–	–	–	13,090	–	–	–		14
			C	–	46.1	48.0	5.9	–	–	–	–	–	13,730	–	–	–		
182	King mine		A	6.0	43.2	45.1	5.6	.6	–	–	–	–	12,920	–	–	–		14
			C	–	46.0	48.0	6.0	–	–	–	–	–	13,750	–	–	–		
183	King mine		A	6.3	42.3	45.1	6.4	.6	–	–	–	–	12,740	–	–	–		14
			C	–	45.1	48.1	6.8	–	–	–	–	–	13,610	–	–	–		
184	King mine		A	0.7	–	–	–	–	–	–	–	–	13,184	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,280	–	–	–		
185	King mine		A	6.7	–	–	–	–	–	–	–	–	12,375	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,767	–	–	–		
186	King mine		A	4.64	41.60	45.58	8.18	–	–	–	–	–	12,660	–	–	–		72
			B	3.04	42.5	46.11	8.4	–	–	–	–	–	12,933	–	–	–		
			C	–	43.6	47.8	8.6	–	–	–	–	–	13,300	–	–	–		
187	King mine		A	4.8	41.7	45.1	8.4	–	–	–	–	–	12,600	–	–	–		72
			B	3.0	42.9	45.5	8.6	–	–	–	–	–	12,948	–	–	–		
			C	–	43.8	47.7	8.8	–	–	–	–	–	13,241	–	–	–		
188	King mine		A	4.5	44.8	42.3	8.5	–	–	–	–	–	12,500	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,100	–	–	–		
189	King mine		A	7.4	40.8	44.1	7.8	–	–	–	–	–	12,120	–	–	–		72
			B	2.5	43.7	45.8	8.1	–	–	–	–	–	12,881	–	–	–		
			C	–	44.0	47.8	8.19	–	–	–	–	–	13,100	–	–	–		
190	King mine		A	4.96	41.6	45.9	7.6	–	–	–	–	–	12,416	–	–	–		72
			B	2.5	42.7	47.1	7.8	–	–	–	–	–	12,737	–	–	–		
			C	–	48.8	48.3	8.0	–	–	–	–	–	13,064	–	–	–		
191	King mine		A	4.61	42.7	43.9	8.8	–	–	–	–	–	12,540	–	–	–		72
			B	–	43.7	–	8.96	–	–	–	–	–	12,857	–	–	–		
			C	–	44.8	–	9.2	–	–	–	–	–	13,180	–	–	–		
192	King mine		A	.9	41.35	45.2	8.6	–	–	–	–	–	12,480	–	–	–		72
			B	3.4	42.3	45.5	8.8	–	–	–	–	–	12,755	–	–	–		
			C	–	43.5	47.5	9.0	–	–	–	–	–	13,100	–	–	–		
193	King mine		A	5.8	42.96	45.2	6.1	.78	–	–	–	–	12,651	–	–	–		72
			B	3.0	44.2	46.5	6.3	.81	–	–	–	–	13,022	–	–	–		
			C	–	45.6	47.95	6.5	.83	–	–	–	–	13,426	–	–	–		
194	King mine		A	4.04	–	–	–	–	–	–	–	–	12,400	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	12,922	–	–	–		
195	King mine		A	1.6	–	–	–	–	–	–	–	–	12,461	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	12,658	–	–	–		
196	King mine		A	7.9	42.6	41.0	8.5	–	–	–	–	–	12,175	–	5.2	–		72
			B	2.2	45.3	43.5	9.0	–	–	–	–	–	12,930	–	–	–		
			C	–	46.3	44.5	9.2	–	–	–	–	–	13,215	–	–	–		
197	King mine		A	5.1	–	–	–	–	–	–	–	–	12,954	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,656	–	–	–		
198	King mine		A	3.98	–	–	–	–	–	–	–	–	12,864	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,397	–	–	–		
199	King mine		A	3.5	–	–	–	–	–	–	–	–	12,933	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,408	–	–	–		
200	King mine		A	3.5	–	–	–	–	–	–	–	–	13,248	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,729	–	–	–		
201	King mine		A	3.7	–	–	–	–	–	–	–	–	12,970	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,474	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
202	King mine		A	5.7	–	–	–	–	–	–	–	–	12,068	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	12,797	–	–	–		
203	King mine		A	–	–	–	–	–	–	–	–	–	12,797	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,308	–	–	–		
204	King mine		A	5.1	39.9	44.7	10.3	–	–	–	–	–	12,096	–	–	–		72
			B	2.3	40.9	45.8	10.6	–	–	–	–	–	12,386	–	–	–		
			C	–	42.1	47.1	10.9	–	–	–	–	–	12,741	–	–	–		
205	King mine		A	5.6	41.8	42.5	10.1	–	–	–	–	–	12,120	–	–	–		72
			B	2.99	42.9	43.7	10.4	–	–	–	–	–	12,465	–	–	–		
			C	–	44.3	45.6	10.7	–	–	–	–	–	12,849	–	–	–		
206	King mine		A	5.2	41.0	47.1	6.7	–	–	–	–	–	12,712	–	–	–		72
			B	3.2	41.9	48.1	6.9	–	–	–	–	–	12,982	–	–	–		
			C	–	43.3	49.7	7.1	–	–	–	–	–	13,406	–	–	–		
207	King mine		A	–	–	–	–	–	–	–	–	–	12,069	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	12,635	–	–	–		
208	King mine		A	1.7	–	–	–	–	–	–	–	–	13,101	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,333	–	–	–		
209	King mine		A	5.7	40.3	45.9	8.1	–	–	–	–	–	12,365	–	–	–		72
			B	3.2	41.3	47.1	8.4	–	–	–	–	–	12,687	–	–	–		
			C	–	42.7	48.7	8.6	–	–	–	–	–	13,108	–	–	–		
210	King mine		A	5.2	38.5	48.3	8.0	–	–	–	–	–	12,586	–	–	–		72
			B	2.9	39.4	49.6	8.2	–	–	–	–	–	12,901	–	–	–		
			C	–	40.6	50.98	8.5	–	–	–	–	–	13,274	–	–	–		
211	King mine		A	7.1	39.5	45.6	7.9	–	–	–	–	–	12,324	–	–	–		72
			B	3.4	41.1	47.4	8.2	–	–	–	–	–	12,815	–	–	–		
			C	–	42.5	49.0	8.5	–	–	–	–	–	13,259	–	–	–		
212	King mine		A	5.2	36.3	49.9	8.7	.29	–	–	–	–	12,273	–	–	–		72
			B	1.96	37.5	51.6	9.0	.31	–	–	–	–	12,692	–	–	–		
			C	–	38.3	52.6	9.2	.31	–	–	–	–	12,946	–	–	–		
213	King mine		A	6.3	39.0	43.8	10.9	–	–	–	–	–	11,819	–	–	–		72
			B	3.6	40.1	45.1	11.2	–	–	–	–	–	12,164	–	–	–		
			C	–	41.6	46.8	11.6	–	–	–	–	–	12,614	–	–	–		
214	King mine		A	5.6	38.3	48.3	7.7	–	–	–	–	–	12,325	–	–	–		72
			B	2.1	39.7	50.1	8.0	–	–	–	–	–	12,785	–	–	–		
			C	–	40.6	51.2	8.2	–	–	–	–	–	13,058	–	–	–		
215	King mine		A	11.0	36.2	43.9	8.9	–	–	–	–	–	11,512	–	–	–		72
			B	3.1	39.5	47.9	9.6	–	–	–	–	–	12,546	–	–	–		
			C	–	40.7	49.4	9.9	–	–	–	–	–	12,941	–	–	–		
216	King mine		A	6.5	41.4	44.8	7.3	–	–	–	–	–	12,538	–	–	–		72
			B	2.3	43.3	46.8	7.6	–	–	–	–	–	13,102	–	–	–		
			C	–	44.3	47.9	7.8	–	–	–	–	–	13,413	–	–	–		
217	King mine		A	5.7	39.5	47.5	7.3	–	–	–	–	–	12,461	–	–	–		72
			B	3.9	40.3	48.4	7.5	–	–	–	–	–	12,697	–	–	–		
			C	–	41.9	50.3	7.8	–	–	–	–	–	13,214	–	–	–		
218	King mine		A	5.8	42.8	42.4	8.9	–	–	–	–	–	12,023	–	–	–		72
			B	3.6	43.9	43.5	9.1	–	–	–	–	–	12,314	–	–	–		
			C	–	45.5	45.1	9.5	–	–	–	–	–	12,767	–	–	–		
219	King mine		A	5.9	38.99	46.9	8.2	–	–	–	–	–	12,562	–	–	–		72
			B	3.6	39.96	48.0	8.5	–	–	–	–	–	12,784	–	–	–		
			C	–	41.4	49.8	8.8	–	–	–	–	–	13,351	–	–	–		
220	King mine		A	5.7	39.6	45.5	9.3	–	–	–	–	–	12,218	–	–	–		72
			B	3.3	40.6	46.6	9.5	–	–	–	–	–	12,530	–	–	–		
			C	–	41.98	48.2	9.8	–	–	–	–	–	12,951	–	–	–		
221	King mine Hiawatha bed		A	3.8	42.0	48.0	6.2	.6	–	–	–	–	13,020	–	–	–	D	70
			C	–	43.7	49.9	6.4	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
222	King mine Hiawatha bed		A	2.9	40.2	51.2	5.7	1.0	–	–	–	–	13,600	–	–	–	D	70
			C	–	41.4	52.7	5.9	–	–	–	–	–	14,010	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,890	–	–	–		
223	King mine Hiawatha bed		A	5.5	41.9	46.9	5.8	.6	–	–	–	–	12,840	–	–	–	D	70
			C	–	44.3	49.6	6.1	–	–	–	–	–	13,590	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
224	King mine Hiawatha bed		A	5.8	40.7	45.5	8.0	.7	–	–	–	–	12,390	–	–	–	WD	70
			C	–	43.2	48.3	8.5	–	–	–	–	–	13,150	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
225	King mine Hiawatha bed		A	5.0	41.6	47.7	5.7	.6	–	–	–	–	12,940	–	–	–	D	70
			C	–	43.8	50.2	6.0	–	–	–	–	–	13,620	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–	–		
226	King mine Hiawatha bed		A	4.9	43.0	46.7	5.4	.7	–	–	–	–	12,970	–	–	–	D	70
			C	–	45.2	49.1	5.7	–	–	–	–	–	13,640	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
227	King mine Hiawatha bed		A	4.1	41.8	48.1	5.9	.6	–	–	–	–	13,030	–	–	–	WD	70
			C	–	43.6	50.2	6.2	–	–	–	–	–	13,590	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
228	King mine		A	3.5	41.8	48.6	6.1	.6	–	–	–	–	13,100	–	–	–	WD	70
	Hiawatha bed		C	–	43.3	50.4	6.3	–	–	–	–	–	13,570	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
229	King mine		A	4.0	42.1	47.8	6.0	.7	–	–	–	–	13,080	–	–	–	D	70
	Hiawatha bed		C	–	43.9	49.8	6.3	–	–	–	–	–	13,630	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,550	–	–	–		
230	King mine		A	5.2	41.0	46.9	6.9	.7	–	–	–	–	12,700	–	–	–	WD	70
	Hiawatha bed		C	–	43.2	49.5	7.3	–	–	–	–	–	13,400	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
231	King mine		A	4.3	42.1	46.9	6.7	.8	–	–	–	–	12,870	–	–	–	WD	70
	Hiawatha bed		C	–	44.0	49.0	7.0	–	–	–	–	–	13,450	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
232	King mine		A	4.5	42.5	46.9	6.1	.6	–	–	–	–	13,050	–	–	–	D	70
	Hiawatha bed		C	–	44.5	49.1	6.4	–	–	–	–	–	13,670	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,600	–	–	–		
233	King mine		A	4.0	41.8	47.2	7.0	.7	–	–	–	–	12,990	–	–	–	D	70
	Hiawatha bed		C	–	43.5	49.2	7.3	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,600	–	–	–		
234	King mine		A	5.9	41.2	45.8	7.1	.7	–	–	–	–	12,620	–	–	–	D	70
	Hiawatha bed		C	–	43.8	48.7	7.5	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,500	–	–	–		
235	King mine		A	5.4	40.5	45.3	8.8	.7	–	–	–	–	12,480	–	–	–	WD	70
	Hiawatha bed		C	–	42.8	47.9	9.3	–	–	–	–	–	13,190	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,540	–	–	–		
236	King mine		A	5.2	40.8	47.6	6.4	.7	–	–	–	–	12,870	–	–	–	D	70
	Hiawatha bed		C	–	43.0	50.2	6.8	–	–	–	–	–	13,580	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,570	–	–	–		
237	King mine		A	5.3	41.2	46.0	7.5	.6	–	–	–	–	12,760	–	–	–	D	70
	Hiawatha bed		C	–	43.5	48.6	7.9	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,630	–	–	–		
238	King mine		A	3.4	42.1	48.6	5.9	.6	–	–	–	–	13,060	–	–	–	D	70
	Hiawatha bed		C	–	43.6	50.3	6.1	–	–	–	–	–	13,520	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
239	King mine		A	4.5	41.7	47.3	6.5	.7	–	–	–	–	12,910	–	–	–	D	70
	Hiawatha bed		C	–	43.7	49.5	6.8	–	–	–	–	–	13,520	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		
240	King mine		A	4.0	43.3	46.7	6.1	.6	–	–	–	–	13,090	–	–	–	D	70
	Hiawatha bed		C	–	45.1	48.6	6.3	–	–	–	–	–	13,640	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,560	–	–	–		
241	King mine		A	6.2	41.3	46.3	6.2	.7	–	–	–	–	12,630	2,190	–	–	T	70
	Hiawatha bed		C	–	44.0	49.4	6.6	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
242	King mine		A	5.6	41.7	46.6	6.0	.6	–	–	–	–	12,740	2,080	–	–	T	70
	Hiawatha bed		C	–	44.2	49.4	6.4	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
243	King mine		A	6.2	41.3	46.2	6.4	.7	–	–	–	–	12,640	2,130	–	–	WT	70
	Hiawatha bed		C	–	44.0	49.2	6.8	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
244	King mine		A	5.4	41.5	46.8	6.2	.6	–	–	–	–	12,780	2,290	–	–	WT	70
	Hiawatha bed		C	–	43.9	49.5	6.6	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
245	King mine		A	5.6	41.3	46.8	6.3	.7	–	–	–	–	12,720	2,290	–	–	WT	70
	Hiawatha bed		C	–	43.7	49.6	6.7	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		
246	King mine		A	8.2	40.3	45.2	6.3	.7	–	–	–	–	12,270	2,280	–	–	WT	70
	Hiawatha bed		C	–	43.9	49.2	6.9	–	–	–	–	–	13,370	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,360	–	–	–		
247	King mine		A	5.6	42.5	45.3	6.6	.6	–	–	–	–	12,770	2,170	–	–	D	70
	Hiawatha bed		C	–	45.0	48.0	7.0	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,550	–	–	–		
248	King mine		A	4.9	41.7	47.6	5.9	.6	–	–	–	–	12,880	–	–	–	WD	70
	Hiawatha bed		C	–	43.8	50.0	6.2	–	–	–	–	–	13,540	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
249	King mine		A	6.3	41.4	47.4	4.9	.6	–	–	–	–	12,860	–	–	–	WD	70
	Hiawatha bed		C	–	44.2	50.6	5.2	–	–	–	–	–	13,720	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
250	King mine		A	5.6	41.3	47.4	5.7	.7	–	–	–	–	12,930	–	–	–	WD	70
	Hiawatha bed		C	–	43.8	50.2	6.0	–	–	–	–	–	13,700	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,570	–	–	–		
251	King mine		A	6.0	44.2	45.8	6.0	.6	–	–	–	–	12,770	–	–	–	WD	70
	Hiawatha bed		C	–	44.9	48.7	6.4	–	–	–	–	–	13,580	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		
252	King mine		A	4.4	42.2	46.7	6.7	.6	–	–	–	–	12,900	–	–	–	D	70
	Hiawatha bed		C	–	44.1	48.9	7.0	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
253	King mine Hiawatha bed		A	5.6	42.4	45.1	6.9	.9	–	–	–	–	12,680	–	–	–	D	70
			C	–	44.9	47.8	7.3	–	–	–	–	–	13,430	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–	–		
254	King mine Hiawatha bed		A	3.6	43.4	47.5	5.5	.9	–	–	–	–	13,200	–	–	–	D	70
			C	–	45.0	49.3	5.7	–	–	–	–	–	13,690	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,520	–	–	–		
255	King mine Hiawatha bed		A	7.7	40.1	46.9	5.4	.7	–	–	–	–	12,390	–	–	–	WD	70
			C	–	43.4	50.8	5.8	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,250	–	–	–		
256	King mine Hiawatha bed		A	2.2	43.1	48.3	6.4	.6	–	–	–	–	13,300	–	–	–	WD	70
			C	–	44.1	49.4	6.5	–	–	–	–	–	13,600	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,550	–	–	–		
257	King mine Hiawatha bed		A	4.8	43.2	45.1	6.9	.7	–	–	–	–	12,900	2,050	–	–	WD	70
			C	–	45.4	47.4	7.2	–	–	–	–	–	13,550	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,600	–	–	–		
258	King mine Hiawatha bed		A	5.4	43.0	45.1	6.4	.7	–	–	–	–	12,840	–	–	–	D	70
			C	–	45.5	47.7	6.8	–	–	–	–	–	13,570	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,560	–	–	–		
259	King mine Hiawatha bed		A	3.6	45.3	45.5	5.6	.7	–	–	–	–	13,180	–	–	–	D	70
			C	–	47.0	47.2	5.8	–	–	–	–	–	13,670	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		
260	King mine Hiawatha bed		A	4.9	42.8	45.6	6.7	.8	–	–	–	–	12,890	–	–	–	D	70
			C	–	45.0	48.0	7.0	–	–	–	–	–	13,550	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,570	–	–	–		
261	King mine Hiawatha bed		A	6.8	42.1	45.4	5.7	.8	–	–	–	–	12,760	–	–	–	D	70
			C	–	45.2	48.7	6.1	–	–	–	–	–	13,690	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,580	–	–	–		
262	King mine Hiawatha bed		A	5.3	42.2	44.8	7.7	.8	–	–	–	–	12,520	2,140	–	–	WD	70
			C	–	44.6	47.3	8.1	–	–	–	–	–	13,220	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
263	King mine Hiawatha bed		A	5.8	42.5	45.0	6.7	.7	–	–	–	–	12,710	2,210	–	–	T	70
			C	–	45.1	47.8	7.1	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,520	–	–	–		
264	King mine Hiawatha bed		A	5.4	43.0	45.2	6.3	.6	–	–	–	–	12,800	2,140	–	–	T	70
			C	–	45.5	47.8	6.7	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,500	–	–	–		
265	King mine Hiawatha bed		A	5.3	42.8	45.4	6.5	.7	–	–	–	–	12,820	2,180	–	–	T	70
			C	–	45.2	47.9	6.9	–	–	–	–	–	13,540	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,540	–	–	–		
266	King mine Hiawatha bed		A	4.8	42.7	45.5	7.0	.7	–	–	–	–	12,760	–	–	–	D	70
			C	–	44.9	47.8	7.3	–	–	–	–	–	13,400	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
267	King mine Hiawatha bed		A	4.8	42.7	45.4	7.1	.6	–	–	–	–	12,710	–	–	–	D	70
			C	–	44.8	47.7	7.5	–	–	–	–	–	13,350	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
268	King mine Hiawatha bed		A	3.9	43.0	47.0	6.2	.9	–	–	–	–	12,990	–	–	–	WD	70
			C	–	44.7	48.9	6.4	–	–	–	–	–	13,520	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		
269	King mine Hiawatha bed		A	6.3	42.5	44.7	6.5	.6	–	–	–	–	12,680	2,210	–	–	WT	70
			C	–	45.4	47.7	6.9	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,530	–	–	–		
270	King mine Hiawatha bed		A	4.3	43.0	45.5	7.3	.7	–	–	–	–	12,800	–	–	–	WD	70
			C	–	44.9	47.5	7.6	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
271	King mine Hiawatha bed		A	5.4	42.3	45.2	7.1	.7	–	–	–	–	12,690	2,270	–	–	WT	70
			C	–	44.7	47.8	7.5	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,500	–	–	–		
272	King mine Hiawatha bed		A	6.2	42.5	44.3	7.0	.7	–	–	–	–	12,600	2,310	–	–	WT	70
			C	–	45.3	47.2	7.5	–	–	–	–	–	13,430	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,520	–	–	–		
273	King mine Hiawatha bed		A	6.0	42.5	45.5	6.0	.7	–	–	–	–	12,690	–	–	–	WD	70
			C	–	45.2	48.4	6.4	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
274	King mine Hiawatha bed		A	6.1	42.1	44.8	7.0	.7	–	–	–	–	12,570	2,210	–	–	WT	70
			C	–	44.8	47.7	7.5	–	–	–	–	–	13,390	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
275	King mine Hiawatha bed		A	5.0	42.8	44.9	7.3	.6	–	–	–	–	12,670	2,180	–	–	D	70
			C	–	45.0	47.3	7.7	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
276	King mine Hiawatha bed		A	4.8	42.7	46.1	6.5	.7	–	–	–	–	12,870	2,080	–	–	D	70
			C	–	44.8	48.4	6.8	–	–	–	–	–	13,520	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		
277	King mine Hiawatha bed		A	4.8	42.7	45.0	7.5	.6	–	–	–	–	12,680	2,210	–	–	WD	70
			C	–	44.8	47.3	7.9	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
278	King mine Hiawatha bed		A	6.3	41.8	44.6	7.3	.6	–	–	–	–	12,500	2,370	–	–	WD	70
			C	–	44.6	47.6	7.8	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
279	King mine Hiawatha bed		A	5.2	41.2	46.5	7.1	.8	–	–	–	–	12,650	2,440	–	–	WD	70
			C	–	43.5	49.0	7.5	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
280	King mine Hiawatha bed		A	6.6	40.9	45.7	6.8	.7	–	–	–	–	12,500	2,370	–	–	WD	70
			C	–	43.8	48.9	7.3	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
281	King mine Hiawatha bed		A	5.8	42.1	46.1	6.0	.6	–	–	–	–	12,710	2,490	–	–	WD	70
			C	–	44.7	48.9	6.4	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,410	–	–	–		
282	King mine Hiawatha bed		A	4.9	42.1	45.7	7.2	.7	–	–	–	–	12,650	2,450	–	–	WD	70
			C	–	44.3	48.1	7.6	–	–	–	–	–	13,300	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
283	King mine Hiawatha bed		A	4.8	42.0	46.4	6.9	.7	–	–	–	–	12,680	2,400	–	–	WD	70
			C	–	44.1	48.7	7.2	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
284	King mine Hiawatha bed		A	4.6	43.4	44.7	7.3	.6	–	–	–	–	12,680	2,280	–	–	WD	70
			C	–	45.5	46.9	7.6	–	–	–	–	–	13,290	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
285	King mine Hiawatha bed		A	5.3	42.1	45.9	6.6	.8	–	–	–	–	12,790	2,400	–	–	T	70
			C	–	44.5	48.5	7.0	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,530	–	–	–		
286	King mine Hiawatha bed		A	5.3	42.1	45.9	6.6	.8	–	–	–	–	12,810	2,360	–	–	T	70
			C	–	44.5	48.5	7.0	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,550	–	–	–		
287	King mine Hiawatha bed		A	5.8	42.1	45.7	6.4	.7	–	–	–	–	12,800	2,450	–	–	WT	70
			C	–	44.7	48.5	6.8	–	–	–	–	–	13,590	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,580	–	–	–		
288	King mine Hiawatha bed		A	5.1	42.5	45.2	7.2	.6	–	–	–	–	12,770	2,420	–	–	WT	70
			C	–	44.8	47.6	7.6	–	–	–	–	–	13,460	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,570	–	–	–		
289	King mine Hiawatha bed		A	5.2	42.2	45.0	7.6	.6	–	–	–	–	12,600	2,340	–	–	WD	70
			C	–	44.5	47.5	8.0	–	–	–	–	–	13,290	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
290	King mine Hiawatha bed		A	5.2	42.4	45.7	6.7	.8	–	–	–	–	12,730	2,340	–	41	WT	70
			C	–	44.7	48.2	7.1	–	–	–	–	–	13,430	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
291	King mine Hiawatha bed		A	4.9	41.7	46.9	6.5	.6	–	–	–	–	12,850	2,460	–	–	WT	70
			C	–	43.9	49.3	6.8	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,500	–	–	–		
292	King mine Hiawatha bed		A	4.2	42.2	46.1	7.5	.6	–	–	–	–	12,770	2,410	–	–	WD	70
			C	–	44.1	48.1	7.8	–	–	–	–	–	13,330	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
293	King mine Hiawatha bed		A	5.4	42.2	45.6	6.8	.6	–	–	–	–	12,750	2,240	–	–	WD	70
			C	–	44.6	48.2	7.2	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,530	–	–	–		
294	King mine Hiawatha bed		A	3.8	42.9	45.9	7.4	.6	–	–	–	–	12,900	2,370	–	–	WD	70
			C	–	44.6	47.7	7.7	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,530	–	–	–		
295	King mine Hiawatha bed		A	3.6	41.8	49.0	5.7	.5	–	–	–	–	13,130	–	–	–	D	70
			C	–	43.4	50.7	5.9	–	–	–	–	–	13,620	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
296	King mine Hiawatha bed		A	4.2	42.8	46.8	6.1	.5	–	–	–	–	13,000	2,110	–	–	WD	70
			C	–	44.7	48.9	6.4	–	–	–	–	–	13,570	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,500	–	–	–		
297	King mine Hiawatha bed		A	4.4	42.0	47.4	6.2	.5	–	–	–	–	12,960	2,120	–	–	WD	70
			C	–	43.9	49.6	6.5	–	–	–	–	–	13,560	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,500	–	–	–		
298	King mine Hiawatha bed		A	5.1	42.4	46.7	5.8	.6	–	–	–	–	13,030	2,080	–	–	T	70
			C	–	44.7	49.2	6.1	–	–	–	–	–	13,730	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,620	–	–	–		
299	King mine Hiawatha bed		A	5.6	41.5	47.7	5.2	.6	–	–	–	–	13,030	2,030	–	–	T	70
			C	–	44.0	50.5	5.5	–	–	–	–	–	13,800	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,600	–	–	–		
300	King mine Hiawatha bed		A	5.6	41.0	48.0	5.5	.6	–	–	–	–	13,010	2,150	–	–	T	70
			C	–	43.4	50.8	5.8	–	–	–	–	–	13,780	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,630	–	–	–		
301	King mine Hiawatha bed		A	5.7	41.8	46.8	5.8	.7	–	–	–	–	12,990	2,090	–	–	WT	70
			C	–	44.3	49.6	6.1	–	–	–	–	–	13,770	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,660	–	–	–		
302	King mine Hiawatha bed		A	5.7	42.5	45.9	5.8	.6	–	–	–	–	12,950	2,090	–	–	WT	70
			C	–	45.1	48.7	6.2	–	–	–	–	–	13,730	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,640	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
303	King mine Hiawatha bed		A C D	5.0 – –	43.3 45.6 –	45.7 48.1 –	6.0 6.3 –	.6 – –	– – –	– – –	– – –	– – –	12,990 13,670 14,590	2,040 – –	– – –	– – –	WT	70
304	King mine Hiawatha bed		A C D	3.1 – –	44.2 45.6 –	46.9 48.4 –	5.8 6.0 –	.5 – –	– – –	– – –	– – –	– – –	– – –	13,270 13,690 14,560	2,060 – –	– – –	– – –	WD	70
305	King mine Hiawatha bed		A C D	5.8 – –	42.7 45.3 –	45.4 48.2 –	6.1 6.5 –	.7 – –	– – –	– – –	– – –	– – –	– – –	12,880 13,670 14,620	2,070 – –	– – –	– – –	WT	70
306	King mine Hiawatha bed		A C D	5.2 – –	42.8 45.1 –	46.5 49.1 –	5.5 5.8 –	.6 – –	– – –	– – –	– – –	– – –	– – –	13,020 13,730 14,580	2,090 – –	– – –	– – –	WD	70
307	King mine Hiawatha bed		A C D	2.1 – –	44.5 45.5 –	47.8 48.8 –	5.6 5.7 –	.7 – –	– – –	– – –	– – –	– – –	– – –	13,480 13,770 14,600	2,040 – –	– – –	– – –	WD	70
308	King mine Hiawatha bed		A C D	4.5 – –	42.8 44.8 –	47.4 49.6 –	5.3 5.6 –	.5 – –	– – –	– – –	– – –	– – –	– – –	13,090 13,710 14,520	– – –	– – –	– – –	D	70
309	King mine Hiawatha bed		A C D	4.8 – –	42.7 44.9 –	47.6 50.0 –	4.9 5.1 –	.5 – –	– – –	– – –	– – –	– – –	– – –	13,180 13,840 14,580	– – –	– – –	– – –	WD	70
310	King mine Hiawatha bed		A C D	5.3 – –	42.2 44.6 –	46.9 49.5 –	5.6 5.9 –	.5 – –	– – –	– – –	– – –	– – –	– – –	12,960 13,690 14,550	– – –	– – –	– – –	WD	70
311	King mine Hiawatha bed		A C D	4.9 – –	42.6 44.8 –	47.5 49.9 –	5.0 5.3 –	.6 – –	– – –	– – –	– – –	– – –	– – –	13,060 13,730 14,500	– – –	– – –	– – –	WD	70
312	King mine Hiawatha bed		A C D	4.6 – –	42.5 44.6 –	47.3 49.6 –	5.5 5.8 –	.6 – –	– – –	– – –	– – –	– – –	– – –	13,050 13,680 14,520	– – –	– – –	– – –	WD	70
313	King mine Hiawatha bed		A C D	5.2 – –	42.6 44.9 –	47.0 49.6 –	5.2 5.5 –	.5 – –	– – –	– – –	– – –	– – –	– – –	13,040 13,750 14,550	2,160 – –	– – –	– – –	WD	70
314	King mine Hiawatha bed		A C D	5.0 – –	42.7 44.9 –	45.7 48.1 –	6.7 7.0 –	.5 – –	– – –	– – –	– – –	– – –	– – –	12,890 13,570 14,590	– – –	– – –	– – –	WD	70
315	King mine Hiawatha bed		A C D	5.3 – –	42.2 44.6 –	46.3 48.9 –	6.2 6.5 –	.5 – –	– – –	– – –	– – –	– – –	– – –	12,930 13,650 14,600	– – –	– – –	– – –	WD	70
316	King mine Hiawatha bed		A C D	4.8 – –	42.6 44.7 –	46.9 49.3 –	5.7 6.0 –	.6 – –	– – –	– – –	– – –	– – –	– – –	13,040 13,700 14,570	2,200 – –	– – –	– – –	WD	70
317	King mine Hiawatha bed		A C D	6.4 – –	42.1 45.0 –	45.5 48.6 –	6.0 6.4 –	.5 – –	– – –	– – –	– – –	– – –	– – –	12,810 13,690 14,630	2,290 – –	– – –	– – –	WD	70
318	King mine Hiawatha bed		A C D	6.0 – –	42.7 45.4 –	45.5 48.4 –	5.8 6.2 –	.6 – –	– – –	– – –	– – –	– – –	– – –	12,900 13,720 14,630	– – –	– – –	– – –	WD	70
319	King mine Hiawatha bed		A C D	6.4 – –	42.5 45.4 –	45.2 48.3 –	5.9 6.3 –	.6 – –	– – –	– – –	– – –	– – –	– – –	12,780 13,650 14,570	2,230 – –	– – –	– – –	T	70
320	King mine Hiawatha bed		A C D	5.9 – –	42.6 45.3 –	45.5 48.4 –	5.9 6.3 –	.6 – –	– – –	– – –	– – –	– – –	– – –	12,780 13,580 14,490	2,130 – –	– – –	– – –	T	70
321	King mine Hiawatha bed		A C D	5.9 – –	42.8 45.5 –	45.3 48.1 –	6.0 6.4 –	.5 – –	– – –	– – –	– – –	– – –	– – –	12,860 13,670 14,600	– – –	– – –	– – –	T	70
322	King mine Hiawatha bed		A C D	5.5 – –	41.5 43.9 –	45.5 48.2 –	7.5 7.9 –	.6 – –	– – –	– – –	– – –	– – –	– – –	12,600 13,330 14,470	2,150 – –	– – –	– – –	WT	70
323	King mine Hiawatha bed		A C D	4.5 – –	42.6 44.6 –	46.3 48.5 –	6.6 6.9 –	.5 – –	– – –	– – –	– – –	– – –	– – –	12,970 13,580 14,590	– – –	– – –	– – –	WD	70
324	King mine Hiawatha bed		A C D	5.5 – –	43.2 45.7 –	45.3 47.9 –	6.0 6.4 –	.6 – –	– – –	– – –	– – –	– – –	– – –	12,900 13,650 14,580	2,260 – –	– – –	– – –	WT	70
325	King mine Hiawatha bed		A C D	4.3 – –	43.2 45.1 –	46.4 48.5 –	6.1 6.4 –	.5 – –	– – –	– – –	– – –	– – –	– – –	13,060 13,650 14,580	2,200 – –	– – –	– – –	WD	70
326	King mine Hiawatha bed		A C D	7.0 – –	42.5 45.7 –	44.7 48.1 –	5.8 6.2 –	.6 – –	– – –	– – –	– – –	– – –	– – –	12,740 13,700 14,610	2,280 – –	– – –	47 – –	WT	70
327	King mine Hiawatha bed		A C D	6.2 – –	42.8 45.6 –	46.2 49.3 –	4.8 5.1 –	.6 – –	– – –	– – –	– – –	– – –	– – –	12,920 13,770 14,510	2,230 – –	– – –	– – –	WT	70

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
				AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
328	King mine		A		4.4	43.1	46.9	5.5	.5	–	–	–	–	13,080	2,200	–	–	WD	70
	Hiawatha bed		C		–	45.1	49.1	5.8	–	–	–	–	–	13,680	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,520	–	–	–		
329	King mine		A		6.1	42.4	45.7	5.7	.5	–	–	–	–	12,820	2,230	–	–	WD	70
	Hiawatha bed		C		–	45.2	48.7	6.1	–	–	–	–	–	13,650	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,540	–	–	–		
330	King mine		A		5.4	42.9	44.7	7.0	.6	–	–	–	–	12,740	2,230	–	–	WD	70
	Hiawatha bed		C		–	45.4	47.2	7.4	–	–	–	–	–	13,470	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,550	–	–	–		
331	King mine		A		4.4	43.4	45.6	6.6	.6	–	–	–	–	13,030	2,270	–	–	WD	70
	Hiawatha bed		C		–	45.4	47.7	6.9	–	–	–	–	–	13,630	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,640	–	–	–		
332	King mine		A		6.4	42.0	46.0	5.6	.5	–	–	–	–	12,850	2,090	–	–	T	70
	Hiawatha bed		C		–	44.9	49.1	6.0	–	–	–	–	–	13,730	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,610	–	–	–		
333	King mine		A		6.7	42.2	45.3	5.9	.6	–	–	–	–	12,750	2,090	–	–	WT	70
	Hiawatha bed		C		–	45.2	48.5	6.3	–	–	–	–	–	13,670	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,590	–	–	–		
334	King mine		A		7.0	42.0	45.0	6.0	.5	–	–	–	–	12,720	2,140	–	–	WD	70
	Hiawatha bed		C		–	45.2	48.4	6.4	–	–	–	–	–	13,680	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,620	–	–	–		
335	King mine		A		6.9	42.8	44.7	5.6	.6	–	–	–	–	12,820	2,080	–	–	WT	70
	Hiawatha bed		C		–	46.0	48.0	6.0	–	–	–	–	–	13,770	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,650	–	–	–		
336	King mine		A		6.2	42.8	45.7	5.3	.6	–	–	–	–	12,950	2,080	–	–	WT	70
	Hiawatha bed		C		–	45.6	48.7	5.7	–	–	–	–	–	13,810	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,640	–	–	–		
337	King mine		A		4.5	42.4	45.8	7.3	.6	–	–	–	–	12,840	2,360	–	–	WD	70
	Hiawatha bed		C		–	44.4	48.0	7.6	–	–	–	–	–	13,440	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,550	–	–	–		
338	King mine		A		7.3	42.3	45.5	4.9	.6	–	–	–	–	12,810	2,070	–	48	WT	70
	Hiawatha bed		C		–	45.6	49.1	5.3	–	–	–	–	–	13,820	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,590	–	–	–		
339	King mine		A		4.7	43.4	45.9	6.0	.6	–	–	–	–	13,040	2,180	–	–	WD	70
	Hiawatha bed		C		–	45.5	48.2	6.3	–	–	–	–	–	13,680	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,600	–	–	–		
340	King mine		A		5.7	42.6	47.3	4.3	.7	–	–	–	–	13,090	2,140	–	–	WT	70
	Hiawatha bed		C		–	45.2	50.2	4.6	–	–	–	–	–	13,880	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,550	–	–	–		
341	King mine		A		6.0	43.0	45.1	5.9	.6	–	–	–	–	12,840	2,120	–	–	D	70
	Hiawatha bed		C		–	45.7	48.0	6.3	–	–	–	–	–	13,660	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,580	–	–	–		
342	King mine		A		4.7	43.9	45.7	5.6	.5	–	–	–	–	13,080	2,100	–	–	WD	70
	Hiawatha bed		C		–	46.1	48.0	5.9	–	–	–	–	–	13,730	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,590	–	–	–		
343	King mine		A		6.1	42.8	45.2	5.9	.6	–	–	–	–	12,850	2,180	–	–	WD	70
	Hiawatha bed		C		–	45.6	48.1	6.3	–	–	–	–	–	13,690	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,610	–	–	–		
344	King mine		A		6.7	42.5	45.0	5.8	.5	–	–	–	–	12,700	2,210	–	–	WD	70
	Hiawatha bed		C		–	45.6	48.2	6.2	–	–	–	–	–	13,610	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,510	–	–	–		
345	King mine		A		6.4	43.1	46.1	4.4	.6	–	–	–	–	12,960	2,060	–	–	T	70
	Hiawatha bed		C		–	46.0	49.3	4.7	–	–	–	–	–	13,850	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,530	–	–	–		
346	King mine		A		7.2	40.4	47.2	5.2	.5	–	–	–	–	12,630	2,080	–	–	T	70
	Hiawatha bed		C		–	43.5	50.9	5.6	–	–	–	–	–	13,610	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,420	–	–	–		
347	King mine		A		7.1	41.3	47.1	4.5	.5	–	–	–	–	12,790	2,060	–	–	WT	70
	Hiawatha bed		C		–	44.5	50.7	4.8	–	–	–	–	–	13,770	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,460	–	–	–		
348	King mine		A		6.0	42.4	46.6	5.0	.5	–	–	–	–	12,930	2,050	–	–	WD	70
	Hiawatha bed		C		–	45.1	49.6	5.3	–	–	–	–	–	13,760	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,530	–	–	–		
349	King mine		A		7.3	42.5	45.5	4.6	.5	–	–	–	–	12,800	2,050	–	–	WT	70
	Hiawatha bed		C		–	45.9	49.1	5.0	–	–	–	–	–	13,810	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,540	–	–	–		
350	King mine		A		6.2	42.7	46.1	5.1	.5	–	–	–	–	12,890	2,060	–	48	WT	70
	Hiawatha bed		C		–	45.5	49.1	5.4	–	–	–	–	–	13,740	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,520	–	–	–		
351	King mine		A		6.1	43.0	45.7	5.2	.5	–	–	–	–	12,930	2,040	–	–	WD	70
	Hiawatha bed		C		–	45.8	48.7	5.5	–	–	–	–	–	13,770	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,570	–	–	–		
352	King mine		A		7.0	42.7	45.8	4.5	.5	–	–	–	–	12,860	2,050	–	–	WT	70
	Hiawatha bed		C		–	45.9	49.3	4.8	–	–	–	–	–	13,830	–	–	–		
			D		–	–	–	–	–	–	–	–	–	14,530	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
353	King mine Hiawatha bed		A C D	6.7 – –	43.0 46.1 –	45.4 48.7 –	4.9 5.2 –	.4 – –	– – –	– – –	– – –	– – –	12,880 13,800 14,560	2,080 – –	– – –	– – –	WD	70
354	King mine Hiawatha bed		A C D	5.6 – –	44.3 46.9 –	46.8 49.6 –	3.3 3.5 –	.5 – –	– – –	– – –	– – –	– – –	13,250 14,040 14,550	2,050 – –	– – –	– – –	WT	70
355	King mine Hiawatha bed		A C D	4.8 – –	44.7 47.0 –	44.6 46.9 –	5.8 6.1 –	.5 – –	– – –	– – –	– – –	– – –	12,990 13,650 14,540	2,060 – –	– – –	– – –	WD	70
356	King mine Hiawatha bed		A C D	6.4 – –	43.0 45.9 –	45.3 48.4 –	5.3 5.7 –	.5 – –	– – –	– – –	– – –	– – –	12,820 13,700 14,530	2,140 – –	– – –	– – –	WD	70
357	King mine Hiawatha bed		A C D	5.9 – –	43.4 46.1 –	44.9 47.7 –	5.8 6.2 –	.5 – –	– – –	– – –	– – –	– – –	12,850 13,660 14,560	– – –	– – –	– – –	WD	70
358	King mine Hiawatha bed		A C D	6.3 – –	42.8 45.7 –	46.2 49.3 –	4.7 5.0 –	.7 – –	– – –	– – –	– – –	– – –	12,880 13,750 14,470	2,370 – –	– – –	– – –	T	70
359	King mine Hiawatha bed		A C D	6.2 – –	43.0 45.8 –	45.3 48.3 –	5.5 5.9 –	.6 – –	– – –	– – –	– – –	– – –	12,820 13,670 14,530	2,100 – –	– – –	– – –	WD	70
360	King mine Hiawatha bed		A C D	5.7 – –	43.3 45.9 –	46.2 49.0 –	4.8 5.1 –	.7 – –	– – –	– – –	– – –	– – –	12,930 13,710 14,450	2,410 – –	– – –	– – –	WT	70
361	King mine Hiawatha bed		A C D	5.0 – –	43.7 46.0 –	45.0 47.4 –	6.3 6.6 –	.6 – –	– – –	– – –	– – –	– – –	12,920 13,600 14,560	2,150 – –	– – –	– – –	WD	70
362	King mine Hiawatha bed		A C D	6.4 – –	42.7 45.6 –	46.1 49.2 –	4.9 5.2 –	.7 – –	– – –	– – –	– – –	– – –	12,830 13,710 14,460	2,380 – –	– – –	– – –	WT	70
363	King mine Hiawatha bed		A C D	6.3 – –	43.1 46.0 –	45.0 48.0 –	5.6 6.0 –	.6 – –	– – –	– – –	– – –	– – –	12,820 13,680 14,550	2,210 – –	– – –	– – –	WD	70
364	King mine Hiawatha bed		A C D	6.3 – –	42.9 45.8 –	45.2 48.2 –	5.6 6.0 –	.6 – –	– – –	– – –	– – –	– – –	12,800 13,660 14,530	2,220 – –	– – –	– – –	WD	70
365	King mine Hiawatha bed		A C D	6.5 – –	42.6 45.6 –	46.5 49.7 –	4.4 4.7 –	.7 – –	– – –	– – –	– – –	– – –	12,940 13,840 14,520	2,320 – –	– – –	– – –	WT	70
366	King mine Hiawatha bed		A C D	5.4 – –	43.3 45.8 –	45.5 48.1 –	5.8 6.1 –	.5 – –	– – –	– – –	– – –	– – –	12,880 13,610 14,490	2,280 – –	– – –	– – –	WD	70
367	King mine Hiawatha bed		A C D	4.8 – –	43.4 45.6 –	46.1 48.4 –	5.7 6.0 –	.5 – –	– – –	– – –	– – –	– – –	12,990 13,640 14,510	2,320 – –	– – –	– – –	WD	70
368	King mine Hiawatha bed		A C D	6.5 – –	42.7 45.7 –	45.3 48.4 –	5.5 5.9 –	.5 – –	– – –	– – –	– – –	– – –	12,750 13,640 14,500	2,290 – –	– – –	– – –	WD	70
369	King mine Hiawatha bed		A C D	6.8 – –	42.7 45.8 –	44.7 48.0 –	5.8 6.2 –	.5 – –	– – –	– – –	– – –	– – –	12,690 13,620 14,520	2,350 – –	– – –	– – –	D	70
370	Mohrland mine	NE.NE.SE.SE.8–16S–8E 4367750mN 496550mE	A C D	4.65 – –	43.39 45.53 –	45.94 48.21 –	5.97 6.26 –	.64 – –	– – –	– – –	– – –	– – –	13,011 13,646 14,557	– – –	– – –	– – –		52
371	Mohrland mine		A C D	5.14 – –	42.31 44.58 –	46.44 48.94 –	6.15 6.48 –	.66 – –	– – –	– – –	– – –	– – –	12,746 13,437 14,368	– – –	– – –	– – –		55
372	Mohrland mine		A C D	5.19 – –	41.81 44.10 –	46.23 48.77 –	6.76 7.13 –	.70 – –	– – –	– – –	– – –	– – –	12,658 13,351 14,376	– – –	– – –	– – –		55
373	Mohrland mine Hiawatha bed		A B	6.0 1.45	41.4 43.45	47.2 49.40	5.4 5.70	.6 .63	– –	– –	– –	– –	12,830 13,450	2,340 –	4.6 –	– –		29
374	Mohrland mine		A	6.1	41.3	46.3	6.3	.7	–	–	–	–	12,460	2,390	4.8	–		29
375	Mohrland mine		A	5.8	41.7	45.4	7.1	.7	–	–	–	–	12,500	1,990	4.5	–		29
376	Mohrland mine		A	6.6	42.5	44.0	6.9	.6	–	–	–	–	12,540	2,340	5.6	–		29
377	Mohrland mine		A C D	6.3 – –	41.6 44.4 47.7	45.7 48.8 52.3	6.4 6.8 –	.7 .7 .8	6.2 5.9 6.3	69.7 74.4 79.8	1.5 1.6 1.7	15.5 10.6 11.4	12,590 13,430 14,420	– – –	4.9 – –	– – –		29
378	Sea Gull mine Blind Canyon bed	C.S.34–16S–7E 4359400mN 489400mE	A C	4.8 –	41.6 43.7	47.0 49.4	6.6 6.9	.6 –	– –	– –	– –	– –	12,950 13,610	– –	– –	– –	T	2
379	Sea Gull mine Blind Canyon bed		A C	4.6 –	40.9 42.9	44.7 46.9	9.7 10.2	.5 –	– –	– –	– –	– –	12,490 13,090	– –	– –	– –	T	2

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES				ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
380	Sea Gull mine		A	5.0	41.7	44.4	8.9	.6	–	–	–	–	12,550	–	–	–	T	2
	Blind Canyon bed		C	–	43.9	46.7	9.4	–	–	–	–	–	13,210	–	–	–		
381	Sea Gull mine		A	5.0	40.9	48.3	5.8	.6	–	–	–	–	13,080	–	–	–	T	4
	Blind Canyon bed		C	–	43.1	50.8	6.1	–	–	–	–	–	13,760	–	–	–		
382	Sea Gull mine		A	4.8	40.6	43.4	11.2	.6	–	–	–	–	12,280	–	–	45		4
	Blind Canyon mine		C	–	42.6	45.6	11.8	–	–	–	–	–	12,910	–	–	–		
383	Sea Gull mine		A	3.96	44.7	41.0	10.3	–	–	–	–	–	12,150	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	12,690	–	–	–		
384	Sea Gull mine		A	4.96	43.5	39.2	12.4	–	–	–	–	–	11,700	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	12,310	–	–	–		
385	Sea Gull mine		A	4.7	–	–	7.3	.50	–	–	–	–	–	–	–	–		73
386	Sea Gull mine		A	5.0	41.1	46.6	7.2	.6	–	–	–	–	12,860	–	–	–		6
			C	–	43.3	49.1	7.6	–	–	–	–	–	13,540	–	–	–		
387	Sea Gull mine		A	5.3	40.2	44.5	9.9	.6	–	–	–	–	12,370	–	–	–		7
			C	–	42.5	47.0	10.5	–	–	–	–	–	13,060	–	–	–		
388	Tie Fork prospect	34–15S–7E	A	3.8	40.7	50.2	5.3	.8	–	–	–	–	13,000	–	1.9	–		29
	Hiawatha bed (?)		C	–	42.3	52.2	5.5	.8	–	–	–	–	13,520	–	–	–		
								HIAWATHA NW QUADRANGLE										
1	Black Magic mine	S.NW.NW.SW.28–16S–7E	A	4.6	–	–	7.0	.47	–	–	–	–	–	–	–	–		73
	Hiawatha bed	4361050mN 487100mE																
2	Black Magic mine		A	4.6	44.1	48.4	3.0	.6	6.0	78.6	1.6	10.1	13,670	–	–	–	T	2
	Blind Canyon bed		C	–	46.2	50.7	3.1	–	–	–	–	–	14,330	–	–	–		
3	Black Magic mine		A	4.4	44.2	48.3	3.2	.6	–	–	–	–	13,690	–	–	–	T	2
	Blind Canyon bed		C	–	46.2	50.5	3.3	–	–	–	–	–	14,320	–	–	–		
4	Black Magic mine		A	6.3	42.5	46.5	4.7	.6	–	–	–	–	13,010	–	–	–	T	2
	Blind Canyon bed		C	–	45.4	49.6	5.0	–	–	–	–	–	13,890	–	–	–		
5	Black Magic mine		A	5.0	42.8	44.7	7.5	.6	5.6	74.4	1.5	10.0	12,870	–	–	46		4
	Hiawatha bed		C	–	45.0	47.1	7.9	–	–	–	–	–	13,540	–	–	–		
6	Black Magic mine		A	5.0	41.7	45.4	7.9	.5	–	–	–	–	12,670	–	–	–	T	7
	Hiawatha bed		C	–	43.9	47.8	8.3	–	–	–	–	–	13,340	–	–	–		
7	Black Magic mine		A	4.6	40.4	47.4	7.6	.5	–	–	–	–	12,960	–	–	–	T	7
	Hiawatha bed		C	–	42.3	49.7	8.0	–	–	–	–	–	13,580	–	–	–		
8	Black Magic mine		A	6.7	41.0	44.8	7.6	.5	–	–	–	–	12,290	–	–	–	T	7
	Hiawatha bed		C	–	43.9	48.0	8.1	–	–	–	–	–	13,170	–	–	–		
9	Black Magic mine		A	4.6	42.5	44.9	7.9	.6	–	–	–	–	12,700	–	–	–	T	9
	Hiawatha bed		C	–	44.6	47.1	8.3	–	–	–	–	–	13,300	–	–	–		
10	Black Magic mine		A	4.4	41.9	46.2	7.6	.6	–	–	–	–	12,840	–	–	–	T	9
	Hiawatha bed		C	–	43.8	48.3	7.9	–	–	–	–	–	13,430	–	–	–		
11	Black Magic mine		A	6.1	40.8	46.1	6.9	.5	–	–	–	–	12,440	–	–	–	T	9
	Hiawatha bed		C	–	43.5	49.1	7.4	–	–	–	–	–	13,240	–	–	–		
12	Black Magic mine		A	4.0	44.0	44.9	7.1	.5	–	–	–	–	12,940	–	–	–	T	11
	Hiawatha bed		C	–	45.8	46.8	7.4	–	–	–	–	–	13,480	–	–	–		
13	Black Magic mine		A	4.2	42.6	44.6	8.2	.5	–	–	–	–	12,660	–	–	–	T	11
	Hiawatha bed		C	–	44.5	46.6	8.9	–	–	–	–	–	13,220	–	–	–		
14	Black Magic mine		A	4.9	42.0	44.9	8.2	.5	–	–	–	–	12,630	–	–	–	T	11
	Hiawatha bed		C	–	44.2	47.2	8.6	–	–	–	–	–	13,270	–	–	–		
15	Black Magic mine		A	3.3	42.4	47.5	6.9	.5	–	–	–	–	12,940	–	–	–	T	11
	Hiawatha bed		C	–	43.8	49.1	7.1	–	–	–	–	–	13,390	–	–	–		
16	Comfort mine	W.SE.SE.NW.28–16S–7E	A	5.8	–	–	5.8	.49	–	–	–	–	–	–	–	–		73
	Hiawatha bed	4361400mN 487190mE																
17	Leamaster mine	SE.SW.16–16S–7E	A	4.2	–	–	5.0	.49	–	–	–	–	–	–	–	–		73
		4363830mN 487910mE																
18	Leamaster mine		A	5.1	43.9	46.1	4.8	.7	–	–	–	–	13,430	–	–	–	T	2
	Blind Canyon bed		C	–	46.3	48.6	5.1	–	–	–	–	–	14,150	–	–	–		
19	Leamaster mine		A	5.3	44.1	45.6	4.9	.5	–	–	–	–	13,280	–	–	–	T	2
	Blind Canyon bed		C	–	46.6	48.2	5.2	–	–	–	–	–	14,030	–	–	–		
20	Leamaster mine		A	6.2	44.3	43.9	5.6	.5	–	–	–	–	13,050	–	–	–	T	2
	Blind Canyon bed		C	–	47.2	46.8	6.0	–	–	–	–	–	13,920	–	–	–		
21	Leamaster mine		A	3.1	42.99	51.1	2.8	.23	–	–	–	–	13,647	–	.98	–		72
			B	1.8	43.6	51.8	2.9	.23	–	–	–	–	13,828	–	–	–		
			C	–	44.4	52.7	2.9	.23	–	–	–	–	14,079	–	–	–		
22	Leamaster mine		A	5.3	44.9	45.6	4.3	.5	–	–	–	–	13,430	–	–	–		6
	Blind Canyon bed		C	–	47.4	48.1	4.5	–	–	–	–	–	14,180	–	–	–		
23	Leamaster mine		A	5.3	43.4	46.5	4.8	.7	–	–	–	–	13,370	–	–	51		6
			C	–	45.8	49.1	5.1	–	–	–	–	–	14,110	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
24	Leamaster mine Blind Canyon bed		A C	6.1 –	43.1 45.9	44.6 47.5	6.2 6.6	.8 –	– –	– –	– –	– –	12,930 13,770	– –	– –	– –		6
25	Leamaster mine Blind Canyon bed		A C	4.2 –	45.6 47.6	45.4 47.4	4.8 5.0	.8 –	– –	– –	– –	– –	13,530 14,120	– –	– –	– –	T	7
26	Leamaster mine Blind Canyon bed		A C	4.8 –	45.3 47.6	44.8 47.1	5.0 5.3	.5 –	– –	– –	– –	– –	13,410 14,080	– –	– –	46 –	T	7
27	Leamaster mine Blind Canyon bed		A C	4.5 –	44.2 46.3	46.4 48.6	4.9 5.1	.6 –	– –	– –	– –	– –	13,330 13,960	– –	– –	– –	T	7
28	Leamaster mine Hiawatha bed		A C	6.8 –	42.5 45.6	46.6 50.0	4.1 4.4	.5 –	– –	– –	– –	– –	12,930 13,860	– –	– –	– –	T	9
29	Leamaster mine Hiawatha bed		A C	4.4 –	45.8 47.9	45.0 47.1	4.8 5.0	.4 –	– –	– –	– –	– –	13,490 14,100	– –	– –	– –	T	9
30	Leamaster mine Hiawatha bed		A C	5.1 –	44.3 46.7	44.4 46.8	6.2 6.5	.5 –	– –	– –	– –	– –	13,050 13,750	– –	– –	– –	T	9
31	Leamaster mine Hiawatha bed		A C	4.7 –	44.9 47.1	44.9 47.1	5.5 5.8	.5 –	– –	– –	– –	– –	13,280 13,920	– –	– –	– –	T	9
32	Leamaster mine		A C	4.4 –	40.9 42.8	44.0 46.0	10.7 11.2	.7 –	– –	– –	– –	– –	12,400 12,980	– –	– –	– –		9
33	Leamaster mine		A C	4.1 –	45.8 47.8	44.6 46.5	5.5 5.7	.6 –	– –	– –	– –	– –	13,360 13,930	– –	– –	– –	T	11
34	Leamaster mine		A C	4.6 –	45.3 47.5	45.6 47.8	4.5 4.7	.6 –	– –	– –	– –	– –	13,430 14,080	– –	– –	– –	T	11
35	Leamaster mine		A C	5.3 –	46.0 48.6	43.5 45.9	5.2 5.5	.7 –	– –	– –	– –	– –	13,110 13,840	– –	– –	– –	T	11
36	Leamaster mine Blind Canyon bed		A	6.3	43.9	45.0	4.8	.6	6.2	71.8	1.3	15.3	13,004	–	–	–		74
37	Rominger mine Hiawatha bed	SE.SW.SW.NW.28–16S–7E 4361380mN 487080mE	A	3.8	–	–	8.1	.77	–	–	–	–	–	–	–	–		73
38	Tip Top mine Hiawatha bed	SW.NW.SE.NE.5–16S–7E 4367760mN 486800mE	A C	4.3 –	43.4 45.4	45.3 47.3	7.0 7.3	.4 –	– –	– –	– –	– –	13,050 13,650	– –	– –	– –	T	7
39	Tip Top mine Hiawatha bed		A C	4.3 –	43.0 44.9	45.8 47.9	6.9 7.2	.4 –	– –	– –	– –	– –	13,000 13,580	– –	– –	50 –	T	7
40	Tip Top mine Hiawatha bed		A	4.3	–	–	5.7	.50	–	–	–	–	–	–	–	–		73
41	Tip Top mine Hiawatha bed		A	4.1	–	–	6.0	.48	–	–	–	–	–	–	–	–		73
	HIAWATHA SE QUADRANGLE																	
1	American mine Blind Canyon bed	10 & 11–17S–7E ~4356250mN 490150mE	A C D	3.2 – –	42.6 44.0 –	46.6 48.1 –	7.6 7.9 –	.5 – –	– – –	– – –	– – –	– – –	12,960 13,390 14,540	– – –	– – –	– – –	D	70
2	American mine Blind Canyon bed		A C D	5.2 – –	41.7 44.0 –	45.1 47.6 –	8.0 8.4 –	.6 – –	– – –	– – –	– – –	– – –	12,780 13,480 14,720	– – –	– – –	– – –	D	70
3	American mine		A	6.0	–	–	5.0	.48	–	–	–	–	–	–	–	–		70
4	American mine Blind Canyon bed		A C D	6.2 – –	41.3 44.0 –	45.3 48.3 –	7.2 7.7 –	.6 – –	– – –	– – –	– – –	– – –	12,670 13,510 14,640	2,170 – –	– – –	– – –	T	70
5	American mine Blind Canyon mine		A C D	6.0 – –	41.5 44.1 –	47.6 50.6 –	5.0 5.3 –	.5 – –	– – –	– – –	– – –	– – –	13,060 13,890 14,670	2,020 – –	– – –	– – –	T	70
6	American mine Blind Canyon bed		A C D	5.6 – –	41.5 44.0 –	44.6 47.2 –	8.3 8.8 –	.5 – –	– – –	– – –	– – –	– – –	12,630 13,380 14,670	2,360 – –	– – –	– – –	T	70
7	American mine Blind Canyon bed		A C D	5.7 – –	41.8 44.3 –	45.0 47.7 –	7.5 8.0 –	.5 – –	– – –	– – –	– – –	– – –	12,690 13,460 14,630	2,280 – –	– – –	– – –	T	70
8	American mine Blind Canyon bed		A C D	6.7 – –	40.6 43.5 –	41.7 44.7 –	11.0 11.8 –	.6 – –	– – –	– – –	– – –	– – –	12,000 12,860 14,580	2,360 – –	– – –	– – –	T	70
9	American mine Blind Canyon bed		A C D	3.2 – –	43.5 44.9 –	47.5 49.1 –	5.8 6.0 –	.4 – –	– – –	– – –	– – –	– – –	13,330 13,770 14,650	2,170 – –	– – –	– – –	D	70
10	American mine Blind Canyon bed		A C D	6.9 – –	42.6 45.8 –	43.6 46.8 –	6.9 7.4 –	.6 – –	– – –	– – –	– – –	– – –	12,620 13,550 14,630	2,080 – –	– – –	– – –	D	70
11	American mine		A B C	3.96 2.5 –	43.3 43.9 45.0	44.4 45.1 46.2	8.4 8.5 8.8	– – –	– – –	– – –	– – –	– – –	12,746 12,942 13,272	– – –	– – –	– – –		72

Table 5. (continued)

No.	Mine or Prospect- Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
12	American mine		A	4.8	41.7	44.5	8.96	–	–	–	–	–	12,689	–	–	–		72
			B	1.9	43.0	45.9	9.2	–	–	–	–	–	13,086	–	–	–		
			C	–	43.9	46.7	9.4	–	–	–	–	–	13,334	–	–	–		
13	American mine		A	5.8	43.5	43.7	7.1	–	–	–	–	–	12,760	–	–	–		72
			B	2.9	45.2	44.6	7.3	–	–	–	–	–	13,328	–	–	–		
			C	–	46.2	46.3	7.5	–	–	–	–	–	13,520	–	–	–		
14	American mine		A	5.2	41.0	43.8	10.0	.4	–	–	–	–	12,490	2,440	–	47	T	70
	Blind Canyon bed		C	–	43.3	46.2	10.5	–	–	–	–	–	13,180	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,730	–	–	–		
15	American mine		A	5.6	41.4	44.7	8.2	.4	–	–	–	–	12,680	2,400	–	–	T	70
	Blind Canyon bed		C	–	43.9	47.4	8.7	–	–	–	–	–	13,430	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,710	–	–	–		
16	American mine		A	7.1	43.5	40.7	8.7	.4	–	–	–	–	12,440	2,360	–	–	T	70
	Blind Canyon bed		C	–	46.8	43.8	9.4	–	–	–	–	–	13,390	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,780	–	–	–		
17	American mine		A	4.9	44.5	44.4	6.2	.5	–	–	–	–	13,180	2,030	–	–	T	70
	Blind Canyon bed		C	–	46.8	46.7	6.5	–	–	–	–	–	13,860	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,820	–	–	–		
18	American mine		A	5.0	43.3	45.8	5.9	.5	–	–	–	–	13,150	2,040	–	–	T	70
	Blind Canyon bed		C	–	45.6	48.2	6.2	–	–	–	–	–	13,840	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,750	–	–	–		
19	American mine		A	4.8	42.4	44.6	8.2	.5	–	–	–	–	12,740	2,390	–	48	T	70
	Blind Canyon bed		C	–	44.5	46.9	8.6	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,640	–	–	–		
20	American mine		A	5.2	41.9	46.2	6.7	.5	–	–	–	–	12,920	2,320	–	–	T	70
	Blind Canyon bed		C	–	44.2	48.7	7.1	–	–	–	–	–	13,630	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,670	–	–	–		
21	American mine		A	6.6	44.1	42.5	6.8	.5	–	–	–	–	12,830	2,050	–	–	T	70
	Blind Canyon bed		C	–	47.2	45.5	7.3	–	–	–	–	–	13,740	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,820	–	–	–		
22	American mine		A	3.1	45.6	45.3	7.1	.5	–	–	–	–	13,230	–	–	–	D	3
	Blind Canyon bed		C	–	46.0	46.7	7.3	–	–	–	–	–	13,650	–	–	–		
23	American mine		A	4.3	42.6	45.6	7.6	.4	–	–	–	–	12,870	2,210	–	–	D	70
	Blind Canyon bed		C	–	44.5	47.6	7.9	–	–	–	–	–	13,450	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,600	–	–	–		
24	American mine		A	4.9	42.2	45.6	7.2	.5	–	–	–	–	12,870	2,090	–	–	D	70
	Blind Canyon bed		C	–	44.4	48.0	7.6	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,640	–	–	–		
25	American mine		A	5.4	43.5	44.7	6.4	.5	–	–	–	–	13,000	2,100	–	–	T	70
	Blind Canyon bed		C	–	46.0	47.2	6.8	–	–	–	–	–	13,740	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,740	–	–	–		
26	American mine		A	4.6	45.1	45.2	5.1	.5	–	–	–	–	13,350	2,000	–	–	T	70
	Blind Canyon bed		C	–	47.3	47.4	5.3	–	–	–	–	–	13,990	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,770	–	–	–		
27	American mine		A	4.6	42.7	46.0	6.7	.4	–	–	–	–	13,120	2,060	–	–	T	70
	Blind Canyon bed		C	–	44.8	48.2	7.0	–	–	–	–	–	13,750	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,780	–	–	–		
28	American mine		A	4.8	42.6	45.3	7.3	.4	–	–	–	–	12,910	2,130	–	–	T	70
	Blind Canyon bed		C	–	44.7	47.6	7.7	–	–	–	–	–	13,560	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,690	–	–	–		
29	American mine		A	4.5	43.0	45.9	6.6	.4	–	–	–	–	13,040	2,040	–	–	D	70
	Blind Canyon bed		C	–	45.0	48.1	6.9	–	–	–	–	–	13,650	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,660	–	–	–		
30	American mine		A	5.3	43.0	44.6	7.1	.5	–	–	–	–	12,860	2,180	–	48	T	70
	Blind Canyon bed		C	–	45.4	47.1	7.5	–	–	–	–	–	13,580	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,680	–	–	–		
31	American mine		A	4.6	41.6	46.2	7.6	.4	–	–	–	–	12,860	–	–	–	D	70
	Blind Canyon bed		C	–	43.6	48.4	8.0	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,650	–	–	–		
32	American mine		A	5.6	42.3	45.2	6.9	.5	–	–	–	–	12,800	2,210	–	–	T	70
	Blind Canyon bed		C	–	44.8	47.9	7.3	–	–	–	–	–	13,560	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,630	–	–	–		
33	American mine		A	5.1	41.5	46.2	7.2	.4	–	–	–	–	12,870	2,120	–	–	D	70
	Blind Canyon bed		C	–	43.7	48.7	7.6	–	–	–	–	–	13,560	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,680	–	–	–		
34	American mine		A	8.0	43.3	41.8	6.9	.6	–	–	–	–	12,540	2,050	–	–	T	70
	Blind Canyon bed		C	–	47.1	45.4	7.5	–	–	–	–	–	13,630	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,740	–	–	–		
35	American mine		A	5.0	41.4	46.5	7.1	.4	–	–	–	–	12,910	–	–	–		6
	Blind Canyon bed		C	–	43.6	48.9	7.5	–	–	–	–	–	13,580	–	–	–		
36	American mine		A	4.8	43.3	45.4	6.5	.4	–	–	–	–	13,170	2,040	–	–	T	6
	Blind Canyon bed		C	–	45.5	47.7	6.8	–	–	–	–	–	13,830	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,840	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
37	American mine Blind Canyon bed		A C D	4.5 – –	42.8 44.8 –	46.3 48.5 –	6.4 6.7 –	.4 – –	– – –	– – –	– – –	– – –	13,100 13,720 14,710	– – –	– – –	– – –	D	70
38	American mine Blind Canyon bed		A C D	4.4 – –	42.3 44.2 –	46.4 48.5 –	7.0 7.3 –	.4 – –	– – –	– – –	– – –	– – –	12,990 13,590 14,660	2,160 – –	– – –	– – –	D	70
39	American mine Blind Canyon bed		A C D	4.0 – –	42.0 43.7 –	47.5 49.5 –	6.5 6.8 –	.4 – –	– – –	– – –	– – –	– – –	13,080 13,620 14,610	2,160 – –	– – –	– – –	D	70
40	American mine Blind Canyon bed		A C D	3.6 – –	43.4 45.0 –	45.9 47.6 –	7.1 7.4 –	.4 – –	– – –	– – –	– – –	– – –	13,100 13,590 14,680	– – –	– – –	– – –	D	70
41	American mine Blind Canyon bed		A C D	5.1 – –	43.0 45.3 –	44.2 46.6 –	7.7 8.1 –	.5 – –	– – –	– – –	– – –	– – –	12,860 13,550 14,740	2,180 – –	– – –	46 – –	T	70
42	American mine Blind Canyon bed		A C D	7.4 – –	44.8 48.4 –	41.6 44.9 –	6.2 6.7 –	.5 – –	– – –	– – –	– – –	– – –	12,920 13,950 14,950	2,060 – –	– – –	– – –	T	70
43	American mine Blind Canyon bed		A C	5.1 –	43.0 45.3	44.2 46.6	7.7 8.1	.5 –	– –	– –	– –	– –	12,850 13,550	– –	– –	46 –	T	7
44	American mine Blind Canyon bed		A C D	4.6 – –	43.2 45.3 –	46.6 48.8 –	5.6 5.9 –	.4 – –	– – –	– – –	– – –	– – –	13,190 13,830 14,700	2,040 – –	– – –	– – –	D	70
45	American mine Blind Canyon bed		A C D	4.0 – –	43.9 45.7 –	46.8 48.7 –	5.4 5.6 –	.4 – –	– – –	– – –	– – –	– – –	13,320 13,870 14,690	2,030 – –	– – –	– – –	D	70
46	American mine Blind Canyon bed		A C D	5.4 – –	44.3 44.7 –	45.6 48.2 –	6.7 7.1 –	.4 – –	– – –	– – –	– – –	– – –	12,880 13,620 14,660	2,150 – –	– – –	– – –	D	70
47	American mine Blind Canyon bed		A C D	4.2 – –	43.0 44.9 –	46.1 48.1 –	6.7 7.0 –	.4 – –	– – –	– – –	– – –	– – –	13,060 13,630 14,660	2,110 – –	– – –	– – –	D	70
48	American mine Blind Canyon bed		A C D	5.8 – –	40.7 43.2 –	47.6 50.5 –	5.9 6.3 –	.4 – –	– – –	– – –	– – –	– – –	12,880 13,670 14,590	2,030 – –	– – –	– – –	T	70
49	American mine Blind Canyon bed		A C D	5.1 – –	41.0 43.2 –	46.9 49.4 –	7.0 7.4 –	.4 – –	– – –	– – –	– – –	– – –	12,930 13,620 14,710	2,160 – –	– – –	– – –	T	70
50	American mine Blind Canyon bed		A C D	3.9 – –	42.6 44.3 –	47.0 48.9 –	6.5 6.8 –	.4 – –	– – –	– – –	– – –	– – –	13,100 13,630 14,620	– – –	– – –	– – –	D	70
51	American mine Blind Canyon bed		A C D	5.4 – –	42.2 44.6 –	45.4 48.0 –	7.0 7.4 –	.4 – –	– – –	– – –	– – –	– – –	12,790 13,520 14,600	2,160 – –	– – –	48 – –	T	70
52	American mine Blind Canyon bed		A C D	5.6 – –	43.9 46.5 –	43.4 46.0 –	7.1 7.5 –	.5 – –	– – –	– – –	– – –	– – –	12,900 13,660 14,770	2,080 – –	– – –	– – –	T	70
53	American mine Blind Canyon bed		A C	5.4 –	42.2 44.6	45.4 48.0	7.0 7.4	.4 –	– –	– –	– –	– –	12,880 13,620	– –	– –	– –	T	9
54	American mine Blind Canyon bed		A C D	5.3 – –	42.6 45.0 –	46.5 49.1 –	5.6 5.9 –	.4 – –	– – –	– – –	– – –	– – –	13,080 13,810 14,680	1,970 – –	– – –	– – –	T	70
55	American mine Blind Canyon bed		A C D	5.5 – –	41.8 44.2 –	45.4 48.0 –	7.4 7.8 –	.4 – –	– – –	– – –	– – –	– – –	12,770 13,510 14,650	2,080 – –	– – –	– – –	T	70
56	American mine Blind Canyon bed		A C D	6.0 – –	41.9 44.6 –	44.4 47.2 –	7.7 8.2 –	.4 – –	– – –	– – –	– – –	– – –	12,600 13,400 14,600	2,150 – –	– – –	– – –	D	70
57	American mine Blind Canyon bed		A C D	7.6 – –	42.1 45.6 –	43.2 46.7 –	7.1 7.7 –	.6 – –	– – –	– – –	– – –	– – –	12,470 13,500 14,630	2,070 – –	– – –	– – –	T	70
58	American mine Blind Canyon bed		A C D	5.3 – –	44.2 46.7 –	43.0 45.4 –	7.5 7.9 –	.4 – –	– – –	– – –	– – –	– – –	12,870 13,590 14,760	2,170 – –	– – –	– – –	T	70
59	American mine Blind Canyon bed		A C D	4.9 – –	43.4 45.6 –	44.2 46.5 –	7.5 7.9 –	.4 – –	– – –	– – –	– – –	– – –	12,910 13,570 14,730	2,050 – –	– – –	– – –	T	70
60	American mine Blind Canyon bed		A C D	4.9 – –	44.2 46.5 –	43.2 45.4 –	7.7 8.1 –	.4 – –	– – –	– – –	– – –	– – –	12,880 13,540 14,730	2,250 – –	– – –	– – –	T	70
61	American mine Blind Canyon bed		A C D	6.4 – –	45.6 48.7 –	40.8 43.6 –	7.2 7.7 –	.4 – –	5.8 – –	75.0 – –	1.4 – –	9.7 – –	12,820 13,700 14,840	2,190 – –	– – –	– – –	T	70
62	American mine		A D	6.7 –	42.5 48.8	44.4 51.2	6.4 –	– .6	– 6.1	– 80.5	– 1.6	– 11.2	– 14,510	– –	– –	– –		43

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	AN	PROXIMATE M	VM	FC	Ash	ULTIMATE S	H	C	N	O	Btu/lb	OTHER TESTS AST	ADL	HGI	Kind of Sample	Ref. Source
63	Anderson mine Hiawatha bed	C.N.SW.SW.26–17S–7E 4351280mN 490300mE	A	4.4	40.6	46.9	8.1	.6	–	–	–	–	12,440	–	1.9	–		56
			C	–	42.5	49.0	8.5	.6	–	–	–	–	13,020	–	–	–		
			D	–	46.5	53.5	–	.7	–	–	–	–	14,230	–	–	–		
64	Anderson mine		A	4.5	39.9	46.7	8.6	.6	–	–	–	–	12,380	–	2.0	–		56
			C	–	41.8	48.9	9.3	.6	–	–	–	–	12,970	–	–	–		
			D	–	46.1	53.9	–	.7	–	–	–	–	14,290	–	–	–		
65	Castle Valley mine Hiawatha bed	NE.NW.NW.NE.27–17S–7E 4352390mN 489430mE	A	11.41	44.72	35.08	8.79	1.50	–	–	–	–	–	–	–	–		31
66	Castle Valley mine		A	10.63	44.74	38.79	5.84	.64	–	–	–	–	–	–	–	–		31
67	Castle Valley mine		A	6.10	37.95	45.50	10.00	.82	–	–	–	–	–	–	–	–		31
68	Castle Valley mine		A	5.2	–	–	6.4	.57	–	–	–	–	–	–	–	–		73
69	Deer Creek mine Blind Canyon bed	NW.SE.NW.11–17S–7E 4356650mN 490600mE	A	4.6	45.2	45.1	5.1	.6	–	–	–	–	13,290	–	2.6	–		29
			C	–	47.4	47.3	5.3	.7	–	–	–	–	13,940	–	–	–		
70	Deer Creek mine		A	4.7	43.6	45.9	5.8	.6	–	–	–	–	13,100	–	2.7	–		29
			C	–	45.8	48.1	6.1	.6	–	–	–	–	13,750	–	–	–		
71	Deer Creek mine Blind Canyon bed		A	5.1	–	–	5.2	.72	–	–	–	–	–	–	–	–		73
72	Deer Creek mine Blind Canyon bed		A	5.14	42.97	46.64	5.25	.45	6.66	73.07	1.43	13.14	13,353	–	–	–		71
			B	4.27	43.37	47.07	5.29	.46	6.62	73.74	1.44	12.45	13,476	–	–	–		
			C	–	45.30	49.17	5.53	.48	6.42	77.03	1.51	9.03	14,077	–	–	–		
			D	–	47.60	52.40	–	–	–	–	–	–	14,169	–	–	–		
73	Deer Creek mine Blind Canyon bed		A	5.0	–	–	6.4	.55	–	–	–	–	–	–	–	–		73
74	Deer Creek mine		A	5.6	38.6	37.5	18.3	–	–	–	–	–	10,800	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	11,450	–	–	–		
75	Deer Creek mine		A	6.5	42.0	37.5	14.0	–	–	–	–	–	11,500	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	12,290	–	–	–		
76	Deer Creek mine Blind Canyon bed		A	4.8	43.2	46.0	6.0	.6	–	–	–	–	13,060	–	–	–	T	2
			C	–	45.4	48.3	6.3	–	–	–	–	–	13,720	–	–	–		
77	Deer Creek mine Blind Canyon bed		A	4.8	42.7	46.4	6.1	.5	–	–	–	–	13,050	–	–	–	T	2
			C	–	44.9	48.7	6.4	–	–	–	–	–	13,720	–	–	–		
78	Deer Creek mine Blind Canyon bed		A	4.6	42.9	45.2	7.3	.4	–	–	–	–	12,930	–	–	–	T	2
			C	–	45.0	47.4	7.6	–	–	–	–	–	13,550	–	–	–		
79	Deer Creek mine Blind Canyon bed		A	5.3	42.4	43.8	8.4	.5	–	–	–	–	12,520	–	–	–	T	2
			C	–	44.8	46.3	8.9	–	–	–	–	–	13,210	–	–	–		
80	Deer Creek mine Blind Canyon bed		A	6.6	42.0	45.1	6.3	.6	–	–	–	–	12,710	–	–	–	T	2
			C	–	45.0	48.3	6.7	–	–	–	–	–	13,610	–	–	–		
81	Deer Creek mine Blind Canyon bed		A	6.5	43.2	46.3	4.0	.6	–	–	–	–	13,260	–	–	–	T	4
			C	–	46.2	49.5	4.3	–	–	–	–	–	14,170	–	–	–		
82	Deer Creek mine Blind Canyon bed		A	5.9	43.9	45.9	4.3	.5	–	–	–	–	13,300	–	–	–	T	4
			C	–	46.6	48.8	4.6	–	–	–	–	–	14,140	–	–	–		
83	Deer Creek mine Blind Canyon bed		A	5.9	43.5	45.6	5.0	.6	–	–	–	–	13,190	–	–	–	T	4
			C	–	46.2	48.5	5.3	–	–	–	–	–	14,020	–	–	–		
84	Deer Creek mine Blind Canyon bed		A	6.4	41.9	45.7	6.0	.6	–	–	–	–	12,990	–	–	50	T	4
			C	–	44.8	48.8	6.4	–	–	–	–	–	13,870	–	–	–		
85	Deer Creek mine		A	4.8	43.0	39.9	12.3	.64	–	–	–	–	12,042	–	–	–		72
			B	3.5	43.6	40.5	12.4	–	–	–	–	–	12,212	–	–	–		
			C	–	45.2	41.9	12.9	–	–	–	–	–	12,650	–	–	–		
86	Deer Creek mine Blind Canyon bed		A	5.4	42.6	45.9	6.1	.6	–	–	–	–	13,000	–	–	–	T	5
			C	–	45.0	48.5	6.5	–	–	–	–	–	13,740	–	–	–		
87	Deer Creek mine Blind Canyon bed		A	4.7	42.5	45.3	7.5	.5	–	–	–	–	12,880	–	–	–	T	5
			C	–	44.6	47.5	7.9	–	–	–	–	–	13,510	–	–	–		
88	Deer Creek mine Blind Canyon bed		A	4.5	43.0	45.3	7.3	.5	–	–	–	–	12,930	–	–	–	T	5
			C	–	45.0	47.4	7.6	–	–	–	–	–	13,530	–	–	–		
89	Deer Creek mine Blind Canyon bed		A	4.2	43.2	45.1	7.5	.6	–	–	–	–	12,960	–	–	47	T	5
			C	–	45.1	47.1	7.8	–	–	–	–	–	13,520	–	–	–		
90	Deer Creek mine Blind Canyon bed		A	4.7	42.0	45.8	7.9	.6	–	–	–	–	12,780	–	–	–	D	5
			C	–	43.6	48.1	8.3	–	–	–	–	–	13,410	–	–	–		
91	Deer Creek mine Blind Canyon bed		A	5.5	44.1	42.6	7.7	.4	–	–	–	–	12,730	–	–	–	T	5
			C	–	46.7	45.1	8.2	–	–	–	–	–	13,470	–	–	–		
92	Deer Creek mine		A	2.96	–	–	–	–	–	–	–	–	12,937	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,332	–	–	–		
93	Deer Creek mine		A	1.42	–	–	–	–	–	–	–	–	13,108	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,297	–	–	–		
94	Deer Creek mine		A	–	–	–	–	–	–	–	–	–	12,897	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,345	–	–	–		
95	Deer Creek mine		A	1.2	–	–	–	–	–	–	–	–	12,898	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,055	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
96	Deer Creek mine		A	2.6	–	–	–	–	–	–	–	–	12,875	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,227	–	–	–		
97	Deer Creek mine		A	6.1	38.9	40.9	14.1	–	–	–	–	–	11,534	–	3.76	–		72
			B	1.98	40.6	42.7	14.7	–	–	–	–	–	12,038	–	–	–		
			C	–	41.4	43.5	15.0	–	–	–	–	–	12,281	–	–	–		
98	Deer Creek mine		A	4.7	42.8	44.7	7.8	.5	–	–	–	–	12,800	–	–	–		6
	Blind Canyon bed		C	–	44.9	46.9	8.2	–	–	–	–	–	13,430	–	–	–		
99	Deseret mine	C.N.SE.NE.26–17S–7E	A	5.1	41.4	46.7	6.8	.7	5.6	74.6	1.5	10.4	12,820	–	–	–		6
	Hiawatha bed	4351800mN 491525mE	C	–	43.6	49.2	7.2	–	–	–	–	–	13,500	–	–	–		
100	Deseret mine		A	5.4	38.6	45.2	10.8	.7	–	–	–	–	12,170	–	–	46		6
			C	–	40.8	47.8	11.4	–	–	–	–	–	12,860	–	–	–		
101	Deseret mine		A	7.7	38.8	42.8	10.7	.8	–	–	–	–	11,660	–	–	–		6
			C	–	42.0	46.4	11.6	–	–	–	–	–	12,630	–	–	–		
102	Deseret mine		A	5.3	40.8	46.9	7.0	.7	–	–	–	–	12,680	–	–	–		8
			C	–	43.1	49.5	7.4	–	–	–	–	–	13,390	–	–	–		
103	Deseret mine		A	5.1	40.9	45.3	8.7	.7	–	–	–	–	12,470	–	–	–		8
			C	–	43.1	47.7	9.2	–	–	–	–	–	13,140	–	–	–		
104	Deseret mine		A	6.8	38.9	46.7	7.6	.8	–	–	–	–	12,310	–	–	–		8
			C	–	41.7	50.1	8.2	–	–	–	–	–	13,200	–	–	–		
105	Deseret mine		A	5.6	44.7	45.2	4.4	.5	5.9	76.2	1.5	11.2	13,080	–	–	–		8
			C	–	47.4	47.9	4.7	–	–	–	–	–	13,850	–	–	–		
106	Deseret mine		A	5.7	40.7	44.5	9.1	.7	–	–	–	–	12,320	–	–	–		10
			C	–	43.2	47.2	9.6	–	–	–	–	–	13,070	–	–	–		
107	Deseret mine		A	5.5	44.4	44.2	6.9	.5	5.7	74.8	1.5	10.3	12,810	–	–	–		10
			C	–	46.5	46.3	7.2	–	–	–	–	–	13,550	–	–	–		
108	Deseret mine		A	5.5	41.2	48.1	6.1	.7	–	–	–	–	12,800	–	–	–	T	13
			C	–	43.2	50.4	6.4	–	–	–	–	–	13,540	–	–	–		
109	Deseret mine		A	5.7	42.4	45.9	5.9	.6	–	–	–	–	12,840	–	–	–	T	13
			C	–	45.0	48.7	6.3	–	–	–	–	–	13,620	–	–	–		
110	Huntington mine	SW.SW.SE.NE.3–17S–7E	A	4.9	–	–	5.7	.54	–	–	–	–	–	–	–	–		73
	Hiawatha bed	4358000mN 489810mE																
111	Huntington mine		A	5.5	44.6	44.8	5.1	.4	6.2	73.1	1.4	13.8	13,290	–	2.6	–		53
	Blind Canyon bed		C	–	47.1	47.5	5.4	.5	5.9	77.4	1.4	9.4	14,050	–	–	–		
			D	–	49.8	50.2	–	.5	6.3	81.8	1.5	9.9	14,860	–	–	–		
112	Huntington mine		A	5.2	43.9	45.9	5.0	.4	–	–	–	–	13,270	–	2.5	–		53
	Blind Canyon bed		C	–	46.4	48.4	5.2	.4	–	–	–	–	13,990	–	–	–		
			D	–	48.9	51.1	–	.5	–	–	–	–	14,770	–	–	–		
113	Paramount mine	SE.SE.SE.SW.2–17S–7E	A	7.7	37.5	38.4	16.4	–	–	–	–	–	10,810	–	–	–		72
		~4357400mN 490850mE	B	–	39.29	–	17.0	–	–	–	–	–	11,315	–	–	–		
			C	–	40.6	–	17.8	–	–	–	–	–	11,710	–	–	–		
114	Paramount mine		A	5.5	41.9	43.8	8.8	–	–	–	–	–	12,310	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,050	–	–	–		
115	Paramount mine		A	5.5	41.4	44.2	8.9	–	–	–	–	–	12,242	–	–	–		72
			B	3.6	42.2	45.1	9.1	–	–	–	–	–	12,491	–	–	–		
			C	–	43.8	46.8	9.4	–	–	–	–	–	12,960	–	–	–		
116	Paramount mine		A	5.8	41.3	44.38	8.6	–	–	–	–	–	12,437	–	–	–		72
			B	3.3	42.8	45.0	8.9	–	–	–	–	–	12,892	–	–	–		
			C	–	43.8	47.1	9.1	–	–	–	–	–	13,199	–	–	–		
117	Paramount mine		A	5.8	39.1	46.5	8.6	–	–	–	–	–	12,328	–	–	–		72
			B	3.3	40.2	47.7	8.8	–	–	–	–	–	12,662	–	–	–		
			C	–	41.5	49.4	9.1	–	–	–	–	–	13,093	–	–	–		
118	Paramount mine		A	4.6	44.7	45.4	5.2	.6	5.8	75.9	1.5	10.7	13,180	–	–	–		2
	Blind Canyon bed		C	–	46.9	47.6	5.5	–	–	–	–	–	13,830	–	–	–		
119	Paramount mine		A	5.0	42.8	44.7	7.5	.5	–	–	–	–	12,750	–	–	–		2
	Blind Canyon bed		C	–	45.1	47.0	7.9	–	–	–	–	–	13,430	–	–	–		
120	Paramount mine		A	4.6	–	–	5.3	.53	–	–	–	–	–	–	–	–		73
	Blind Canyon bed																	
121	Paramount mine		A	5.4	40.3	44.6	9.7	.8	–	–	–	–	12,430	–	–	–		5
	Blind Canyon bed		C	–	42.6	47.1	10.3	–	–	–	–	–	13,140	–	–	–		
122	Paramount mine		A	4.7	40.2	44.0	11.1	.7	–	–	–	–	12,310	–	–	–		5
	Blind Canyon bed		C	–	42.2	46.2	11.6	–	–	–	–	–	12,920	–	–	–		
123	Paramount mine		A	4.5	42.9	47.6	5.1	.8	–	–	–	–	13,260	–	–	–		10
	Blind Canyon bed		C	–	44.9	49.8	5.3	–	–	–	–	–	13,880	–	–	–		
124	Paramount mine		A	4.7	41.0	48.4	5.9	.9	–	–	–	–	13,080	–	–	–		10
	Blind Canyon bed		C	–	43.0	50.8	6.2	–	–	–	–	–	13,720	–	–	–		
125	Paramount mine		A	5.6	38.9	45.0	10.5	1.0	–	–	–	–	12,170	–	–	–		10
	Blind Canyon bed		C	–	41.2	47.7	11.1	–	–	–	–	–	12,890	–	–	–		
126	Paramount mine		A	5.3	40.5	48.0	6.2	1.0	–	–	–	–	12,850	–	–	–		10
	Blind Canyon bed		C	–	42.8	50.7	6.5	–	–	–	–	–	13,560	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
127	Paramount mine Blind Canyon bed		A C	5.8 –	40.1 42.6	45.5 48.3	8.6 9.1	1.1 –	– –	– –	– –	– –	12,360 13,120	– –	– –	– –		10
128	Stump Flat mine	24–17S–7E ~4352450mN 492400mE	A	4.9	–	–	6.6	.89	–	–	–	–	–	–	–	–		73
129	Stump Flat mine Hiawatha bed		A C	4.4 –	42.8 44.8	46.5 48.6	6.3 6.6	.9 –	– –	– –	– –	– –	12,860 13,450	– –	– –	– –	T	5
130	Stump Flat mine Hiawatha bed		A C	4.2 –	42.0 43.8	46.8 48.9	7.0 7.3	.9 –	– –	– –	– –	– –	12,780 13,330	– –	– –	– –	T	5
131	Stump Flat mine Hiawatha bed		A C	4.0 –	41.9 43.6	46.5 48.4	7.7 8.0	.9 –	– –	– –	– –	– –	12,650 13,170	– –	– –	45 –	T	5
132	Stump Flat mine Hiawatha bed		A C	4.2 –	41.9 43.7	45.6 47.6	8.3 8.7	1.3 –	– –	– –	– –	– –	12,380 12,920	– –	– –	– –	T	5
133	Stump Flat mine Hiawatha bed		A C	5.3 –	41.6 43.9	46.0 48.6	7.1 7.5	1.0 –	– –	– –	– –	– –	12,610 13,310	– –	– –	– –		10
134	Wilburg mine Hiawatha bed	NE.NW.NW.NE.27–17S–7E 4352390mN 489430mE	A C	6.4 –	38.5 41.1	47.8 51.1	7.3 7.8	.5 –	– –	– –	– –	– –	12,280 13,120	– –	– –	– –	D	3
135	Wilburg mine Hiawatha bed		A C	5.3 –	41.8 44.1	44.1 46.6	8.8 9.3	.6 –	5.6 –	72.2 –	1.5 –	10.8 –	12,280 13,100	– –	– –	47 –		4
136	Wilburg mine Hiawatha bed		A C	6.4 –	40.2 43.0	43.7 46.7	9.6 10.3	.7 –	– –	– –	– –	– –	12,110 12,940	– –	– –	– –		5
137	Wilburg mine Hiawatha bed		A C	6.4 –	41.2 44.0	45.9 49.0	6.6 7.0	.4 –	– –	– –	– –	– –	12,570 13,430	– –	– –	– –	T	6
138	Wilburg mine Hiawatha bed		A C	5.2 –	41.4 43.7	44.6 47.0	8.8 9.3	.6 –	– –	– –	– –	– –	12,370 13,060	– –	– –	– –	T	6
139	Wilburg mine Hiawatha bed		A C	4.9 –	41.7 43.8	44.0 46.3	9.4 9.9	.6 –	– –	– –	– –	– –	12,410 13,050	– –	– –	– –	T	6
140	Wilburg mine Hiawatha bed		A C	5.7 –	41.3 43.8	43.8 46.4	9.2 9.8	.7 –	– –	– –	– –	– –	12,230 12,970	– –	– –	46 –	T	6
141	Wilburg mine Hiawatha bed		A C	7.7 –	40.1 43.4	42.5 46.0	9.8 10.6	.9 –	– –	– –	– –	– –	11,850 12,840	– –	– –	– –	T	6
142	Wilburg mine		A C	5.4 –	41.9 44.3	44.9 47.5	7.8 8.2	.5 –	5.4 –	72.6 –	1.5 –	11.8 –	12,460 13,180	– –	– –	– –		7
143	Wilburg mine Hiawatha bed		A C	5.8 –	41.1 43.6	45.8 48.6	7.3 7.8	.6 –	– –	– –	– –	– –	12,550 13,320	– –	– –	– –	T	9
144	Wilburg mine Hiawatha bed		A C	5.1 –	40.8 43.0	44.2 46.6	9.9 10.4	.7 –	– –	– –	– –	– –	12,350 13,010	– –	– –	– –	T	9
145	Wilburg mine Hiawatha bed		A C	5.2 –	40.4 42.6	43.4 45.8	11.0 11.6	.8 –	– –	– –	– –	– –	12,120 12,780	– –	– –	– –	T	9
146	Wilburg mine Hiawatha bed		A C	6.1 –	40.1 42.7	43.5 46.3	10.3 11.0	.9 –	– –	– –	– –	– –	11,910 12,690	– –	– –	– –	T	9
147	Wilburg mine Hiawatha bed		A C	5.4 –	41.1 43.4	45.3 47.9	8.2 8.7	.5 –	– –	– –	– –	– –	12,480 13,200	– –	– –	– –	T	3
148	Wilburg mine Hiawatha bed		A C	4.6 –	42.4 44.4	45.2 47.4	7.8 8.2	.5 –	– –	– –	– –	– –	12,660 13,270	– –	– –	– –	T	3
149	Wilburg mine Hiawatha bed		A C	5.0 –	41.3 43.5	44.1 46.4	9.6 10.1	.5 –	– –	– –	– –	– –	12,330 12,980	– –	– –	– –	T	3
150	Wilburg mine Hiawatha bed		A C	4.8 –	41.2 43.3	43.7 45.9	10.3 10.8	.5 –	– –	– –	– –	– –	12,190 12,800	– –	– –	– –	T	3
151	Wilburg mine Hiawatha bed		A C	5.4 –	41.0 43.3	44.3 46.8	9.4 9.9	.6 –	– –	– –	– –	– –	12,250 12,950	– –	– –	– –	T	3
152	Wilburg mine		A B C	5.8 4.0 –	37.4 38.1 39.7	45.6 46.5 48.4	11.2 11.5 11.9	.31 .32 .33	– – –	– – –	– – –	– – –	12,247 12,479 12,996	– – –	3.36 – –	– – –		72
153	Wilburg mine		A B	2.0 –	– –	– –	– –	– –	– –	– –	– –	– –	13,274 13,550	– –	– –	– –		72
154	Wilburg mine		A B	3.6 –	– –	– –	– –	– –	– –	– –	– –	– –	13,259 13,760	– –	– –	– –		72
155	Wilburg mine		A B	2.8 –	– –	– –	– –	– –	– –	– –	– –	– –	13,272 13,657	– –	– –	– –		72
								HIAWATHA SW QUADRANGLE										
1	Black Diamond mine Hiawatha bed	SW.NE.NW.NW.12–18S–6E 4347220mN 482520mE	A B	3.0 –	– –	– –	– –	– –	– –	– –	– –	– –	13,209 13,623	– –	– –	– –		72
2	Black Diamond mine		A B	2.2 –	– –	– –	– –	– –	– –	– –	– –	– –	13,389 13,693	– –	– –	– –		72
3	Black Diamond mine		A B	1.9 –	– –	– –	– –	– –	– –	– –	– –	– –	13,450 13,711	– –	– –	– –		72

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
4	Black Diamond mine		A	4.0	–	–	–	–	–	–	–	–	13,086	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,634	–	–	–		
5	**Black Diamond mine**		**A**	5.95	42.8	45.99	5.3	–	–	–	–	–	**13,005**	–	–	–		72
			B	2.6	44.3	47.7	5.5	–	–	–	–	–	13,470	–	–	–		
			C	–	45.5	48.9	5.6	–	–	–	–	–	13,828	–	–	–		
6	Black Diamond mine		A	13.2	37.9	43.2	5.7	–	–	–	–	–	11,376	–	–	–		72
			B	3.3	42.3	48.1	6.4	–	–	–	–	–	12,673	–	–	–		
			C	–	43.7	49.8	6.6	–	–	–	–	–	13,099	–	–	–		
7	**Black Diamond mine**		**A**	2.4	–	–	–	–	–	–	–	–	12,938	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,259	–	–	–		
8	Black Diamond mine		A	1.5	–	–	–	–	–	–	–	–	13,452	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,654	–	–	–		
9	Black Diamond mine		A	2.4	–	–	–	–	–	–	–	–	13,046	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,367	–	–	–		
10	**Black Diamond mine**		**A**	5.3	43.7	46.9	4.2	.4	–	–	–	–	13,390	–	–	–	T	7
			C	–	46.1	49.5	4.4	–	–	–	–	–	13,130	–	–	–		
11	Black Diamond mine		A	5.1	43.2	44.8	6.9	.4	–	–	–	–	12,940	–	–	48	T	7
			C	–	45.5	47.2	7.3	–	–	–	–	–	13,630	–	–	–		
12	Black Diamond mine		A	5.1	43.5	44.3	7.1	.6	–	–	–	–	12,900	–	–	–	T	7
			C	–	45.8	46.7	7.5	–	–	–	–	–	13,590	–	–	–		
13	Johnson mine Hiawatha bed	SW.SW.NE.25–17S–6E 4351900mN 483575mE	A	4.1	39.7	47.6	8.6	.7	–	–	–	–	12,470	–	1.9	–		56
			C	–	41.5	49.5	9.0	.8	–	–	–	–	13,000	–	–	–		
			D	–	45.5	54.5	–	.8	–	–	–	–	14,290	–	–	–		
14	Johnson mine		A	5.5	–	–	5.0	.38	–	–	–	–	–	–	–	–		73
15	Oliphant mine Hiawatha bed	SW.NE.NE.NE.11–18S–6E 4347265mN 482010mE	A	4.6	40.4	46.2	8.8	.6	–	–	–	–	12,520	2,200	1.9	–		56
			C	–	42.3	48.5	9.2	.6	–	–	–	–	13,120	–	–	–		
			D	–	46.6	53.4	–	.65	–	–	–	–	14,460	–	–	–		
16	**Oliphant mine**		**A**	4.7	–	–	6.7	.62	–	–	–	–	–	–	–	–		73
17	Oliphant mine		A	4.7	–	–	7.2	.61	–	–	–	–	–	–	–	–		73
18	Trail Mtn. mine	NW.SE.25–17S–6E 4351700mN 483550mE	A	4.5	–	–	7.9	.51	–	–	–	–	–	–	–	–		73
19	Trail Mtn. mine		A	4.8	42.2	47.1	5.9	.5	–	–	–	–	12,910	–	–	46		4
			C	–	44.3	49.5	6.2	–	–	–	–	–	13,560	–	–	–		
20	Trail Mtn. mine		A	4.8	41.9	48.1	5.2	.7	–	–	–	–	13,140	–	–	–	T	7
			C	–	44.0	50.5	5.5	–	–	–	–	–	13,800	–	–	–		
21	Trail Mtn. mine		A	4.6	41.2	46.0	8.2	.6	–	–	–	–	12,670	–	–	45	T	7
			C	–	43.2	48.2	8.6	–	–	–	–	–	13,290	–	–	–		
22	Trail Mtn. mine		A	4.9	40.6	48.7	5.8	.6	5.5	76.3	1.5	10.0	12,950	–	–	–	T	7
			C	–	42.7	51.2	6.1	–	–	–	–	–	13,630	–	–	–		
23	Trail Mtn. mine		A	5.9	41.3	46.5	6.3	.6	–	–	–	–	12,710	–	–	–	T	7
			C	–	43.9	49.4	6.7	–	–	–	–	–	13,500	–	–	–		
24	Trail Mtn. mine		A	5.2	41.9	47.1	5.8	.6	–	–	–	–	12,860	–	–	–	T	9
			C	–	44.2	49.7	6.1	–	–	–	–	–	13,560	–	–	–		
25	Trail Mtn. mine		A	4.8	41.6	46.3	7.3	.7	–	–	–	–	12,670	–	–	–	T	9
			C	–	43.7	48.6	7.7	–	–	–	–	–	13,310	–	–	–		
26	Trail Mtn. mine		A	5.1	41.9	47.9	5.0	.5	–	–	–	–	13,060	–	–	–	T	11
			C	–	44.2	50.5	5.3	–	–	–	–	–	13,760	–	–	–		
27	Trail Mtn. mine		A	5.3	42.1	45.8	6.7	.7	–	–	–	–	12,680	–	–	–	T	11
			C	–	44.5	48.4	7.1	–	–	–	–	–	13,390	–	–	–		
	SCOFIELD NE QUADRANGLE																	
1	Gordon Creek mine Hiawatha lower split	NW.NW.SW.SE.18–13S–8E ≃4393250mN 494180mE	A	12.6	38.1	45.3	4.0	.5	–	–	–	–	10,550	–	–	–		54
			C	–	43.6	51.8	4.6	–	–	–	–	–	12,070	–	–	–		
2	McGowan mine Castlegate A bed	SE.SE.NE.SW.17–13S–8E 4393330mN 495540mE	A	6.1	–	–	4.7	.49	–	–	–	–	–	–	–	–		73
3	McGowan mine		A	5.7	–	–	5.7	.39	–	–	–	–	–	–	–	–		73
4	**McGowan mine**		**A**	5.3	43.8	45.9	5.0	.5	–	–	–	–	12,830	–	–	–		54
			C	–	46.2	48.5	5.3	–	–	–	–	–	13,540	–	–	–		
5	McGowan mine		A	5.9	44.1	43.9	6.1	.4	–	–	–	–	12,700	–	–	–		54
			C	–	46.9	46.6	6.5	–	–	–	–	–	13,500	–	–	–		
6	McGowan mine		A	4.5	44.1	44.4	7.0	.4	–	–	–	–	12,730	–	–	–		54
			C	–	46.2	46.5	7.3	–	–	–	–	–	13,330	–	–	–		
7	**McGowan mine**		**A**	6.1	42.2	45.1	6.7	.6	–	–	–	–	12,330	–	–	–		54
			C	–	44.9	48.0	7.1	–	–	–	–	–	13,130	–	–	–		
8	McGowan mine		A	4.1	44.2	45.3	6.4	.4	–	–	–	–	12,840	–	–	–	D	3
			C	–	46.1	47.2	6.7	–	–	–	–	–	13,390	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
				AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
9	National mine Hiawatha bed	17–13S–8E ≃4393500mN 495250mE	A	6.8	–	–	4.0	.49	–	–	–	–	–	–	–	–			73
10	National mine		A	6.1	43.4	44.9	5.6	.6	–	–	–	–	12,660	–	–	–			54
			C	–	46.2	47.8	6.0	–	–	–	–	–	13,480	–	–	–			
11	National mine		A	6.6	42.4	44.5	6.5	.5	–	–	–	–	12,190	–	–	–			54
			C	–	45.4	47.6	7.0	–	–	–	–	–	13,050	–	–	–			
12	National mine		A	6.6	42.3	44.7	6.4	.6	–	–	–	–	12,200	–	–	–			54
			C	–	45.3	47.9	6.8	–	–	–	–	–	13,060	–	–	–			
13	National mine		A	8.1	41.7	44.0	6.2	.6	–	–	–	–	12,280	–	–	–			54
			C	–	45.4	47.9	6.7	–	–	–	–	–	13,360	–	–	–			
14	National mine		A	4.8	44.0	43.7	7.4	.4	–	–	–	–	12,650	–	–	–	D		3
			C	–	46.3	45.9	7.8	–	–	–	–	–	13,290	–	–	–			
15	National mine		A	6.5	42.7	44.7	6.1	.5	–	–	–	–	12,570	–	–	–	D		3
			C	–	45.7	47.8	6.5	–	–	–	–	–	13,440	–	–	–			
16	National mine		A	5.27	41.51	46.43	6.79	.60	–	–	–	–	13,078	–	–	–			72
			B	4.0	42.1	47.1	6.9	.60	–	–	–	–	13,251	–	–	–			
			C	–	43.8	49.0	7.2	.63	–	–	–	–	13,806	–	–	–			
17	National mine		A	5.3	41.5	46.4	6.8	.60	–	–	–	–	13,078	–	2.44	–			72
			B	4.0	42.1	47.0	6.9	.60	–	–	–	–	13,251	–	–	–			
			C	–	43.8	49.0	7.2	.63	–	–	–	–	13,806	–	–	–			
18	New Ewing mine Hiawatha bed	7, 18–13S–8E ≃4394590mN 494270mE	A	7.8	37.5	49.1	5.7	.87	–	–	–	–	11,696	–	–	–			72
			B	3.5	39.2	51.3	5.9	.91	–	–	–	–	12,238	–	–	–			
			C	–	40.6	53.2	6.7	.94	–	–	–	–	12,687	–	–	–			
19	New Ewing mine		A	–	–	–	–	–	–	–	–	–	11,704	–	–	–			72
			B	–	–	–	–	.91	–	–	–	–	12,247	–	–	–			
			C	–	–	–	–	–	–	–	–	–	12,696	–	–	–			
20	Sweet mine Hiawatha lower split	C.E.SW.17–13S–8E ≃4393380mN 495290mE	A	6.5	–	–	3.7	.52	–	–	–	–	–	–	–	–			73
21	Sweet mine		A	8.1	–	–	4.7	.46	–	–	–	–	–	–	–	–			73
22	Sweet mine		A	8.1	42.0	45.1	4.8	.5	5.4	73.4	1.6	13.9	12,160	–	–	–			54
			C	–	45.7	49.1	5.2	–	–	–	–	–	13,230	–	–	–			
23	Sweet mine		A	7.8	41.7	45.6	4.9	.5	–	–	–	–	12,490	–	–	–			54
			C	–	45.2	49.5	5.3	–	–	–	–	–	13,540	–	–	–			
24	Sweet mine		A	6.1	42.7	46.6	4.6	.6	–	–	–	–	12,850	–	–	–			54
			C	–	45.5	49.6	4.9	–	–	–	–	–	13,680	–	–	–			
25	Sweet mine		A	5.6	42.7	47.0	4.7	.5	–	–	–	–	12,750	–	–	–			54
			C	–	45.2	49.8	5.0	–	–	–	–	–	13,510	–	–	–			
26	Sweet mine		A	5.4	43.0	44.2	7.4	.5	–	–	–	–	12,440	–	–	–			54
			C	–	45.5	46.7	7.8	–	–	–	–	–	13,150	–	–	–			
27	Sweet mine		A	4.6	43.3	45.6	6.5	.7	–	–	–	–	12,730	–	–	–			54
			C	–	45.4	47.8	6.8	–	–	–	–	–	13,340	–	–	–			
28	Sweet mine		A	8.7	41.3	42.9	7.1	.5	–	–	–	–	11,590	–	–	–			54
			C	–	45.2	47.0	7.8	–	–	–	–	–	12,700	–	–	–			
29	Sweet mine		A	5.8	42.1	46.4	5.7	.6	–	–	–	–	12,510	–	–	–			54
			C	–	44.7	49.3	6.0	–	–	–	–	–	13,280	–	–	–			
30	Sweet mine		A	11.7	39.2	41.7	7.4	.6	–	–	–	–	10,960	–	–	–			54
			C	–	44.4	47.2	8.4	–	–	–	–	–	12,410	–	–	–			
31	Sweet mine		A	11.6	39.3	42.7	6.4	.5	–	–	–	–	10,830	–	–	–			54
			C	–	44.5	48.3	7.2	–	–	–	–	–	12,250	–	–	–			
32	Sweet mine		A	4.2	42.9	47.2	5.7	.5	–	–	–	–	12,540	–	–	–			54
			C	–	44.8	49.3	5.9	–	–	–	–	–	13,100	–	–	–			
33	Sweet mine		A	5.8	42.9	45.2	6.1	.6	–	–	–	–	12,590	–	–	–			54
			C	–	45.5	48.0	6.5	–	–	–	–	–	13,360	–	–	–			
34	Sweet mine		A	9.9	39.6	47.7	2.9	–	–	–	–	–	12,187	–	5.5	–			54
			B	4.2	41.6	51.2	3.1	–	–	–	–	–	12,809	–	–	–			
			C	–	43.4	53.4	3.2	–	–	–	–	–	13,370	–	–	–			
35	Sweet mine		A	10.1	40.8	45.7	3.4	–	–	–	–	–	11,820	–	5.8	–			54
			B	3.2	43.9	49.2	3.7	–	–	–	–	–	12,722	–	–	–			
			C	–	45.4	50.8	3.8	–	–	–	–	–	13,144	–	–	–			
36	Sweet mine		A	11.1	37.3	44.2	7.4	–	–	–	–	–	11,301	–	6.9	–			54
			B	3.96	40.3	47.8	7.98	–	–	–	–	–	12,214	–	–	–			
			C	–	41.96	49.7	8.3	–	–	–	–	–	12,718	–	–	–			
37	Sweet mine		A	3.2	–	–	–	–	–	–	–	–	11,651	–	–	–			54
			B	–	–	–	–	–	–	–	–	–	12,031	–	–	–			
38	Sweet mine		A	3.8	–	–	–	–	–	–	–	–	12,487	–	–	–			54
			B	–	–	–	–	–	–	–	–	–	12,980	–	–	–			
39	Sweet mine		A	6.4	44.4	41.5	7.75	–	–	–	–	–	12,000	–	–	–			72
			B	–	–	–	–	–	–	–	–	–	12,870	–	–	–			

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
40	Sweet mine		A	6.8	44.0	39.9	9.3	–	–	–	–	–	12,000	–	–	–		72
			B	–	45.7	–	9.7	–	–	–	–	–	12,477	–	–	–		
			C	–	47.2	–	10.0	–	–	–	–	–	12,890	–	–	–		
41	Sweet mine		A	6.7	40.6	44.5	8.2	–	–	–	–	–	12,570	–	–	–		72
			B	3.1	42.2	46.2	8.5	–	–	–	–	–	13,046	–	–	–		
			C	–	43.5	47.7	8.8	–	–	–	–	–	13,470	–	–	–		
42	Sweet mine		A	9.1	37.6	44.9	7.8	.52	–	–	–	–	11,789	–	–	–		72
			B	4.7	39.5	46.9	8.4	.54	–	–	–	–	12,363	–	–	–		
			C	–	41.4	49.2	8.8	.57	–	–	–	–	12,972	–	–	–		
43	Sweet mine		A	7.98	41.6	44.9	5.6	.41	–	–	–	–	12,440	–	–	–		72
			B	2.7	43.4	47.4	5.9	.43	–	–	–	–	13,154	–	–	–		
			C	–	45.2	48.8	6.1	.44	–	–	–	–	13,519	–	–	–		
44	Sweet mine		A	6.97	40.6	42.0	10.4	–	–	–	–	–	11,190	–	–	–		72
			B	3.5	42.6	42.97	10.9	–	–	–	–	–	11,732	–	–	–		
			C	–	43.6	45.3	11.1	–	–	–	–	–	12,000	–	–	–		
45	Sweet mine		A	5.2	43.4	44.6	6.8	–	–	–	–	–	12,578	–	–	–		72
			B	3.3	44.3	45.5	6.95	–	–	–	–	–	12,838	–	–	–		
			C	–	45.8	47.0	7.2	–	–	–	–	–	13,269	–	–	–		
46	Sweet mine		A	7.5	41.8	39.7	11.1	–	–	–	–	–	11,715	–	–	–		72
			B	3.5	43.6	41.4	11.5	–	–	–	–	–	12,221	–	–	–		
			C	–	45.1	42.9	11.95	–	–	–	–	–	12,663	–	–	–		
47	Sweet mine		A	8.4	37.6	46.2	7.8	–	–	–	–	–	11,961	–	–	–		72
			B	3.1	39.8	48.9	8.3	–	–	–	–	–	12,658	–	–	–		
			C	–	41.1	50.4	8.5	–	–	–	–	–	13,064	–	–	–		
48	Sweet mine		A	7.7	38.9	41.95	11.5	–	–	–	–	–	11,564	–	–	–		72
			B	4.97	40.0	43.2	11.8	–	–	–	–	–	11,906	–	–	–		
			C	–	42.1	45.5	12.5	–	–	–	–	–	12,529	–	–	–		
	SCOFIELD NW QUADRANGLE																	
1	Clear Creek mine Castlegate "A" bed	NW.SE.SW.NW.33–13S–7E ≃4388470mN 487050mE	A	7.02	41.89	45.80	5.29	.57	–	–	–	–	–	–	3.1	–		47
			C	–	45.05	49.26	5.69	.61	–	–	–	–	–	–	–	–		
			D	–	47.77	52.23	–	.65	–	–	–	–	–	–	–	–		
2	Clear Creek mine		A	8.1	40.2	45.9	5.7	.86	–	–	–	–	–	–	3.9	–		20
			B	4.4	41.8	47.8	6.0	.89	–	–	–	–	–	–	–	–		
3	Clear Creek mine		A	6.9	–	–	4.5	.49	–	–	–	–	–	–	–	–	T	73
4	Clear Creek mine		A	6.6	38.3	41.7	13.5	–	–	–	–	–	11,135	–	–	–		72
			B	2.8	39.8	43.4	14.0	–	–	–	–	–	11,667	–	–	–		
			C	–	40.95	44.6	14.4	–	–	–	–	–	12,002	–	–	–		
5	Clear Creek mine		A	8.5	37.6	41.6	12.3	–	–	–	–	–	10,914	–	–	–		72
			B	5.4	38.9	43.0	12.7	–	–	–	–	–	11,277	–	–	–		
			C	–	41.1	45.5	13.4	–	–	–	–	–	11,923	–	–	–		
6	Clear Creek mine		A	7.2	37.99	41.35	13.4	–	–	–	–	–	11,201	–	–	–		72
			B	2.8	39.8	43.3	14.1	–	–	–	–	–	11,735	–	–	–		
			C	–	40.95	44.6	14.5	–	–	–	–	–	12,075	–	–	–		
7	Clear Creek mine		A	5.99	40.65	47.3	6.1	–	–	–	–	–	11,589	–	–	–		72
			B	5.6	40.8	47.4	6.1	–	–	–	–	–	11,637	–	–	–		
			C	–	43.2	50.3	6.5	–	–	–	–	–	12,327	–	–	–		
8	Clear Creek mine		A	11.8	37.4	42.4	8.4	–	–	–	–	–	10,629	–	–	–		72
			B	7.8	39.1	44.3	8.8	–	–	–	–	–	11,104	–	–	–		
			C	–	42.4	48.1	9.6	–	–	–	–	–	12,046	–	–	–		
9	Clear Creek mine		A	7.5	40.2	43.5	8.9	–	–	–	–	–	11,606	–	–	–		72
			B	5.2	41.2	44.5	9.2	–	–	–	–	–	11,895	–	–	–		
			C	–	43.4	46.95	9.7	–	–	–	–	–	12,540	–	–	–		
10	Clear Creek mine		A	5.7	38.9	46.7	8.7	–	–	–	–	–	12,276	–	–	–		72
			B	3.3	39.9	47.9	8.9	–	–	–	–	–	12,598	–	–	–		
			C	–	41.3	49.6	9.2	–	–	–	–	–	13,021	–	–	–		
11	Clear Creek mine		A	8.0	37.3	46.6	8.1	–	–	–	–	–	11,421	–	–	–		72
			B	5.8	38.2	47.7	8.3	–	–	–	–	–	11,700	–	–	–		
			C	–	40.6	50.7	8.8	–	–	–	–	–	12,419	–	–	–		
12	Clear Creek mine		A	6.8	38.6	42.5	12.1	–	–	–	–	–	11,500	–	–	–		72
			B	4.1	40.1	43.3	12.5	–	–	–	–	–	11,915	–	–	–		
			C	–	41.5	45.5	13.0	–	–	–	–	–	12,350	–	–	–		
13	Clear Creek mine		A	6.2	40.4	44.7	8.7	–	–	–	–	–	12,000	–	–	–		72
			B	4.3	41.5	45.3	9.0	–	–	–	–	–	12,328	–	–	–		
			C	–	43.1	47.2	9.3	–	–	–	–	–	12,800	–	–	–		
14	Clear Creek mine		A	4.5	43.2	45.9	6.4	–	–	–	–	–	12,500	–	–	–		72
			B	4.3	43.6	46.8	6.4	–	–	–	–	–	12,605	–	–	–		
			C	–	45.4	47.9	6.7	–	–	–	–	–	13,110	–	–	–		
15	Clear Creek mine		A	7.8	–	–	5.4	.63	–	–	–	–	–	–	–	–	T	73
16	Clear Creek mine		A	8.2	41.0	45.1	5.7	.5	–	–	–	–	12,300	–	–	–	T	3
			C	–	44.7	49.1	6.2	–	–	–	–	–	13,400	–	–	–		
17	Clear Creek mine		A	7.8	41.7	45.1	5.4	.7	5.6	74.6	1.6	11.6	12,340	–	–	47	T	3
			C	–	45.2	48.9	5.9	–	–	–	–	–	13,390	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
18	Clear Creek mine		A	7.4	41.4	45.5	5.7	.5	–	–	–	–	12,350	–	–	–	T	3
			C	–	44.7	49.1	6.2	–	–	–	–	–	13,330	–	–	–		
19	Clear Creek mine		A	5.5	42.8	45.7	6.0	.5	–	–	–	–	13,650	–	–	–		7
			C	–	45.3	48.4	6.3	–	–	–	–	–	13,390	–	–	–		
20	Clear Creek mine		A	10.3	40.3	45.7	3.8	.5	–	–	–	–	12,280	–	–	–		13
			C	–	44.9	50.9	4.2	–	–	–	–	–	13,690	–	–	–		
21	Clear Creek mine		A	8.2	40.1	47.1	4.6	.4	–	–	–	–	12,400	–	–	–		15
			C	–	43.7	51.3	5.0	–	–	–	–	–	13,510	–	–	–		
22	Clear Creek mine		A	9.6	40.0	46.2	4.2	.5	5.4	76.0	1.4	12.0	12,210	–	–	–		15
			C	–	44.2	51.1	4.7	–	–	–	–	–	13,500	–	–	–		
23	Clear Creek mine		A	8.2	39.3	47.5	5.0	.4	–	–	–	–	12,160	–	–	–		15
			C	–	42.8	51.7	5.5	–	–	–	–	–	13,250	–	–	–		
24	Clear Creek mine		A	7.6	39.4	43.1	9.9	–	–	–	–	–	11,290	–	–	–		72
			B	4.5	40.8	44.5	10.2	–	–	–	–	–	11,672	–	–	–		
			C	–	42.7	46.6	10.7	–	–	–	–	–	12,221	–	–	–		
25	Clear Creek mine		A	9.5	39.1	40.5	10.98	–	–	–	–	–	10,860	–	–	–		72
			B	4.0	41.1	41.7	11.5	–	–	–	–	–	11,427	–	–	–		
			C	–	43.2	44.7	12.1	–	–	–	–	–	12,000	–	–	–		
26	Clear Creek mine		A	6.1	36.6	50.7	6.5	–	–	–	–	–	12,551	–	–	–		72
			B	2.2	38.6	52.4	6.8	–	–	–	–	–	13,069	–	–	–		
			C	–	39.5	53.6	6.95	–	–	–	–	–	13,368	–	–	–		
27	Clear Creek mine		A	12.7	54.3	28.3	4.7	–	–	–	–	–	10,780	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	12,345	–	–	–		
28	Clear Creek mine		A	7.96	45.0	42.5	4.5	–	–	–	–	–	12,010	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,100	–	–	–		
29	Clear Creek No. 2 mine Castlegate "A" bed	SW.NW.33–13S–7E 4388470mN 487050mE	A	7.0	41.9	45.8	5.3	.6	–	–	–	–	12,220	–	3.1	–		47
			B	4.0	43.2	47.3	5.5	.58	–	–	–	–	–	–	–	–		
			C	–	45.1	49.2	5.7	.7	–	–	–	–	12,920	–	–	–		
			D	–	47.7	52.3	–	.7	–	–	–	–	–	–	–	–		
30	Clear Creek No. 3 mine Castlegate "A"	SW.SE.34–13S–7E 4387450mN 489250mE	A	6.4	–	–	4.5	.47	–	–	–	–	–	–	–	–	T	73
31	Clear Creek No. 3 mine		A	6.4	41.9	46.2	5.5	.5	–	–	–	–	12,430	2,350	1.5	–		29
32	Clear Creek No. 3 mine		A	5.4	43.1	46.2	5.3	.5	–	–	–	–	12,580	2,350	.9	–		29
33	Clear Creek No. 3 mine		A	5.9	42.4	46.4	5.3	.5	5.7	69.4	1.5	17.6	12,490	–	1.2	–		29
			C	–	45.1	49.2	5.7	.5	5.3	73.8	1.5	13.1	13,280	–	–	–		
			D	–	47.8	52.2	–	.6	5.6	78.2	1.6	14.0	14,080	–	–	–		
34	Clear Creek No. 3 mine		A	6.11	41.93	46.93	5.32	.48	6.31	70.45	1.44	16.00	12,832	–	–	–		72
			B	3.77	42.97	47.81	5.45	.50	6.20	72.21	1.48	14.16	13,152	–	–	–		
			C	–	44.66	49.68	5.66	.52	6.00	75.04	1.54	11.24	13,667	–	–	–		
			D	–	47.00	53.00	–	–	–	–	–	–	13,624	–	–	–		
35	Clear Creek No. 4 mine Bob Wright main bed	SE.SW.34–13S–7E 4387450mN 489050mE	A	2.8	46.0	46.9	4.3	.5	–	–	–	–	13,070	2,150	.9	–		29
			C	–	47.4	48.2	4.4	.5	–	–	–	–	13,450	–	–	–		
36	Clear Creek No. 4 mine		A	8.2	42.0	44.8	5.0	.5	–	–	–	–	13,100	2,320	6.4	–		29
			C	–	45.7	48.9	5.4	.6	–	–	–	–	14,260	–	–	–		
37	Clear Creek No. 4 mine		A	6.5	45.6	44.4	3.5	.5	6.1	71.1	1.4	17.4	12,780	–	2.2	–		29
			C	–	48.8	47.5	3.7	.5	5.8	76.1	1.5	12.4	13,670	–	–	–		
			D	–	50.6	49.6	–	.6	6.0	79.0	1.6	12.8	14,200	–	–	–		
38	Clear Creek No. 4 mine		A	6.6	44.8	44.8	3.8	.6	–	–	–	–	12,680	2,110	2.1	–		29
39	Clear Creek No. 4 mine		A	6.7	46.1	44.1	3.1	.5	–	–	–	–	12,870	2,130	2.3	–		29
40	Colombine mine Castlegate "A" (?)	NW.NW.NW.SW.33–12S–7E 4397680mN 486930mE	A	9.6	39.4	46.3	4.7	.52	–	–	–	–	11,861	–	–	–		72
			B	5.8	40.99	48.3	4.9	.54	–	–	–	–	12,358	–	–	–		
			C	–	43.52	51.26	5.2	.58	–	–	–	–	13,122	–	–	–		
41	Colombine mine		A	4.7	37.4	53.5	4.4	.61	–	–	–	–	12,268	–	–	–		72
			B	1.4	38.7	55.3	4.6	.63	–	–	–	–	12,693	–	–	–		
			C	–	39.3	56.1	4.6	.64	–	–	–	–	12,876	–	–	–		
42	Columbine mine		A	11.4	35.3	41.6	11.7	.5	–	–	–	–	10,550	–	–	–		10
			C	–	39.8	47.0	13.2	–	–	–	–	–	11,900	–	–	–		
43	Colombine mine		A	6.8	41.9	45.9	5.3	.6	–	–	–	–	12,570	–	–	–		13
			C	–	45.0	49.3	5.7	–	–	–	–	–	13,500	–	–	–		
44	Colombine mine		A	6.8	41.9	45.9	5.3	.6	–	–	–	–	12,580	2,310	–	–	T	70
			C	–	45.0	49.3	5.7	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,320	–	–	–		
45	Colombine mine		A	7.6	41.0	45.4	6.0	.7	–	–	–	–	12,220	2,400	–	–	T	70
			C	–	44.4	49.1	6.5	–	–	–	–	–	13,230	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,150	–	–	–		
46	Colombine mine		A	7.3	41.2	45.9	5.7	.5	5.5	74.8	1.4	11.6	12,380	2,480	–	–	T	70
			C	–	44.4	49.5	6.1	–	–	–	–	–	13,360	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,230	–	–	–		
47	Colombine mine		A	8.5	40.5	44.0	7.0	.7	–	–	–	–	11,760	2,150	–	–	T	70
			C	–	44.3	48.1	7.6	–	–	–	–	–	12,850	–	–	–		
			D	–	–	–	–	–	–	–	–	–	13,910	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
48	Colombine mine		A	7.3	41.2	45.9	5.7	.6	5.5	74.8	1.4	11.6	12,390	–	–	–	T	70
			C	–	44.4	49.5	6.1	–	–	–	–	–	13,360	–	–	–		
49	Colombine mine		A	8.5	40.5	44.0	7.0	.7	–	–	–	–	11,760	–	–	–	T	70
			C	–	44.3	48.1	7.6	–	–	–	–	–	12,850	–	–	–		
50	Colombine mine		A	7.2	41.8	44.5	6.6	.6	–	–	–	–	12,080	2,190	–	–	T	70
			C	–	45.0	47.9	7.1	–	–	–	–	–	13,020	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,020	–	–	–		
51	Colombine mine		A	6.9	42.0	45.0	6.1	.6	5.3	73.7	1.3	12.5	12,250	2,170	–	–	T	70
			C	–	45.1	48.3	6.6	–	–	–	–	–	13,160	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,090	–	–	–		
52	Colombine mine		A	6.5	42.5	45.1	5.9	.5	–	–	–	–	12,440	2,280	–	–	D	70
			C	–	45.5	48.2	6.3	–	–	–	–	–	13,300	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,190	–	–	–		
53	Colombine mine		A	5.6	43.2	45.7	5.5	.5	–	–	–	–	12,710	2,370	–	–	D	70
			C	–	45.8	48.4	5.8	–	–	–	–	–	13,460	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,290	–	–	–		
54	Colombine mine		A	7.1	42.3	44.6	6.0	.5	–	–	–	–	12,340	2,350	–	–	D	70
			C	–	45.5	48.0	6.5	–	–	–	–	–	13,280	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,200	–	–	–		
55	Colombine mine		A	8.3	41.0	42.7	8.0	.7	–	–	–	–	11,550	2,240	–	–	T	70
			C	–	44.7	46.6	8.7	–	–	–	–	–	12,590	–	–	–		
			D	–	–	–	–	–	–	–	–	–	13,790	–	–	–		
56	Colombine mine		A	6.1	42.6	45.4	5.8	.5	–	–	–	–	12,560	2,390	–	–	D	70
			C	–	45.4	48.4	6.2	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,260	–	–	–		
57	Colombine mine		A	6.2	42.5	46.5	4.8	.5	–	–	–	–	12,650	–	–	–	D	70
			C	–	45.3	49.6	5.1	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,210	–	–	–		
58	Colombine mine		A	6.9	41.6	45.5	6.0	.5	–	–	–	–	12,350	2,340	–	–	D	70
			C	–	44.7	48.9	6.4	–	–	–	–	–	13,270	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,180	–	–	–		
59	Eccles Canyon mine Castlegate "A"	SE.SW.13–13S–6E 4392450mN 482630mE	A	6.6	–	–	5.8	.59	–	–	–	–	–	–	–	–		73
60	Kinney mine Castlegate "A"	NE.SW.SW.NW.33–12S–7E 4398090mN 487050mE	A	7.9	40.4	45.8	5.9	.8	–	–	–	–	12,270	2,240	3.2	–		29
61	Kinney mine		A	8.3	42.2	44.0	5.5	.8	–	–	–	–	12,210	2,240	3.2	–		29
62	Kinney mine		A	8.1	41.3	45.0	5.6	.92	5.8	67.6	1.4	18.7	12,220	–	3.2	–		56
			C	–	45.0	48.9	6.1	1.00	5.4	73.6	1.5	12.5	13,300	–	–	–		
			D	–	47.9	52.1	–	1.06	5.7	78.3	1.6	13.3	14,160	–	–	–		
63	Kinney mine		A	7.0	42.4	42.9	7.7	.7	5.5	72.6	1.5	11.4	12,070	–	–	–		2
			B	–	45.6	46.1	8.3	–	–	–	–	–	12,980	–	–	–		
64	Kinney mine		A	4.5	–	–	–	–	–	–	–	–	12,711	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,307	–	–	–		
65	Kinney mine		A	13.2	37.3	44.5	5.0	–	–	–	–	–	11,774	–	8.03	–		72
			B	4.5	41.0	49.0	5.5	–	–	–	–	–	12,945	–	–	–		
			C	–	43.0	51.3	5.8	–	–	–	–	–	13,558	–	–	–		
66	Kinney mine		A	10.6	39.6	45.6	4.1	–	–	–	–	–	11,947	–	7.2	–		72
			B	3.2	42.9	49.4	4.5	–	–	–	–	–	12,930	–	–	–		
			C	–	44.3	51.0	4.6	–	–	–	–	–	13,362	–	–	–		
67	Kinney mine		A	7.8	41.4	45.5	5.3	–	–	–	–	–	12,285	–	4.75	–		72
			B	2.7	43.7	48.1	5.6	–	–	–	–	–	12,969	–	–	–		
			C	–	44.9	49.4	5.8	–	–	–	–	–	13,323	–	–	–		
68	Kinney mine		A	7.1	39.7	45.7	7.5	–	–	–	–	–	11,852	–	–	–		72
			B	5.6	40.4	46.4	7.6	–	–	–	–	–	12,045	–	–	–		
			C	–	42.75	49.2	8.1	–	–	–	–	–	12,756	–	–	–		
69	Kinney mine		A	7.6	40.4	46.9	5.1	–	–	–	–	–	12,264	–	–	–		72
			B	5.2	41.5	48.1	5.3	–	–	–	–	–	12,582	–	–	–		
			C	–	43.7	50.7	5.6	–	–	–	–	–	13,274	–	–	–		
70	Kinney mine		A	6.34	–	–	–	–	–	–	–	–	12,024	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	12,838	–	–	–		
71	Kinney mine		A	10.3	40.4	41.2	8.1	.83	–	–	–	–	11,267	–	–	–		72
			B	6.7	42.1	42.9	8.4	.86	–	–	–	–	11,721	–	–	–		
			C	–	45.1	45.9	9.0	.92	–	–	–	–	12,557	–	–	–		
72	Kinney mine		A	8.2	43.1	42.6	6.2	.6	–	–	–	–	12,120	–	–	48		6
			C	–	46.9	46.4	6.7	–	–	–	–	–	13,200	–	–	–		
73	Kinney mine		A	8.0	42.3	45.3	4.4	.8	–	–	–	–	12,450	–	–	50		7
			C	–	46.0	49.2	4.8	–	–	–	–	–	12,450	–	–	–		
74	O'Conner mine Castlegate "A"	SW.SW.NE.32–13S–7E 4388440mN 486270mE	A	8.4	42.3	42.9	6.4	.6	–	–	–	–	11,880	–	–	–		8
			C	–	46.2	46.8	7.0	–	–	–	–	–	12,970	–	–	–		
75	O'Conner No. 2 mine		A	8.7	40.4	45.6	5.4	.5	–	–	–	–	12,200	–	–	–		14
			C	–	44.2	49.9	5.9	–	–	–	–	–	13,350	–	–	–		
76	Scofield mine Castlegate A bed	SW.SW.NW.NW.4–13S–7E 4369720mN 486860mE	A	10.0	39.9	45.4	4.8	.5	–	–	–	–	11,830	–	–	–		7
			C	–	44.3	50.4	5.3	–	–	–	–	–	13,140	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
77	Scofield mine		A	7.1	42.8	44.9	5.2	.5	–	–	–	–	12,250	–	–	–		8
			C	–	46.1	48.3	5.6	–	–	–	–	–	13,190	–	–	–		
78	Smith mine Castlegate "A"	SW.SW.NE.31–12S–7E 4397920mN 485030mE	A	13.6	38.0	42.9	5.5	.5	–	–	–	–	10,700	–	–	–		54
			C	–	44.0	49.6	6.4	–	–	–	–	–	12,390	–	–	–		
79	Smith mine		A	14.5	36.0	43.3	6.2	.5	–	–	–	–	10,250	–	–	–		54
			C	–	42.1	50.7	7.2	–	–	–	–	–	11,990	–	–	–		
80	Utah mine Castlegate "A"	SE.SE.NE.NE.17–13S–7E 4393520mN 486820mE	A	4.93	44.86	44.32	5.89	.55	–	–	–	–	–	–	–	–		31
81	Utah mine		A	4.95	44.50	45.43	5.12	.73	–	–	–	–	–	–	–	–		31
82	Utah mine		A	5.20	44.96	46.00	3.84	1.06	–	–	–	–	–	–	–	–		31
83	Utah mine		A	5.04	45.31	44.99	4.66	.86	–	–	–	–	–	–	–	–		31
84	Utah No. 2 mine Castlegate "A"		A	3.6	–	–	5.4	.56	–	–	–	–	–	–	–	–		73
85	Winter Quarters mine Castlegate "A"	SE.NW.SW.6–13S–7E 4396000mN 483960mE	A	4.80	39.75	49.94	5.50	.27	–	73.05	–	–	–	–	–	–		23
86	Winter Quarters mine		A	6.37	41.65	46.18	5.77	.62	–	–	–	–	12,389	–	–	–		55
			C	–	44.50	49.34	6.16	–	–	–	–	–	13,232	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,101	–	–	–		
87	Winter Quarters mine		A	8.10	40.21	45.91	5.78	.86	–	–	–	–	12,162	–	3.9	–		47
			C	–	43.75	49.96	6.29	.94	–	–	–	–	13,237	–	–	–		
			D	–	46.69	53.31	–	1.00	–	–	–	–	14,125	–	–	–		
88	Winter Quarters No. 1 mine	C.1–13S–6E 4396400mN 482800mE	A	8.1	40.2	45.9	5.8	.9	–	–	–	–	12,160	–	3.9	–		47
			B	4.4	41.8	47.8	6.0	.89	–	–	–	–	12,660	–	–	–		
			C	–	43.8	49.9	6.3	.9	–	–	–	–	13,240	–	–	–		
89	Winter Quarters No. 1 mine		A	6.7	43.6	44.9	4.8	.9	–	–	–	–	12,570	2,060	1.8	–		29
90	Winter Quarters No. 1 mine		A	7.4	42.0	46.8	3.8	.6	–	–	–	–	12,420	2,260	2.1	–		29
91	Winter Quarters No. 1 mine		A	7.0	42.2	44.4	6.4	.8	–	–	–	–	12,290	2,130	2.5	–		29
92	Winter Quarters No. 1 mine		A	6.8	42.7	44.6	5.9	.7	–	–	–	–	12,360	2,060	2.4	–		29
93	Winter Quarters No. 1 mine		A	6.9	43.1	44.8	5.2	.7	6.0	69.1	1.4	17.6	12,470	–	2.2	–		29
			C	–	46.3	48.1	5.6	.8	5.6	74.2	1.5	12.3	13,400	–	–	–		
			D	–	49.0	51.0	–	.8	5.9	78.6	1.5	13.2	14,190	–	–	–		
								SCOFIELD SE QUADRANGLE										
1	Prospect Unknown bed	S.24–14S–7E	A	6.04	38.96	48.40	6.60	.83	–	–	–	–	–	–	2.9	–		47
			C	–	41.46	51.52	7.02	.88	–	–	–	–	–	–	–	–		
			D	–	44.59	55.41	–	.95	–	–	–	–	–	–	–	–		
2	Wattis mine Wattis bed Hiawatha bed	NE.NE.NE.NE.17–15S–8E 4375100mN 496500mE	A	7.3	41.0	47.7	4.0	.9	–	–	–	–	12,530	2,800	4.5	–		29
3	Wattis mine		A	6.5	41.3	47.7	4.5	.9	–	–	–	–	12,680	2,450	3.8	–		29
4	Wattis mine		A	6.9	41.2	47.1	4.8	.9	–	–	–	–	12,450	2,390	4.2	–		29
5	Wattis mine		A	6.9	41.4	47.2	4.5	.8	5.9	70.1	1.4	17.3	12,590	–	4.1	–		29
			C	–	44.4	50.8	4.8	.9	5.5	75.3	1.5	12.0	13,520	–	–	–		
			D	–	46.7	53.3	–	1.0	5.8	79.1	1.6	12.5	14,200	–	–	–		
6	Wattis mine		A	7.4	40.8	46.1	5.7	.8	–	–	–	–	12,350	2,740	4.5	–		29
			C	–	44.0	49.9	6.1	.9	–	–	–	–	13,330	–	–	–		
7	Wattis mine		A	6.7	41.6	47.1	4.6	.7	–	–	–	–	12,550	2,450	4.0	–		29
8	Wattis mine		A	7.9	40.2	48.9	2.6	.70	–	–	–	–	12,830	–	2.6	–		56
			C	–	43.6	53.1	3.2	.76	–	–	–	–	13,610	–	–	–		
			D	–	45.1	54.9	–	.79	–	–	–	–	14,060	–	–	–		
9	Wattis mine		A	7.3	39.7	46.7	6.3	.59	–	–	–	–	12,240	–	3.0	–		56
			C	–	42.8	50.4	6.8	.64	–	–	–	–	13,210	–	–	–		
			D	–	45.9	54.1	–	.69	–	–	–	–	14,180	–	–	–		
10	Wattis mine		A	6.8	41.4	47.3	4.5	.84	5.9	70.1	1.4	17.2	12,390	–	4.1	–		56
			C	–	44.4	50.8	4.9	.90	5.5	75.3	1.5	12.0	13,520	–	–	–		
			D	–	46.7	53.3	–	.95	5.8	79.1	1.6	12.6	14,200	–	–	–		
11	Wattis mine		A	6.22	40.43	47.47	5.88	.61	6.33	70.13	1.38	15.67	12,737	–	–	–		71
			B	3.63	41.55	48.78	6.04	.63	6.20	72.07	1.42	13.64	13,089	–	–	–		
			C	–	43.11	50.62	6.27	.65	6.02	74.78	1.47	10.81	13,582	–	–	–		
			D	–	45.60	54.40	–	–	–	–	–	–	13,629	–	–	–		
12	Wattis mine		A	6.3	–	–	3.9	.71	–	–	–	–	–	–	–	–		73
13	Wattis mine		A	5.0	42.4	45.9	6.7	.9	–	–	–	–	12,620	–	–	–		54
			C	–	44.6	48.3	7.1	–	–	–	–	–	13,280	–	–	–		
14	Wattis mine		A	5.5	42.0	45.8	6.7	.7	–	–	–	–	12,440	–	–	–		54
			C	–	44.4	48.5	7.1	–	–	–	–	–	13,160	–	–	–		
15	Wattis mine		A	7.8	40.8	44.5	6.9	1.0	–	–	–	–	12,060	–	–	–		54
			C	–	44.2	48.3	7.5	–	–	–	–	–	13,080	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
16	Wattis mine		A	6.1	41.3	45.9	6.7	1.0	–	–	–	–	12,370	–	–	–		54
			C	–	44.0	48.9	7.1	–	–	–	–	–	13,170	–	–	–		
17	Wattis mine		A	7.0	40.6	45.8	6.5	1.0	–	–	–	–	12,280	–	–	–		54
			C	–	43.7	49.3	7.0	–	–	–	–	–	13,200	–	–	–		
18	Wattis mine		A	6.8	–	–	5.5	.85	–	–	–	–	–	–	–	–		73
19	Wattis mine		A	7.4	40.1	46.0	6.5	1.1	–	–	–	–	12,330	–	–	–		54
			C	–	43.3	49.7	7.0	–	–	–	–	–	13,320	–	–	–		
20	Wattis mine		A	6.3	40.5	46.3	6.9	.9	–	–	–	–	12,330	–	–	–		54
			C	–	43.2	49.4	7.4	–	–	–	–	–	13,160	–	–	–		
21	Wattis mine		A	6.6	41.6	45.4	7.5	–	–	–	–	–	11,950	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	12,800	–	–	–		
22	Wattis mine		A	7.9	40.1	45.5	6.5	–	–	–	–	–	12,000	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,010	–	–	–		
23	Wattis mine		A	7.1	37.3	46.7	8.9	–	–	–	–	–	11,579	–	–	–		72
			B	3.3	38.8	48.6	9.3	–	–	–	–	–	12,054	–	–	–		
			C	–	40.1	50.2	9.6	–	–	–	–	–	12,467	–	–	–		
24	Wattis mine		A	7.2	39.4	46.5	8.9	–	–	–	–	–	11,984	–	–	–		72
			B	3.9	38.8	48.2	9.2	–	–	–	–	–	12,418	–	–	–		
			C	–	40.3	50.1	9.6	–	–	–	–	–	12,917	–	–	–		
25	Wattis mine		A	5.7	41.1	47.0	6.1	–	–	–	–	–	12,276	–	–	–		72
			B	3.9	41.9	47.9	6.3	–	–	–	–	–	12,511	–	–	–		
			C	–	43.6	49.9	6.5	–	–	–	–	–	13,024	–	–	–		
26	Wattis mine		A	4.9	41.2	46.1	7.2	–	–	–	–	–	12,473	–	–	–		72
			B	2.8	42.1	47.7	7.4	–	–	–	–	–	12,745	–	–	–		
			C	–	43.3	49.1	7.6	–	–	–	–	–	13,112	–	–	–		
27	Wattis mine		A	7.4	43.6	39.8	9.2	–	–	–	–	–	11,527	–	–	–		72
			B	4.1	46.0	40.2	9.7	–	–	–	–	–	12,166	–	–	–		
			C	–	47.1	42.95	9.9	–	–	–	–	–	12,457	–	–	–		
28	Wattis mine		A	7.3	40.1	45.6	6.9	.61	–	–	–	–	12,014	–	–	–		72
			B	1.98	42.4	48.3	7.3	.64	–	–	–	–	12,709	–	–	–		
			C	–	43.3	49.3	7.5	.65	–	–	–	–	12,966	–	–	–		
29	Wattis mine		A	7.7	39.9	44.9	7.3	.81	–	–	–	–	11,901	–	–	–		72
			B	4.99	41.0	45.7	7.5	.83	–	–	–	–	12,251	–	–	–		
			C	–	43.2	48.1	7.8	.87	–	–	–	–	12,894	–	–	–		
30	Wattis mine		A	6.8	40.4	46.7	6.1	.84	–	–	–	–	12,445	–	–	–		72
			B	3.7	41.76	48.3	6.3	.87	–	–	–	–	12,853	–	–	–		
			C	–	43.4	50.1	6.5	.91	–	–	–	–	13,346	–	–	–		
31	Wattis mine		A	5.9	41.2	48.3	4.6	.9	–	–	–	–	12,840	–	–	–	T	4
			C	–	43.8	51.3	4.9	–	–	–	–	–	13,640	–	–	–		
32	Wattis mine		A	6.2	41.2	46.9	5.7	1.0	–	–	–	–	12,640	–	–	–	T	4
			C	–	43.9	50.0	6.1	–	–	–	–	–	13,480	–	–	–		
33	Wattis mine		A	6.1	41.7	47.2	5.0	1.1	–	–	–	–	12,740	–	–	–	T	4
			C	–	44.4	50.3	5.3	–	–	–	–	–	13,570	–	–	–		
34	Wattis mine		A	9.1	40.6	43.7	6.5	1.1	–	–	–	–	11,770	–	–	–	T	4
			C	–	44.7	48.1	7.2	–	–	–	–	–	12,950	–	–	–		
35	Wattis mine		A	7.1	41.2	45.0	6.8	.9	–	–	–	–	12,200	–	–	–	D	4
			C	–	44.3	48.4	7.3	–	–	–	–	–	13,130	–	–	–		
36	Wattis mine		A	11.1	39.8	40.6	8.4	1.2	–	–	–	–	11,360	–	–	–	T	4
			C	–	44.8	45.7	9.5	–	–	–	–	–	12,770	–	–	–		
37	Wattis mine		A	7.4	40.2	44.2	8.3	–	–	–	–	–	11,843	–	4.1	–		72
			B	2.6	42.3	46.4	8.7	–	–	–	–	–	12,451	–	–	–		
			C	–	43.4	47.7	8.9	–	–	–	–	–	12,782	–	–	–		
38	Wattis mine		A	9.2	39.1	44.5	7.2	–	–	–	–	–	11,206	–	5.2	–		72
			B	3.6	41.5	47.3	7.6	–	–	–	–	–	11,903	–	–	–		
			C	–	43.1	49.0	7.9	–	–	–	–	–	12,346	–	–	–		
39	Wattis mine		A	7.1	38.7	45.2	9.1	–	–	–	–	–	11,828	–	–	–		72
			B	2.4	40.6	47.5	9.5	–	–	–	–	–	12,419	–	–	–		
			C	–	41.6	48.6	9.8	–	–	–	–	–	12,727	–	–	–		
40	Wattis mine		A	5.1	–	–	–	–	–	–	–	–	12,464	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	13,123	–	–	–		
41	Wattis mine		A	5.78	–	–	–	–	–	–	–	–	12,121	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	12,865	–	–	–		
42	Wattis mine		A	8.3	40.3	41.6	9.8	–	–	–	–	–	11,847	–	–	–		72
			B	1.3	43.4	44.7	10.6	–	–	–	–	–	12,748	–	–	–		
			C	–	43.98	45.3	10.7	–	–	–	–	–	12,916	–	–	–		
43	Wattis mine		A	2.7	–	–	–	–	–	–	–	–	12,853	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,212	–	–	–		
44	Wattis mine		A	6.8	41.8	47.4	4.0	.6	5.6	76.6	1.6	11.3	12,860	–	–	–	T	11
			C	–	44.8	50.9	4.3	–	–	–	–	–	13,800	–	–	–		
45	Wattis mine		A	6.8	41.3	47.6	4.3	.6	–	–	–	–	12,760	–	–	–	T	11
			C	–	44.3	51.1	4.6	–	–	–	–	–	13,690	–	–	–		

Table 5. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
46	Wattis mine		A	7.1	41.1	47.1	4.7	.7	–	–	–	–	12,620	–	–	–	T	11
			C	–	44.2	50.7	5.1	–	–	–	–	–	13,580	–	–	–		
47	Wattis mine		A	6.5	41.5	46.5	5.5	.7	–	–	–	–	12,600	–	–	–	T	11
			C	–	44.4	49.7	5.9	–	–	–	–	–	13,470	–	–	–		
48	Wattis mine		A	6.4	41.9	44.7	6.9	.9	–	–	–	–	12,270	–	–	–	T	11
			C	–	44.8	47.8	7.4	–	–	–	–	–	13,110	–	–	–		
49	Wattis mine		A	6.5	41.1	46.5	5.9	–	–	–	–	–	–	–	–	–		43
			D	–	46.9	53.1	–	.9	5.8	79.4	1.7	12.2	14,210	–	–	–		
	SCOFIELD SW QUADRANGLE																	
1	Arrowhead mine Castlegate "A"	NE.11–14S–6E 4385450mN 481540mE	A	7.2	–	–	4.7	.52	–	–	–	–	–	–	–	–		73
2	Huntington mine Castlegate "A"	SW.SW.SW.NE.11–14S–6E 4385110mN 481320mE	A	4.9	40.7	43.2	11.2	–	–	–	–	–	11,820	–	–	–		72
			B	–	–	–	–	–	–	–	–	–	12,480	–	–	–		
3	Huntington mine		A	6.05	42.02	47.06	4.87	.55	5.76	72.32	1.38	15.12	13,151	–	3.8	–		47
			C	–	44.73	50.09	5.18	.59	5.42	76.98	1.47	10.36	13,997	–	–	–		
			D	–	47.17	52.83	–	.62	5.71	81.19	1.55	10.93	14,794	–	–	–		
4	Huntington mine		A	5.19	43.89	46.91	4.01	.31	–	–	–	–	–	–	2.3	–		47
			C	–	46.29	49.48	4.23	.33	–	–	–	–	–	–	–	–		
			D	–	48.34	51.66	–	.34	–	–	–	–	–	–	–	–		
5	Huntington mine		A	7.1	40.0	47.6	5.3	1.6	–	–	–	–	12,350	2,110	4.2	–		29
6	Huntington mine		A	6.9	40.1	47.8	5.2	1.1	5.7	69.9	1.3	16.8	12,440	–	4.1	–		29
			C	–	43.1	51.4	5.5	1.2	5.3	75.1	1.4	11.5	13,370	–	–	–		
			D	–	45.7	54.3	–	1.3	5.6	79.5	1.5	12.1	14,160	–	–	–		
7	Huntington mine		A	6.9	40.2	48.0	4.9	.7	–	–	–	–	12,490	2,110	4.0	–		29
8	Huntington mine Castlegate A bed		A	6.9	–	–	3.7	.47	–	–	–	–	–	–	–	–		73
9	Larsen mine Castlegate "A"	NE.SE.SW.2–15S–6E 4376860mN 481050mE	A	7.8	42.4	47.0	2.8	.52	–	–	–	–	–	–	3.9	–		60
			B	4.0	44.1	49.0	2.9	.54	–	–	–	–	–	–	–	–		
			C	–	46.0	51.0	3.0	.56	–	–	–	–	–	–	–	–		
			D	–	47.4	52.6	–	.58	–	–	–	–	–	–	–	–		
10	Larsen mine		A	8.46	41.17	46.09	4.28	.48	–	–	–	–	–	–	3.5	–		47
			C	–	44.97	50.35	4.68	.52	–	–	–		–	–	–	–		
			D	–	47.18	52.82	–	.55	–	–	–	–	–	–	–	–		
11	Larsen mine		A	11.0	37.7	47.1	4.2	.6	–	–	–	–	11 640	2,200	5.4	–		29
12	Larsen mine		A	8.7	38.7	48.0	4.6	.6	–	–	–	–	12.230	2,130	4.1	–		29
13	Larsen mine		A	9.8	38.3	47.4	4.5	.6	5.8	67.5	1.3	20.3	11,860	–	4.7	–		29
			C	–	42.5	52.5	5.0	.7	5.3	74.9	1.4	12.7	13,260	–	–	–		
			D	–	44.7	55.3	–	.7	5.5	78.8	1.5	13.5	13,950	–	–	–		
14	Larson & Rigby mine Castlegate "A"	NW.25–14S–6E ≃4380800mN 482950mE	A	6.9	–	–	5.4	.45	–	–	–	–	–	–	–	–		73
15	Larson & Rigby mine		A	6.4	–	–	5.2	.46	–	–	–	–	–	–	–	–		73
16	Larson & Rigby mine		A	6.3	44.0	44.9	4.8	.7	–	–	–	–	12,660	–	–	–	T	7
			C	–	47.0	47.9	5.1	–	–	–	–	–	13,520	–	–	–		
17	Larson & Rigby mine		A	6.8	43.8	44.3	5.1	.7	–	–	–	–	12,490	–	–	53	T	7
			C	–	47.0	47.5	5.5	–	–	–	–	–	13,410	–	–	–		
18	Larson & Rigby mine		A	6.9	43.9	44.8	4.5	.6	–	–	–	–	12,630	–	–	–	T	9
			C	–	47.1	48.1	4.8	–	–	–	–	–	13,560	–	–	–		
19	Larson & Rigby mine		A	6.5	43.4	45.0	5.1	.6	–	–	–	–	12,600	–	–	–	T	9
			C	–	46.4	48.1	5.5	–	–	–	–	–	13,480	–	–	–		
20	Larson & Rigby mine		A	9.1	42.5	42.8	5.6	.7	–	–	–	–	12,120	–	–	–	T	9
			C	–	46.7	47.1	6.2	–	–	–	–	–	13,330	–	–	–		
21	Larson & Rigby mine		A	6.0	45.1	44.4	4.5	.4	–	–	–	–	12,750	–	–	–	T	11
			C	–	48.0	47.2	4.8	–	–	–	–	–	13,570	–	–	–		
22	Larson & Rigby mine		A	6.9	44.2	44.4	4.5	.4	–	–	–	–	12,660	–	–	–	T	11
			C	–	47.5	47.7	4.8	–	–	–	–	–	13.600	–	–	–		

Moisture

The moisture content of 914 samples from the entire field ranges from 0.7 to 14.5 percent and averages 6.1 percent (table 6). The lowest moisture coal is located in the west Hiawatha quadrangles, a little less than 5 percent; it increases to the north and south.

Volatile Matter

Based on more than 700 analyses, the average volatile matter content for the field is 42.0 percent (table 7). The groupings are close except for two quadrangles that have less than five samplings each; the highest averages come from the Hiawatha quadrangles.

Fixed Carbon

Fixed carbon increases gradually from north to south, except for the southernmost quadrangle; it averages 45.4 percent (table 8).

Ash

More than 800 samples indicate that ash content in Wasatch Plateau coal is 6.5 percent (table 9). No regional trend characterizes ash.

Table 6. Moisture content of coal, Wasatch Plateau coal field.

Quadrangle	No. of Samples	Percent	
		Average	Range
Soldier Summit SE	0	–	–
Scofield NE	47	6.9	3.2-12.6
Scofield NW	93	7.5	2.8-14.5
Scofield SE	49	6.5	2.7-11.1
Scofield SW	22	7.2	4.9-11.0
Hiawatha NE	386	5.6	0.7-11.0
Hiawatha NW	41	4.9	3.1- 6.8
Hiawatha SE	154	5.2	1.2-11.4
Hiawatha SW	27	4.7	1.5-13.2
Castle Dale NW	3	7.7	6.4-9.8
Ferron Canyon	0	–	–
Castle Dale SW	0	–	–
Flagstaff Peak	1	8.4	8.4
Acord Lakes NE	7	8.3	7.0-12.9
Acord Lakes NW	12	8.7	5.6-10.4
Acord Lakes SW	0	–	–
Emery 3 NW	2	13.4	12.9-13.9
Wasatch Plateau field	844	6.1	0.7-14.5

Table 7. Volatile matter content of coal, Wasatch Plateau coal field.

Quadrangle	No. of Samples	Percent	
		Average	Range
Soldier Summit SE	0	–	–
Scofield NE	40	41.6	37.3-44.4
Scofield NW	86	41.3	35.3-54.3
Scofield SE	44	40.8	37.3-43.6
Scofield SW	18	41.8	37.7-45.1
Hiawatha NE	372	42.4	36.3-46.4
Hiawatha NW	35	43.4	40.4-46.0
Hiawatha SE	140	42.1	37.4-45.6
Hiawatha SW	16	41.6	37.9-43.7
Castle Dale NW	3	38.8	34.4-41.0
Ferron Canyon	0	–	–
Castle Dale SW	0	–	–
Flagstaff Peak	1	39.1	39.1
Acord Lakes NE	5	38.1	37.5-38.6
Acord Lakes NW	11	38.3	36.2-40.6
Acord Lakes SW	0	–	–
Emery 3 NW	2	36.2	35.2-37.2
Wasatch Plateau field	773	42.0	34.4-54.3

Table 8. Fixed carbon content of coal, Wasatch Plateau coal field.

Quadrangle	No. of Samples	Percent	
		Average	Range
Soldier Summit SE	0	–	–
Scofield NE	40	44.7	39.7-49.1
Scofield NW	86	44.9	28.3-53.5
Scofield SE	44	46.0	39.8-48.9
Scofield SW	18	45.9	42.8-48.0
Hiawatha NE	372	45.6	38.3-51.2
Hiawatha NW	35	45.7	43.5-51.1
Hiawatha SE	140	44.8	35.1-48.4
Hiawatha SW	16	46.4	43.2-48.7
Castle Dale NW	3	49.5	47.0-54.4
Ferron Canyon	0	–	–
Castle Dale SW	0	–	–
Flagstaff Peak	1	45.2	45.2
Acord Lakes NE	5	48.6	45.3-46.4
Acord Lakes NW	11	46.6	43.3-50.4
Acord Lakes SW	0	–	–
Emery 3 NW	2	43.8	43.6-43.9
Wasatch Plateau field	773	45.4	28.3-54.4

Table 9. Ash content of coal, Wasatch Plateau coal field.

Quadrangle	No. of Samples	Percent	
		Average	Range
Soldier Summit SE	0	–	–
Scofield NE	45	6.4	2.9-11.5
Scofield NW	91	6.1	3.1-13.5
Scofield SE	46	6.3	2.6- 9.8
Scofield SW	22	5.0	2.8-11.2
Hiawatha NE	375	6.3	3.3-12.4
Hiawatha NW	41	6.0	2.8-10.7
Hiawatha SE	147	7.6	4.0-18.3
Hiawatha SW	20	6.5	4.2- 8.8
Castle Dale NW	3	4.3	1.4- 6.3
Ferron Canyon	0	–	–
Castle Dale SW	0	–	–
Flagstaff Peak	1	7.3	7.3
Acord Lakes NE	7	8.0	5.4-10.0
Acord Lakes NW	12	6.5	5.9- 7.1
Acord Lakes SW	0	–	–
Emery 3 NW	2	6.7	6.0- 7.3
Wasatch Plateau field	812	6.5	1.4-18.3

Table 10. Sulfur content of coal, Wasatch Plateau coal field.

Quadrangle	No. of Samples	Percent	
		Average	Range
Soldier Summit SE	0	–	–
Scofield NE	34	0.53	0.39-1.60
Scofield NW	70	0.60	0.40-1.10
Scofield SE	34	0.85	0.59-1.20
Scofield SW	21	0.62	0.31-1.60
Hiawatha NE	344	0.61	0.29-1.10
Hiawatha NW	40	0.55	0.23-0.80
Hiawatha SE	136	0.57	0.31-1.50
Hiawatha SW	18	0.57	0.38-0.70
Castle Dale NW	3	0.77	0.60-0.90
Ferron Canyon	0	–	–
Castle Dale SW	0	–	–
Flagstaff Peak	1	0.47	0.47
Acord Lakes NE	7	0.42	0.40-0.50
Acord Lakes NW	12	0.46	0.30-0.60
Acord Lakes SW	0	–	–
Emery 3 NW	2	0.60	0.60
Wasatch Plateau field	722	0.60	0.23-1.60

Sulfur

The sulfur content of 700 plus analyses of Wasatch Plateau coal averages 0.6 percent (table 10).

The U. S. Bureau of Mines (Walker and Hartner, 1966) subdivided 37 samples from the Wasatch Plateau coal field into sulfur groups (table 11).

Table 11. Sulfur-type determinations of coal, Wasatch Plateau coal field.

Type	Percent	
	Average	Range
Sulfate	0.01	0.00-0.03
Pyritic	0.10	0.04-0.20
Organic	0.41	0.18-0.69
Total Sulfur	0.52	0.36-0.89

Calorific Value

The average Btu/lb of 788 samples for the field is 12,589 with a range between 10,250 and 13,690 (table 12). The higher

Table 12. Calorific value of coal, Wasatch Plateau coal field.

Quadrangle	No. of Samples	Btu/lb Average	Range
Soldier Summit SE	0	–	–
Scofield NE	43	12,216	10,550-13,078
Scofield NW	81	12,095	10,250-13,650
Scofield SE	45	12,286	11,206-12,860
Scofield SW	15	12,459	11,640-13,350
Hiawatha NE	380	12,718	10,840-13,600
Hiawatha NW	35	13,080	12,290-13,690
Hiawatha SE	144	12,704	10,800-13,353
Hiawatha SW	23	12,905	11,376-13,452
Castle Dale NW	3	12,363	12,200-12,400
Ferron Canyon	0	–	–
Castle Dale SW	0	–	–
Flagstaff Peak	1	11,922	11,922
Acord Lakes NE	5	11,674	11,570-11,770
Acord Lakes NW	11	11,770	11,390-12,260
Acord Lakes SW	0	–	–
Emery 3 NW	2	10,570	10,540-10,600
Wasatch Plateau field	788	12,589	10,250-13,690

values lie in the Hiawatha quadrangles and drop markedly to the south.

In summary the Wasatch Plateau field coal has the following characteristics, as-received: moisture 6.1 percent, volatile matter 42.0 percent, fixed carbon 45.4 percent, ash 6.5 percent, sulfur 0.6 percent and Btu/lb 12,589.

The American Society for Testing and Materials classifies the coal of the Wasatch Plateau field as high-volatile B bituminous. The coal is noncoking. Two early attempts in Pleasant Valley and upper Huntington Creek produced a devolatilized coal.

Buranek and Crawford (1952) and Spieker (1931) noted that some of the coals vary in resin content from almost nothing to 14.9 percent by volume. They found significant percentages present in the Byron Howard and American Fuel mines, both on the Blind Canyon bed in the Huntington area (Hiawatha SE). The Ivie bed in the south area and the Bob Wright coal at Pleasant Valley and Gordon areas are also resinous. Concentration of these resins is a part of coal preparation at the U. S. Fuel Co. mine at Hiawatha.

Reserves

Several beds in the lower third of the Blackhawk Formation of the Mesaverde Group (Upper Cretaceous) contain all the coal resources of the Wasatch Plateau field. Of most importance are the Castlegate "A" in the north, Hiawatha in the center and Ivie beds in the south part of the field.

The reserves in table 13 are calculated by Spieker (1931, p. 204-206). They are modified to fit quadrangles and discount beds averaging less than 4 feet. No distinction was made among measured reserves (Class I), estimated reserves (Class II) and inferred reserves (Class III).

Table 13. Original reserves and estimated production (principal reserve only; in short tons in beds averaging 4 feet or more thick under less than 3,000 feet of cover).

Quadrangle	Reserve	Estimated Production ending January 1, 1970
Acord Lakes NE	164,896,200	164,000
Acord Lakes NW	491,256,000	1,106,600
Acord Lakes SW	300,393,000	1,000±
Castle Dale NW	377,725,500	8,000
Castle Dale SW	24,321,600	<1,000
Emery 3 NW	134,481,600	<1,000[1]
Ferron Canyon	57,664,800	<1,000
Flagstaff Peak	392,154,500	40,000
Hiawatha NE	466,054,740	51,776,000
Hiawatha NW	764,426,920	232,500
Hiawatha SE	110,165,420	4,040,300
Hiawatha SW	538,048,020	96,000
Scofield NE	608,784,120	5,400,000
Scofield NW	594,727,740	28,300,000
Scofield SE	302,598,000	8,077,600
Scofield SW	461,930,940	230,000
Soldier Summit SE	462,342,600	6,000
Other areas	126,880,000	–
	6,378,851,700	99,481,000

[1]Includes only Blackhawk Formation production.

Reserves outside the quadrangles are Class IV for the most part; lack of drilling and surface exposures limit data, but there is adequate proof of underlying coal. The outcrops on the upper part of the Blackhawk Formation exposed to the west near Fairview and Mt. Pleasant were drilled and three beds of minable thickness were discovered. The beds, 68, 60 and 42 inches thick, are not as thick as beds farther east and north, but they are comparable to those near Ferron Canyon and Flagstaff Peak. To the south in the Salina Canyon field, drilling encountered 5 to 7 feet of coal.

Including the average thickness of the coal in adjacent townships, 10.8 feet of coal in beds more than 4 feet thick are estimated present. About 200,000 acres with less than 3,000 feet of cover are west of the area calculated by Spieker. According to his 1,800 tons per acre-foot there should be an additional 3,888,000,000 tons of reserve (Class IV).

Reserves calculated for this report are classed and summarized as follows:

Class I (measured)	Based on adequate exploration and development data, properly correlated.	6,378.9 x 10^6 short tons
Class II (indicated)	Based on geologic measurement supplemented by limited drill-hole information or limited to 1½ miles from a control point.	
Class III (inferred)	Based on geologic inference and projection of the habit of the coal beyond 1½ miles from control points.	
Class IV (potential)	Based on geographic and geologic position with little supporting data and includes coal to 3,000 feet of cover.	3,888.0 x 10^6 short tons
	Total	10,266.9 x 10^6 short tons

Coal Seams

The Wasatch Plateau coal field is subdivided into 16 areas by Spieker (1931, p. 78). Areal divisions larger than Spieker's 16, yet smaller than the field, are grouped to form the following new areas (figure 18). Because of its importance and geographic isolation Spieker's Pleasant Valley area is intact.

Spieker (1931)	Wasatch Coal Field Report (1970)
Pleasant Valley	Pleasant Valley
Part of Price River, Beaver, North Gordon, Bob Wright	Gordon Creek
Hiawatha, Mohrland	Hiawatha
Upper Huntington, Lower Huntington	Huntington Canyon
Cottonwood, Rock Canyon	Cottonwood Canyon
Ferron Canyon, Muddy Canyon	Flagstaff Peak
Convulsion, Saleratus, Ivie	South

The remainder of Spieker's Price River area is best combined with the Book Cliffs coal field. Twenty-two coal bed names indicate that there are abundant coal beds in the field. The coal beds are lenticular, limited in extent and have a specific area in which they are thick and well developed.

The Hiawatha resting immediately on the Star Point Sandstone has the greatest areal extent (figure 19). It occurs in thick beds in all areas but the Pleasant Valley area. Only small parts of the South and Flagstaff Peak areas are involved. The Hiawatha is best developed in the Hiawatha area, where beds up to 28 feet have been mined. It has been and promises to continue to be the most important bed of the field.

The Castlegate "A" bed, second important in the field, is well developed in the northwest part in the Pleasant Valley, Gordon Creek and Huntington Canyon areas. It is important northwest of a line commencing at the jog in the Emery-Sanpete County line through Coal Canyon in the Gordon Creek area. To the northwest of Pleasant Valley its extent is unknown. The

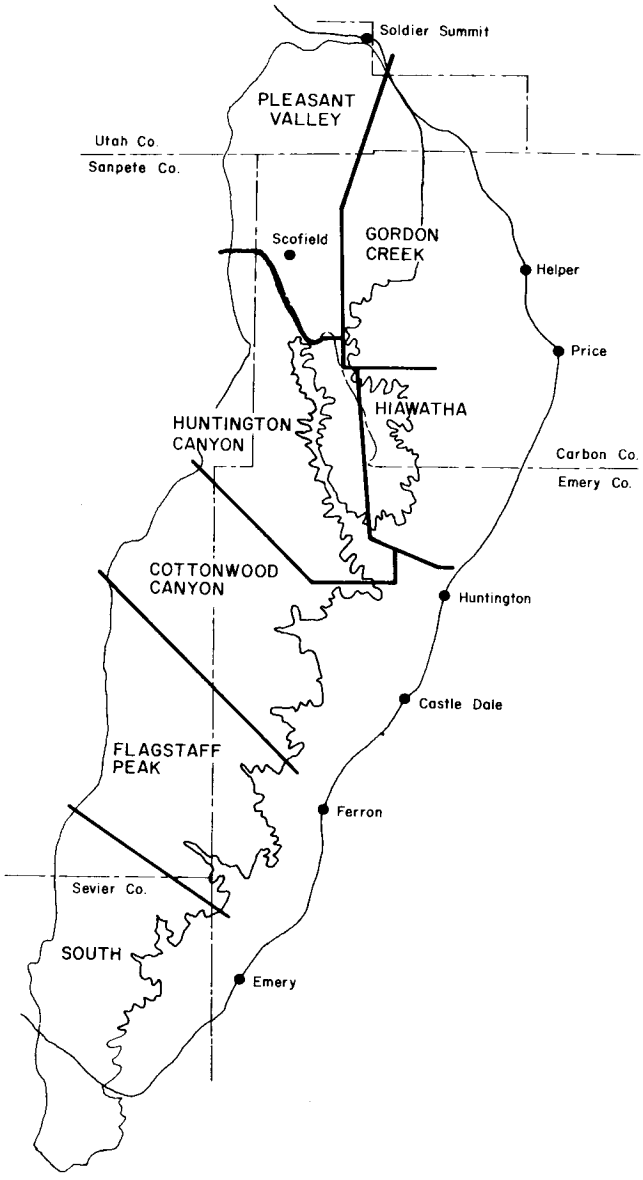


Figure 18. Coal field areas, Wasatch Plateau coal field.

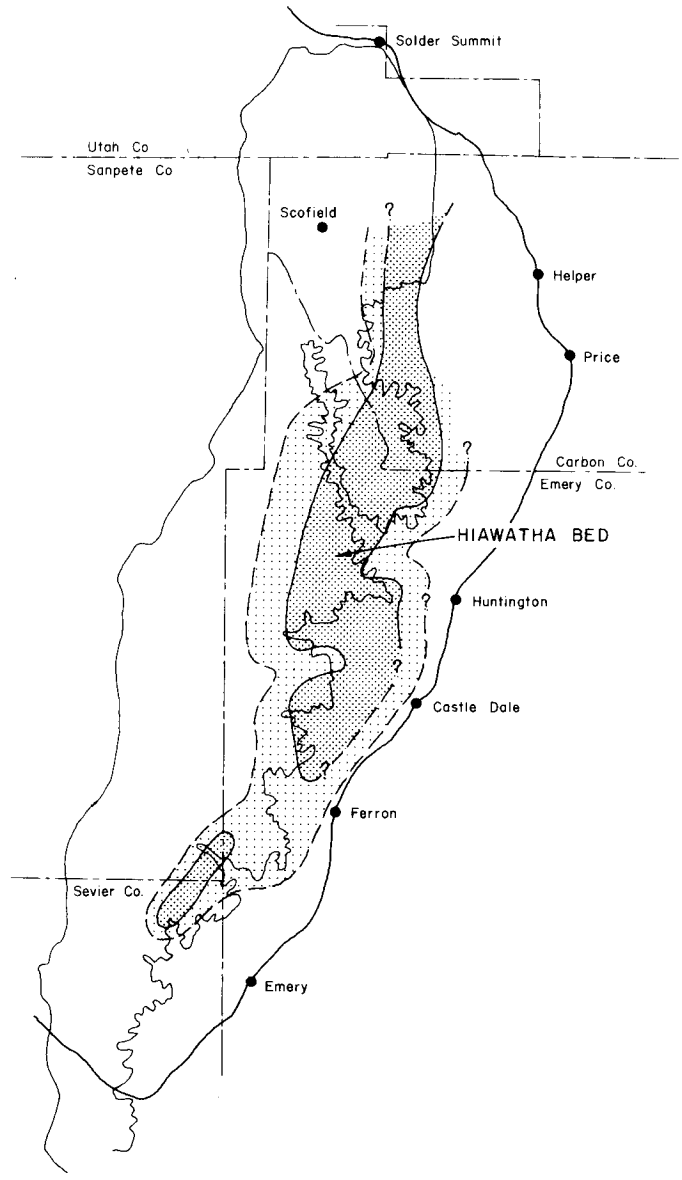


Figure 19. Approximate area of Hiawatha coal bed development, Wasatch Plateau coal field.

Castlegate "A" is found up to 19 feet thick, 160 to 210 feet above the Star Point Sandstone.

Other beds include:

Coal Bed	Area of Importance
Bear Canyon bed	Cottonwood-Huntington Canyon
Upper Bear Canyon bed	Huntington Canyon
Blind Canyon bed	Huntington and Cottonwood Canyon
Bob Wright coal zone	Gordon Creek and Pleasant Valley
Candland bed	Huntington Canyon
Cottonwood bed	Cottonwood Canyon
Fourth bed	Huntington Canyon
Gordon bed	Gordon Creek
Haley bed	Pleasant Valley
Ivie bed	South
Upper Ivie bed	South
Muddy No. 1 bed	Flagstaff Peak
Muddy No. 2 bed	South
Second bed	Hiawatha
Slide Hollow bed	Flagstaff Peak
Tank bed	Hiawatha
Third bed	Huntington Canyon
Union Pacific bed	Pleasant Valley
Upper bed of Grimes Wash	Cottonwood Canyon
Upper Hiawatha bed	Cottonwood Canyon, Flagstaff Peak, South
Wattis	Hiawatha

Most of these beds are presented on figures 19 and 20 illustrating coal bed development; beds of limited extent are marked with an x. They are discussed in the quadrangle reports. Some local beds attain a thickness of more than 4 feet. Usually they are referred to as upper beds because they have not been explored adequately.

WATER RESOURCES

Subsurface Water

Precipitation that falls on the plateau as snow or rain permeates the more porous sandstones and limestones. The less permeable rocks are the shales. The faster percolation of water in the more permeable media allows less chemical material to be dissolved into the water during its migration through the strata. Where the subterranean flow is impeded there is more time for the chemicals associated with the rock to go into solution. Eventually the water is released to the surface as springs that feed the surface waters.

The Flagstaff Limestone yields water to many springs in the Wasatch Plateau. The water, as tested, contains from 290 to 428 ppm dissolved solids. Limestone is slowly dissolved by water and although the rock appears impermeable it is usually riddled with solution channels. Individual springs in the Flagstaff have yielded up to 1,900 gallons per minute.

The North Horn Formation (Tw) has mixed lithology and alternating aquifers and impermeable beds. Dissolved material in and around the Wasatch Plateau from springs and wells in the North Horn varies from 256 to 562 ppm. In the west of the plateau one spring has produced up to 1,800 gallons per minute.

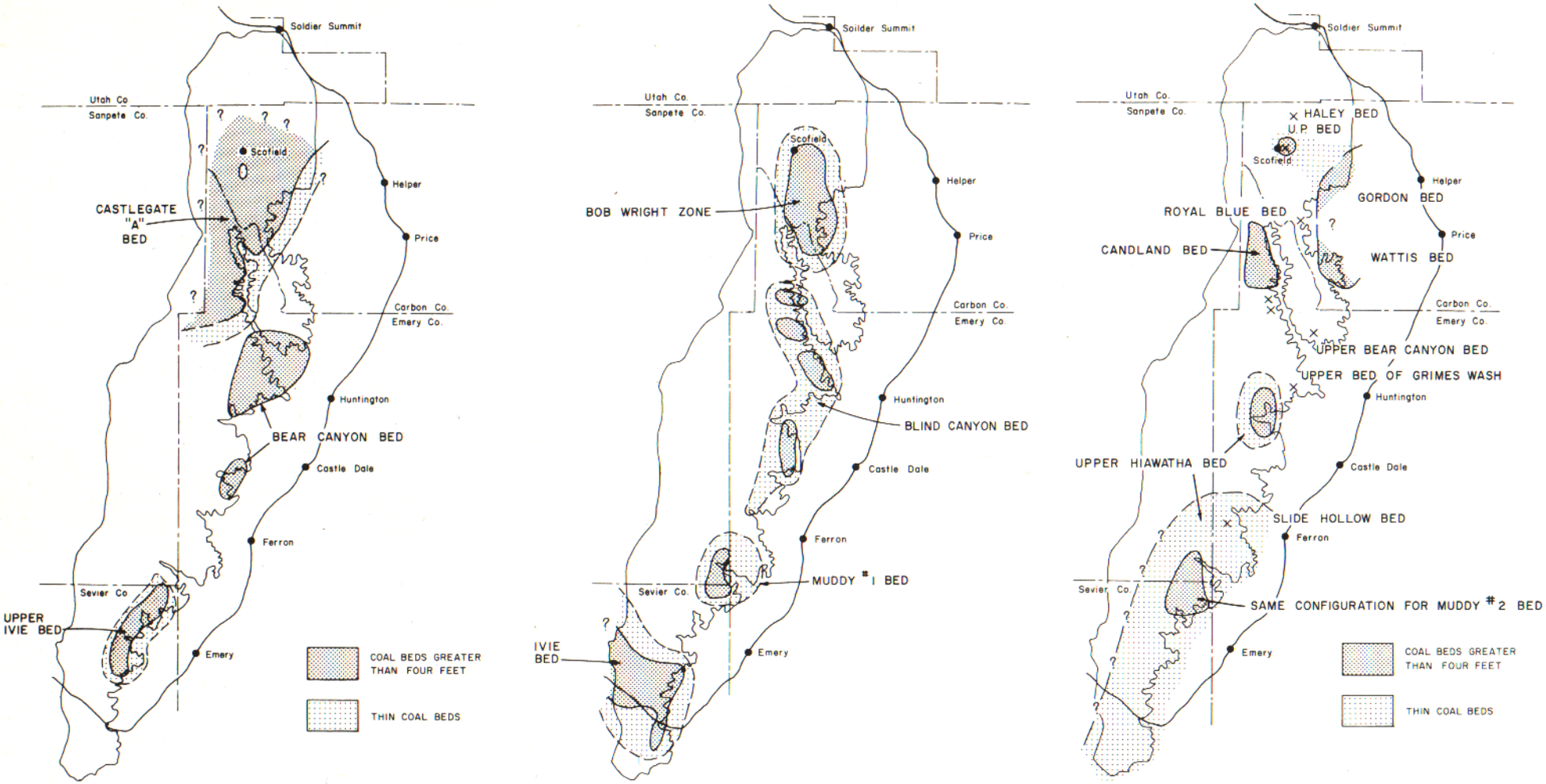


Figure 20. Approximate areas of coal bed development, Wasatch Plateau coal field.

The Price River and Castlegate sandstones yield fresh water to springs at several localities in the Wasatch Plateau. Dissolved solids content ranges from 238 to 303 ppm. Largest flow recorded is 25 gallons per minute.

The Blackhawk Formation has fewer springs than the above formations. In places where wells have been driven, good water has been encountered; in other places the water is somewhat saline. Dissolved solids range from 245 to 903 ppm where tested. A coal mine to the west of the Wasatch Plateau intercepted water flowing 1,600 gpm with over 900 ppm dissolved solids. A gas well in T. 22 S., R. 4 E. tapped water in the Star Point, possibly the Blackhawk, containing 2,384 ppm dissolved solids.

The shale members of the Mancos are aquicludes; they do not carry appreciable quantities of water and actually act as barriers. If springs issued from the unit, they would be from the sandy units, the water would contain a large amount of dissolved material and the flow would be small.

The Emery Sandstone Member of the Mancos Shale has produced fresh to slightly saline water from gas wells with a dissolved solids content from 421 to 1,793 ppm. One well produced up to 600 gpm. The Ferron Sandstone Member is similar to the Emery in its water-bearing characteristics. Data for the Ferron come mainly from oil and gas wells that produce water. They produced water that contained dissolved solids ranging from 63 to 25,931 ppm at a maximum rate of only 75 gpm. Average mineral content is estimated about 5,000 ppm.

The water percolates into the formations through interconnected pore spaces, bedding planes, fractures in the rock and also through the highly fractured fault zones. Too much water could be a problem to mining and a hazard near fault zones.

Surface Water

Usually a permanent stream in the major canyons cuts into the Wasatch Plateau. The smaller canyons have intermittent streams or are mostly dry except during periods of heavy summer rainfall and flash floods. From north to south the streams of consequence include the Price River, Huntington Creek, Cottonwood Creek, Ferron Creek, Muddy Creek, Quitchupah Creek and Ivie Creek.

During the water years 1939 to 1957 the Price River, measured at a point just above the Scofield Reservoir in the Pleasant Valley area, discharged an average of 47.52 cubic feet per second of water. The average annual flow fluctuated from a low of 27.40 cfs to a high of 107.70 cfs. The river at that point drains about 62 square miles. The White River joins the Price River near Colton and drains about 53 square miles. During the water years 1940 to 1957 the flow ranged on a yearly average basis from 8.38 to 66.33 cfs. The average flow for all years was 20.79 cfs. The Price River near Helper, Utah, drains about 530 square miles and during the water years 1914 to 1934 flowed at an average annual rate of 137.74 cfs ranging from 42.12 to 273.52 cfs. From 1935 to 1957 the check on flow was made at Heiner, a few miles upstream from Helper where the Price River drains 455 square miles. During those years the average annual flow ranged from 66.58 to 311.14 cfs and averaged 113.70 cfs.

Huntington Creek measured near Huntington drains about 188 square miles. In 42 years the average annual flow was 98.63 cfs ranging from about 35.6 to 208.2 cfs. Cottonwood Creek drains 200 square miles near Orangeville and in 40 years the average annual flow was 104.1 cfs with an annual range from 32.9 to 46.6 cfs.

Ferron Creek in 22 years had an average annual flow of 72.6 cfs (38.4 to 131.5) and Muddy Creek in 11 years of measurement had an average annual flow of 41.1 cfs (20.0 to 82.2). Ferron Creek drains 57 square miles near Ferron and Muddy Creek drains 89 square miles near Emery.

There are no flow figures for Quitchupah and Ivie creeks. At a point where they join, the drainage area for both is about 200 square miles with an area to effectively gain water of about 115 square miles. If the flow of these two streams is correlated by drainage area the flow should be about 60.3 cfs in an average year.

The water for all creeks in the area of the Wasatch Plateau proper has a low dissolved solids content (figure 21); it ranges between 100 and 300 ppm except in the south area where the range is between 10 and 100. The streams flowing across the Mancos Shale pick up chemical matter from irrigation return water and part from the chemical nature of the Mancos. The increase is gradual from 300 ppm to over 1,200 ppm in a west to east direction.

Reservoirs

The Scofield Reservoir in the Pleasant Valley area and the Joes Valley Reservoir in the Cottonwood area are the larger reservoirs constructed in and around the Wasatch Plateau. The Scofield Reservoir has a capacity of 65,784 acre-feet, the Joes Valley 54,610 acre-feet.

Water is used in general mining and cleaning processes in coal production. When coal is used to generate power, large quantities of water can be consumed. The Four Corners Power Plant installed near Farmington, New Mexico, operates with a factor of 0.625 gallons of water consumption per Kwhr generated (625 million gallons per billion Kwhr). Six hundred and twenty-five million gallons equal about 1,925 acre-feet. In 1966 it had an installed generating capacity of 633.6 megawatts and produced 3,547,700,000 Kwhr using 6,830 acre-feet of water. Utah Power and Light Co. announced a new powerplant with plans to achieve full production by 1975. It will have a generating capacity of 2,000 megawatts and consume about 22,000 acre-feet of water. The new reservoir being built in lower Huntington Canyon by Utah Power and Light Co. has a proposed capacity of 30,000 acre-feet.

ECONOMIC CONSIDERATIONS AND FORECAST

Coal production has dominated in the north half of the field where most of the thicker coal seams of the Wasatch Plateau coal field occur. Access to transportation routes and markets is also more convenient in this part of the field.

The cost of producing coal under even the most efficient methods is estimated to be $5.00 per ton. Equipment, safety and pollution control costs continue to rise and costs are expected to rise to $5.50 to $6.00 or more in a few years. Wasatch Plateau coal must be mined underground and coal reserves with little overburden are rapidly becoming depleted.

Geologic factors which influence costs, mining and the effective use of reserves include: heavy overburden mining, rock falls from bad rock, splits, etc., "wants", burned coal, multiple coal seams, variable dip and undulations of coal seams (floor and roof), methane gas accumulation, variable seam thickness, too much or not enough water and faulting.

Much of the easy-to-get coal already has been mined. Locally some thick-seamed coal with little cover or that is strippable remains. By far the better reserve is under more than 1,000 feet of cover. As mining proceeds deeper the distance of haulage increases, pockets of methane gas tend to accumulate and the possibility of coal mine "earthquakes" increases. Coursing of strong ventilation currents to dispel the gas under heavy cover is costly and delays mining operations.

Rock falls, splits, rock spars in seams, and rock and clay impurities from floors under seams add to mining and preparation difficulties. Islands of rock replacing portions of coal seams ("wants") reduce coal recovery; many are present in the King

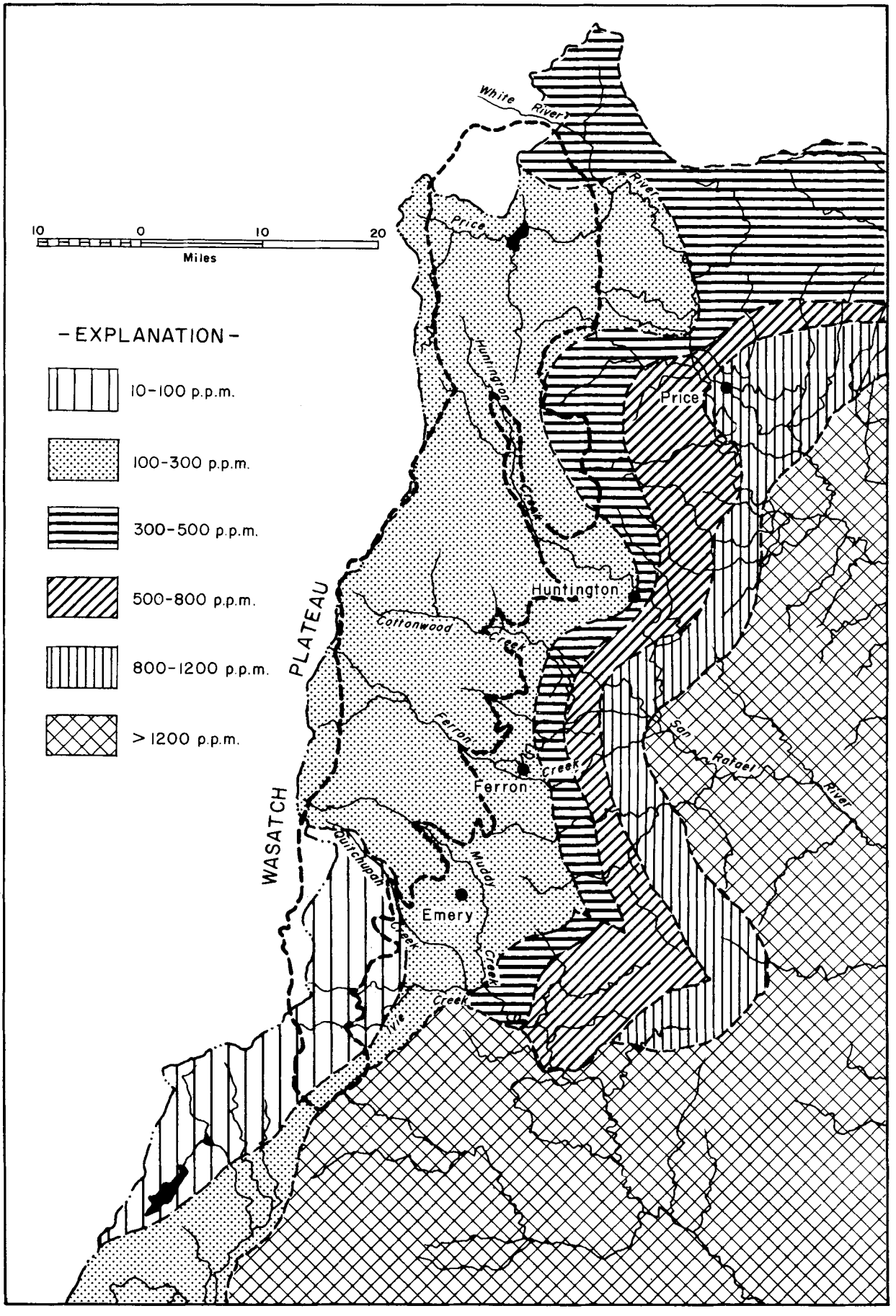


Figure 21. Dissolved solids, weighted-average concentration of surface waters (after Iorns and others, 1964).

mine of U. S. Fuel. Burned coal area extending from coal outcrops varies from a few feet to ½ mile in width depending on local conditions. All mines bounded by outcrop lines are affected.

In some areas the thicker coal seams come close together. Thus some seams are unminable. Where thick seams occur one over the other, only one is considered minable unless solid pillars are superimposed carefully over lower pillars; even then coal extraction from either seam is reduced. The character of the interval determines the safe thickness between seams.

Variable dip, fluctuating thickness of the coal seam and undulating coal require frequent changes in mining plans to accommodate mining machinery and to solve problems of ventilating and dewatering the mine. Haulage is impeded and special grading within the mine often is required.

Many faults in the Wasatch Plateau field displace the coal; locally extensive shearing and crushing along the fault plane reduce the volume of minable coal. Faults are avenues for underground water, in places dewatering the rock and in others channeling the water in.

Recoverability of Wasatch Plateau coal varies from 33 1/3 percent to more than 90 percent. It is expected to average 50 percent or more in the north part of the field and about 40 percent in the south. This, of course, involves single seam estimations; the extraction of the total reserve will be about 30 percent.

Important mining in the Wasatch Plateau began in the Pleasant Valley area because of its proximity to the Salt Lake City market. After the turn of the century, impetus shifted to the Hiawatha area. Both areas remained important until 1960 when most of the easy coal had been removed at Pleasant Valley. In 1900 practically all the coal produced was used in-state in space heating. Gradually markets outside the state developed for space heating and coal-fired steam railroads. This trend continued until 1930 when rival energy sources began to make inroads into the space heating market; dieselization of railroads began cutting into the transportation market. At present coal from the Wasatch Plateau is consumed in space heating, power generation and export.

The low demand for coal is expected to rise as the nation's power demands increase. With the emphasis on air pollution the plateau's low sulfur content has been examined carefully in recent years. By 1975 a new 2,000-megawatt powerplant will be operating at the mouth of Hungtington Canyon consuming 1.2 million tons annually. This indicates that production will double for the field in 5 years. Thereafter the increase will be slower but steady.

Utah Power and Light Co. administration building for new power plant, looking north near the mouth of Huntington Canyon. Masuk Shale is at base of cliff followed by several cliff-forming sandstones of the Star Point Sandstone. The coal-bearing Blackhawk is at the top.

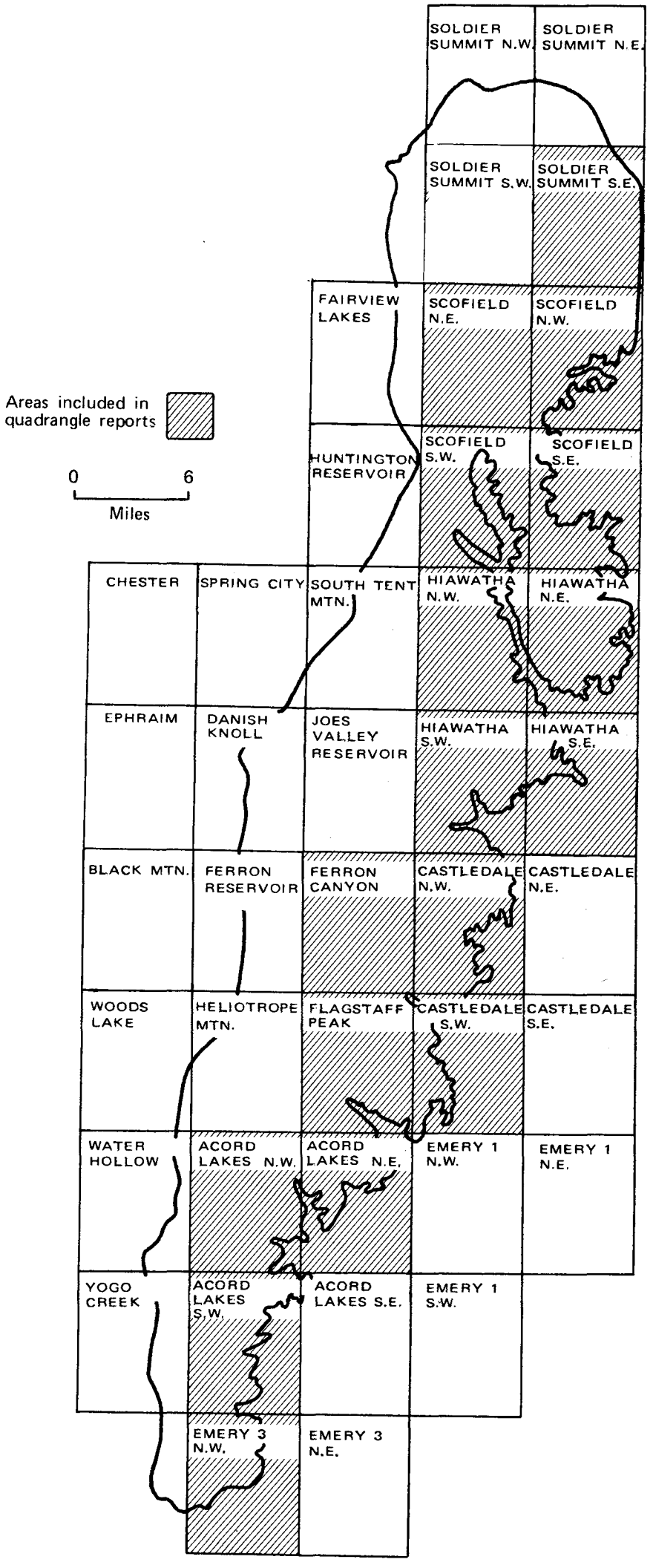


Figure 22. Quadrangle index map, Wasatch Plateau coal field.

QUADRANGLE REPORTS

ACORD LAKES NE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Acord Lakes NE quadrangle is in the south third of the Wasatch Plateau coal field; parts of Sevier and Emery counties are represented on the map (figures 22 and 23). The town of Emery is located along the east edge of the map about 50 miles south of Price and the railroad; Utah Highway 10 cuts across the southeast corner. Salina is about 40 miles west. Unimproved roads and a jeep trail join Emery with the cliffs. The upper Wasatch Plateau surface is mainly in the northwest corner of the map and takes in about one-third of the land area. The cliffs have an average relief of 2,000 feet. Below the cliffs the land is rugged with rounded and dissected benches and a few lower cliffs. Only in the southeast corner is the land relatively flat (Castle Valley).

Elevations range from 6,100 feet in Castle Valley to a little more than 9,000 feet at Wildcat Knolls on the plateau. Coal exposures occur between 7,300 and 8,000 feet except in the fault blocks to the east (6,500 to 7,200 feet).

STRATIGRAPHY

The usual suite of rock formations is present on the quadrangle. The oldest unit, the Mancos Shale, outcrops below the major cliff. The cliff itself and the higher parts caught in the fault blocks are of the Mesaverde Group. The upper surface of the plateau is made up of the Price River Formation, the youngest consolidated unit. The exposed units are listed below with their approximate thicknesses. The important Blackhawk Formation bears the coal in its lower part. All units are upper Cretaceous in age.

Formation	Approximate thickness (feet)	Remarks
Price River Formation	Incomplete	On Wasatch Plateau
Castlegate Sandstone	200- 250	
Blackhawk Formation	850-	Coal in lower part of cliff
Star Point Sandstone	200- 300	
Mancos Shale		
Masuk Shale Member	600-1,000	Thickens to north below cliff
Emery Sandstone Member	800-	
Blue Gate Shale Member	1,650	

STRUCTURE

The Wasatch Plateau is free of faults on the quadrangle but the Joes Valley fault zone cuts across the map just west of Emery. There are as many as six faults with the strata dropped graben-fashion between them. The east and west boundary faults have displacements of at least 1,000 feet. Coal is exposed in fault blocks 1/4 to 3/4 mile wide. The rocks are badly shattered in many places and the coal may be unminable.

Gently inclined strata dip about 2 degrees to the northwest.

PROPERTY CONTROL

Most of the coal land, 41.7 percent of the quadrangle area, is in the National Forest; a few promontories project into Bureau of Land Management controlled acreage. Except for a block of private land in Quitchupah Canyon, all of the land is below the cliffs. Bureau of Land Management owns 41.5 percent, National Forest Service 39.2 percent, private property 14.1 percent and state of Utah 5.2 percent. Only 376 acres are held for coal in two separate areas–one at the head of Link Canyon and the other near the head of Quitchupah Canyon. This acreage is held (1970) by Heiner Coal Co. and others and amounts to 2.4 percent of the coal land.

COAL

Surface Information

An approximate section showing the position of coal beds in the column indicates the presence of four important beds.

	Feet
Upper beds	
Interval	85
Upper Ivie bed	0-4
Interval	5
Muddy No. 2 bed	0-6
Interval	35
Upper Hiawatha bed	1-15
Interval	25
Hiawatha bed	0-7
Star Point Sandstone	

Thirty-six sections are devoted to the Upper Hiawatha and Hiawatha bed indicating the presence of individual coal seams to 15 feet thick (figure 24). The Hiawatha is mostly less than 4 feet thick except in Quitchupah Canyon where it may be as thick as 7 feet. The Upper Hiawatha is best developed in Quitchupah Canyon (at least 15 feet) and at the head of Link Canyon. Elsewhere it is thin.

The only available section of the Muddy No. 2 bed (figure 24) is located on the promontory between Link and Quitchupah canyons. It is more than 6 feet thick. The available section of the Upper Ivie bed is near the Muddy No. 2 measurement. The coal is a little less than 4 feet thick. These two beds may be of greater importance since outcrops to the west are obscured by burning and measurements are unattainable.

Beds higher in the column are usually too thin or too lenticular to be of importance.

Subsurface Information

Drill-hole data are unavailable but surface information reflects the condition of the subsurface coal. Only the northwest corner of the area is inferred reserve. All the coal is under less than 2,000 feet of cover; 42.8 percent between 1,000 and 2,000 feet and 57.2 percent under less than 1,000 feet of cover.

Quality of Coal

There are seven available analyses, all from the Upper Hiawatha at the Link Canyon mine (table 14). Table 15 gives sulfur-type determinations of the coal.

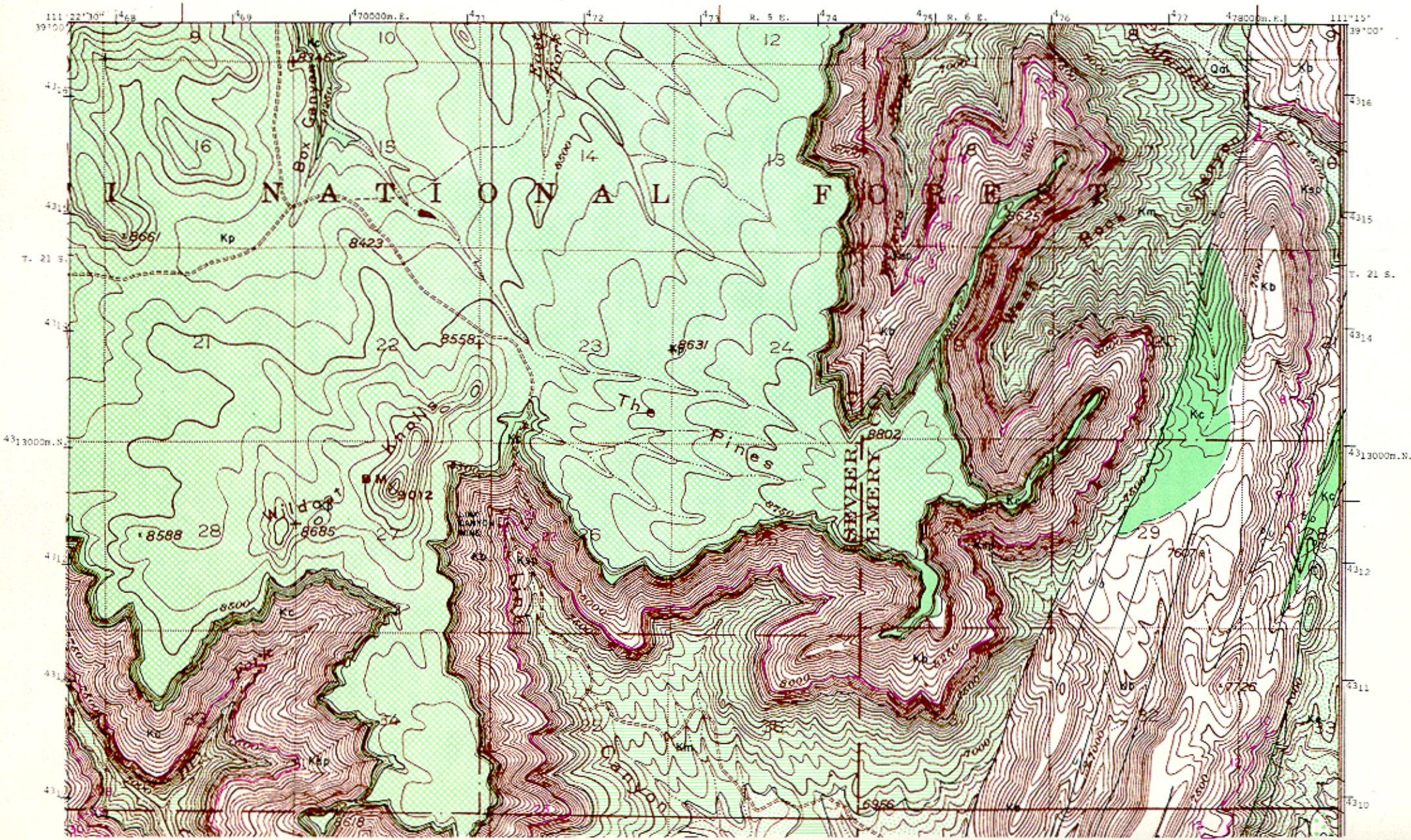
Table 14. Average coal analyses, Acord Lakes NE quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	7	8.3	7.0-12.9
Volatile matter	5	38.1	37.5-38.6
Fixed carbon	5	46.0	45.3-46.4
Ash	7	8.0	5.4-10.0
Sulfur	7	0.42	0.4- 0.5
Btu/lb	5	11,674	11,570-11,770

Table 15. Sulfur-type determinations of coal, Acord Lakes NE quadrangle (Walker and Hartner, 1966, p. 38).

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Link Canyon	Upper Ivie	0.41	0.00	0.05	0.36
Link Canyon	Upper Ivie	0.45	0.01	0.09	0.35

ACORD LAKES N.E., UTAH



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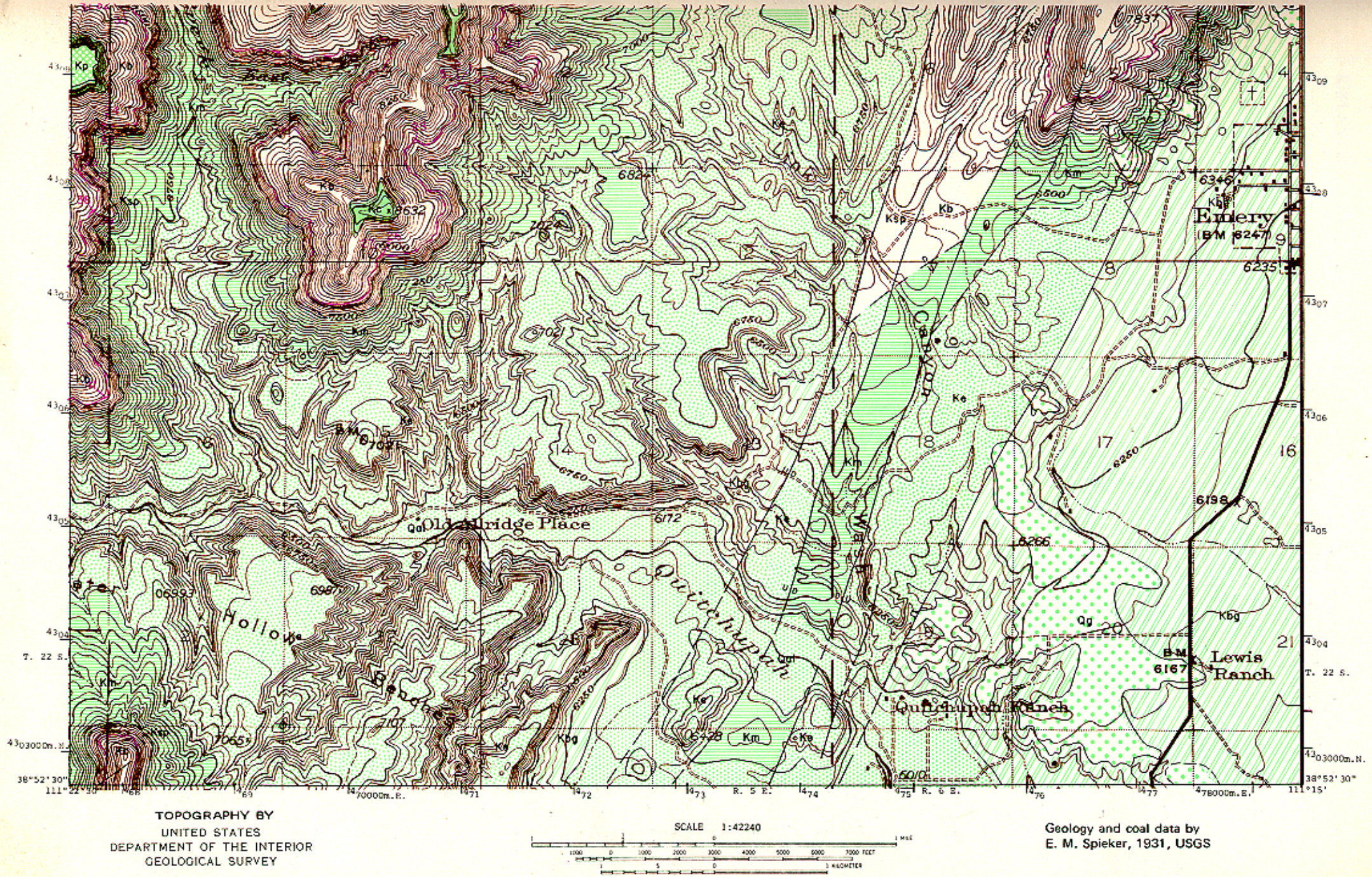


Figure 23. Coal and geology map, Acord Lakes NE quadrangle (explanation pages 136-137).

EXPLANATION (figures 23, 25, 27, 29, 31, 33, 35, 38, 40, 42, 44, 46, 48, 51, 53, 55 and 57)

32 LO — Purple — Coal bed
Dashed where inferred or poorly exposed, dotted where burned. Thickness of coal in feet measured at triangles. Larger numbers refer to location of measured section shown on accompanying sheets.

Prospect

Coal mine

Purple — Burned zone
Area covered with natural clinker or red-burned sandstone.

DH — Coal drill hole

3 — Strike and dip of beds

Apparent dip of beds

Syncline
Axis, dashed where approximately located or where ill defined.

Anticline
Axis, dashed where approximately located or where ill defined.

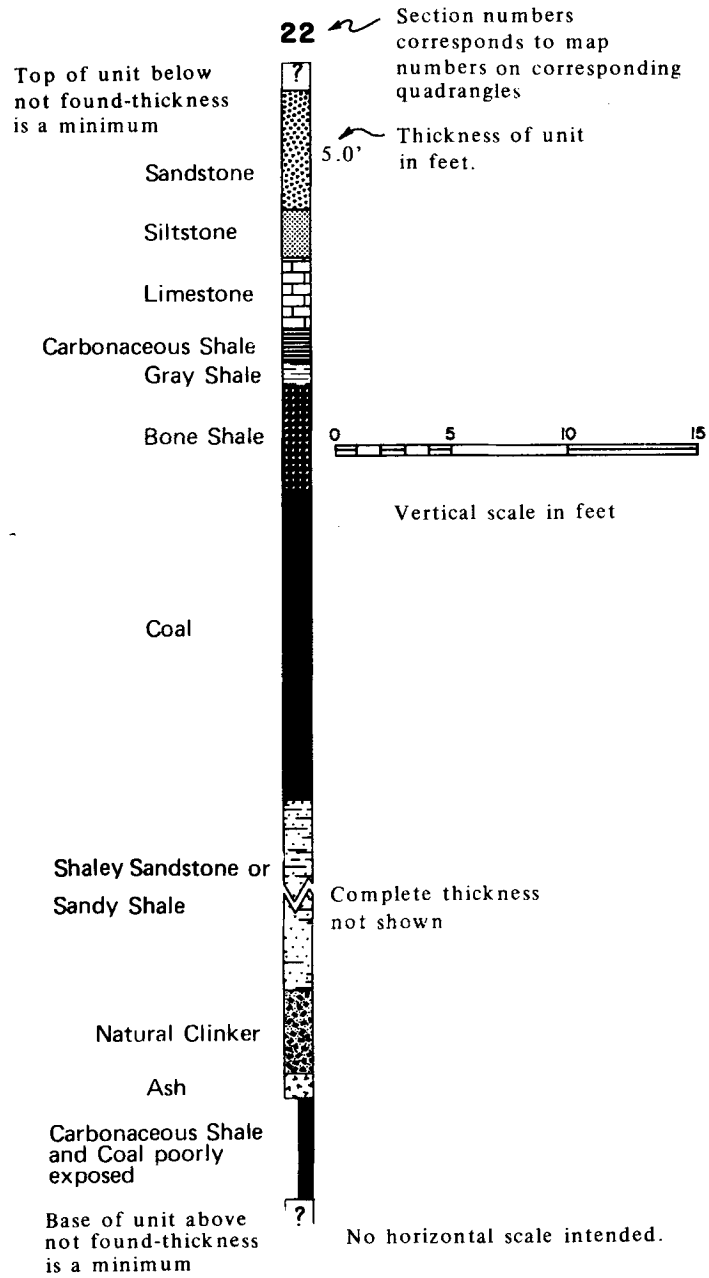
Monocline
Arrow points in direction of dip, dashed where approximately located or where ill defined.

Geologic unit contact
Dashed where location is approximate.

Horizontal strata

D — U — Fault
Dashed where inferred or ill defined.

Explanation For Measured Sections



EXPLANATION (continued)

QUATERNARY

Qal — **Alluvium**
Stratified clay, silt, sand, gravel and some unsorted flood deposits.

Ql — **Landslide Deposits**
Mixed rubble and blocks of material slumped from formations at higher elevations.

Qg — **Gravel Deposits**
Partly consolidated poorly sorted and stratified deposits of rock fragments of local origin, pediments or terrace, up to 75 feet thick.

TERTIARY

Tv — **Volcanic Flows**
Bullion Canyon Series, volcanic flows.

Tg — **Green River Formation**
Chiefly greenish lacustrine shale and siltstone.

Tc — **Colton Formation**
Varicolored shale with sandstone and limestone lenses, thickest to the north. 300-1,500 feet.

Tf — **Flagstaff Formation**
Dark yellow-gray to cream limestone, evenly bedded with minor amounts of sandstone, shale and volcanic ash, ledge former. 200-1,500 feet.

TERTIARY
CRETACEOUS

Tw — **North Horn Formation**
Variegated shales with subordinate sandstone, conglomerate and freshwater limestone, thickens to north, slope former. 500-2,500 feet.

Kp — **Price River Formation**
Gray to white gritty sandstone interbedded with subordinate shale and conglomerate, ledge and slope former. 200-1,000 feet.

Kc — **Castlegate Sandstone**
White to gray, coarse-grained often conglomeratic sandstone, cliff former, weathers to shades of brown. 150-500 feet.

-Unconformity-

Kb — **Blackhawk Formation**
Yellow to gray, fine- to medium-grained sandstone, interbedded with subordinate gray and carbonaceous shale, several thick coal seams. 600-1,500 feet.

Ksp — **Star Point Sandstone**
Yellow-gray massive cliff-forming sandstone, often in several tongues separated by Masuk Shale, thickens westward. 90-1,000 feet.

Km — **Masuk Shale**
Yellow to blue-gray sandy shale, slope former, thick in north and central plateau area thins southward. 300-1,300 feet.

Ke — **Emery Sandstone**
Yellow-gray friable sandstone tongue or tongues, cliff former, may contain coal (?) in south part of plateau if mapping is correct, thickens to west and south. Coal may be present in subsurface to west. 50-800 feet.

Kbg — **Blue Gate Shale**
Pale blue-gray, nodular and irregularly bedded marine mudstone and siltstone with several arenaceous beds, weathers into low rolling hills and badlands, thickens northerly. 1,500-2,800 feet.

Kf — **Ferron Sandstone**
Alternating yellow-gray sandstone, sandy shale and gray shale with important coal beds of Emery coal field, resistant cliff former, thickens to the south. 50-950 feet.

Kt — **Tununk Shale**
Blue-gray to black sandy marine slope forming mudstone. 400-650 feet.

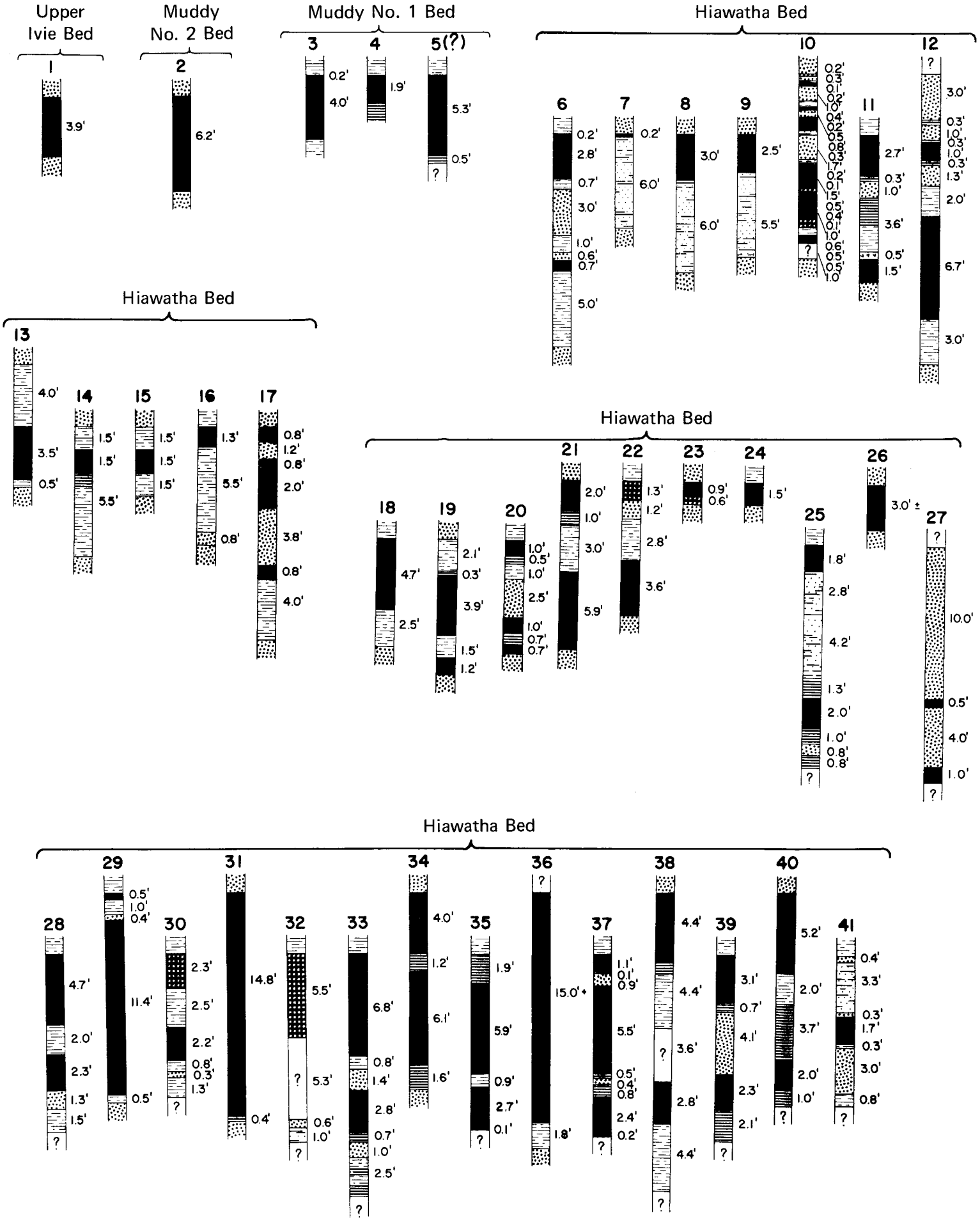


Figure 24. Coal sections of Acord Lakes NE quadrangle (vertical scale: 1 inch = 8 feet).

Table 5 gives individual analyses for the mines and prospects in the quadrangle.

Gomez, Landers and Boyd (1967, p. 12) calculated carbonization product yields for the Link Canyon mine coal (end carbonization temperature 500° C; table 16).

Table 16. Carbonization product yields, Link Canyon mine coal, Acord Lakes NE quadrangle.

Carbonization yields, wt. percent of maf coal				Gas vol. scf/lb maf coal	Heating value of gas Btu/scf
Char	Water of decomposition	Tar plus light oil	Gas		
74.0	5.9	14.3	6.0	1,048	739

Mines and Development

The only important mine opened on the quadrangle is the Link Canyon mine, SW. NW. 26-21S-5E., 4,312,300mN. 471,300m.E. It operated from 1940 to 1952 when about 164,000 tons were produced from the Upper Hiawatha bed. The bed is about 8 feet thick at the mine portal.

Reserves

Reserves in beds more than 4 feet thick are spotty. The best area appears in and around Quitchupah Canyon and at the head of Link Canyon (table 17).

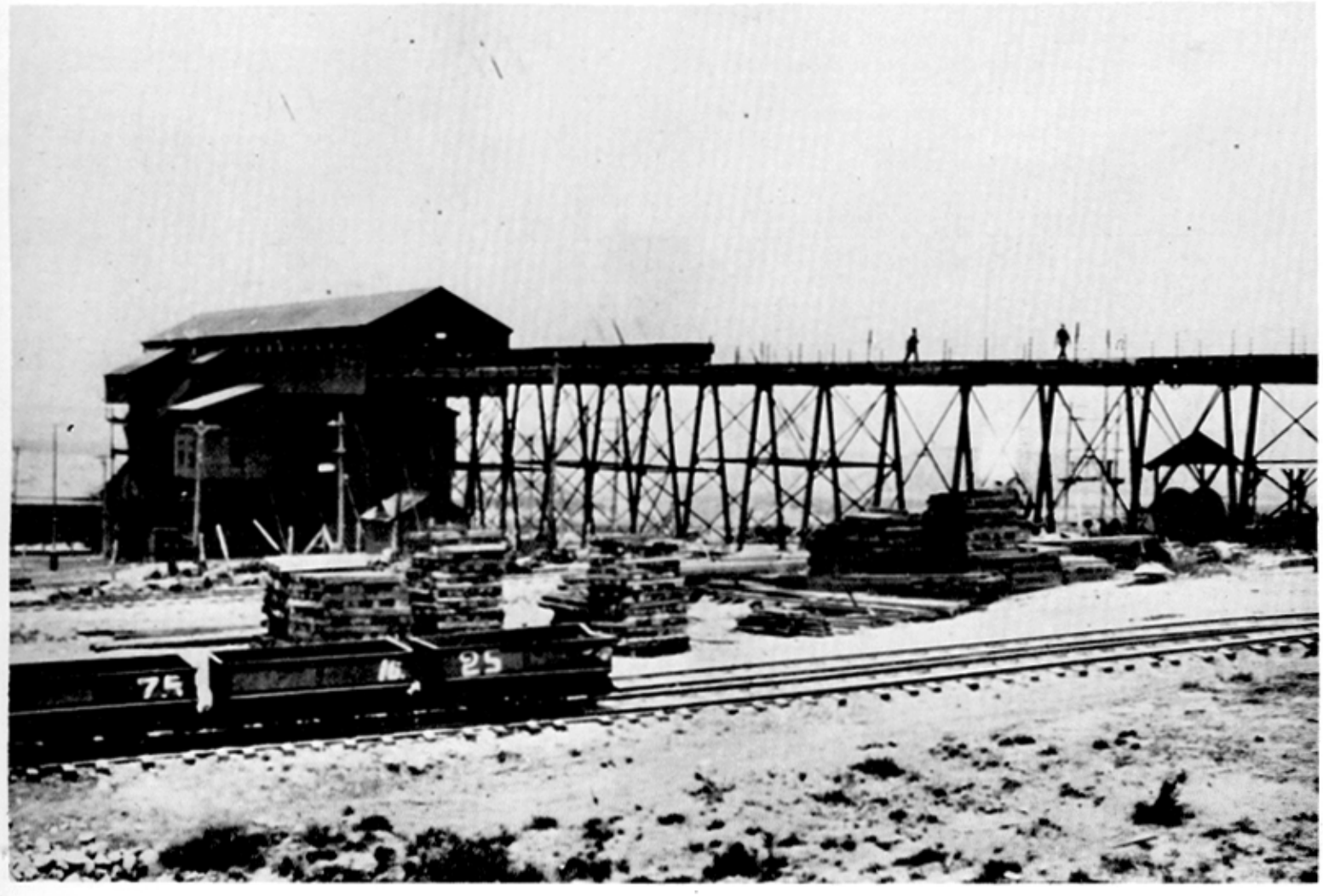
With an assumed recoverability of 50 percent, 82 million tons could be extracted from the quadrangle; at one-third recoverability the figure is 55 million tons.

Table 17. Coal reserves of the Acord Lakes NE quadrangle.

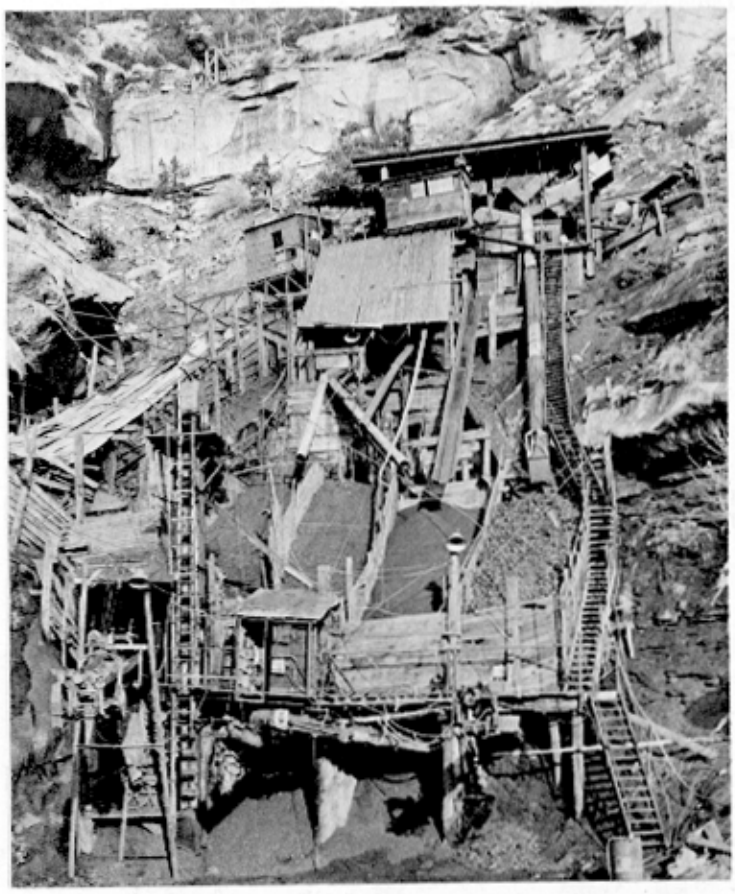
Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.21S. R.5E.	450	4.5	3,645,000	Hiawatha bed sec. 29, 32, 33
	2,130	8.0	30,672,000	Upper Hiawatha bed secs. 19-22, 27-34
	400	14.0	10,080,000	Upper Hiawatha bed secs. 29, 32, 33
	1,435	5.0	12,915,000	Muddy No. 1 bed secs. 11-14, 24
	955	4.0	6,876,000	Muddy No. 2 bed secs. 11-13
	3,900	6.0	42,120,000	Upper beds-southern 1/3 of Twp.
	1,626	17.0	49,755,600	All beds secs. 8-10-15-17
T.21S. R.6E.	173	4.0	1,245,600	Muddy No. 2 bed
T.22S. R.5E.	185	7.0	2,331,000	Hiawatha secs. 4, 5, 8
	140	5.0	1,260,000	Hiawatha secs. 5-8
	185	12.0	3,996,000	Upper Hiawatha bed secs. 4, 5, 8
		Total coal	164,896,200	

PRINCIPAL WORK

Almost all the data presented for this quadrangle report were taken from Spieker's 1931 work on the Wasatch Plateau field.

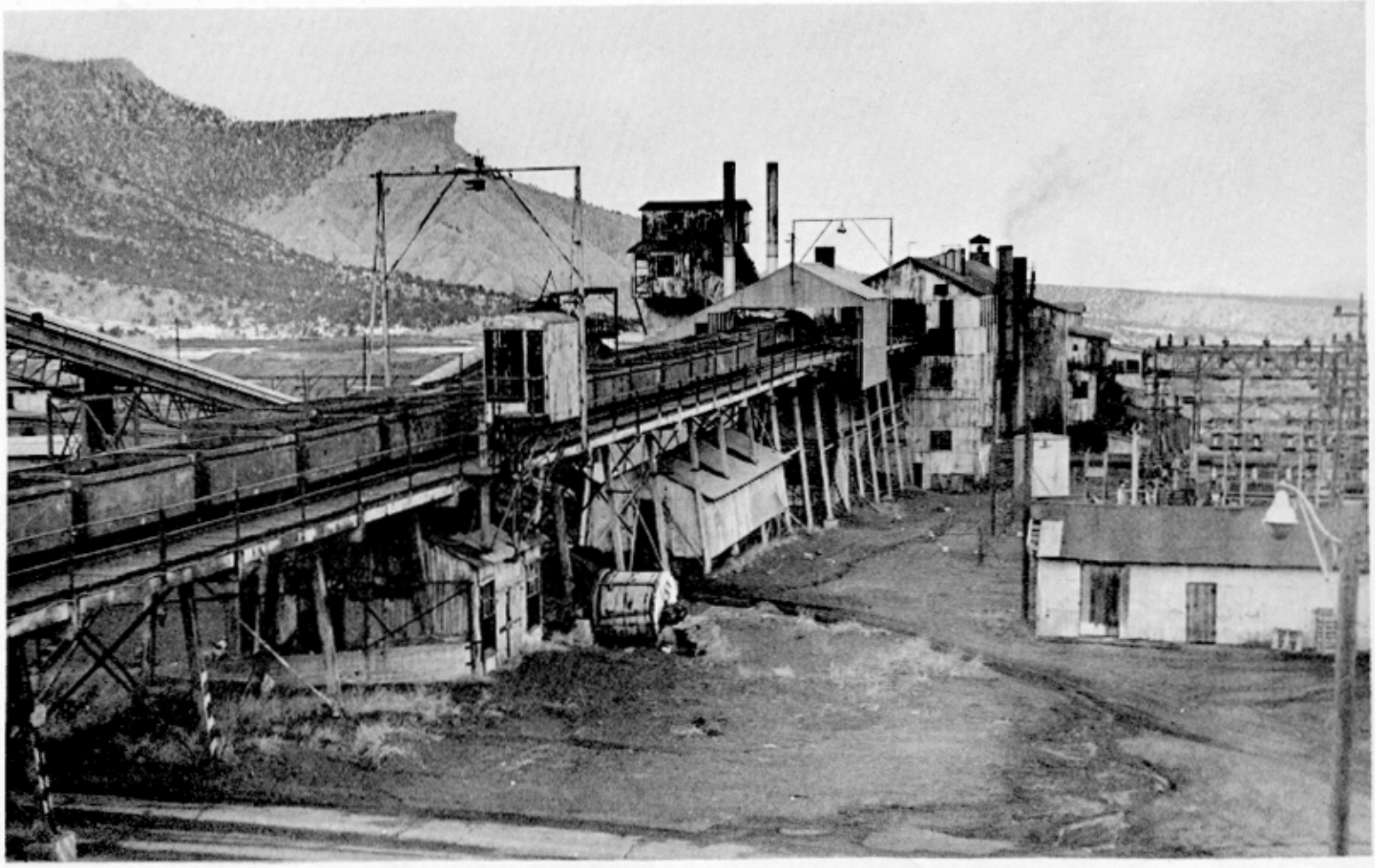


Old tipple at Hiawatha, prior to 1920. Photo from Helper Mining Museum original.



Co-op mine loading paraphernalia in Trail Canyon, tributary to Huntington Canyon.

Portal of King mine (Blackhawk mine) south of Hiawatha.



U. S. Fuel tipple at Hiawatha, February 1972.

ACORD LAKES NW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

This quadrangle is located in the south part of the Wasatch Plateau coal field (figures 22 and 25). The nearest town is Emery 7 miles to the east; Salina, the nearest major town, and the railroad are about 25 miles to the west. Most of the area is represented by a hilly plateau top. Deep canyons cut into the plateau from the southeast. The low elevation at the bottom of Convulsion Canyon is 6,700 feet and the high elevation at White Mountain in the northwest corner is 10,844 feet. The top of the plateau ranges between 8,000 and 9,000 feet for the most part and the coal is exposed in the deep canyon walls between 7,300 and 7,700 feet above sea level.

A jeep road aligned along Convulsion Canyon provides access to Emery. High clearance roads skirt the cliff edge and connect to Utah Highway 10 (Interstate 70) to the southwest and Salina.

STRATIGRAPHY

The normal suite of rock formations are exposed on the Acord Lakes NW quadrangle. The Mancos members–Emery Sandstone and Masuk Shale–are in the bottoms of Convulsion and Water Hollow canyons; the Mesaverde Group–Star Point Sandstone, Blackhawk Formation and Castlegate Sandstone–make up the walls of the deeper canyons and the Price River, North Horn and Flagstaff formations cover the top of the plateau. The younger Flagstaff Limestone occurs only in the northwest map corner at White Mountain. The coal is contained in the lower third of the Blackhawk and is exposed only in the deeper canyons. Thicknesses of the units are shown as follows:

	Feet
Flagstaff Limestone	1,200+
North Horn Formation	1,150
Price River Formation	550
Castlegate Sandstone	90-200
Blackhawk Formation	950
Star Point Sandstone	200-300
Masuk Shale	700
Emery Sandstone	800

STRUCTURE

The Acord Lakes fault is the only important deformation in the area. The amount of displacement is probably equal to the thickness of the Castlegate Sandstone at its maximum point. The strata are inclined about 2 degrees to the west or northwest.

PROPERTY CONTROL

Most of the land is National Forest Service property (81.4 percent) and the next largest block is private property (17.6 percent). The remainder belongs to the Bureau of Land Management and is not coal land. Coal land amounts to 94 percent of the quadrangle. About 12.9 percent of the coal land are held as leases or private fee land (all acreages are approximate and made to fit the quadrangle):

	Feet (approximate)	Type
Southern Utah Fuel	2,300	Lease
	80	Fee
Heiner and others	264	Lease
Nelson	80	Fee
Jesse Knight	1,984	Lease
Jesse Knight	1,984	Lease[1]

[1]Immediately west of the quadrangle.

COAL

Surface Information

An approximate section showing the position of coal in the column indicates the presence of four important beds.

	Feet
Upper beds	
Interval	85
Upper Ivie bed	0-14
Interval	5
Muddy No. 2 bed	0-6
Interval	35
Upper Hiawatha bed	1-17
Interval	25
Hiawatha bed	0-7
Star Point Sandstone	

The condition of both Hiawatha beds is shown in 23 measured sections (figure 26). The lower Hiawatha is mostly too thin to be of value. At the head of Quitchupah Canyon the coal is a little thicker than 7 feet but the bed is split by a band of bone. The Upper Hiawatha is the thickest seam on Acord Lakes NW. Again the thickest seams are located in the area of Quitchupah Canyon. The bed thins elsewhere except in a gulch on the south side of Convulsion Canyon where the bed measures 9 feet.

The Muddy No. 2 bed is valuable in Convulsion Canyon where it averages 4 feet. The Upper Ivie bed is the only one currently mined and this bed is exceptionally thick along a north-south axis along UTM line 464000m.E. The Southern Utah Fuel mine operates in the bed where it is 13 feet thick.

Subsurface Information

More than two-thirds of the quadrangle must be evaluated by inference because of limited drill-hole data; only the east and southeast parts have coal outcrops from which data have been gleaned. Information from two wells located at the south end of Duncan Mountain near Corral Knoll is available. Drill hole 1 in NW SW 5-22S-5E is drilled to a depth of 928.3 feet. Two coal beds of interest are encountered, one at 875.0 feet depth and 1.9 feet thick, the second at 915.8 feet depth and 12.3 feet thick. The latter has a roof consisting of 8.5 feet of sandstone and a floor of carbonaceous shale. The second drill hole in SE NE 7-22S-5E has a depth of 910.5 feet. Shows of coal were recorded at 302, 648, 696, 778, 808, 853 and 885 feet. The latter two exceed 14 inches thick and are believed to be the Upper Hiawatha and the Hiawatha. The Upper Hiawatha is 4.3 feet thick and the lower bed is 2.1 feet thick split in two places by bone and shale. The data correlate well with the surface information.

Of the total coal land, most is under 1,000 to 2,000 feet of cover: 23.6 percent under 0 to 1,000 feet; 64.2 percent, 1,000 to 2,000 feet, 9.6 percent, 2,000 to 3,000 feet and 2.6 percent (White Mountain) more than 3,000 feet.

Quality of Coal

Twelve analyses, all representative of the Upper Ivie bed in Convulsion Canyon, indicate a typical low-sulfur, low-ash coal (table 18).

Table 18. Average coal analyses, Acord Lakes NW quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	12	8.7	5.6-10.4
Volatile matter	11	38.3	36.2-40.6
Fixed carbon	11	46.6	43.3-50.4
Ash	12	6.5	5.9- 7.1
Sulfur	12	0.46	0.3- 0.6
Btu/lb	11	11,770	11,390-12,260

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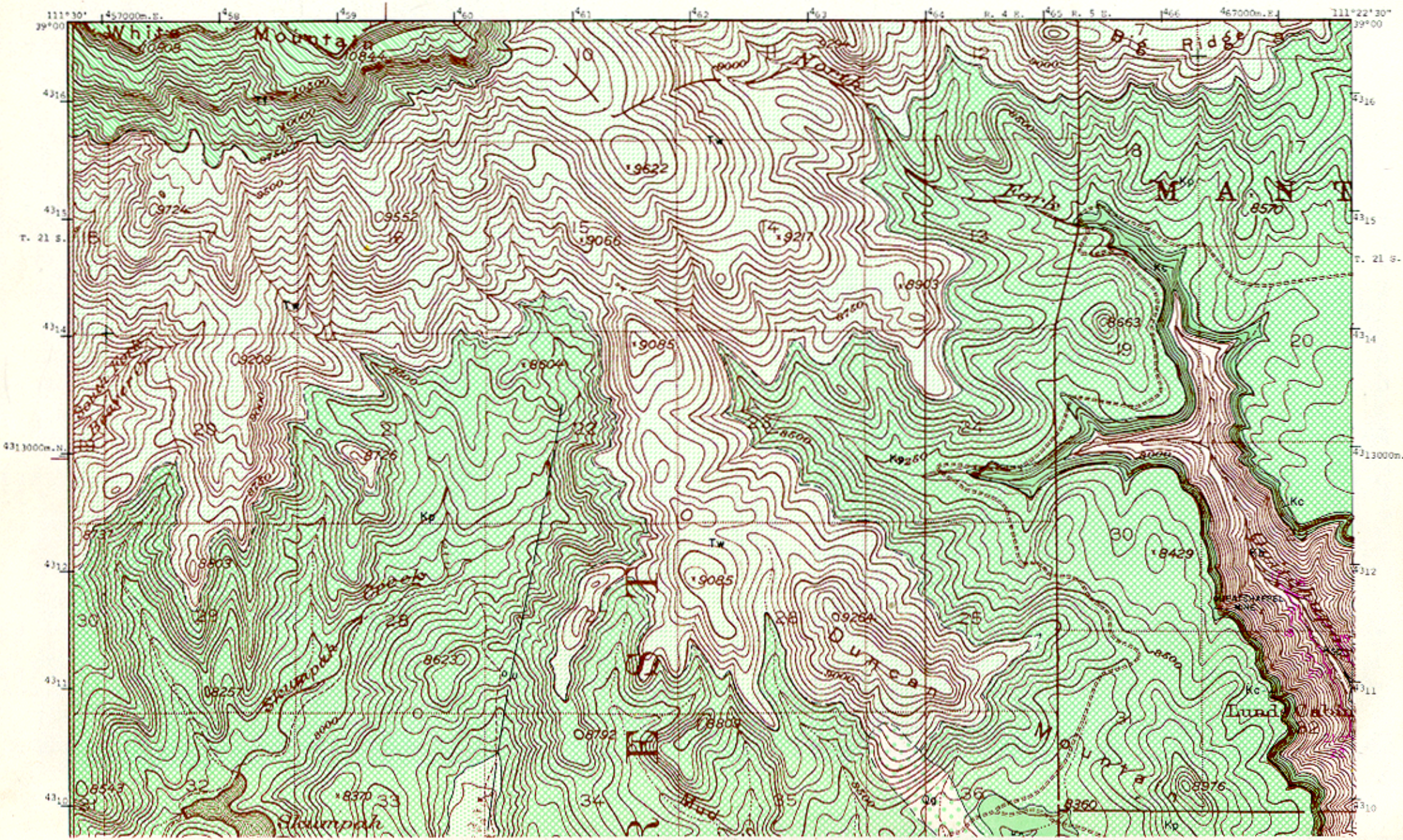

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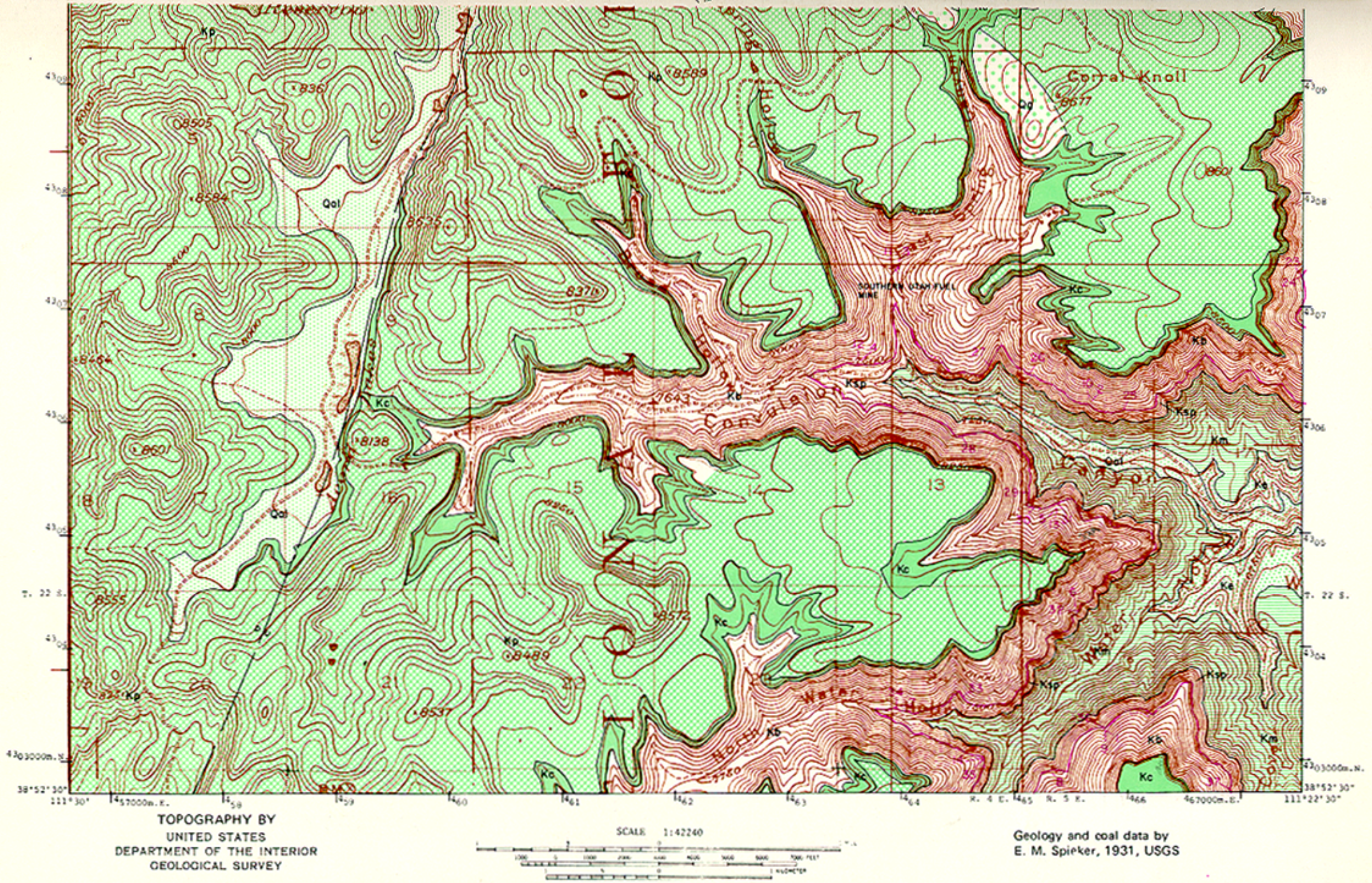


Figure 25. Coal and geology map, Acord Lakes NW quadrangle (explanation pages 136-137).

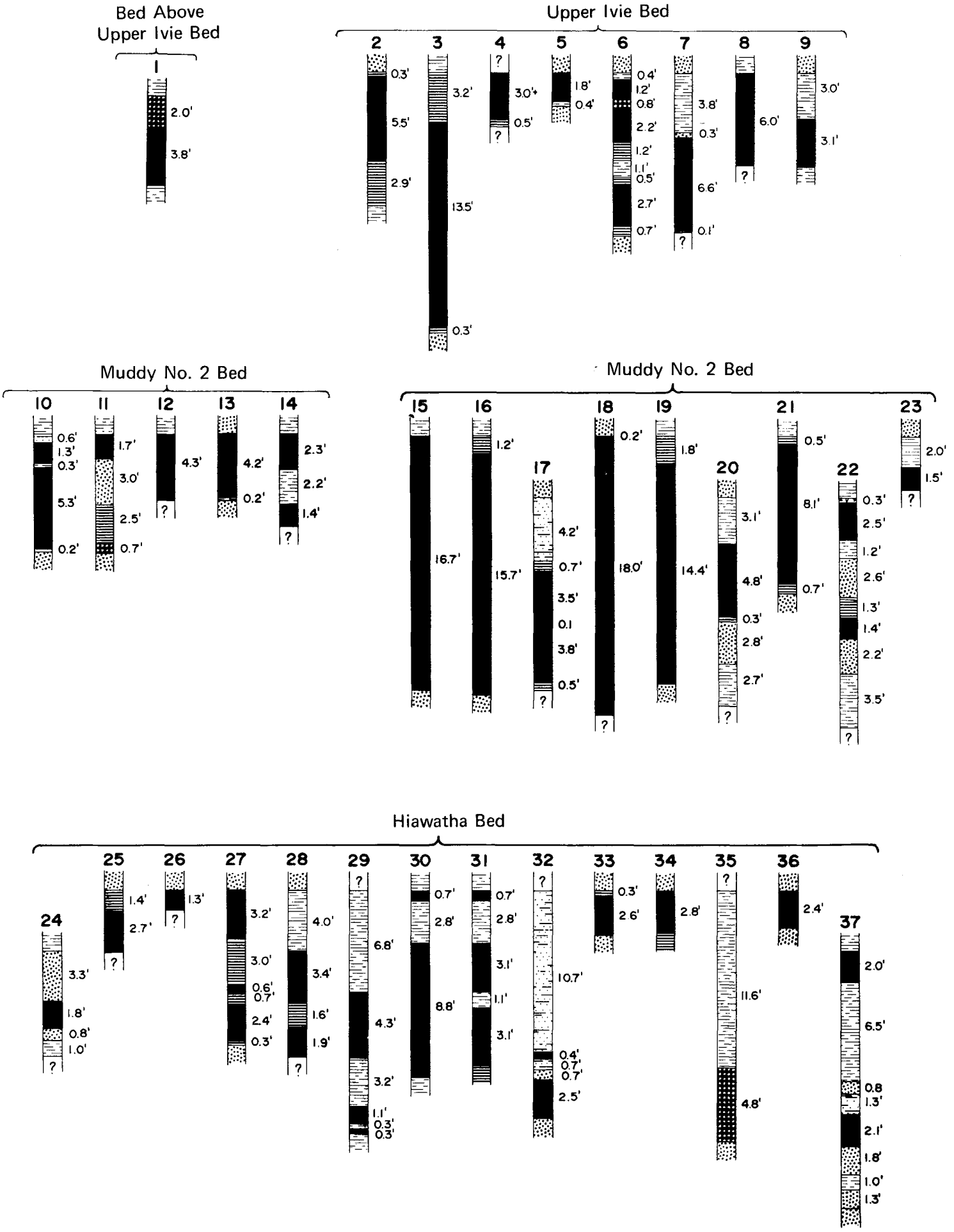


Figure 26. Coal sections of Acord Lakes NW quadrangle (vertical scale: 1 inch = 8 feet).

Table 19 lists sulfur-type determinations for the coal. Gomez, Landers and Boyd (1967, p. 12) calculated carbonization product yields for the Southern Utah Fuel Co. mine coal (end carbonization temperature 500° C; table 20).

Table 19. Sulfur-type determinations of coal, Acord Lakes NW quadrangle (Walker and Hartner, 1966).

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Convulsion	Upper Ivie	0.37	0.01	0.13	0.23

Table 20. Carbonization product yields, Southern Utah Fuel Co. mine, Acord Lakes NW quadrangle.

Carbonization yields, wt. percent of maf coal				Gas vol. scf/lb maf coal	Heating value of gas Btu/scf
Char	Water of decomposition	Tar plus light oil	Gas		
71.9	6.5	14.3	7.0	1.128	695

Mines and Development

The two known mines opened on the Acord Lakes NW quadrangle are the Southern Utah Fuel Co. mine in Spring Canyon, a north-side tributary of Convulsion Canyon, and the Queatch-up-pah Creek mine near the head of Quitchupah Creek (table 21). The Southern Utah Fuel mine is the only active mine on the quadrangle (1970).

Table 21. Mines and their locations, Acord Lakes NW quadrangle.

Mine	Location	Remarks
Queatch-up-pah Creek (Queatchappel)	SE.SW.29-21S-5E 4,311,610m.N. 467,080m.E.	Intermittently active 1901-1920
Southern Utah Fuel Co. (New Salina, Convulsion Canyon, Hanson)	NW.SE.NW.12-22S-4E 4,307,300m.N. 463,910m.E.	Active 1941-1970 1970-operating mine

The Queatch-up-pah Creek mine produced about 6,600 tons in its 20-year history. It is not known which bed was mined, the upper Hiawatha or Upper Ivie bed. The mine is believed in a bed almost 7 feet thick.

The Southern Utah Fuel Co. mine is active in the Upper Ivie bed which is 13½ feet at the portal. The coal bed is reportedly 18 feet thick 3½ miles northwest of the mine in the subsurface. The mine produced 71,523 tons in 1969 and total production is estimated at 1.1 million tons.

Reserves

Spieker's (1931, p. 205) reserves for the Acord Lakes NW quadrangle amount to 491 million tons (table 22).

Table 22. Original reserves in short tons, Acord Lakes NW quadrangle (beds 30 or more inches thick).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.21S. R.4E.	1,760	6.0	19,000,000	Upper Hiawatha SE corner
	6,300	6.0	68,000,000	Upper Ivie SE corner
T.21S. R.5E.	1,450	4.5	11,745,000	Hiawatha secs. 29-32
	1,700	8.0	24,480,000	Upper Hiawatha secs. 19, 20, 29-32
	400	14.0	10,080,000	Upper Hiawatha secs. 29, 32
	2,500	6.0	27,000,000	Upper beds, south 1/3 of Twp.
	1,070	17.0	32,742,000	All beds, part of Twp. not in est. of separate beds
T.22S. R.4E.	13,000	8.0	187,200,000	Ivie bed
	6,860	4.5	55,566,000	Upper Ivie bed all beds
	576	15.0	15,552,000	Western tier in Convulsion area
T.22S. R.5E.	240	7.0	3,024,000	Hiawatha secs. 5, 8
	669	5.0	6,021,000	Hiawatha secs. 5, 8
	240	12.0	5,184,000	Upper Hiawatha secs. 5, 8
	210	5.0	1,890,000	Upper Hiawatha secs. 18, 19
	400	5.0	3,600,000	Muddy No. 2
	2,200	5.0	19,800,000	Upper Ivie
		Total coal	490,884,000	

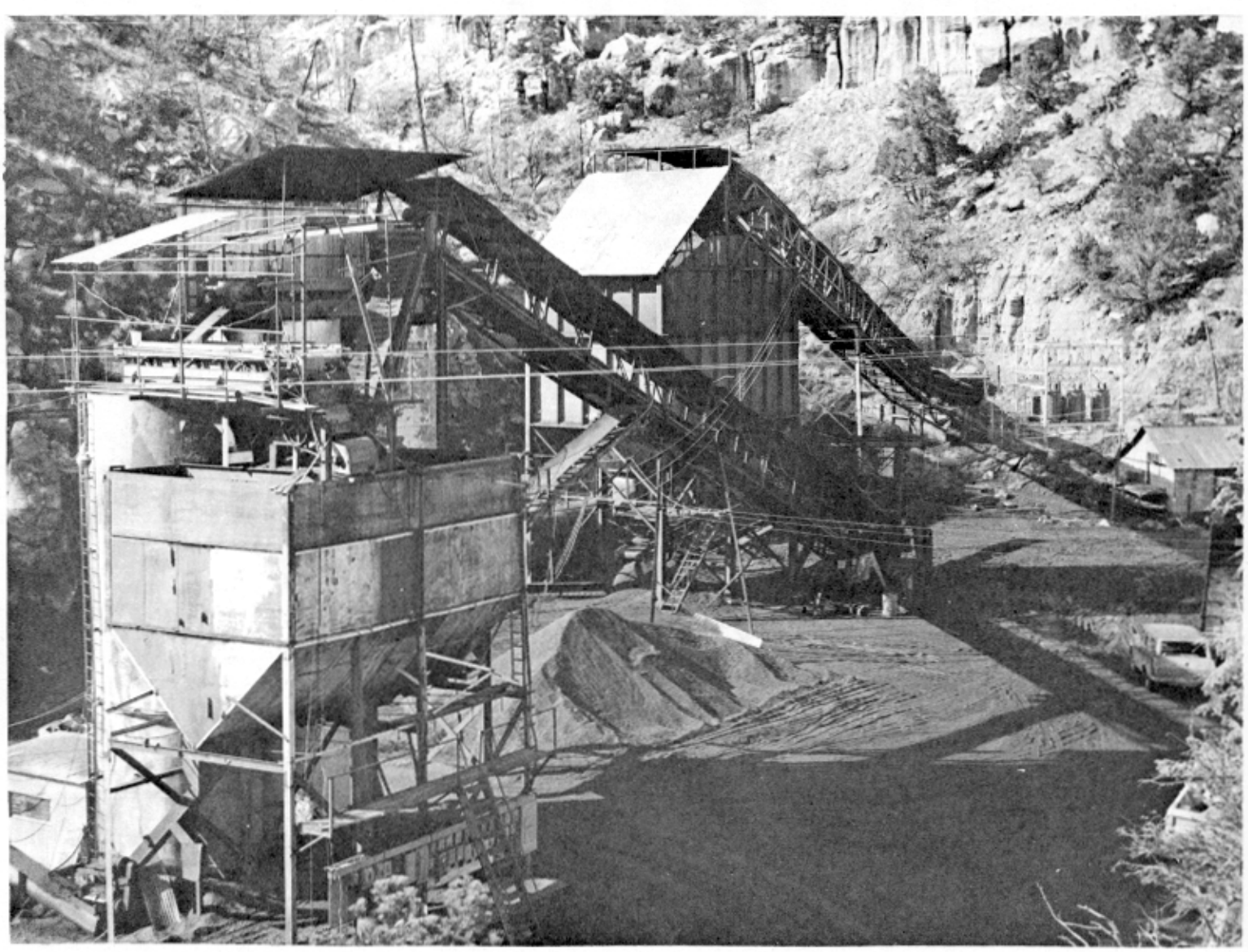
In addition approximately 88 million tons are present in beds in the west tier of sections immediately west of the quadrangle in T. 22 S., R. 4 E.

No mention is made by Spieker about the remainder of T. 21 S., R. 4 E. that has less than 3,000 feet of cover. About 324 million additional tons of reserve may be deduced using Spieker's inferences in T. 22 S., R. 4 E. and T. 21 S., R. 5 E. that the amount of coal is 15 feet for all beds and calculating that 12,000 acres of land have not been included (Class IV reserve).

PRINCIPAL WORK

Most of the data presented in this quadrangle report are derived from Spieker's 1931 work on the Wasatch Plateau coal field. Other sources were consulted to update and augment his presentation.

Left: Resin plant at U. S. Fuel's King mine. Produces two carloads of resin (55 percent) each week. *Below*: Southern Utah Fuel's Convulsion Canyon operation, south area.



ACORD LAKES SW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

Acord Lakes SW quadrangle in the south part of the Wasatch Plateau coal field is entirely within Sevier County (figures 22 and 27). The main access road, Utah 10, in the south part of the quadrangle joins Price with Salina. The landscape is rugged and mountainous; cliffs at the edge of the plateau trend almost north-south but are scalloped westward by the principal drainages. The most important drainage is Ivie Creek which parallels the highway.

Elevations range from 6,700 feet along Ivie Creek to more than 8,800 feet atop the plateau. The coal crops out between 7,500 and 7,750 feet above sea level.

STRATIGRAPHY

The stratigraphic range extends from the Blue Gate Shale Member of the Mancos Shale to the Price River Formation, all Upper Cretaceous in age. The Blue Gate occurs in the extreme southeast map corner on the east side of the Paradise fault zone (south extension of the Joes Valley zone). Most of the area below the cliffs consists of Emery Sandstone Member exposures typically forming a step-like series of cliffs. The exposures are at least 800 feet thick on the quadrangle. They are overlain by the uppermost member of the Mancos Shale, the Masuk Shale, which forms the slope at the base of the cliff. The Masuk Shale consists of blue-gray sandy shale, 350 to 450 feet thick, and thins slightly in a southerly direction, although regionally it supposedly thins to the west.

The remaining stratigraphic units belong to the Mesaverde Group. The initial Star Point Sandstone varies in thickness from 300 to 450 feet on the quadrangle. It is a cliff former and usually easily recognizable along the Wasatch Plateau cliff. The following measurement describes the Star Point:

Section of Star Point Sandstone on south side of Mill Hollow in sec. 25, T. 23 S., R. 4 E., by Spieker (1931, p. 23):

	Feet
1. Sandstone, white at top, very massive, forming vertical cliff	100
2. Sandstone, largely in thin massive beds separated by thinner partings of shale	128
3. Shale, very sandy, harder than main body of Mancos Shale, containing increasing number of thin sandstone beds toward top Mancos Shale (main body)	160
Total	388

The Blackhawk Formation makes up the remainder of the cliff in the Acord Lakes SW area. The unit is nearly 750 feet thick; its lithology is generalized by Spieker (1931, p. 35):

	Feet
Upper massive sandstone, little or no coal	280
Blocky sandstone, shale and thin coal beds	350
Lower massive sandstone and thick coal beds	120
Total	750

In the south part of the quadrangle the overlying Price River and/or Castlegate sandstones have been eroded back from the promontories so that part of the upper surface of the Wasatch Plateau is Blackhawk strata. The Castlegate Sandstone differentiates from the Price River in its weathering characteristics; it forms a bold cliff below the less resistant Price River. In the Acord Lakes SW quadrangle, however, this characteristic is not well developed and the coarse-grained sandstone beds cannot be so differentiated. Where both units appear more like the Price River, they are so mapped. About 600 to 700 feet of the units are exposed on the quadrangle.

STRUCTURE

Only a few insignificant faults cut the coal beds of the Acord Lakes SW quadrangle. Two pairs trend northeast; one crosses Tommy Hollow in the southwest and the other lies just north of Saleratus Creek. The Saleratus faults have displacements to 60 feet but are unimportant because they are close to and parallel to the edge of the cliff. The Joes Valley fault zone cuts across the southeast tip of the quadrangle but it is located below the cliffs and does not affect the coal. The Musinia fault zone is about 3 miles to the west of the quadrangle and marks the west boundary of the Wasatch Plateau coal field.

The inclination of strata on the quadrangle is gentle, rarely exceeding 3 degrees.

PROPERTY CONTROL

Most of the coal lands of the Acord Lakes SW quadrangle are controlled by the National Forest Service and the remainder is private property. Lands of the quadrangle are divided as follows: National Forest Service 66.2 percent, Bureau of Land Management 18.1 percent, private property 13.7 percent and state of Utah 2.0 percent.

BLM lands and those of the state of Utah are below the cliffs. Coal land amounts to a little less than 70 percent of the area. Leases for coal held along the west edge of the map north of Utah Highway 10 cover 3.5 percent of the coal land. The same leases extend into the Yogo Creek quadrangle and the total acreage is more than 4,100 acres. They are held by Jesse Knight. One thousand four hundred additional acres are taxed as unassigned coal lands bringing held coal lands to 8.9 percent of the available for the quadrangle.

COAL

Surface Information

Sixty-seven coal sections attest to the value of the coal in the Acord Lakes SW quadrangle (figure 28). They represent at least four individual coal beds.

	Feet
Saleratus bed	0-3
Interval	70
Upper Ivie bed	0-3
Interval	20
Ivie bed	5-10
Interval	40
Upper Hiawatha bed	0-4
Interval	18
Hiawatha bed	0-3
Star Point Sandstone	

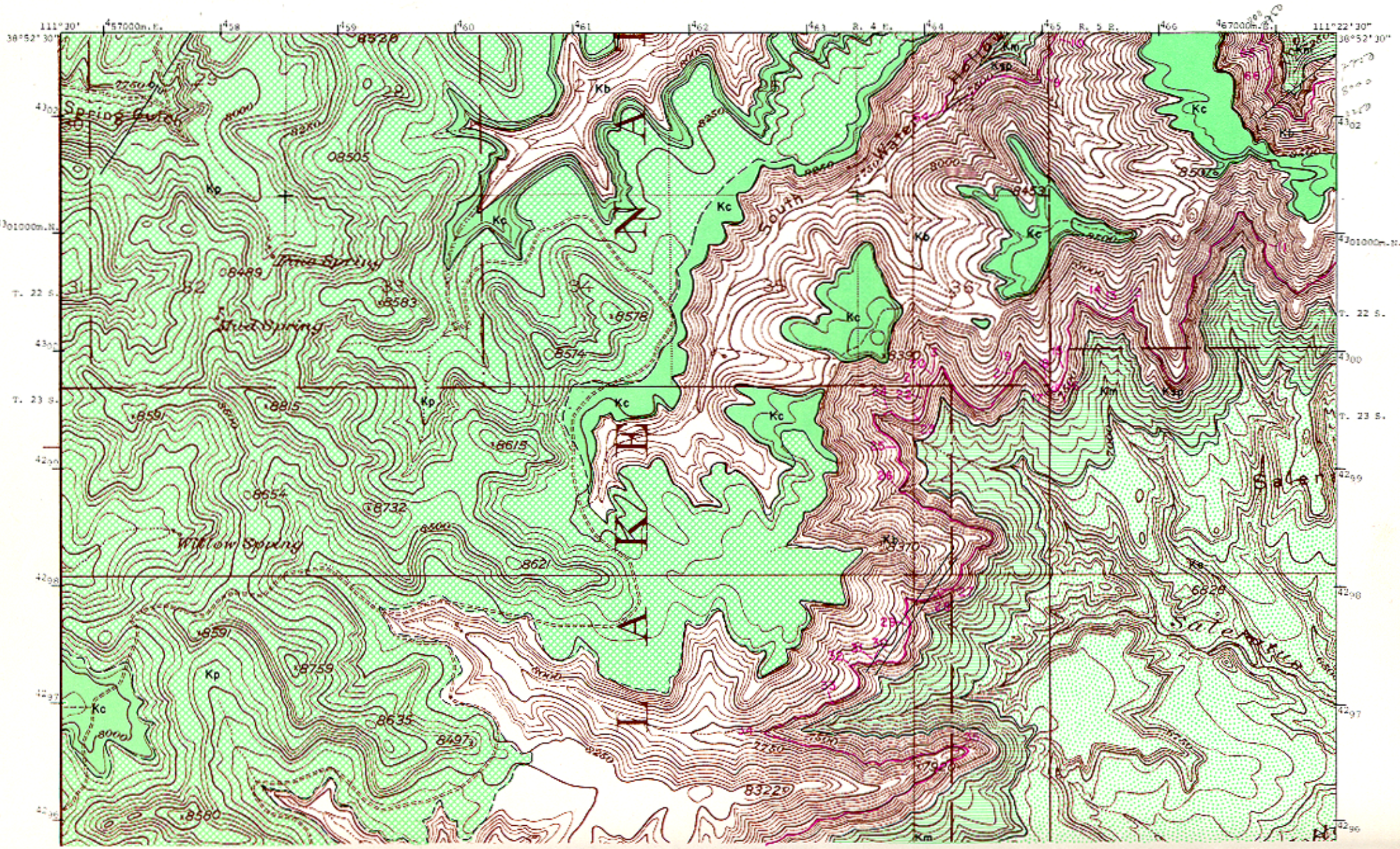
The Hiawatha bed is completely missing in much of the area and is not of value on the quadrangle. It appears to the south and north as a mostly thin bed. The Upper Hiawatha is not much better. Two representative sections are found to the north. Elsewhere it is thin or lacking.

The Ivie bed is the most valuable. It is 5 to 10 feet thick in most sections except along Ivie Creek west of Clear Creek where it is present but badly split. Beds above the Ivie bed are also thin or split. In the vicinity of Saleratus Creek the upper Saleratus bed varies in measured section to 2½ feet thick and is valueless.

Subsurface Information

Information from a drill hole located in SE SE 26-22S-4E shows 8.3 feet of coal at a depth of 217 feet, presumably in the Upper Ivie bed. The roof is sandstone with a 1-inch sandstone split

ACORD LAKES S.W., UTAH



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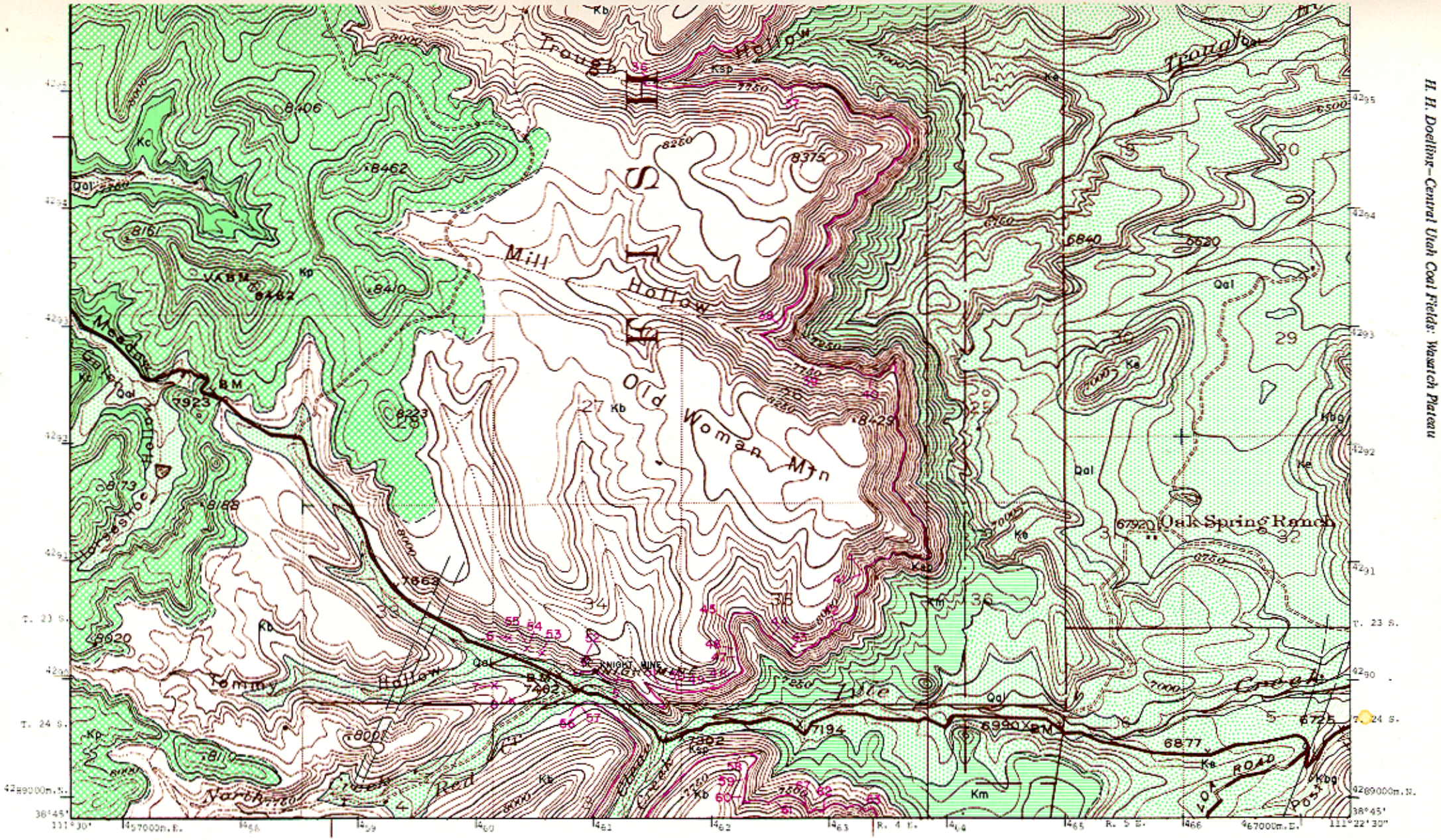


Figure 27. Coal and geology map, Acord Lakes SW quadrangle (explanation pages 136-137).

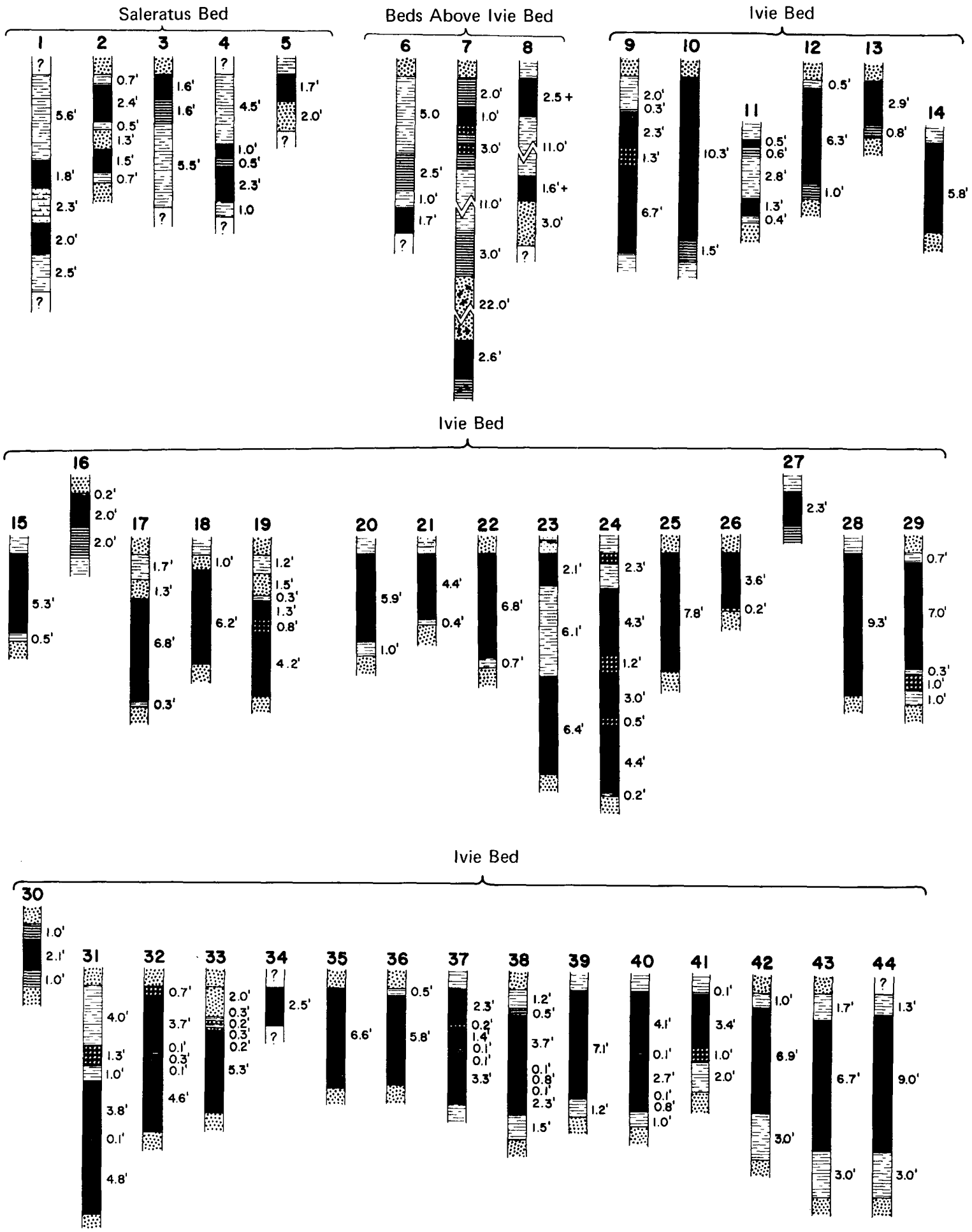


Figure 28. Coal sections of Acord Lakes SW quadrangle (vertical scale: 1 inch = 8 feet).

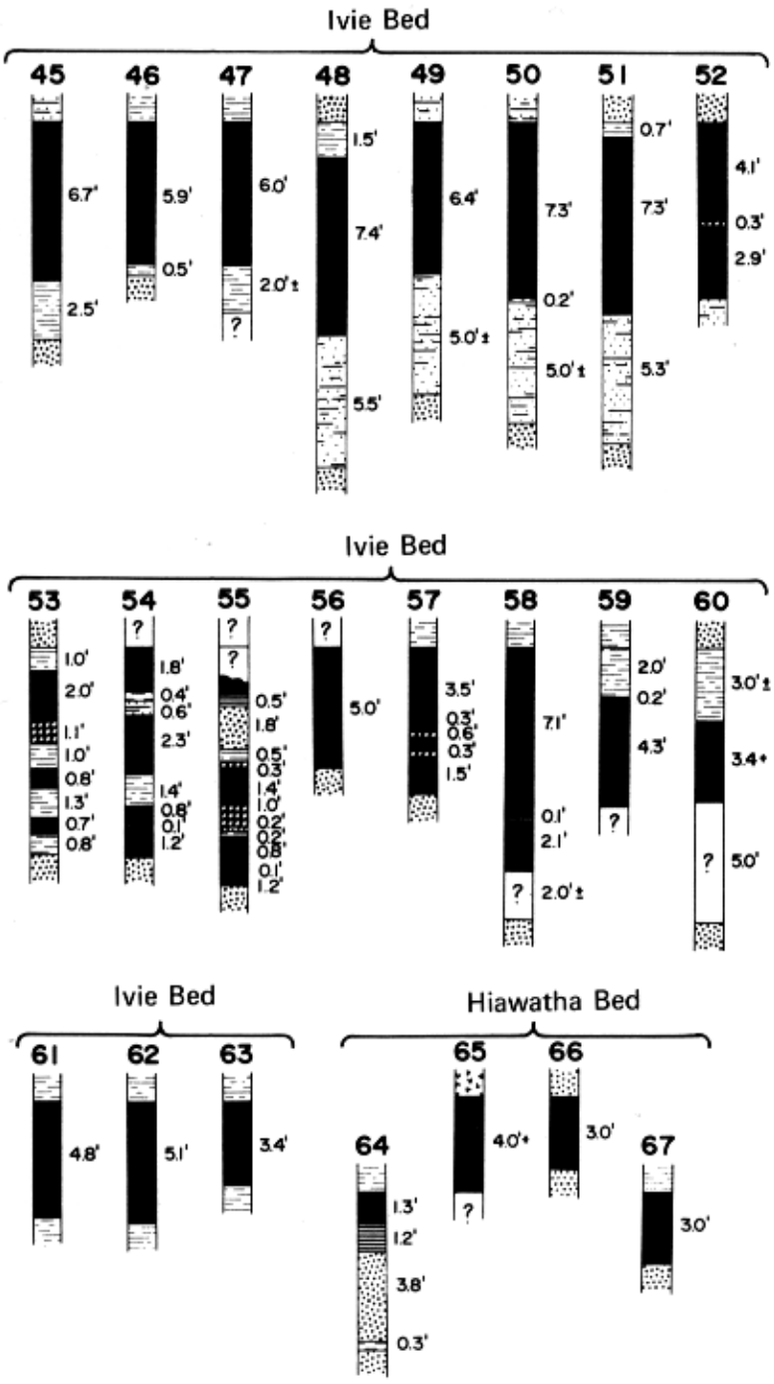


Figure 28. (continued)

1 foot from the top. The hole was drilled in South Water Hollow near the north end of the quadrangle. Of the coal land, 76.6 percent are under less than 1,000 feet of cover and the remainder is under between 1,000 and 2,000 feet of cover. The more deeply buried coal is to the northwest.

Quality of Coal

No analyses for the Acord Lakes SW quadrangle are available.

Mines and Development

Activity in the area has been slight. One mine and some prospects have been opened along Ivie Creek. The Knight mine (Ivie Creek), SW. 34-23S-4E, 4,290,140m.N. 460,940m.E., was active from 1923-?. Some prospects also have been opened along Ivie Creek.

Nothing is known about the Knight mine except that two adits were driven into the Ivie bed and that the Ivie is seriously split. Other prospects are present around Ivie Creek, Red Creek and Clear Creek canyons. Production figures are unknown, but judging from the ruins visible in 1970, they were small, probably less than 1,000 tons.

Reserves

Estimates for the Acord Lakes SW quadrangle, as calculated by Spieker (1931, p. 206) and modified to fit the area, amount to 300 million tons of original reserve (table 23).

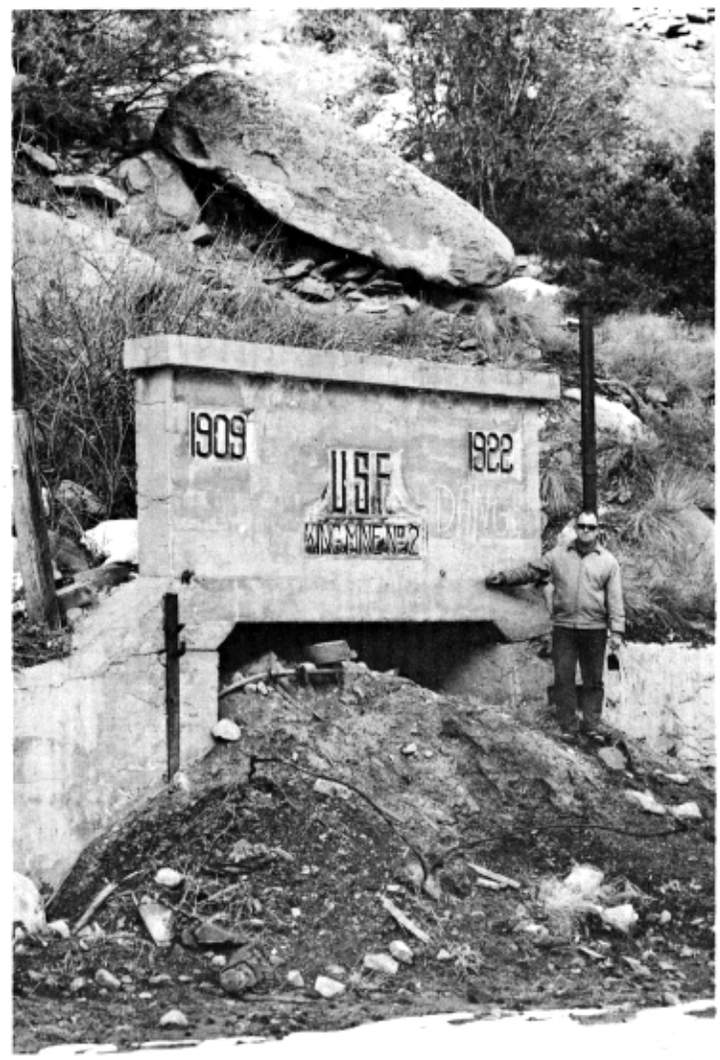
Table 23. Original reserves in short tons, Acord Lakes SW quadrangle.

Location	Acres	Average thickness (feet)	Tons	Bed
T.22S. R.4E.	3,310	8.0	47,664,000	Ivie bed
T.22S. R.5E.	320	5.0	2,880,000	Ivie bed
	957	5.0	8,613,000	Upper Ivie bed
T.23S. R.4E.	16,136	7.5	217,836,000	Ivie bed
T.24S. R.4E.	1,500	6.0	16,200,000	Ivie bed
	1,000	4.0	7,200,000	Upper beds south of Ivie Creek
		Total coal	300,393,000	

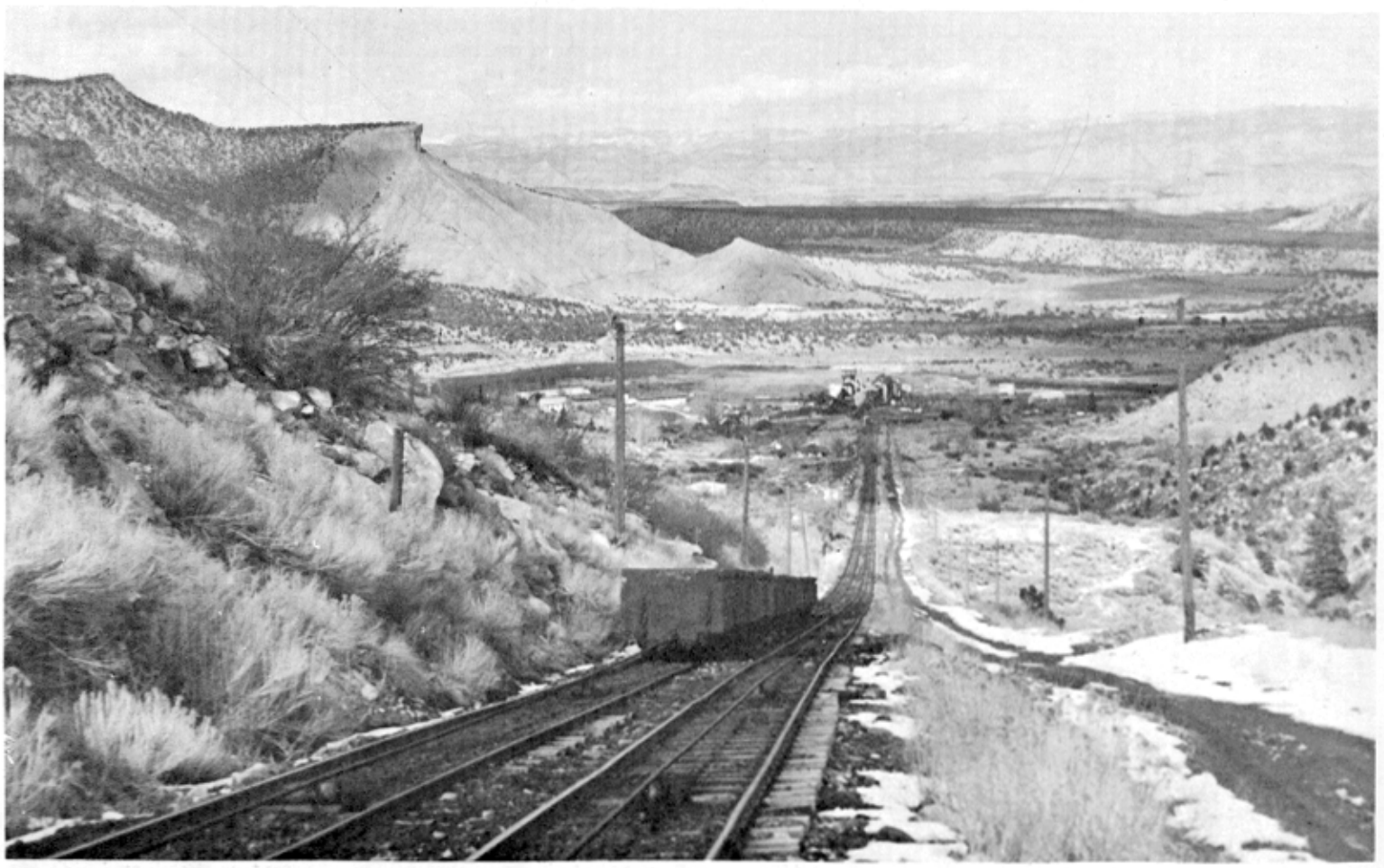
A portion of T. 23 S., R. 4 E. extends into the Yogo Creek quadrangle to the west. Spieker assigned 7.5 feet of Ivie bed coal to these 2,880 acres and added 38,880,000 tons to the reserve list.

PRINCIPAL WORK

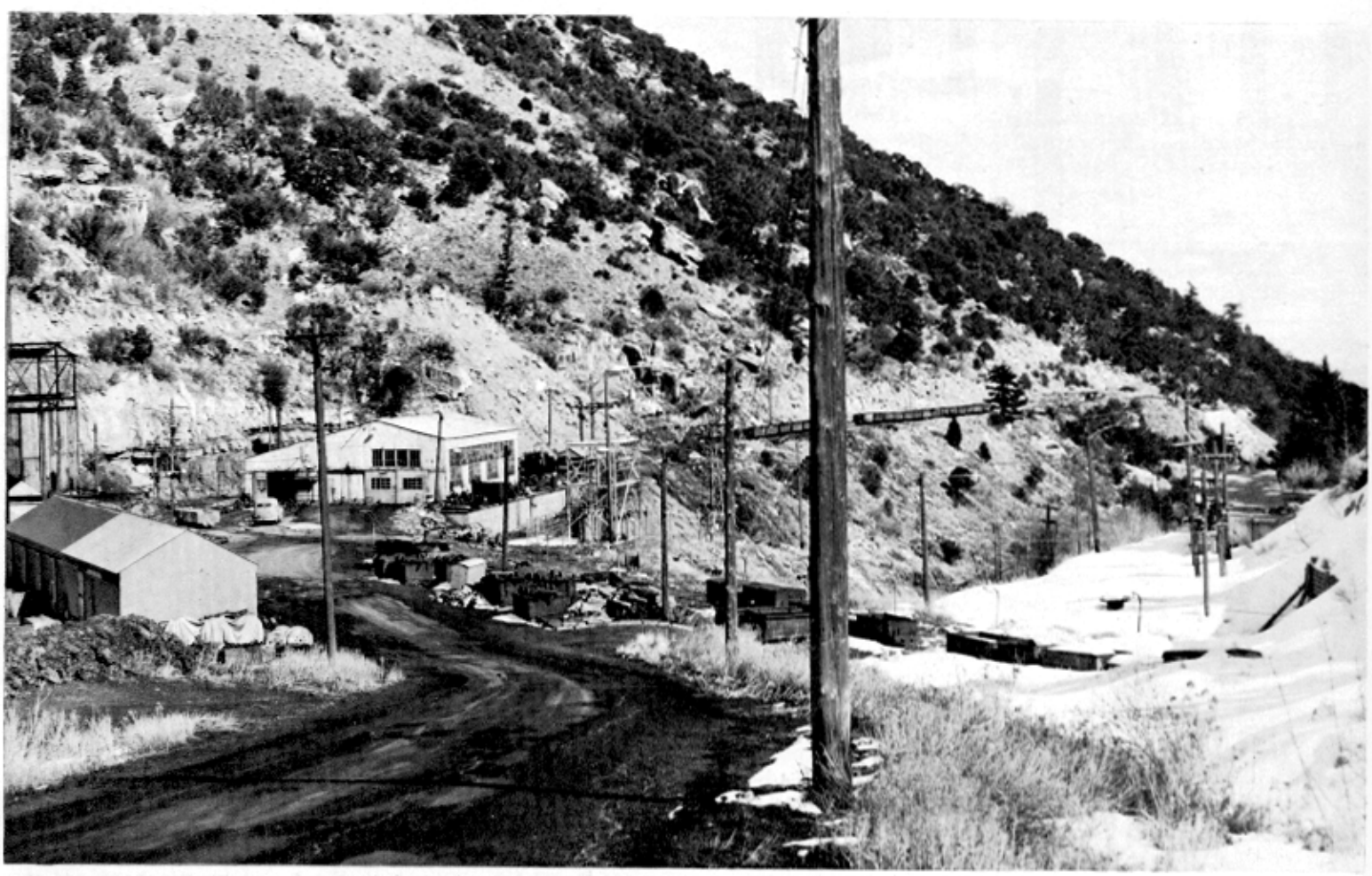
Practically all of the geology and coal data presented are derived from Spieker's 1931 account of the Wasatch Plateau coal field.



U. S. Fuel Co., King Mine No. 2 portal, now abandoned at Mohrland, Hiawatha area.



The only operating tramway in Utah leading from King mine portal to Hiawatha where railroad loading facilities are present.



Abandoned King mine portal west of Hiawatha. Buildings presently are used for storage, offices and shops.

CASTLE DALE NW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Castle Dale NW quadrangle is located in the central part of the Wasatch Plateau field and lies entirely within Emery County (figures 22 and 29). The nearest towns of importance are Orangeville and Castle Dale located 4 and 6 miles east of the northeast map area, and Ferron, 3 miles south of the southeast map corner. Utah Highway 10 joins Castle Dale with Ferron. There are no well maintained roads on the quadrangle; jeep roads connect Highway 10 with the Rock Canyon area.

Elevations range from about 6,100 feet in the southeast map corner to 9,600 feet above sea level at the southwest corner of The Cap. Coal crops out along the cliffs between 7,300 and 7,800 feet above sea level.

STRATIGRAPHY

Below the cliffs are three members of the Mancos Shale: the Blue Gate Shale, the Emery Sandstone and the Masuk Shale. The two marine shales are mostly blue-gray shale with subordinate siltstone. The Masuk is about 750 feet thick on Castle Dale NW; only the upper part of the Blue Gate is exposed. The intervening yellow-gray Emery consists of two sandstone tongues each 50 feet thick with thick blue-gray shale between. Total thickness of the Emery is 250 to 350 feet.

The cliff edge outcrops are made up of members of the Mesaverde Group: Star Point Sandstone, Blackhawk Formation, Castlegate Sandstone and Price River Formation. To the north the Star Point is cliffy; southward from North Horn Mountain it becomes more and more split by bedding planes and is less easily recognized apart from the Blackhawk. It becomes shaley in the lower part. The unit is about 400 feet thick in the Castle Dale NW area. The Blackhawk, with its sandstone tongues and intervening shale with coal, lies above the Star Point; its most important coal beds are in the lower part. It forms staircase outcrops and is about 750 feet thick.

The 150- to 200-foot thick Castlegate Sandstone consists of massive white to gray coarse-grained and gritty sandstone. Above the Castlegate, rock formations are not cliffy and so cap the plateau surface. The Price River is lithologically like the Castlegate but contains subordinate shale and conglomerate. It makes up the entire upper surface of South Horn Mountain and fringes North Horn Mountain. The Price River is about 250 to 350 feet thick here.

The North Horn Formation (Tw) and Flagstaff Limestone are present only on North Horn Mountain. The lower unit is about 1,250 feet thick and consists of variegated shales with subordinate sandstone, conglomerate and freshwater limestone. The Flagstaff forms "The Cap" of North Horn Mountain and is mostly yellow-gray limestone. It is a resistant ledge former.

STRUCTURE

As far as is known no structural problems on the quadrangle will hinder mining. The strata are only slightly inclined and except for the southwest edge of the map, no faults occur. To the southwest the Biddlecome Hollow fault, the easternmost fracture of the Joes Valley fault zone, displaces at least 100 feet.

PROPERTY CONTROL

The land of the Castle Dale NW quadrangle is 79.8 percent National Forest Service land which includes most of the coal. Private land amounts to 2 percent of the quadrangle area and about two-thirds of it are coal land. The 2.7 percent that is state land contain no coal acreage. The Bureau of Land Management controls most of the land under the cliffs (15.5 percent).

The coal land amounts to more than 25,000 acres or 70 percent of the map area. There are no current coal leases and the only land held for coal is the private land between Axel Anderson and Killpack mines.

COAL

Surface Information

Seventy-four measured sections (figure 30) attest to the value of coal in the Castle Dale NW quadrangle. Most are from the Hiawatha bed, but the Blind Canyon and Bear Canyon beds are represented as well.

The Hiawatha coal is the best seam in the area; to the north of Rock Canyon in R. 7 E., it is thick but elsewhere it is thin or vanishes entirely. In Olsen Hollow it has an upper split. The Blind Canyon coal is best developed on the north side of Rock Canyon where it is 13 feet thick. It thins southward and westward. The Bear Canyon bed is present on both sides of Rock Canyon but only locally is it of minable thickness.

Subsurface Information

No drill-hole data are available and almost half of the coal land is more than 1½ miles distant from the outcrop. The greatest overburden under The Cap, 2,000 to 3,000 feet, represents 14.1 percent of the coal land. Most of the upper surface of South Horn Mountain and the area of Price River exposures on North Horn Mountain is between 1,000 and 2,000 feet above the coal (52.2 percent of the coal land) and 33.7 percent has less than 1,000 feet of overburden covering the coal.

Quality of Coal

Only three analyses are available for the Castle Dale NW quadrangle and all are from the Hiawatha bed. Averages and ranges are listed in table 24.

Table 24. Average coal analyses, Castle Dale NW quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	3	7.7	6.4- 9.8
Volatile matter	3	38.8	34.4-41.0
Fixed carbon	3	49.5	47.0-54.4
Ash	3	4.3	1.4- 6.3
Sulfur	3	0.77	0.6- 0.9
Btu/lb	3	12,363	12,200-12,400

Spieker (1931, p. 166) notes that the Rock Canyon coal is inferior to coal farther north in physical characteristics such as stocking quality; insufficient samples make generalizing why impossible. Near the Killpack mine a layer of bright coal with the appearance of birds-eye coal differs from most Wasatch Plateau coals. The bed, which is above the Hiawatha, is 1 to 1½ feet thick; the ratio of fixed carbon to volatile matter is greater and the coal contains more sulfur and is low in ash. Spieker suggests the coal might coke.

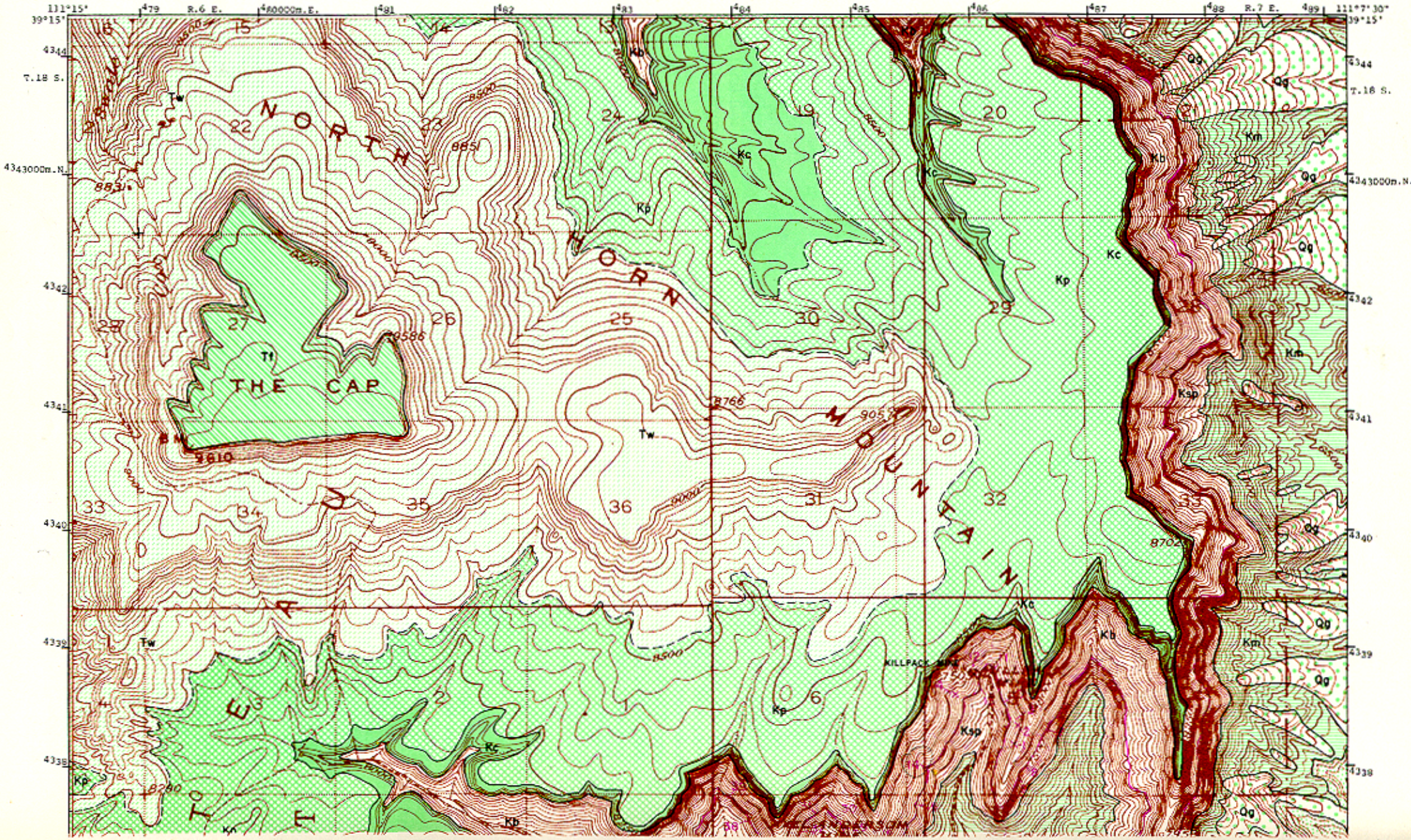
Table 5 gives analyses of individual mines and prospects.

Mines and Development

The few mines opened on the quadrangle (table 25) have seen little production. Most of the coal is high on inaccessible cliffs and it thins to the south.

Little is known about the Rock Canyon area mines. At the Axel Anderson mine, the Hiawatha is 10 to 12 feet thick and

CASTLE DALE, UTAH N.W.



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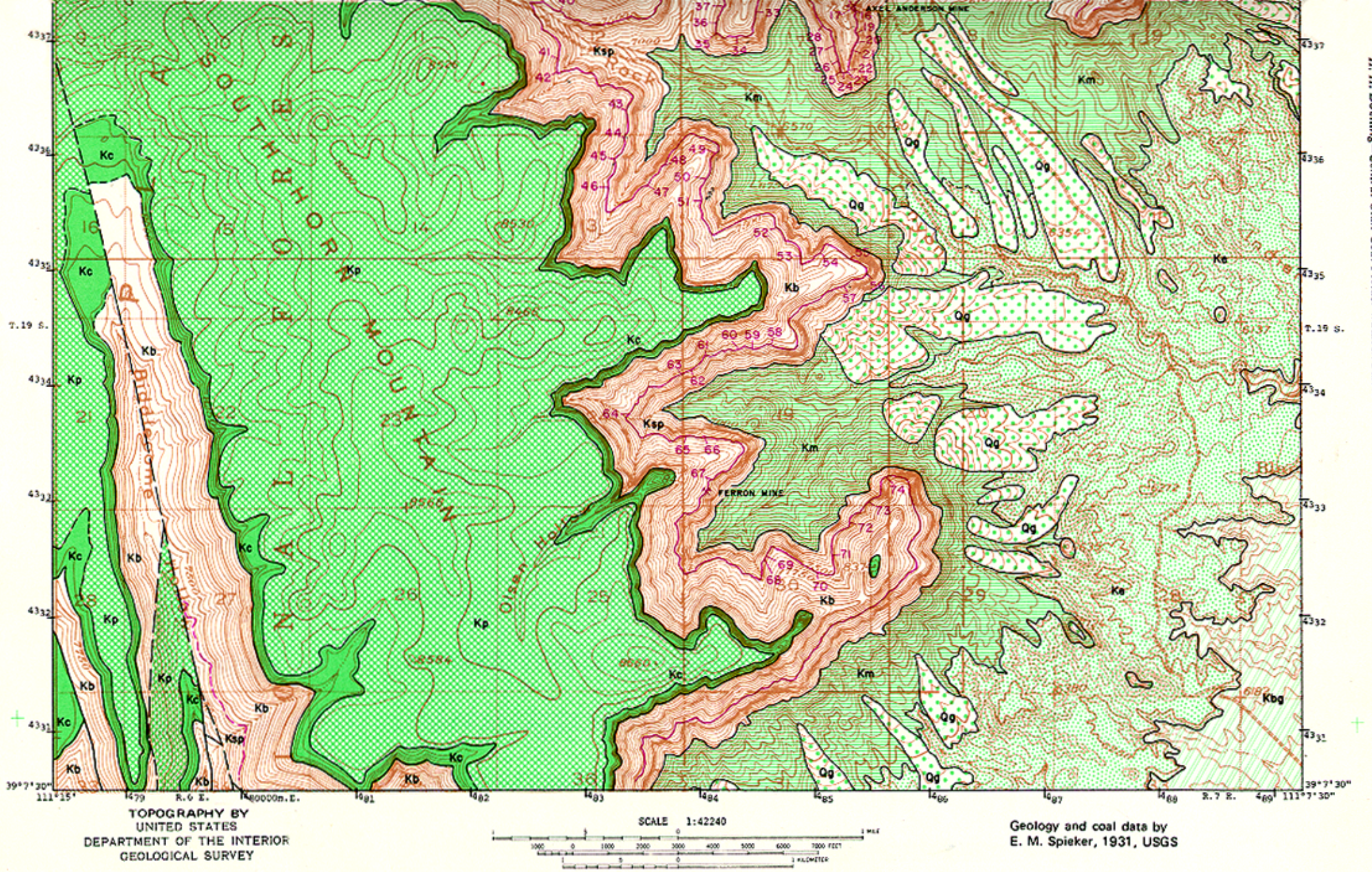


Figure 29. Coal and geology map, Castle Dale NW quadrangle (explanation pages 136-137).

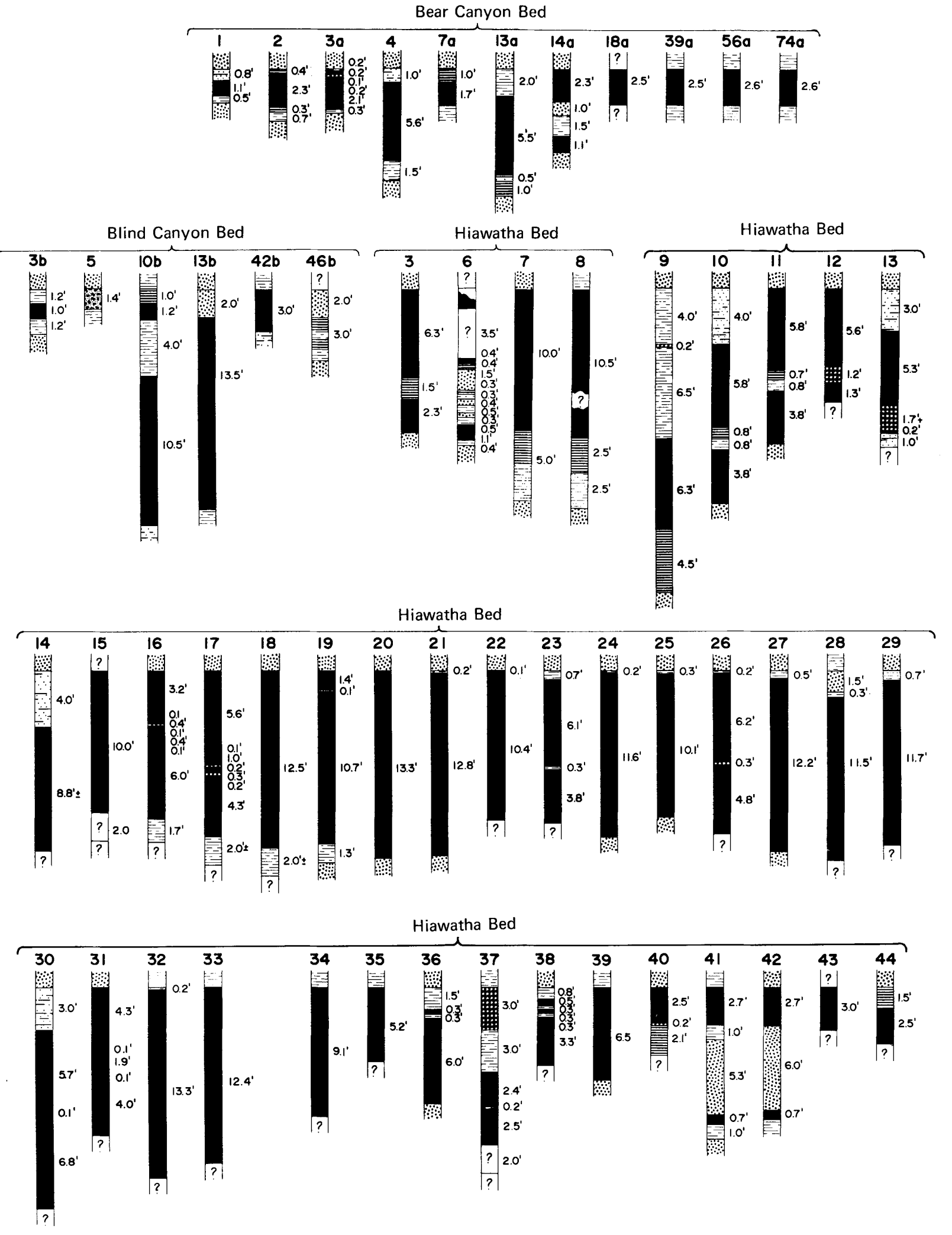


Figure 30. Coal sections of Castle Dale NW quadrangle (vertical scale: 1 inch = 8 feet).

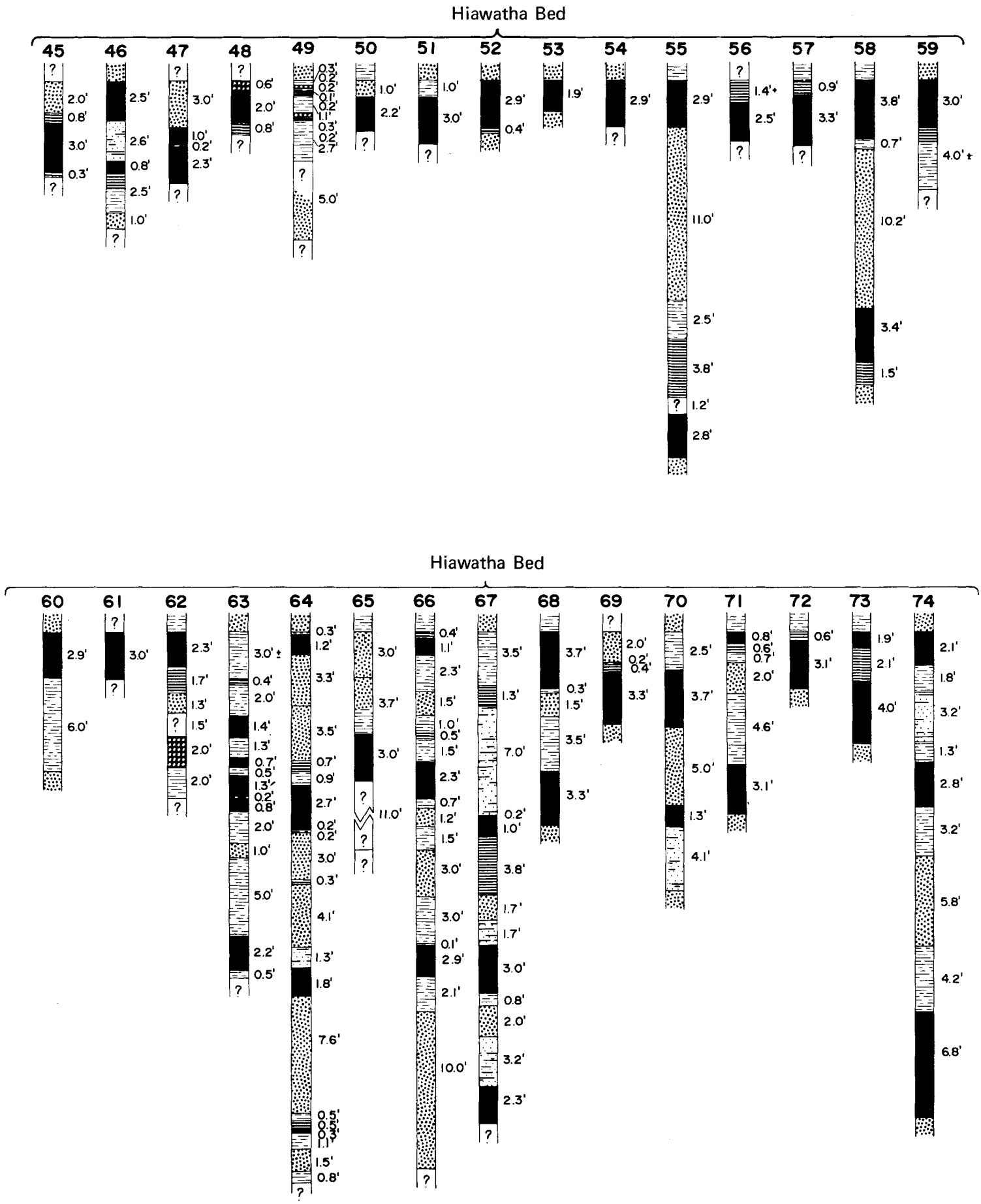


Figure 30. (continued)

Table 25. Mines and their locations, Castle Dale NW quadrangle.

Mine	Location	Remarks
Axel Anderson mine (Rock Canyon, Clawson, Peterson)	NE.SE.NE.7-19S-7E 4,337,260m.N. 485,300m.E.	1906-1932
Ferron mine	SE.19-19S-7E ≃4,333,085m.N. 484,075m.E.	Active 1901-1906
Killpack mine	SE.NW.5-19S-7E 4,338,790m.N. 486,000m.E.	

mining conditions were reported excellent. According to Spieker (1931, p. 168), in 1922 the mine was driven 275 or 300 feet northwest from the mouth and four large rooms were turned from the main entry. In 1944 the tunnel was 900 feet long. Exact production figures are unknown but estimated to be about 5,000 tons. In the neighboring Killpack mine Spieker noted about 350 feet of tunnel. The Hiawatha bed is 6 feet thick and estimated production is small. The mine was active in 1922. The Ferron mine in Olsen Hollow is reported to be in 8 feet of Hiawatha coal. Total production from the quadrangle is estimated about 8,000 tons.

Reserves

Since little coal has been removed from the Castle Dale NW quadrangle practically all the original reserve still remains. Spieker's (1931, p. 205) reserves are modified here to fit the quadrangle and list almost 378 million tons (table 26). Only those beds averaging more than 4 feet were included.

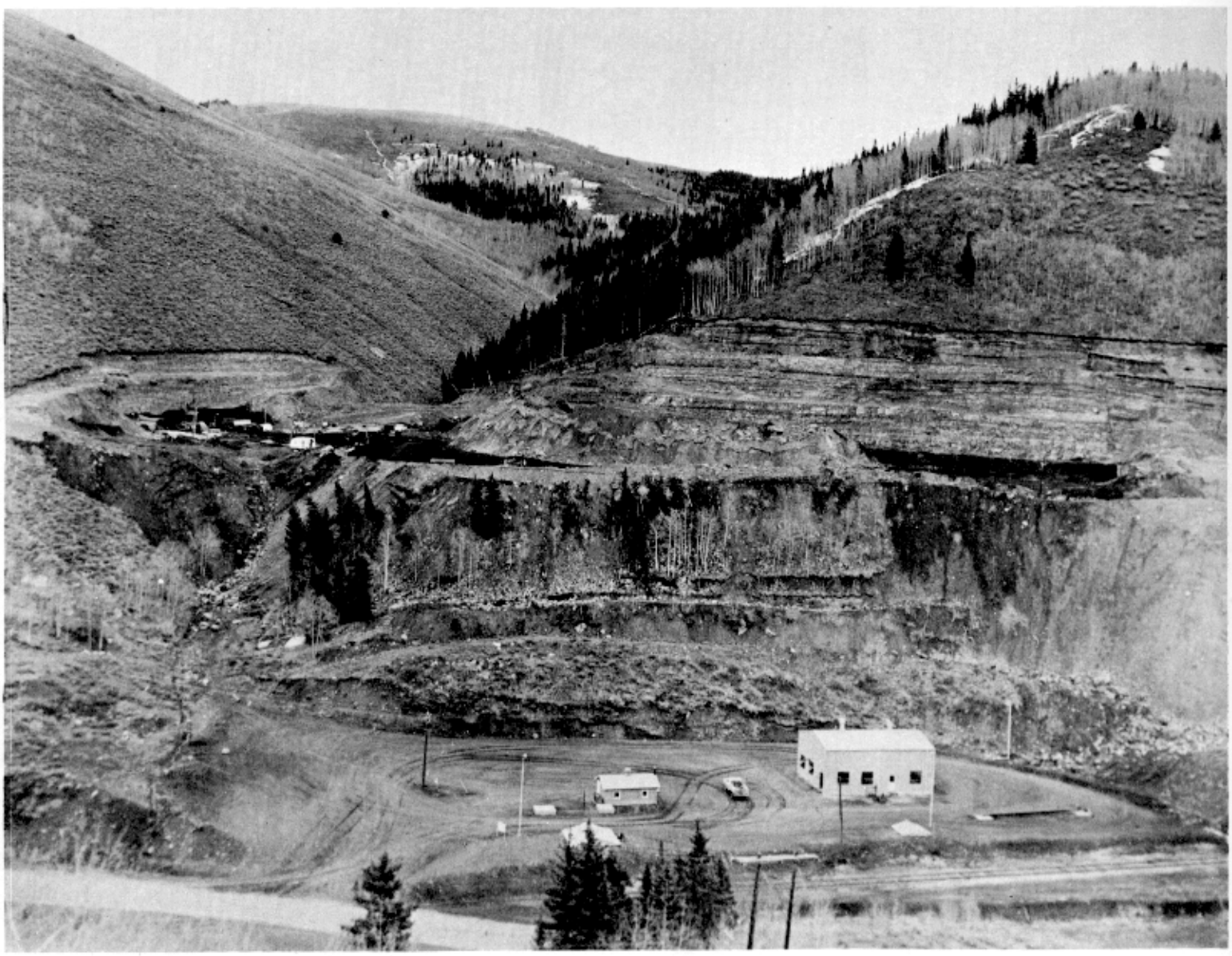
Table 26. Original reserves in short tons, Castle Dale NW quadrangle.

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.18S. R.6E.	6,577	4.5	53,270,800	Hiawatha
	1,020	6.0	11,016,000	Blind Canyon
T.18S. R.7E.	5,535	5.0	49,815,000	Hiawatha
	5,120	9.5	87,552,000	Blind Canyon
T.19S. R.6E.	10,100	4.0	72,720,000	Hiawatha
	8,450	4.0	60,948,000	Upper beds
T.19S. R.7E.	1,635	9.6	28,252,800	Hiawatha secs. 4-9
	720	11.0	14,256,000	Blind Canyon
		Total coal	377,830,600	

Mining conditions should be excellent with an expected recoverability of 50 percent or 189 million tons.

PRINCIPAL WORK

Most of the geology and coal data presented here are taken from Spieker's 1931 account of the Wasatch Plateau coal field. It is updated and augmented by U. S. Bureau of Mines sources, published and unpublished.



Contour mining near Clear Creek, Scofield NW quadrangle, in early 1972.

CASTLE DALE SW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Castle Dale SW quadrangle is located in the central part of the Wasatch Plateau coal field along the east edge (figures 22 and 31). Utah Highway 10 and the town of Ferron lie along the east map edge. Most of the quadrangle is part of Castle Valley or part of the foothills leading to the Wasatch Plateau cliffs along the west edge of the map. Elevations range from 5,900 feet near Ferron to 8,852 feet on Sage Flat. Most coal outcrops between 7,500 and 7,700 feet above sea level, but some lies at other elevations, especially in beds caught in fault blocks. Cliffs are steep and mostly inaccessible. The road along Ferron Creek is the only access into the plateau.

STRATIGRAPHY

Because the major part of the quadrangle represents Castle Valley, the outcrops are dominated by the upper three members of the Mancos Shale. The Blue Gate's estimated 1,700 feet is the oldest exposed unit. Only the upper half of the pale blue-gray marine mudstone and siltstone is exposed. The Emery Sandstone Member overlies the Blue Gate and consists of two sandstone tongues with an intervening marine shale. The entire sequence is 450 feet thick, the sandstone lenses measure 50 feet each. These thicken somewhat in a southerly direction. The youngest member of the Mancos, the marine Masuk Shale, is about 900 feet thick and forms the base of the cliff. It is supported by the more resistant formations of the Mesaverde Group. Like the Blue Gate the Masuk is a blue-gray shale although sandier, especially near the top.

The cliffs are outcrops of the Star Point Sandstone, the Blackhawk Formation and the Castlegate Sandstone. The yellow-gray sandstones of the Star Point are less massive in this quadrangle than in quadrangles to the north. The lower sandstone beds give place to shale and the upper part is more platy and thin-bedded. The unit is estimated to be about 400 feet thick. The Blackhawk Formation overlies the Star Point. At least two-thirds of the unit are sandstone, thin-bedded to massive and calcareously cemented. The other third is gray and carbonaceous shale with subordinate coal. The best seams lie in the lower third of the Blackhawk which is about 750 feet thick on the quadrangle. The Castlegate Sandstone found unconformably on the Blackhawk is 150 feet thick and cliffy. The sands are coarser and grittier than those of the Blackhawk.

The Price River Formation caps Nelson Mountain and fringes Sage Flat. Similiar in lithology to the Castlegate, it is less resistant and less massive than the Castlegate and contains intervening shale beds; it is about 200 feet thick. About 1,250 feet of the North Horn Formation and an incomplete 500-foot section of Flagstaff Limestone form the top of the plateau on Sage Flat. The North Horn consists primarily of reddish or variegated shales and the Flagstaff is a yellow-gray limestone.

Large portions of Castle Valley are covered with alluvium and the major creek bed of Ferron Creek is filled with it. Benches between gullies below the cliff are often covered with gravel to 75 feet thick.

STRUCTURE

The Joes Valley fault system is the most prominent structural feature of the quadrangle. The north-south trending faults cut the coal-bearing strata into narrow to 2-mile wide strips. The inclination of strata is gentle everywhere except locally in the narrow fault blocks. Near the faults the rocks often are sheared, slightly jointed and drag-folded. Only the east side of the fault zone is on the quadrangle and the larger fault blocks between the major east and west side faults have dropped to form grabens.

PROPERTY CONTROL

The lands of the Castle Dale SW quadrangle are owned as follows: National Forest Service 42.9 percent, Bureau of Land Management 30.9 percent, private property 21.6 percent and state of Utah 4.6 percent.

Practically all the coal land is on National Forest property. Coal lands amount to 21.8 percent of the quadrangle. None is leased or held for coal.

COAL

Surface Information

The 21 available sections are from the Hiawatha bed and most show thin badly split seams (figure 32). The Hiawatha is divided into two zones separated by about 20 feet of rock. The lower beds are set down on figure 32. Individual seams vary in thickness to 4.5 feet.

Subsurface Information

No drill-hole data are available. Presumably the beds are generally thin throughout the quadrangle, even within the fault zone. About 45 percent of the coal are under less than 1,000 feet of cover, 45.1 percent lie under 1,000 to 2,000 feet of cover and the remaining 9.9 percent (under Sage Flat) are under more than 2,000 feet of cover.

Quality of Coal

No analyses of the coal for Castle Dale SW quadrangle are available.

Mines and Development

The only development on the quadrangle consists of two prospects noted by Spieker (1931, p. 174):

> In Biddlecome Hollow two mines have been driven on a bed, probably about 25 feet above the Star Point Sandstone, in one of the narrow fault blocks west of the Paradise fault. These mines are about half a mile by road from Ferron Canyon and about 6½ miles from the town of Ferron . . . Both mines are about 50 feet above the bottom of Biddlecome Hollow.
>
> The southern of the two mines consists merely of an entry which has been driven N 50° W about 50 feet to a fault that cuts the coal off completely . . .The northern mine, the mouth of which is about 270 feet N 15° E of the southern one, has been driven N 45° W about 100 feet and one room has been turned to the south. The entry ends against the same fault as that in the other mine.

The coal beds are thin at these localities, to 3.5 feet, but about 5 feet of coal are available if two seams are mined. The upper seam is resinous. The amount of coal mined is unknown but is estimated to be less than 1,000 tons.

Reserves

Small reserves are confined to thin beds. Spieker's (1931, p. 205-206) reserves are modified here to fit the quadrangle (table 27).

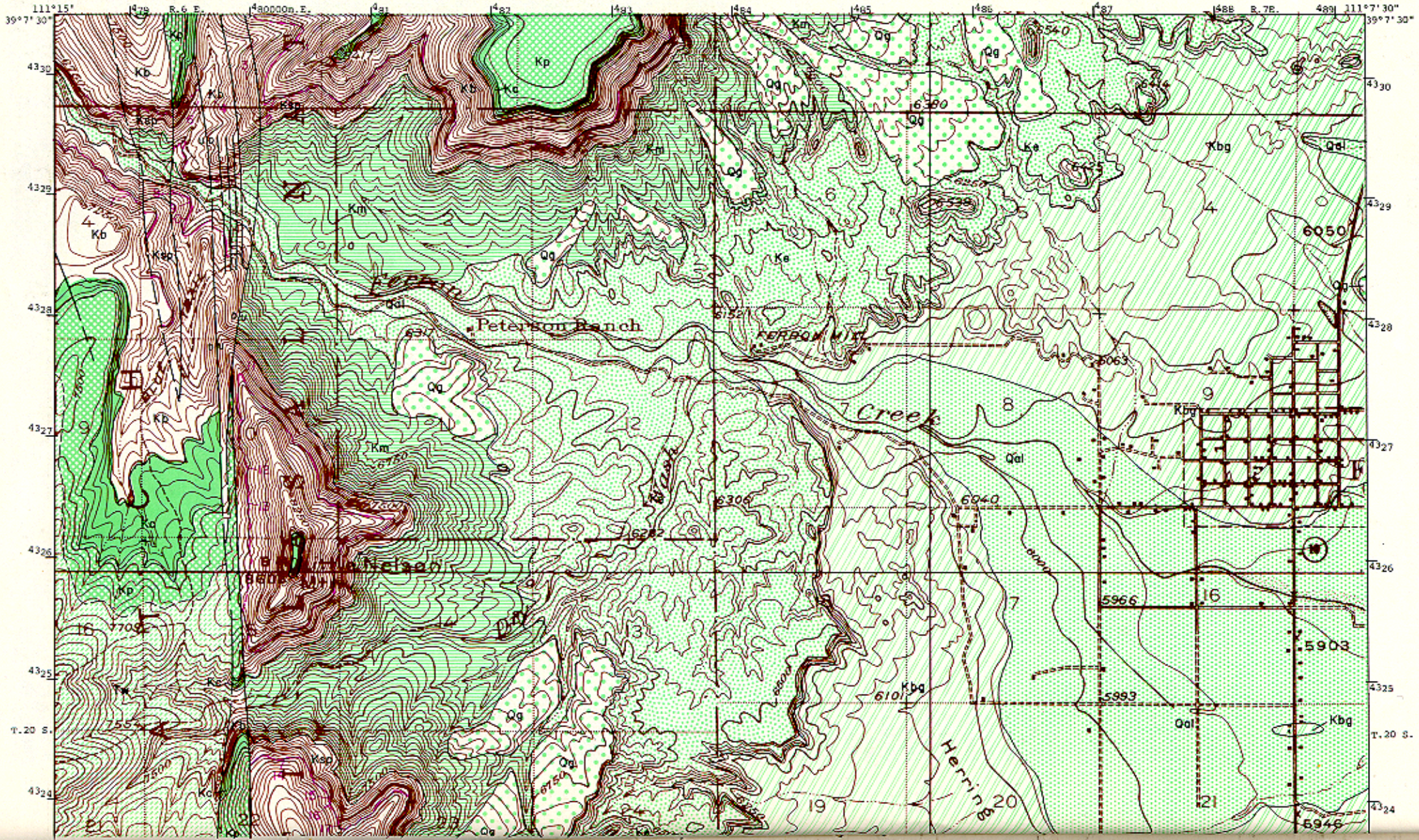
Table 27. Original reserves in the Castle Dale SW quadrangle (in short tons).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.19S. R.6E.	560	4.0	4,032,000	Hiawatha E of fault
	500	4.0	3,600,000	Upper beds E of fault
T.20S. R.6E.	598	4.0	4,305,600	Hiawatha secs. 28, 33
	1,720	4.0	12,384,000	Upper Hiawatha, Nelson Mtn.
		Total coal	24,321,600	

PRINCIPAL WORK

Almost all the data presented in this quadrangle report are derived from Spieker's 1931 work on the Wasatch Plateau field.

CASTLE DALE, UTAH S.W.



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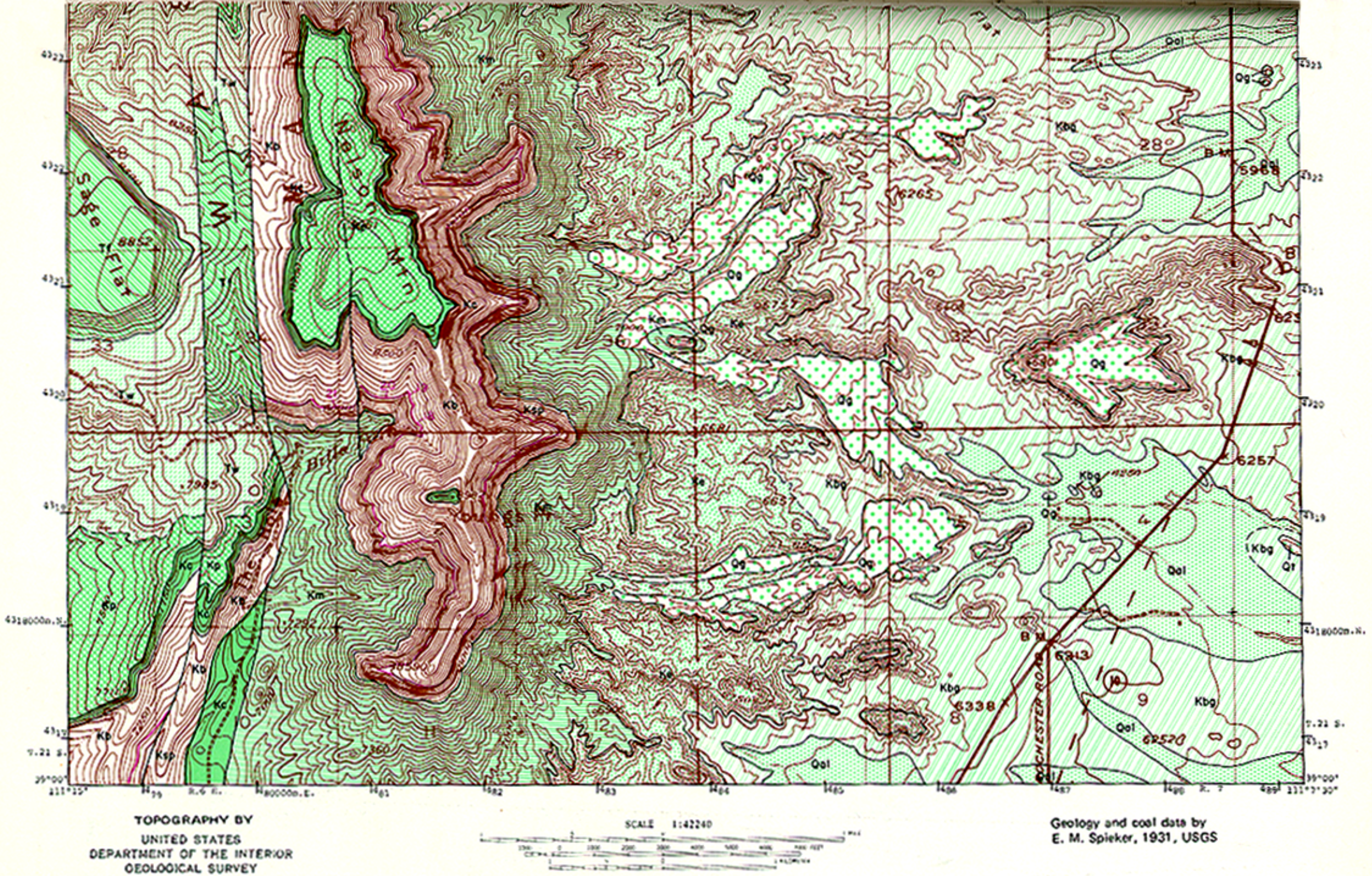


Figure 31. Coal and geology map, Castle Dale SW quadrangle (explanation pages 136-137).

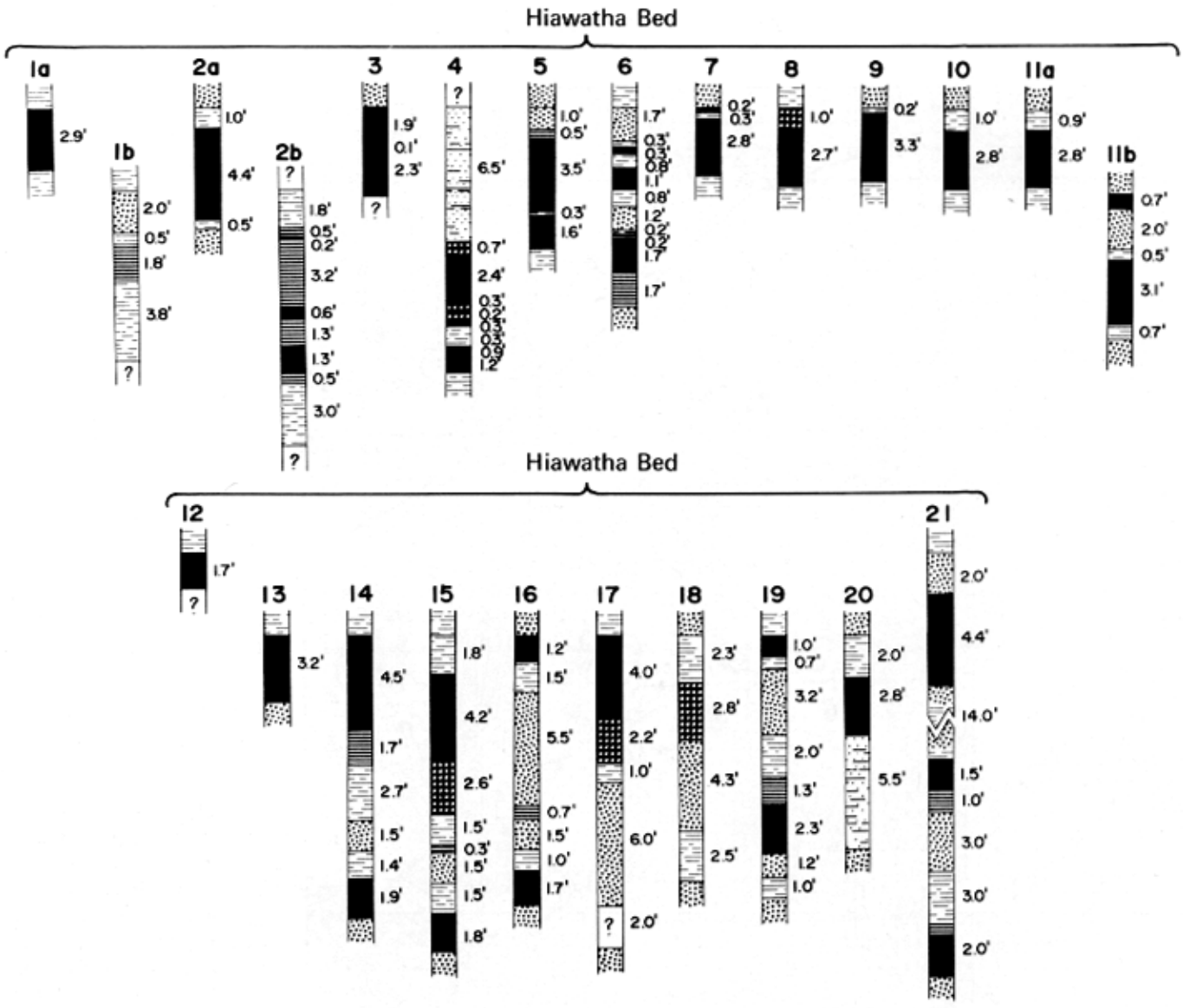
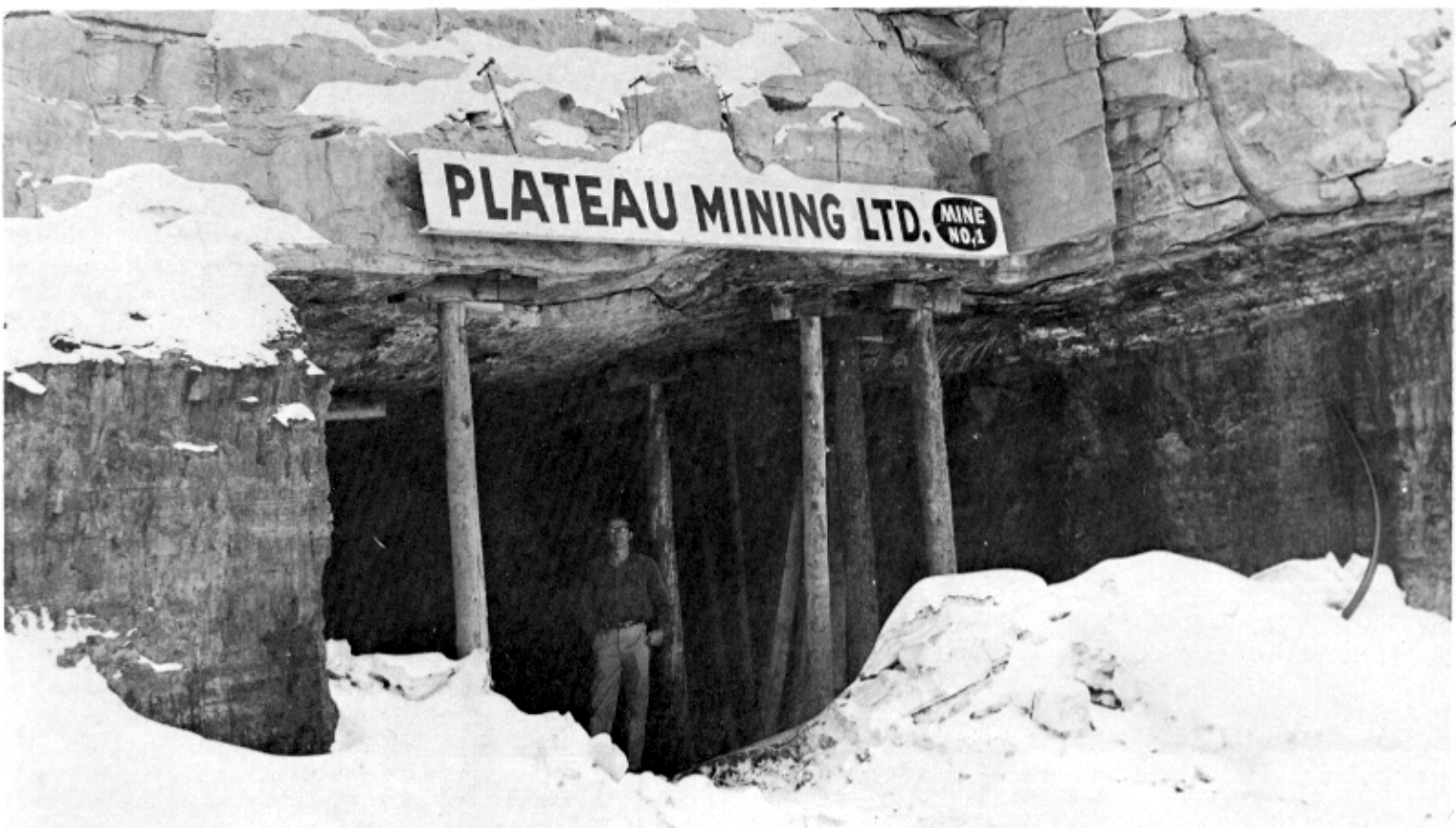


Figure 32. Coal sections of Castle Dale SW quadrangle (vertical scale: 1 inch = 8 feet).



Portal of Plateau Mining Ltd. No. 1 near Wattis (Star Point mine), Hiawatha area.

EMERY 3 NW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The quadrangle is located at the south end of the Wasatch Plateau field where it abuts against the Fish Lake Plateau, south of Utah Highway 10 (Interstate 70; figures 22 and 33). The land is difficult of access, mountainous and rugged. Altitudes range from 6,800 feet near the mouth of Last Chance Creek to more than 10,000 feet in the southwest map corner. Coal beds occur at elevations between 6,800 and 9,200 feet.

The principal road, Utah Highway 72, is a gravel road joining Utah 10 with Fremont and other towns in Wayne County. It roughly parallels the Paradise fault in the east third of the quadrangle; other roads are rough mountain trails.

Parts of two coal fields are represented in the quadrangle: Emery coal field east of the Paradise fault and Wasatch Plateau field west of the fault.

STRATIGRAPHY

Both unconsolidated and consolidated beds have significant outcrop areas on the Emery 3 NW quadrangle. East of Paradise fault the outcrops consist of the lower members of the Mancos Shale. West of the fault the consolidated units are typically Wasatch Plateau commencing with the Emery Sandstone and extending up section to the North Horn (Tw). The uniformity of outcrop is unlike that of the north quadrangles because of the presence of many faults and covering gravel deposits.

The Tununk Shale Member of the Mancos is the oldest unit and is exposed in the southeast map corner. It forms badland topography in the desert east of the Coal Cliffs. It is a black to brown-black clay and siltstone shale and is about 600 feet thick. The Tununk is capped by a resistant sandstone unit, the Ferron, which supports the Coal Cliffs. The Ferron consists of alternating sandstone and shale beds with as many as ten coal beds above a basal 180-foot sandstone unit. Drainages have not cut deeply into this unit; during flash floods waterfalls develop. The Ferron Sandstone forms the basis of the Emery coal field and is about 800 feet thick.

The Blue Gate Shale Member of the Mancos is the uppermost unit east of the fault. At least 1,000 feet of the Blue Gate are exposed in rounded hills, mountains and knolls atop the Ferron. The Blue Gate is a blue-gray shaley and silty unit much like the Tununk with intermittent thin beds of sandstone. Alluvium derived mainly from the clay of the Blue Gate occurs in numerous patches on its surface. The complete Blue Gate is estimated at least 2,000 feet thick.

The next unit, the Emery Sandstone, is confined to the west side of the fault. The mapping is preliminary; exposures noted as the Emery may be similar units. Cretaceous sandstones out of their usual sequence are difficult to separate and identify. The Emery forms a series of step-like cliffs, the sandstone beds separated by intervening shale. The unit is normally barren of coal but a 12- to 13-foot seam is in the south end of the quadrangle just west of the fault in a fault slice. Palynological evidence, however, suggests this is a block of the Blackhawk Formation. Another bed higher on the opposite side of a fault is about 3 feet thick. These are possibly fault slivers of the Ferron or the Blackhawk, but for the present they are assigned to the Emery. Because no base of the unit can be determined and the lower part is against the fault, no complete thickness can be measured. At least 800 feet are exposed in outcrop. In a well drilled NE SE 8-25S-4E the initial unit was logged as Blue Gate Shale and an orderly sequence of beds followed to the Dakota. Faults or improper mapping may explain this enigma.

The blue-gray drab shales of the Masuk Shale Member of the Mancos are exposed above the Emery. The unit is much like the Blue Gate except it is sandier and often exhibits a yellow-gray color. In the north part of the quadrangle the outcrop is continuous; to the south it is broken into islands separated by seas of gravel. The Masuk is the youngest member of the Mancos and is about 600 feet thick in Emery 3 NW.

The Star Point Sandstone as usual forms a cliff above the Masuk. Thick-bedded to massive sandstone beds yellow-gray in color predominate; each bed is separated by shale or sandy shale. The Star Point is about 200 feet thick and thickens slightly northward. The upper contact is more difficult to discern on this quadrangle because the lower part of the Blackhawk is cliffy and the Hiawatha coal bed is not developed.

The north central map area consists dominantly of exposures of the Blackhawk Formation, which forms the basis of the Wasatch Plateau coal field. All the coal beds are believed in the lower part of the unit. The lithology of the 750-foot formation is alternating sandstone and shale; Spieker (1931, p. 35) provided a rough generalization of its lithology:

	Feet
Upper massive sandstone, little or no coal	280
Blocky sandstone, shale and thin coal beds	350
Lower massive sandstone and thick coal beds	120
Total	750

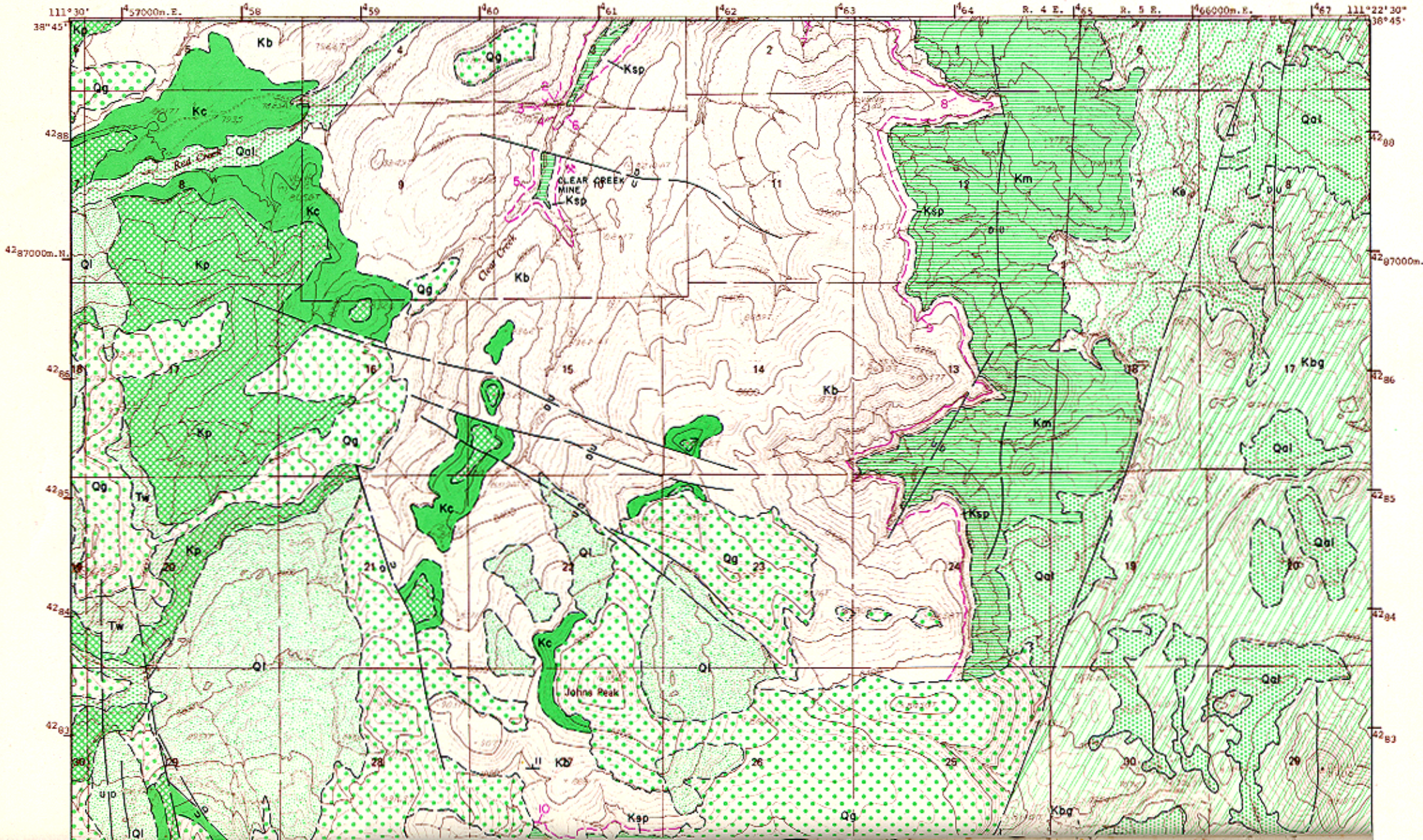
The next younger unit is the Castlegate Sandstone, a massive coarse-grained and cliff-building unit. The Price River Formation is similar except that the bedding is not so massive and has intervening shaley units. Consequently the formation is less resistant. In places the initial coarse-grained unit above the Blackhawk is not a massive cliff former and the entire sequence is assigned to the Price River Formation. The entire Castlegate-Price River sequence may be 800 feet thick; exposures are located in the northwest part of the map.

Wedged between faults to the northwest are small patches of the North Horn Formation (Tw). Thickness of the variegated shale unit is impossible to determine because of faulting. In the southwest map corner outcrops of the Bullion Canyon volcanics of Tertiary age cap a large part of the Fish Lake Plateau. The volcanics effectively end the coal field and continue southward in one plateau block after another for 50 miles where Cretaceous rocks again reappear in the Kaiparowits Plateau. In the Kaiparowits the rocks are also coal bearing. The area surrounding the volcanics is covered with an apron of high-level gravel composed of volcanics, quartzites, chert and limestone. The latter constituents appear to have a Precambrian or Paleozoic primary age which probably indicates a major uplift beneath the volcanics. Large patches of landslide have developed on some of the incompetent units.

STRUCTURE

Numerous faults on Emery 3 NW probably represent a clash between the Joes Valley fault zone (Paradise system) and those faults uplifting to the south. The Joes Valley faults trend mainly north-south and have larger displacements. The Ferron is exposed just east of the major fault and a little to the south. Other faults trend irregularly although in clusters they are similar; they are probably radial and concentric to the high centered in the south. Most of these faults have less than 100 feet of displacement. One north-south fault along the west map edge has at least a 1,500-foot displacement with Price River against the Masuk. This fault may be a southward extension of the Musinia fault zone. East of the Paradise fault rocks are slightly faulted but moderately folded. At least one pair of structural axes can be determined and dips between them range to 15 degrees. Less is known about the

EMERY 3N.W., UTAH



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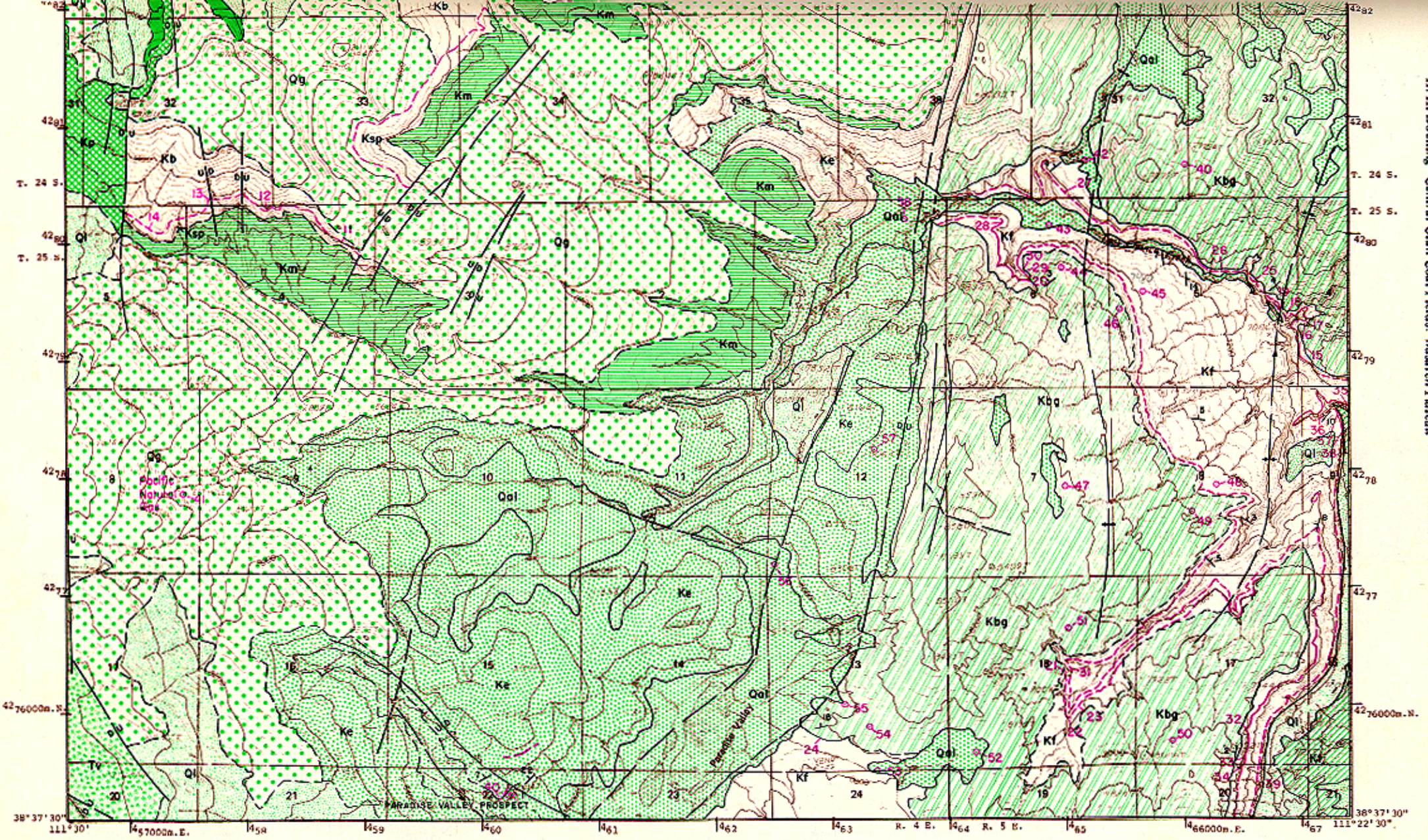

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SCALE 1:42240

Geology and coal data by
E. M. Spieker, 1931, USGS

Figure 33. Coal and geology map, Emery 3 NW quadrangle (explanation pages 136-137).

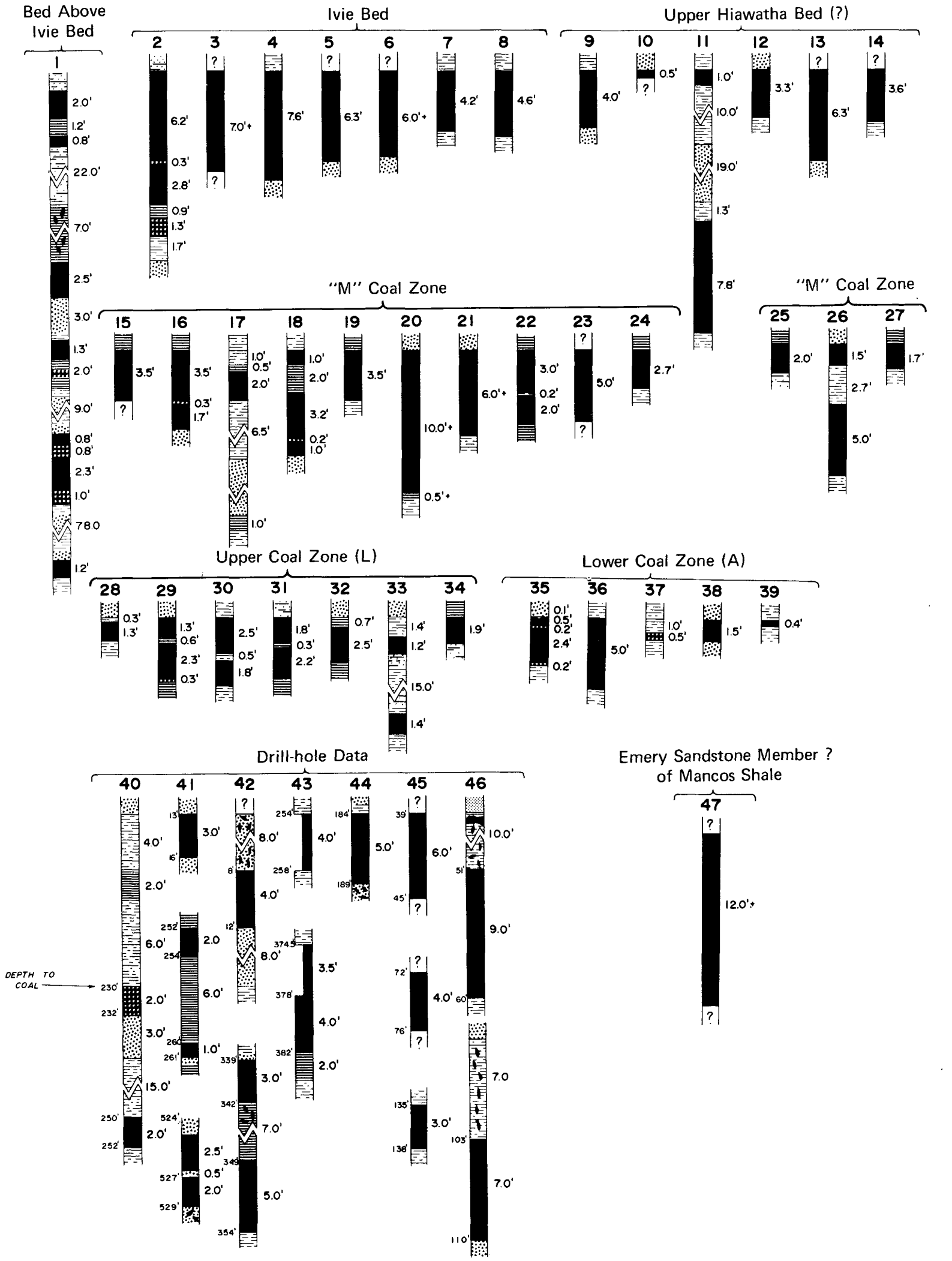

Figure 34. Coal sections of Emery 3 NW quadrangle (vertical scale: 1 inch = 8 feet).

attitude of beds to the west. Regionally they dip gently westward or northwestward as in the north part of the quadrangle. Farther south the beds are inclined more to the north at steeper angles.

PROPERTY CONTROL

On January 1, 1970, lands of the Emery 3 NW quadrangle were divided as follows: National Forest Service 78.5 percent, Bureau of Land Management 16.7 percent, private property 2.9 percent and state of Utah 1.9 percent.

BLM and state of Utah lands are located along the east edge of the map; private land is mostly in the Paradise Valley area. Coal lands are divided between the Blackhawk, bearing Wasatch Plateau coal, and the Emery coal field (Ferron coal). An estimated 70 percent or more of the land may be classed for coal–only a few hundred acres are not underlain with coal. A strip of land between the Blackhawk and Emery outcrops, however, is considered over the 3,000-foot limit for the Ferron. Of the coal lands 51.3 percent are assigned to the Wasatch Plateau and 48.7 percent to the Emery field.

More than 77 percent of the Emery portion of the coal lands are leased or permitted, all by Mountain States Resources Co. This includes the state lease 32-24S-5E. No land is held in the Wasatch Plateau area (1970).

COAL

Surface Information

Of the 47 sections of coal available for the Emery 3 NW quadrangle, 14 represent the Wasatch Plateau and the remainder the Emery field (figure 34). Two important beds in separate areas and inconsequential upper beds as indicated by measured section 1 are in the quadrangle. The Upper Hiawatha (?) is well developed along the upper reaches of the North Fork of Last Chance Creek (coal sections 9 to 14); it is 20 feet above the base of the Blackhawk and varies in thickness to a maximum of 8 feet. Estimated to be 80 to 90 feet above the Star Point, the Ivie bed is developed in the north part of the area. According to Spieker (1931, p. 196), "It is 3 to 11 feet thick throughout the area controlled by exposures in Ivie, Clear, and Red Creeks, and only at the westernmost exposures does any sign of inferiority appear. There the bed is split, and it is unfortunate that no exposures are available farther west, so that the extent of the area of poor coal is not known."

The coal in the Emery field is in the Ferron Sandstone Member of the Mancos Shale. A discussion of this coal is given in the Emery 3 NW quadrangle report of the Emery coal field. Just west of Paradise Valley a coal bed presently assigned to the Emery Sandstone is 12 feet thick. Palynological evidence suggests the coal is in the Blackhawk.

Subsurface Information

No drill holes are available for the Wasatch Plateau south area. The coal is mostly under less than 1,000 feet of cover except in part of the west tier of sections. The overburden is supposedly not more than 2,000 feet on the quadrangle. Drill-hole data for the Ferron coal are given in the Emery coal field report.

Quality of Coal

Three analyses, two from the Ivie bed in the Blackhawk Formation and one from the lower zone of the Ferron at map location 36, are available for coal in the quadrangle (table 5). On all three sulfur content is low, between 0.5 and 0.6 percent. Moisture content is high but samples were collected from weathered outcrops or prospects. Ash content of the Ferron coal is higher than that of the Ivie bed (9.0 percent to 6.7 percent) and the calorific value for the Ferron is lower.

Mines and Development

A few small mines and several prospects have been opened on the Emery 3 NW quadrangle. Adits have been driven in Clear Creek Canyon, Red Creek Canyon, Last Chance Canyon and on the west side of Paradise Valley. Those in Red Creek and Clear Creek canyons are in the Ivie bed. Those in Last Chance Canyon are in the Upper zone of the Ferron and the one on the west side of Paradise Valley is mapped in the Emery Sandstone. Lupton (1916, p. 76) makes no mention of the prospect at this locality and digging is believed to have come after 1916. The other prospects were noted by Spieker in his 1922 field work. Nothing is known about these mines or their production. Some of the workings were visited by the present writer; all seem old and as if little coal was removed.

Reserves

Spieker (1931, p. 206) calculated the reserves for the Wasatch Plateau part of the field (table 28):

Table 28. Original reserves in the Emery 3 NW quadrangle (in short tons; beds 30 inches or more thick).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.24S. R.4E.	8,852	6.0	95,601,600	Ivie bed secs. 1-18, 21-24
	5,400	4.0	38,880,000	Other beds
		Total coal	134,481,600	

Lupton (1916, p. 86) estimated reserves for the Emery field. They are high because he figured all beds regardless of thickness in his estimates. His reserves adjusted to the quadrangle are as follows (table 29):

Table 29. Recalculated reserves in the Emery 3 NW quadrangle (includes all beds).

	Total	Recoverable
T.24S. R.5E.	92,259,000	51,255,000
T.25S. R.4E.	10,031,000	5,580,300
T.25S. R.5E.	37,630,000	20,905,500
Total coal	139,920,000	77,740,800

Emery coal is not considered and Ferron coal reserves are tabulated in the Emery coal field report.

PRINCIPAL WORK

Data for the Emery 3 NW quadrangle have come mostly from Spieker (1931).

West approach to the U. S. Fuel mine, town of Hiawatha.

FERRON CANYON QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Ferron Canyon quadrangle straddles the Sanpete-Emery County line in the central part of the Wasatch Plateau coal field (figures 22 and 35). The southeast corner of the map is about 8 miles west of the town of Ferron which is located in Castle Valley. Access roads from Ferron connect with the forest roads in the quadrangle but many areas are difficult of access.

The area is mountainous; the outstanding physiographic feature is the canyon of Ferron Creek with walls of 1,200 feet. Southwest of the canyon is Ferron Mountain and to the north is Wagon Road Ridge. These mountains rise above 10,000 feet while the bottom of Ferron Canyon is 6,500 feet above sea level, a relief of about 3,500 feet.

Coal is exposed in the canyon walls at about 6,800 feet of elevation. Outcrop extent is small but practically the entire quadrangle must contain subsurface seams.

STRATIGRAPHY

Only the Mesaverde Group and younger units are exposed. The initial unit, the Star Point Sandstone, outcrops in two small localities: immediately west of the westernmost fault of the Joes Valley fault zone in Ferron Canyon and west of the same fault in Stevens Canyon. The yellow-gray massive sandstones are incompletely exposed. The coal-bearing Blackhawk Formation occurs in the walls of Ferron Canyon and along certain fault slivers. The unit is about 750 feet thick in Ferron Canyon and the coal beds are localized in the lower third of the formation. The upper rim of the canyon wall is made up of Castlegate Sandstone. Younger units crop out on the tops of the mountains; the higher peaks consist of Flagstaff Limestone, youngest consolidated unit on the quadrangle.

Unit	Thickness (feet)
Flagstaff Limestone	900+
North Horn Formation	1,600-2,000
Price River Formation	300- 400
Castlegate Sandstone	90- 150
Blackhawk Formation	750
Star Point Sandstone	Incomplete

STRUCTURE

The most significant structural feature on the Ferron Canyon quadrangle, Joes Valley fault zone, is just inside Emery County and is about 2 to 2½ miles wide (figure 36). The system is more complex to the south with at least nine prominent faults. Displacements range up to 1,200 feet. The rocks between the east- and west-bounding faults have mostly collapsed to form grabens.

Strata are sometimes steeply inclined in the fault blocks but generally in and outside the fault zone, the beds are inclined less than 5 degrees.

PROPERTY CONTROL

Except for 3.7 percent of the quadrangle area (private property), all is controlled by the National Forest Service. None of the land is held as leases or permits. The coal land amounts to 99.7 percent of the quadrangle.

COAL

Surface Information

Actual outcrop area is small and the amount of surface information minimal. All of the 19 sections (figure 37) are representative of the Hiawatha or Upper Hiawatha beds.

	Feet
Slide Hollow bed	0-8
Interval	150
Blind Canyon bed	0-5
Interval	15
Upper Hiawatha bed	2-5
Interval	20
Hiawatha bed	0-8
Star Point Sandstone	

The most valuable bed appears to be the Hiawatha. No sections were taken in the fault zone so the data represent the area to the west. Here the coal ranges between 4 and 8 feet thick. The Upper Hiawatha bed is much less valuable and averages between 2 and 4 feet on the south side of Ferron Canyon.

Blind Canyon bed, 5 feet thick, has only been discovered at location 8, 45 feet above the Hiawatha. Slide Hollow bed is 8 feet thick on Birch Creek just south of the quadrangle in the fault zone. The bed possibly extends onto the map area.

Subsurface Information

No drill-hole data are available and little is known about the coal behind the outcrops. Nearly all the area is underlain by coal; 15 percent lie at depths less than 1,000 feet, 49.3 percent 1,000 to 2,000 feet, 30.6 percent 2,000 to 3,000 feet and 5.1 percent deeper than 3,000 feet. The areas of deepest coal are under the peaks capped with Flagstaff Limestone.

Quality of Coal

No analyses are available for the Ferron Canyon quadrangle.

Mines and Development

No mines have been opened in the Ferron Canyon area; several prospect pits have been dug, however. No significant production has come from these prospects.

Reserves

Spieker's reserves calculated for the Ferron Canyon quadrangle are small compared with other quadrangles in the field (table 30). All of the area was not considered, especially to the west and north, but the coal beds are not as thick and do not appear as continuous as in other areas of the field.

Table 30. Original reserves in the Ferron Canyon quadrangle (in short tons).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.18S. R.6E.	1,508	4.5	12,214,800	Hiawatha
T.19S. R.5E.	3,250	5.0	29,250,000	Hiawatha secs. 13, 14, 23-26, 36
T.19S. R.6E.	1,000	4.0	7,200,000	Hiawatha E of fault zone
	1,000	5.0	9,000,000	Hiawatha secs. 18, 19, 30, 31
		Total coal	57,664,800	

PRINCIPAL WORK

Data for this quadrangle are modified from Spieker (1931).

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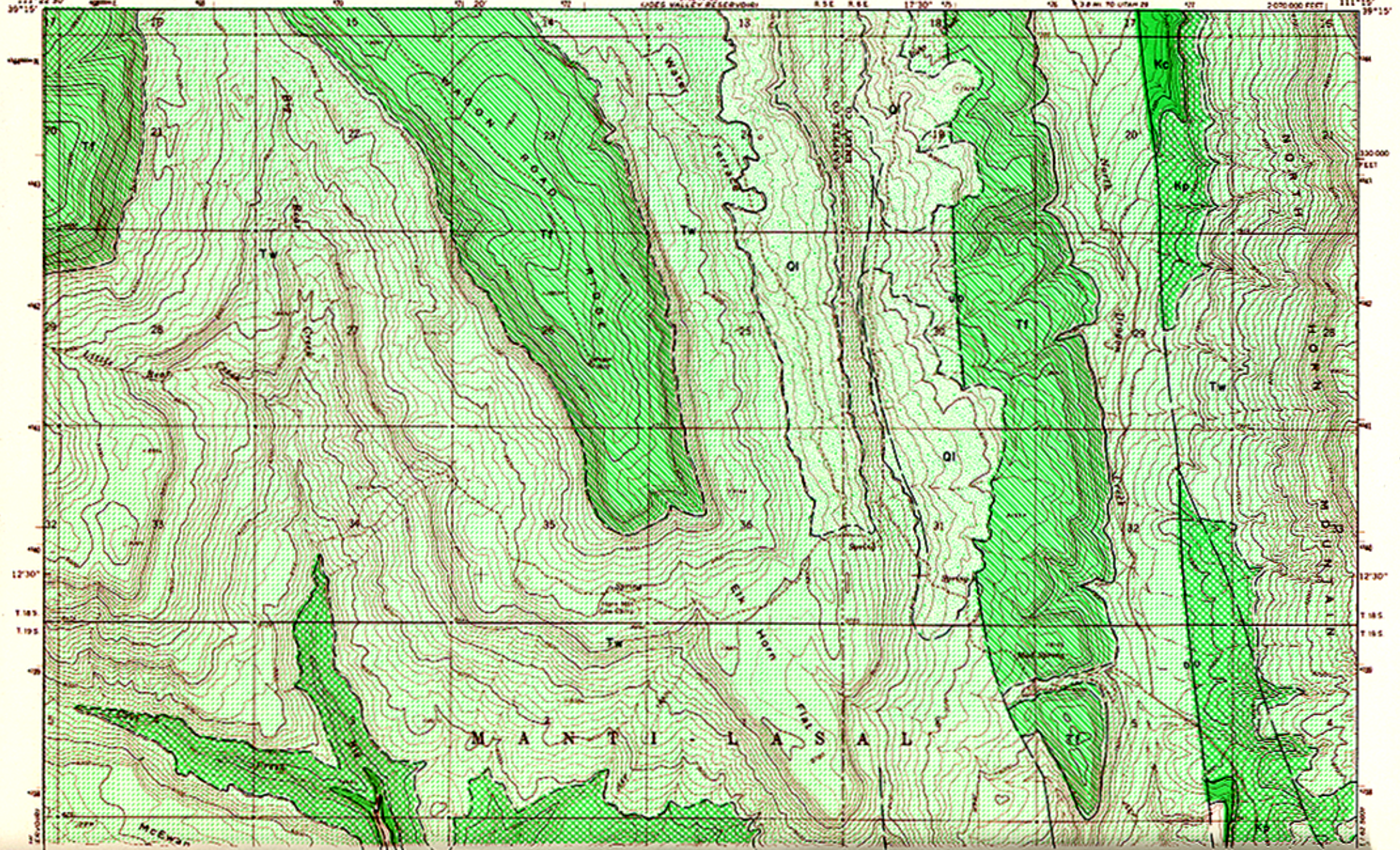
FERRON CANYON QUADRANGLE
UTAH
7.5 MINUTE SERIES (TOPOGRAPHIC)



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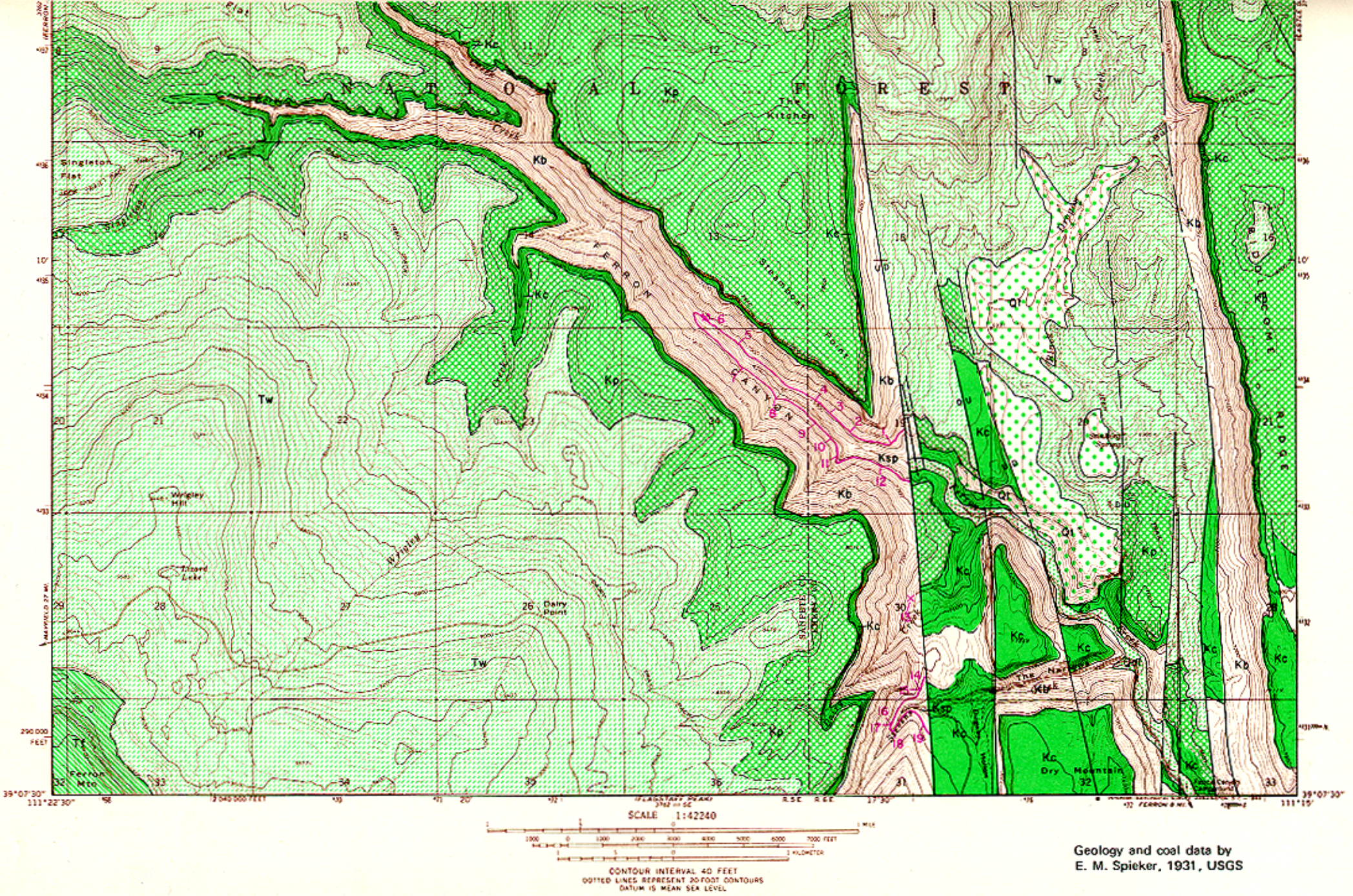


Figure 35. Coal and geology map, Ferron Canyon quadrangle (explanation pages 136-137).

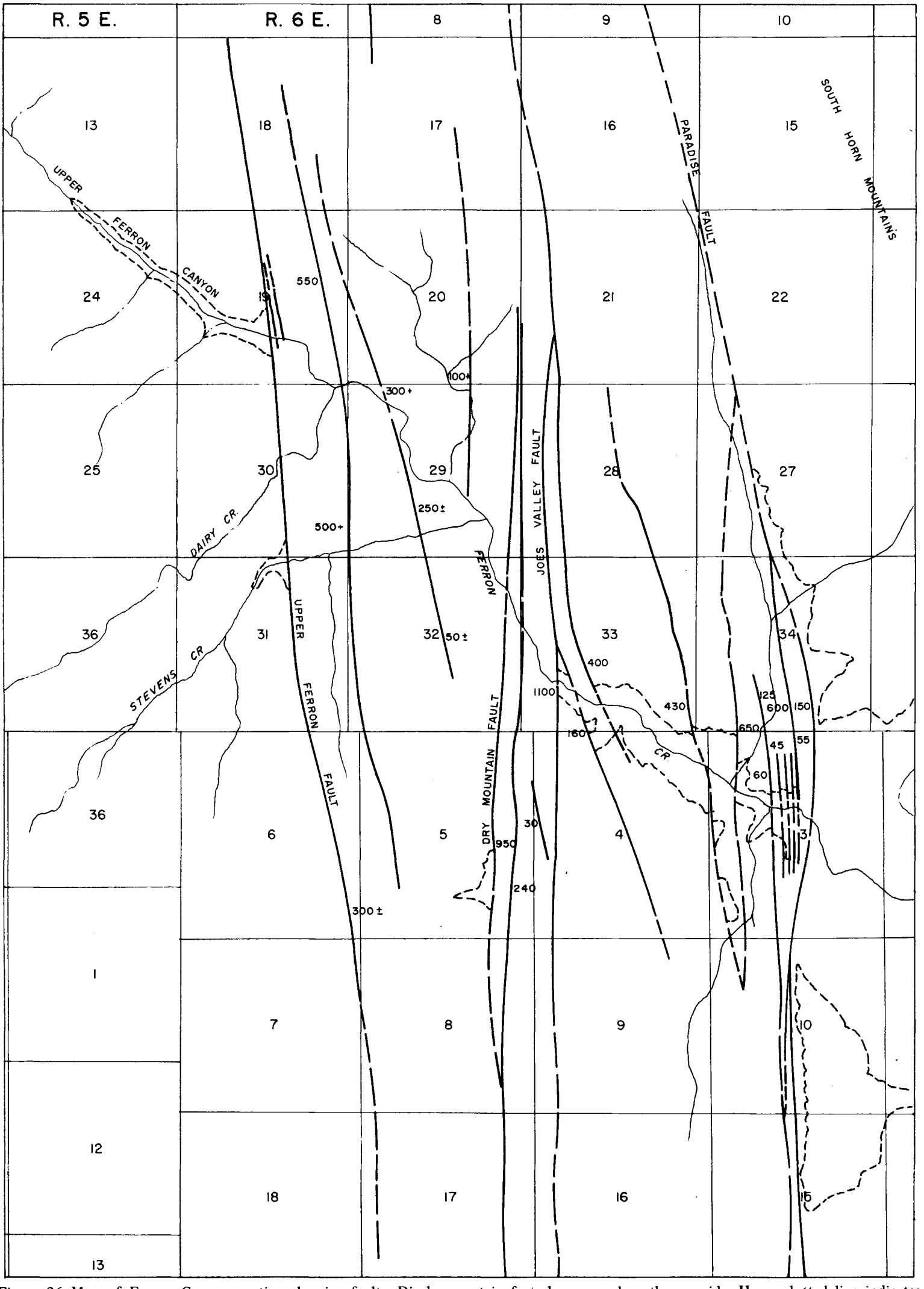


Figure 36. Map of Ferron Canyon section showing faults. Displacement in feet shown on downthrown side. Heavy dotted line indicates outline of Hiawatha coal bed.

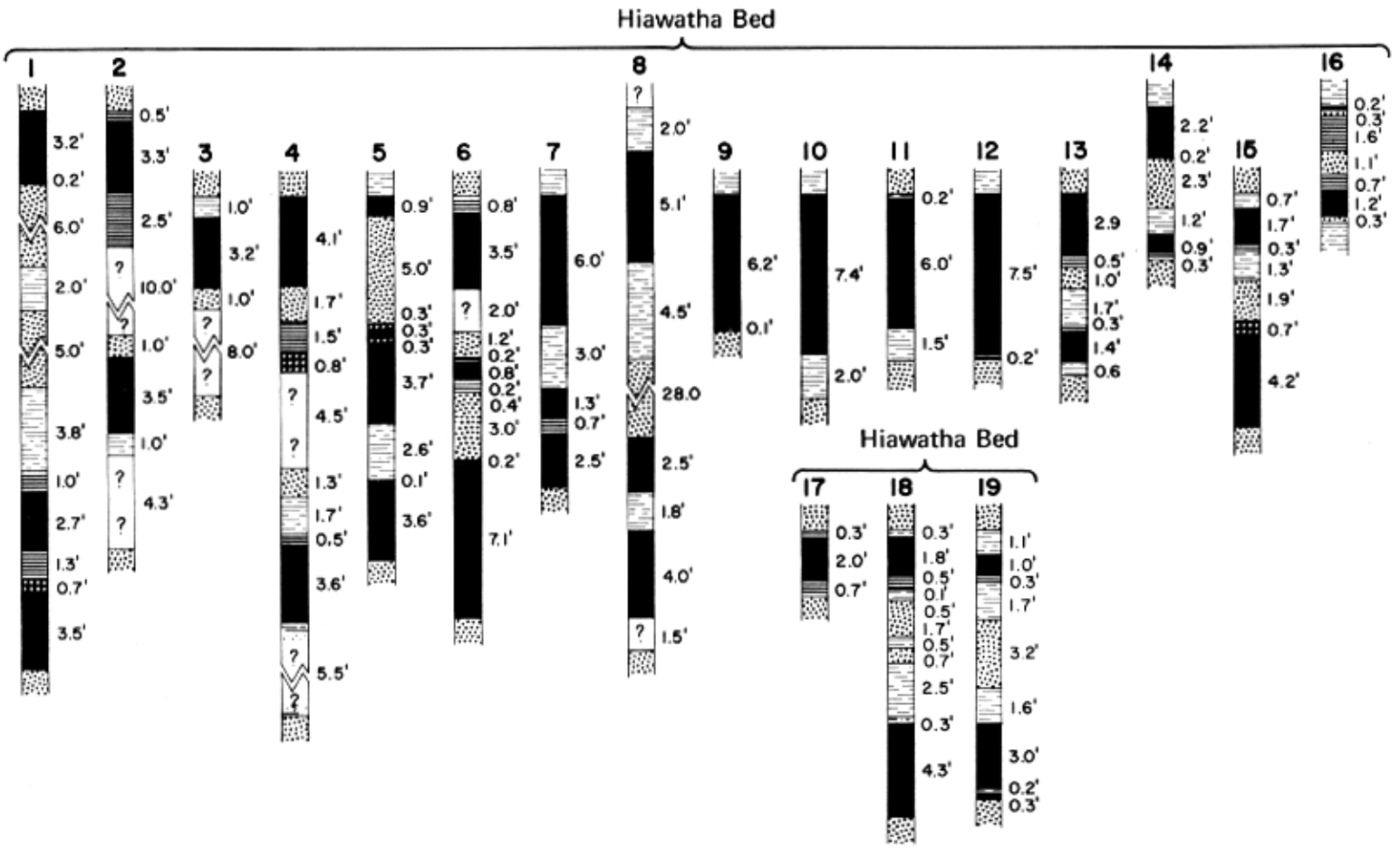
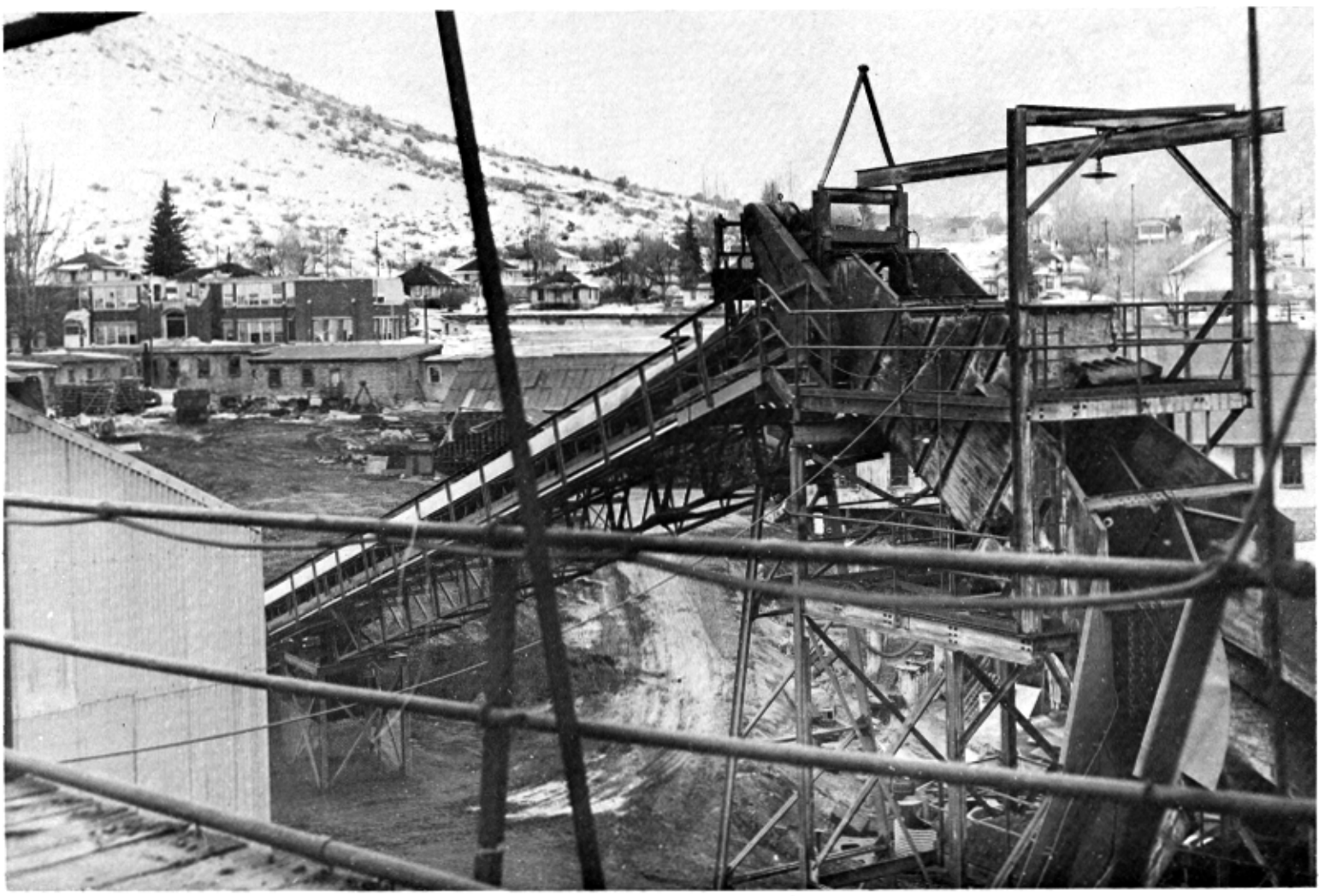
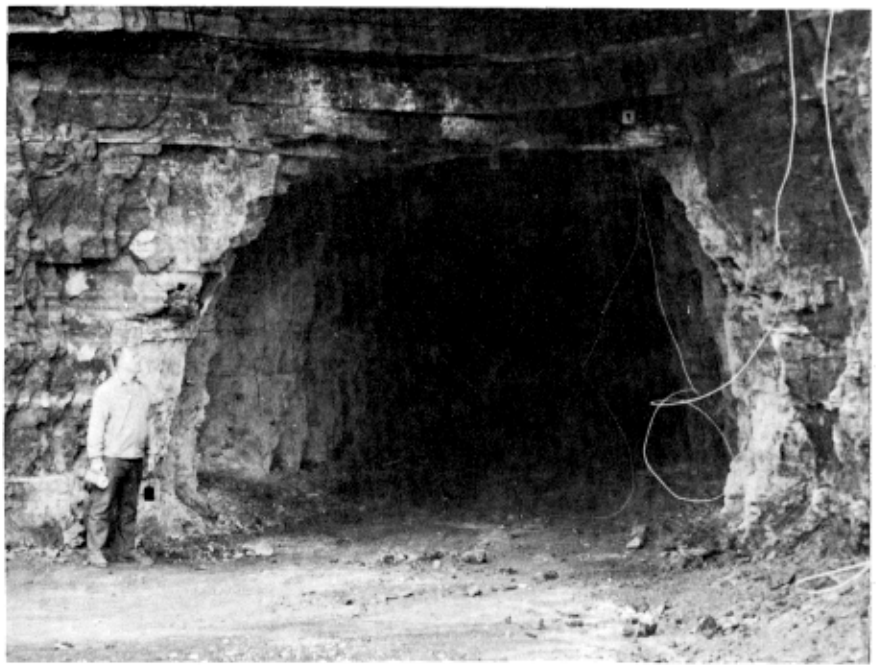


Figure 37. Coal sections of Ferron Canyon quadrangle (vertical scale: 1 inch = 8 feet).



Conveyors at U. S. Fuel's Hiawatha tipple; town in background.



Left: Portal to Wilberg (Castle Valley) mine, Grimes Wash along Cottonwood Canyon; now abandoned. *Below*: Loading arrangement of Plateau Mining, north end of Gentry Mountain, Hiawatha area.

FLAGSTAFF PEAK QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Flagstaff Peak quadrangle is located a few miles south of the center of the Wasatch Plateau where Emery, Sanpete and Sevier counties join (figures 22 and 38). The dominant geographic feature, Ferron Mountain, has as one of its prominences Flagstaff Peak. Muddy Creek is the main drainage south of Ferron Mountain and Ferron Creek is the dominant drainage to the north. Ferron Creek just cuts into the quadrangle in the northeast corner. Access is poor; a good road follows Ferron Creek but the others are inadequately maintained. Utah Highway 10 is 5 to 7 miles east and the town of Ferron 7 miles east of the map area.

Elevations range from 6,600 feet in the major creek bottoms to more than 10,500 feet on Ferron Mountain. Flagstaff Peak is 10,222 feet above sea level. Coal exposures are found between 6,600 and 7,750 feet.

STRATIGRAPHY

Because the Flagstaff Peak quadrangle lies deeper in the plateau, most rock exposures are the younger part of the stratigraphic sequence. The oldest beds–the Masuk Shale Member of the Mancos Shale–outcrop in the lower half of Muddy Creek Canyon. About 800 feet of exposed dark gray shales are believed to represent a nearly complete section. In the Castle Dale SW quadrangle the unit is 900 feet thick.

Exposures of the Star Point Sandstone in Muddy Creek and Ferron Creek canyons vary from 350 to 450 feet thick. The unit is cliffy yellow-gray sandstone. The Blackhawk makes up most of the canyon walls of Muddy and Ferron creeks and their principal tributaries. It consists of sandstone, shale and coal in order of abundance; coal occurs in thick beds in the lower one-third of the unit. The Blackhawk is about 700 feet thick along Muddy Creek.

The Castlegate Sandstone and its lithological counterpart, the Price River Formation, are the next younger formations. They complete the canyon walls and make up part of the Wasatch Plateau upper surface. The initial part of the gritty sandstone units, a massive cliff about 200 feet thick, is assigned to the Castlegate. The upper Price River is less resistant, more step-like in its outcrop pattern and ranges from 250 to 700 feet thick. Variation in thickness is attributed to differences in sediment received.

Most of the upper surface of Ferron Mountain is composed of North Horn Formation (Tw). The nearly 1,500-foot unit of variegated shales and subordinate conglomerate, sandstone and limestone straddles the Cretaceous-Tertiary time line. The Flagstaff Limestone is the youngest consolidated unit and forms the capping cliffs atop the North Horn. The light colored limestone is easily recognizable and resistant. At least 500 feet of the unit remain uneroded.

STRUCTURE

The Joes Valley fault zone cuts north-south along the east edge of the quadrangle. The remainder of the area is relatively free of deformation. The east and west boundaries of the fault zone, the Paradise and Muddy faults, have at least two other major faults between them; rocks in the middle form a graben. The west fault near Sage Flat uplifted the base of the Flagstaff against the top of the Blackhawk displacing 2,000 feet.

Beds west of the fault zone are slightly disturbed and inclined to 4 degrees to the northwest. Even between the faults, degree of folding is slight except immediately adjacent to a fault. Beds steepen somewhat in the southeast corner of the map east of the fault.

PROPERTY CONTROL

The Flagstaff Peak quadrangle is under the jurisdiction of the National Forest Service. Nearly 95 percent of the land are coal land, but none currently is leased as such.

COAL

Surface Information

Surface data reveal the presence of four coal beds of possible value in the Flagstaff Peak area (figure 39). The lowest bed is the Hiawatha and according to Spieker (1931, p. 178):

> In Muddy Canyon the bed is variable to an extent that is surprising to one who is familiar with it farther north. It is thin near the Muddy Canyon fault on both sides of the canyon. On the north side it thickens rapidly westward and between locations (23) and (32) it is for the most part over 4 feet thick with a maximum observed thickness of 8 feet 7 inches at location (32). Between locations (32) and (33) it thins to about 2 feet, and as far west as Last Water Canyon it is no thicker. Still farther west it disappears completely and the evidence found on the south side of the canyon indicates that it is almost completely absent there...

In the Slide Hollow area to the north the bed is 3 to 4 feet thick.

Next, the Upper Hiawatha bed is thickest in the same area as that of the Hiawatha, but even here does not attain a thickness of 4 feet. The Upper Hiawatha has little value on this quadrangle.

The Muddy No. 1 bed is 4 to 6 feet thick in the portion of Muddy Canyon in Sevier and Sanpete counties. To the east it is thin. The Muddy No. 2 bed has a variable thickness throughout the area. The bed splits into two 2-foot thick members where it V's across Muddy Canyon. Between Box Canyon and the canyon to the east, it is 5 feet thick; elsewhere it is thin.

In the Slide Hollow-Birch Creek area a thick bed occurs that would be valuable except for its proximity to faults. It is, however, local in extent.

	Feet
Slide Hollow bed	0-8
Interval	120
Muddy No. 2 bed	0-5
Interval	28
Muddy No. 1 bed	0-9
Interval	10
Upper Hiawatha bed	0-4
Interval	25
Hiawatha bed	0-9
Star Point Sandstone	

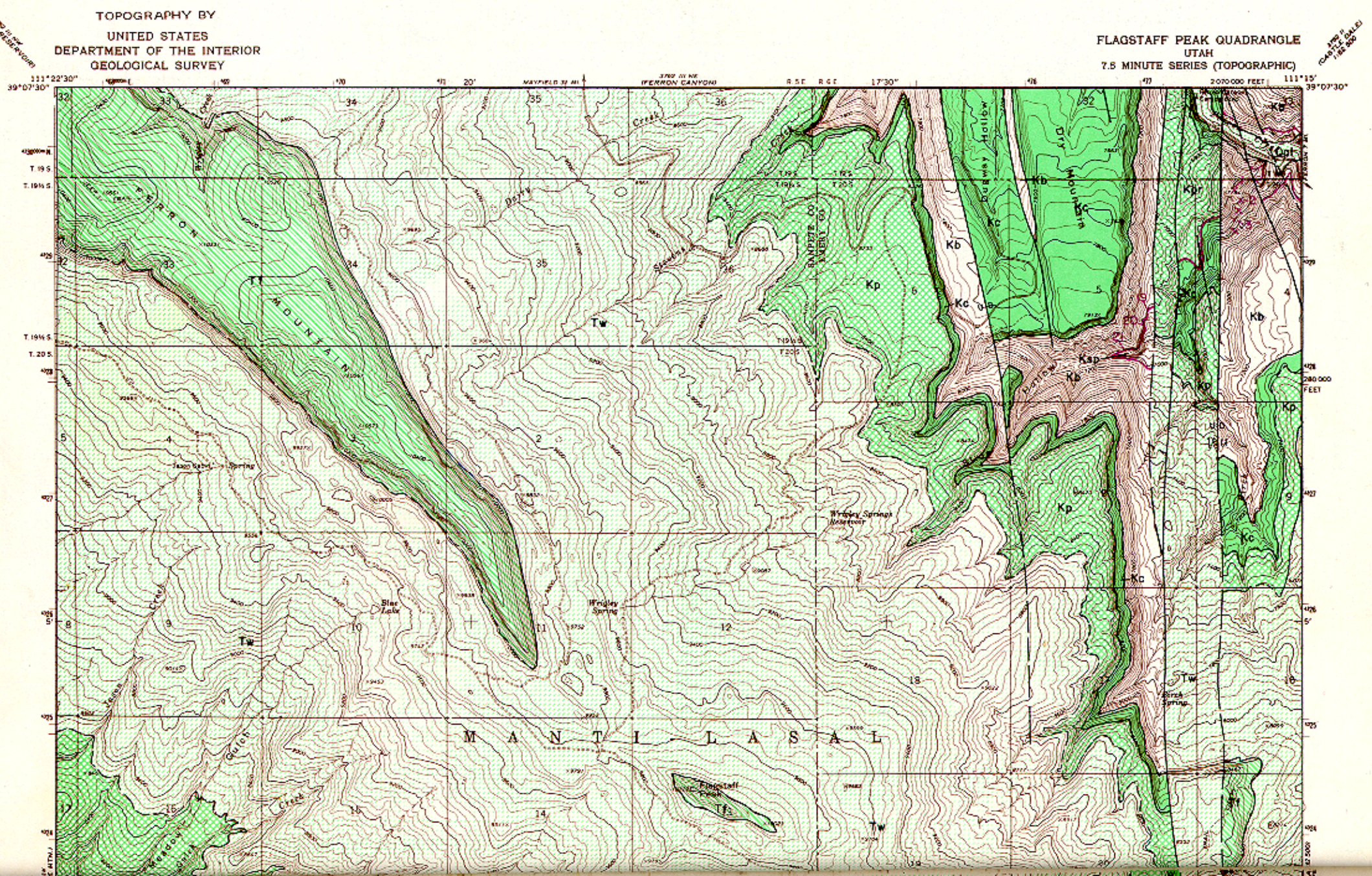
Subsurface Information

No drill-hole data are available and at least 60 percent of the coal land are more than 1½ miles from a control point. The amount of cover above the coal with respect to total coal land is as follows: 3,000 feet or more 5.5 percent, 2,000 to 3,000 feet 26.5 percent, 1,000 to 2,000 feet 52.6 percent and 0 to 1,000 feet 15.4 percent.

Quality of Coal

From one analysis (table 5) 8.4 percent moisture content was reported, 7.3 percent ash and 0.47 percent sulfur. Coal is believed to be from the Muddy No. 1 bed.

Walker and Hartner (1966, p. 37) subdivided the sulfur content into 0.01 percent sulfate, 0.20 percent pyritic and 0.26 percent organic. Gomez, Landers and Boyd (1967, p. 12) calculated carbonization yields for the same sample (table 31; end carbonization temperature 500° C).



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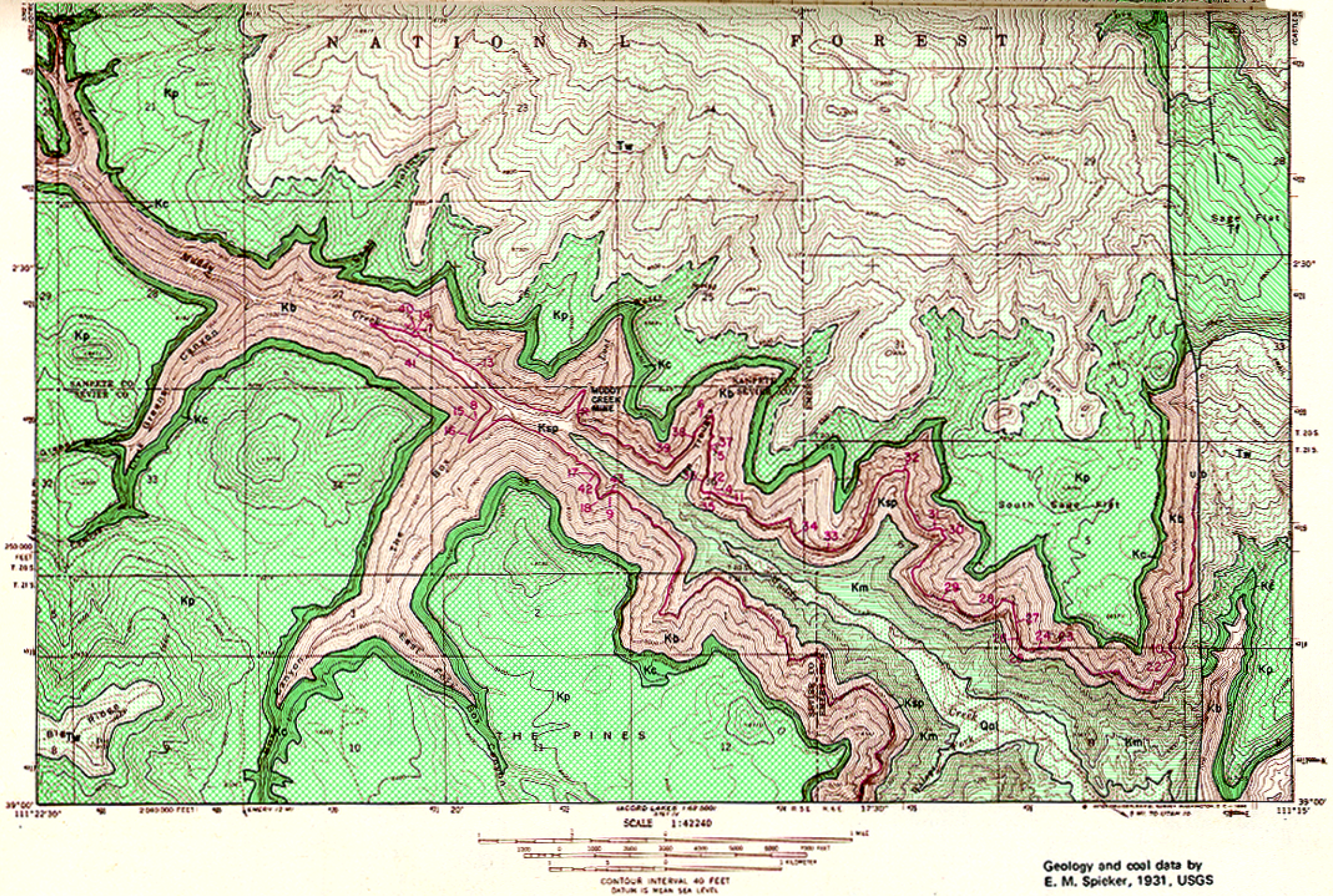


Figure 38. Coal and geology map, Flagstaff Peak quadrangle (explanation pages 136-137).

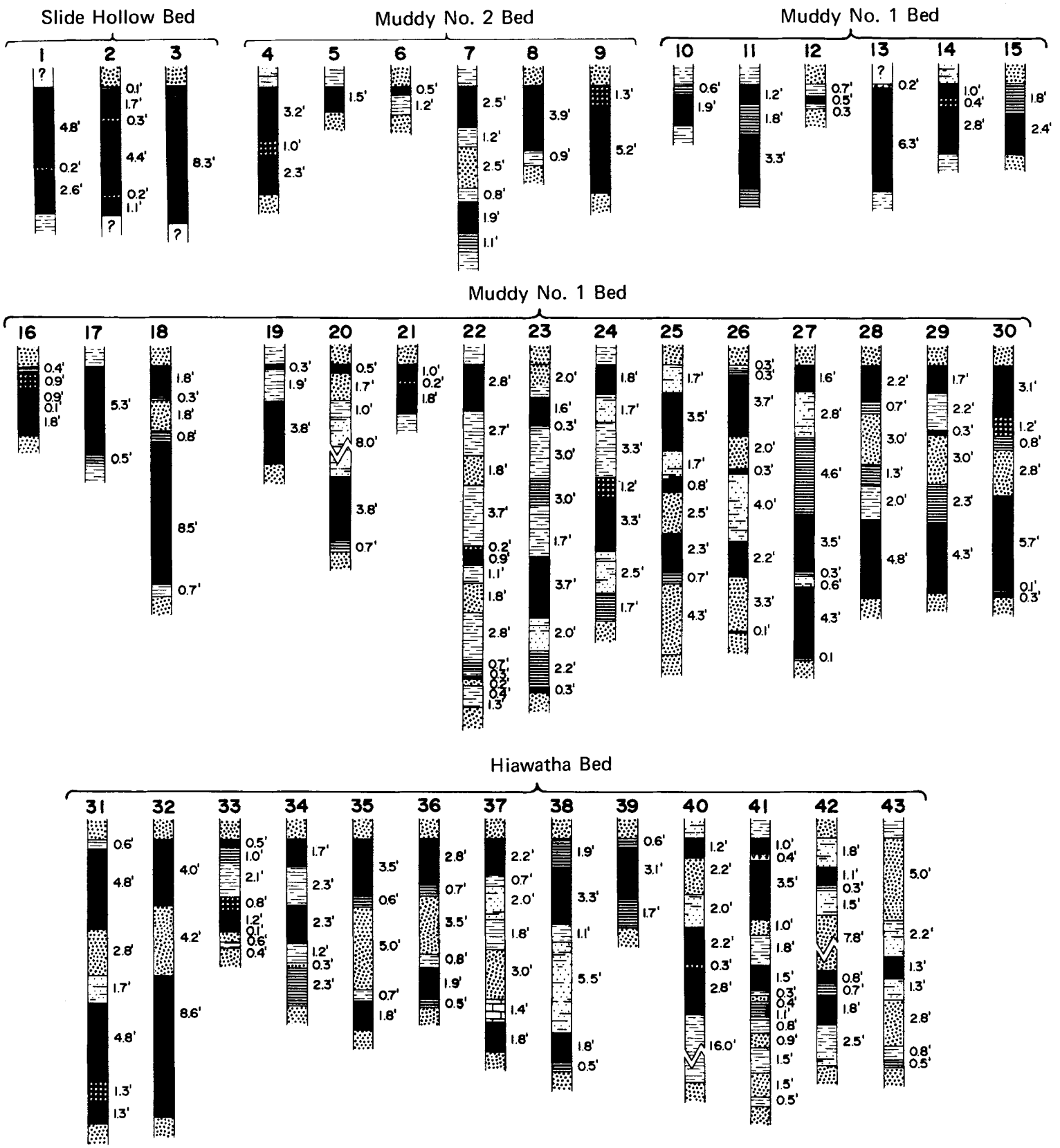


Figure 39. Coal sections of Flagstaff Peak quadrangle (vertical scale: 1 inch = 8 feet).

Table 31. Carbonization product yields, Flagstaff Peak quadrangle.

Carbonization yields, wt. percent of maf coal				Gas volume scf/lb maf coal	Heating value of gas Btu/scf
Char	Water of decomposition	Tar plus light oil	Gas		
71.1	5.9	16.1	6.2	1.054	731

Mines and Development

At least two mines have been opened on the Flagstaff Peak quadrangle (table 32): in the Muddy Creek drainage basin and in the Ferron Creek Basin.

Table 32. Mines and their locations, Flagstaff Peak quadrangle.

Mine	Location	Remarks
Ricci mine (Muddy Creek)	NE.NE.35-20S-5E 4,319,940m.N. 472,270m.E.	Active 1941-1953
Slide Hollow mine	4-20S-6E (exact location unknown)	Very old and presently (1970) abandoned

The Ricci mine in Muddy Canyon just south of the Sanpete-Sevier County line near the mouth of Last Water Canyon has two minable seams, the Muddy No. 1 and No. 2. The lower is at least 12 feet thick and the upper 4 feet thick with 12 to 18 feet between them. The thicker seam has a parting up to 6 inches thick about one-third from the top of the bed. At least 35,000 tons have been mined.

All that is known about the Slide Hollow mine is reported by Spieker (1931, p. 175):

> In the little gorge of Birch Creek, part of the large depression known as Slide Hollow, is an old mine from which a moderate amount of coal has been taken but which has not operated for a number of years. The mine is a little more than half a mile from the main road in Ferron Canyon and was formerly accessible by a mine road, but in 1922 only slight traces of this road remained and even saddle-horse travel in the canyon was difficult.
>
> The main entry of the mine has been driven about 250 feet S. 20° E., and five rooms have been turned. In the mine the coal dips 9° W., and the strike is about N. 25° W. The entry has been driven approximately on the strike of the rocks. At the end of the entry the roof dips down suddenly, in manner similar to that common in "wants," and the coal thins abruptly from 8 feet to 3½ feet. The coal here is friable and powdery and the upper part of the bed has the appearance of burned coal. Between the coal and the overlying sandstone is 1 to 2 inches of a powdery white material much like ash. It is thus possible that the coal had been burned here, although it is difficult to account for the origin of a fire 250 feet from the outcrop, with the intervening coal unburned.
>
> The coal in this mine is not as fresh and hard as that normal to the field but has more the appearance of outcrop coal. The joint planes are covered with rusty-looking resin. The lower part of the bed is better than the upper part. Near the roof and floor the coal contains many inclusions of sand, called "spar" by miners in the field.
>
> The roof of the mine is a homogeneous massive sandstone, that is so friable that huge blocks of it have fallen into all the rooms, although it appears solid and massive. It crumbles readily in the hand. Timbers in the main entry show no sign of stress, yet the roof has caved completely in all the rooms save one. The condition of this sandstone and the coal shows how far from the outcrop the effect of weather may penetrate in faulted zones.

Neither the definition of "moderate amount" of coal nor the size of the five rooms is given to estimate production. It is probably less than 5,000 tons so not more than 40,000 tons of coal have been removed from the quadrangle.

Reserves

Reserves for the quadrangle according to Spieker (1931, p. 205-206) are modified to fit the quadrangle (table 33).

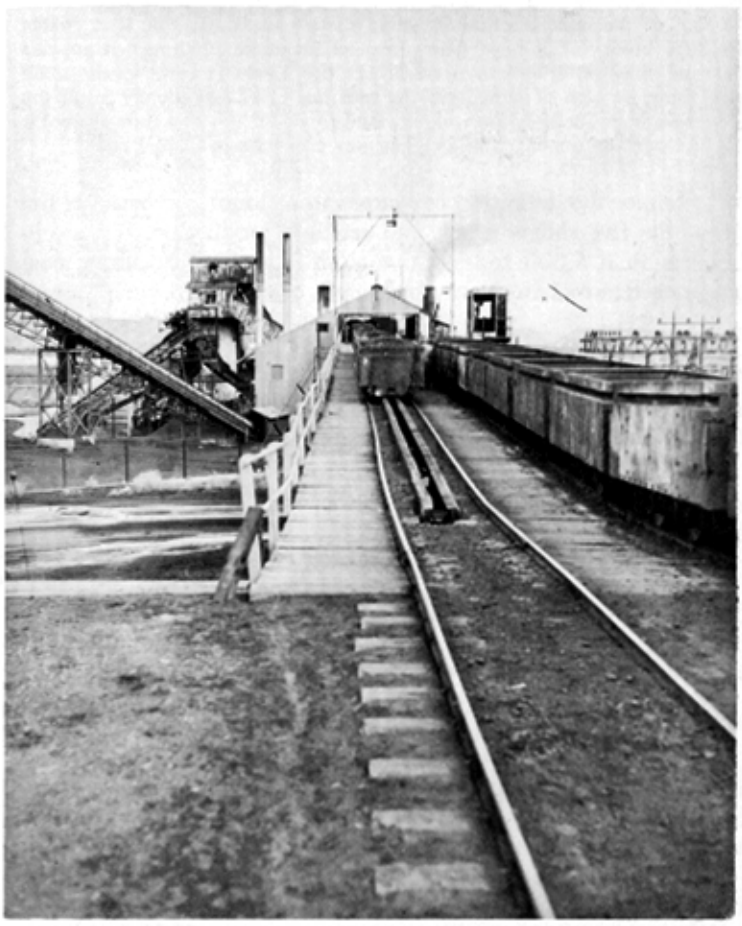
Table 33. Original reserves in the Flagstaff Peak quadrangle (in short tons).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.19S. R.5E.	310	5.0	2,790,000	Hiawatha, sec. 36
T.19S. R.6E.	212	4.0	1,526,400	Hiawatha, sec. 33
	307	5.0	2,763,000	Hiawatha, sec. 31
T.19 ½S. R.5E.	1,548	4.0	11,000,000	Muddy No. 1, parts of secs. 26, 27, 34-36.
	1,388	4.0	10,000,000	Muddy No. 2, parts of secs. 26, 27, 34-36.
	9,900	11.0	196,000,000	All beds remainder of E. ½ Twp.
T.20S. R.6E.	1,447	4.0	10,418,400	Hiawatha secs. 28-33.
	960	5.0	9,000,000	Muddy Nos. 1 and 2, SW corner Twp.
	212	6.0	2,000,000	Slide Hollow bed, includes parts in T.19S. R.6E. where 7 ft. thick.
	3,200	5.0	31,000,000	All beds secs. 17-20, parts of 29-30.
T.21S. R.5E.	1,000	5.0	9,000,000	Muddy No. 1, parts secs. 1, 2, 11, 12.
	800	4.0	5,760,000	Muddy No. 2, parts secs. 1, 2, 11, 12.
	2,984	17.0	91,310,400	All beds, part of Twp. excluded in est. of other beds
T.21S. R.6E.	1,133	4.2	9,000,000	Hiawatha bed
	348	5.0	3,000,000	Muddy No. 1 bed
		Total coal	394,568,200	

In the estimates Spieker may not have included the west part of T. 20 S., R. 5 W., inasmuch as his mapping ended about halfway across the township; the field extends an additional 3 to 6 miles west into R. 4 E. Nothing is known about this west coal; its presence is inferred and considered a Class IV reserve.

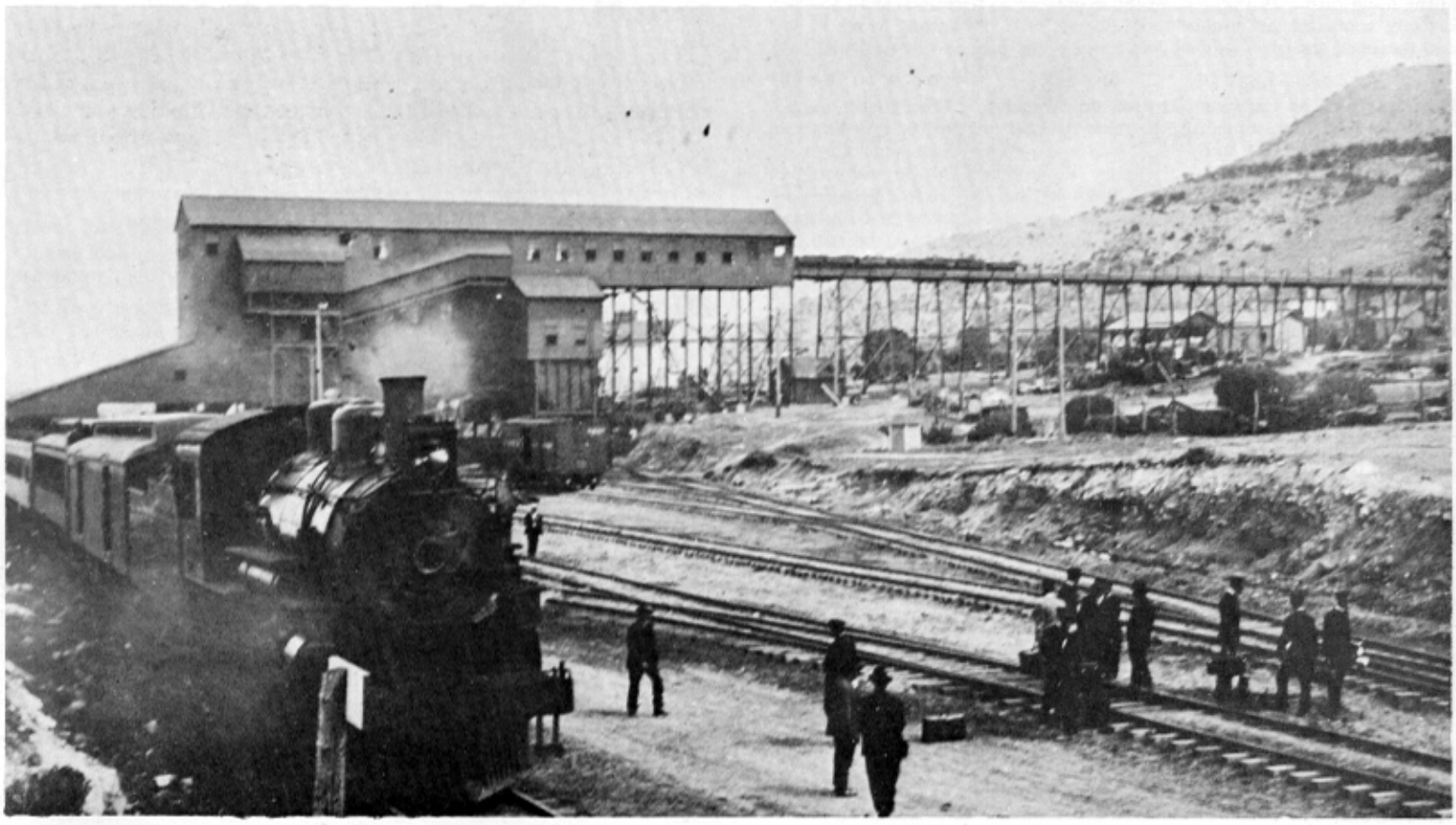
PRINCIPAL WORK

Nearly all the data presented for the Flagstaff Peak quadrangle were derived from Spieker (1931).



Looking northerly from just above the portal of the King mine above Hiawatha. A load of empty cars is just reaching the top.

Manway to U. S. Fuel's Hiawatha mines in canyon immediately west of Hiawatha; coal is taken from the King mine portal, 5 miles away underground.



Hiawatha railroad station and coal tipple, early 1900's. Photo from Helper Mining Museum original.

HIAWATHA NE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

Hiawatha NE is located in the north central part of the Wasatch Plateau coal field, centered around the south half of Gentry Mountain (figures 22 and 40). The coal mining towns of Hiawatha and Mohrland are located along the east edge of the map. The mouth of Huntington Canyon is in the south part of the quadrangle.

The landscape is rugged and cliffy. The only flat land is on top of Gentry Mountain between 9,250 and 9,750 feet above sea level. The highest elevation on the quadrangle at the north end of Gentry Mountain is more than 9,850 feet above sea level; at Hiawatha elevation is 7,181 feet, at Mohrland about 7,400 feet and along Huntington Creek lowest elevation is 6,300 feet. The coal lies between 7,500 and 8,250 feet. The town of Huntington is located about 4 miles to the southeast.

Highway accessibility is available to Mohrland, Hiawatha and along Huntington Canyon; the remaining area is inaccessible by vehicle. The Utah Railway (Utah Coal Route) extends from Helper to Mohrland via Hiawatha. Most of Hiawatha NE is in Emery County. The northeast corner, including Hiawatha, is in Carbon County.

STRATIGRAPHY

The exposed geologic column extends from the Emery Sandstone Member of the Mancos Shale to the North Horn Formation. Terrace gravels on the Mancos below the cliffs occur nearly everywhere between stream channels; alluvium is in the dominant stream channels.

In Hiawatha NE the Emery Sandstone is a pair of yellow-gray sandstone tongues. Between the tongues is a gray sandy shale of the same description as the shale members of the Mancos above and below the Emery. The tongues are possibly discontinuous in outcrop; it is difficult to differentiate the Masuk from the Blue Gate Shale. The Emery outcrops in the southeast map area.

The upper shale member of the Mancos exposed at the base of the cliffs is estimated to be more than 1,000 feet thick; it consists of blue-gray sandy shale. The initial cliffy unit is the Star Point Sandstone, the lower formation of the Mesaverde Group. It is basically a littoral sandstone with thick-bedded to massive beds separated by subordinate Mancos-like shale.

The Blackhawk Formation, named for the Blackhawk mine in sec. 3, T. 16 S., R. 8 E., just south of Hiawatha, is the most important unit. The alternating sandstone, shale and coal unit is about 1,000 feet thick in the vicinity of Mohrland. The outcrops form a step and slope topography slightly less resistant than the Star Point below and the Castlegate above. At least five valuable coal beds in the Hiawatha area occur in the lower 350 feet of the formation.

The upper Mesaverde or Castlegate and Price River formations are thin on Gentry Mountain compared to elsewhere. The coarse-grained sandstone beds are cliffy and resistant. The combined thickness varies from 350 to 500 feet on the Hiawatha NE.

Atop Gentry Mountain is the North Horn Formation (Tw). The variegated shales, thin limestone and sandstone beds are basically nonresistant. At least 750 feet of the unit are present on the Hiawatha NE quadrangle.

STRUCTURE

The beds under Gentry Mountain are nearly flat; except for disturbed beds near the faults in the west half of the quadrangle, all beds dip almost unnoticeably. Of concern are the faults of the Pleasant Valley fault zone trending nearly north-south which are located from Bear Creek Canyon westward to Trail Canyon. According to Spieker (1931, p. 144-145):

> In Tie Fork Canyon (in the northwest corner of the Hiawatha NE quadrangle) the zone comprises five well defined faults, but between Trail and Bear Creek Canyons, where the zone crosses Huntington Canyon it includes 12 major faults, many of which are accompanied by shear zones containing numerous smaller faults. These faults have obviously disturbed the strata bordering Huntington Canyon in the southeastern part of T. 16 S., R. 7 E., to an extent that will greatly hamper mining, but in the northeastern parts of both T. 16 S., and T. 17 S., R. 7 E., the larger faults seem to be spaced widely enough to allow considerable mining in the intervening blocks.

The displacements of these faults vary to 450 feet.

PROPERTY CONTROL

The breakdown of land ownership of the Hiawatha NE quadrangle is as follows: private 54 percent, National Forest Service 24 percent, Bureau of Land Management 20 percent and state of Utah 3 percent.

Coal lands amount to 60.6 percent of the area; they are equally divided between the National Forest Service and private coal companies. State of Utah and BLM properties are mainly barren with respect to Blackhawk coal. Four coal companies own and control the leases. Listed acreages are approximate and dated January 1, 1970.

	Acres	Type
Huntington Corp.	3,720	Fee
	3,200	Lease
Kingston	20	Lease
Paramount Fuel	180	Fee
	1,160	Lease
U. S. Fuel Co.	10,250	Fee
	4,250	Lease

Acreages held in leases plus coal fee lands total more than the acreages of actual coal land. Much of the fee land is in canyon bottoms or below the cliffs. The only large block of open land is in the northwest corner of the map area in the vicinity of Wild Cattle Hollow, Gentry Ridge and Gentry Hollow. Locations of land holdings are shown on figure 16.

COAL

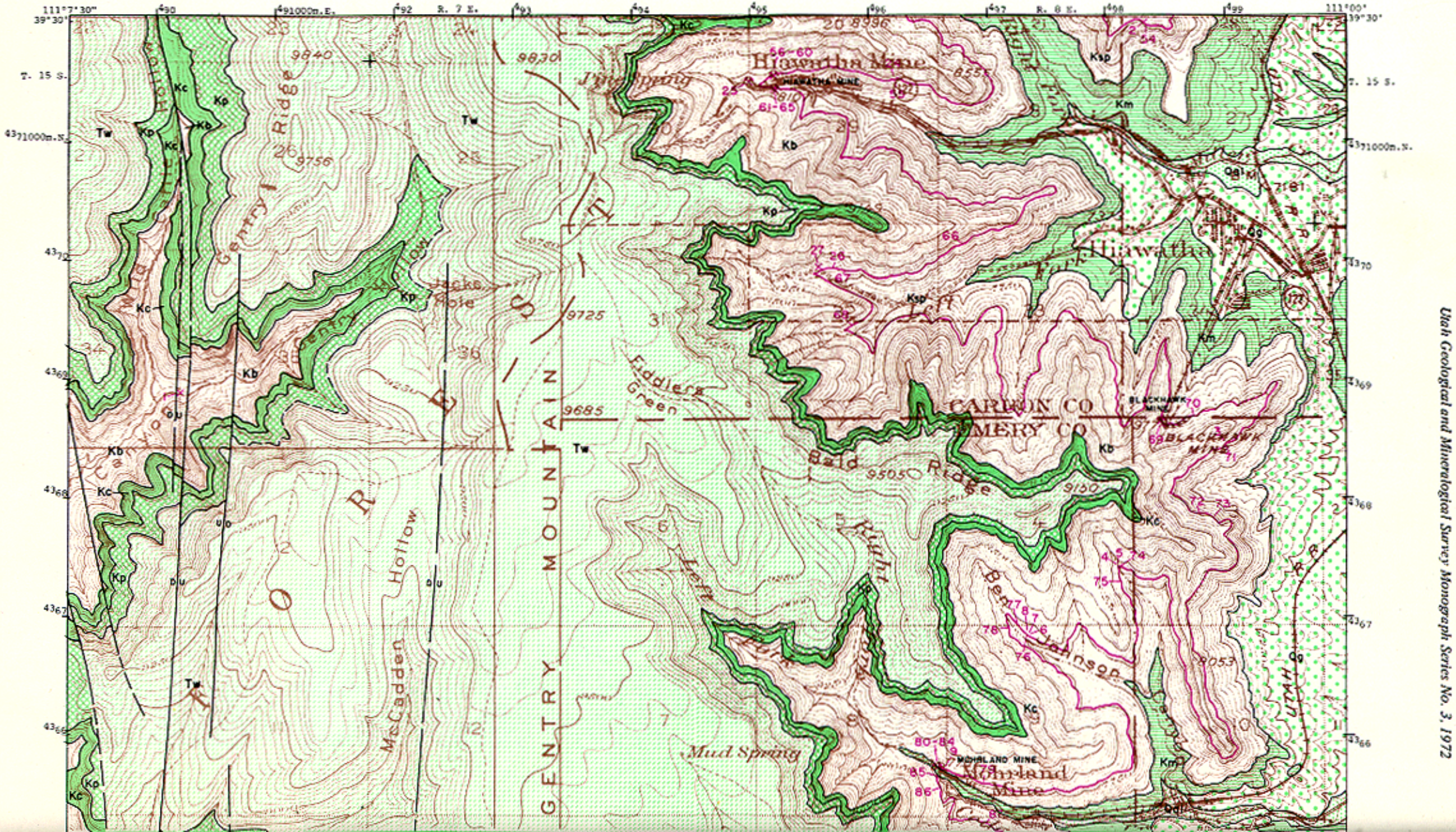
Surface Information

Six beds or zones are represented by 119 measured coal sections (figure 41) which attest to the condition of the coal in the Hiawatha NE quadrangle. The beds and zones are described by their relative positions in the column: the first section is near Hiawatha, the second near Mohrland and the third in lower Huntington Canyon.

Hiawatha	Feet	Mohrland	Feet	Lower Huntington Canyon	Feet
Tank bed	0-6	Upper beds–	thin beds	Upper beds	0-6
Interval	200		in a	Interval	200
Wattis bed	8-12		250-foot	Bear Canyon bed	0-10
Interval	70		interval	Interval	40-60
Third bed	0-9	Interval	50	Blind Canyon	
Interval	20	Bear Canyon bed	0-6	bed	0-10
Second bed	0-7	Interval	100	Interval	40-60
Interval	30	Hiawatha	2-28	Hiawatha	5-8
Hiawatha	5-20	Star Point Sandstone		Star Point Sandstone	
Star Point Sandstone					

The Hiawatha bed is present in all three localities; it is important and valuable almost everywhere and only locally shrinks

HIAWATHA, UTAH N.E.



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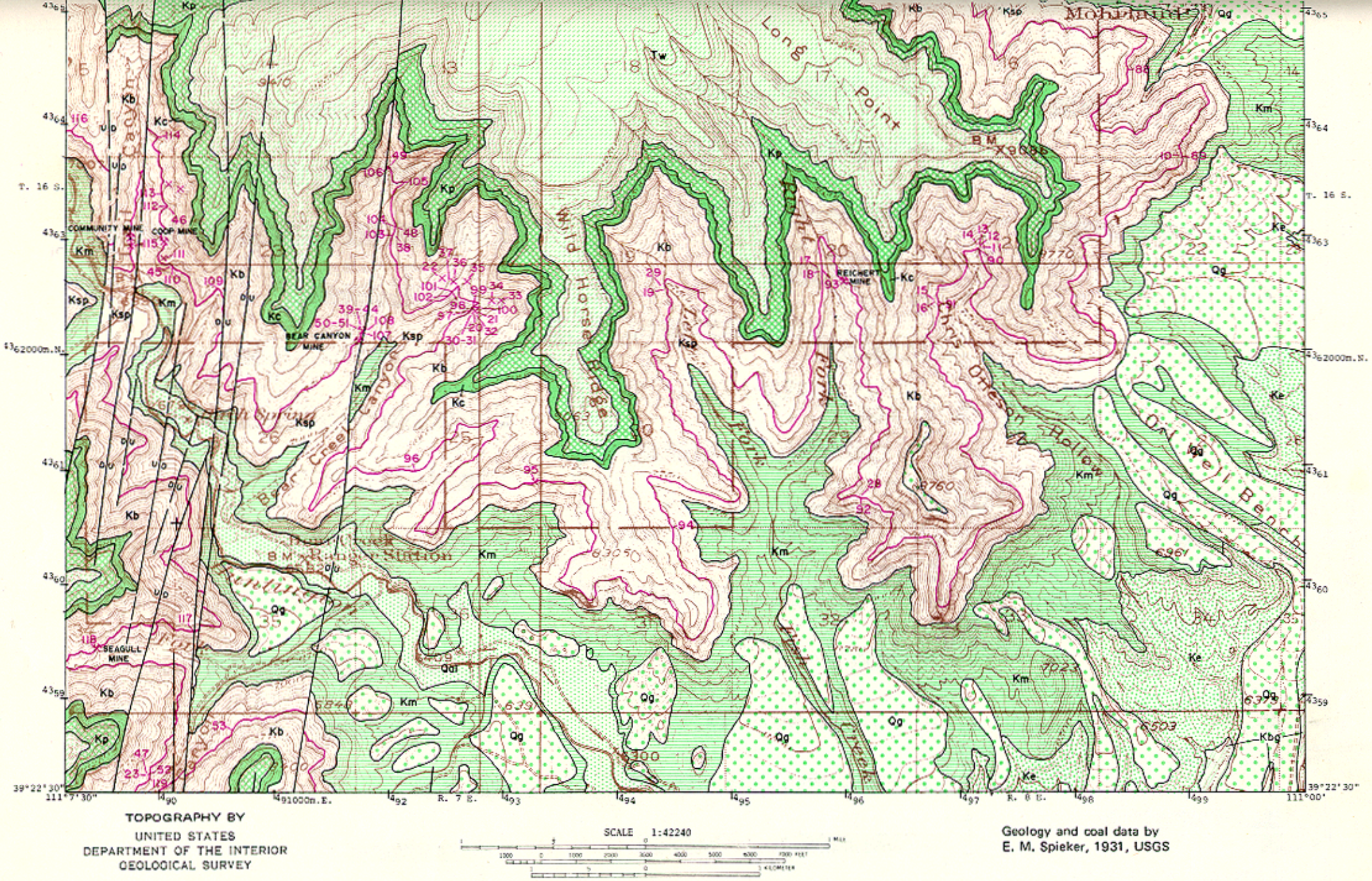


Figure 40. Coal and geology map, Hiawatha NE quadrangle (explanation pages 136-137).

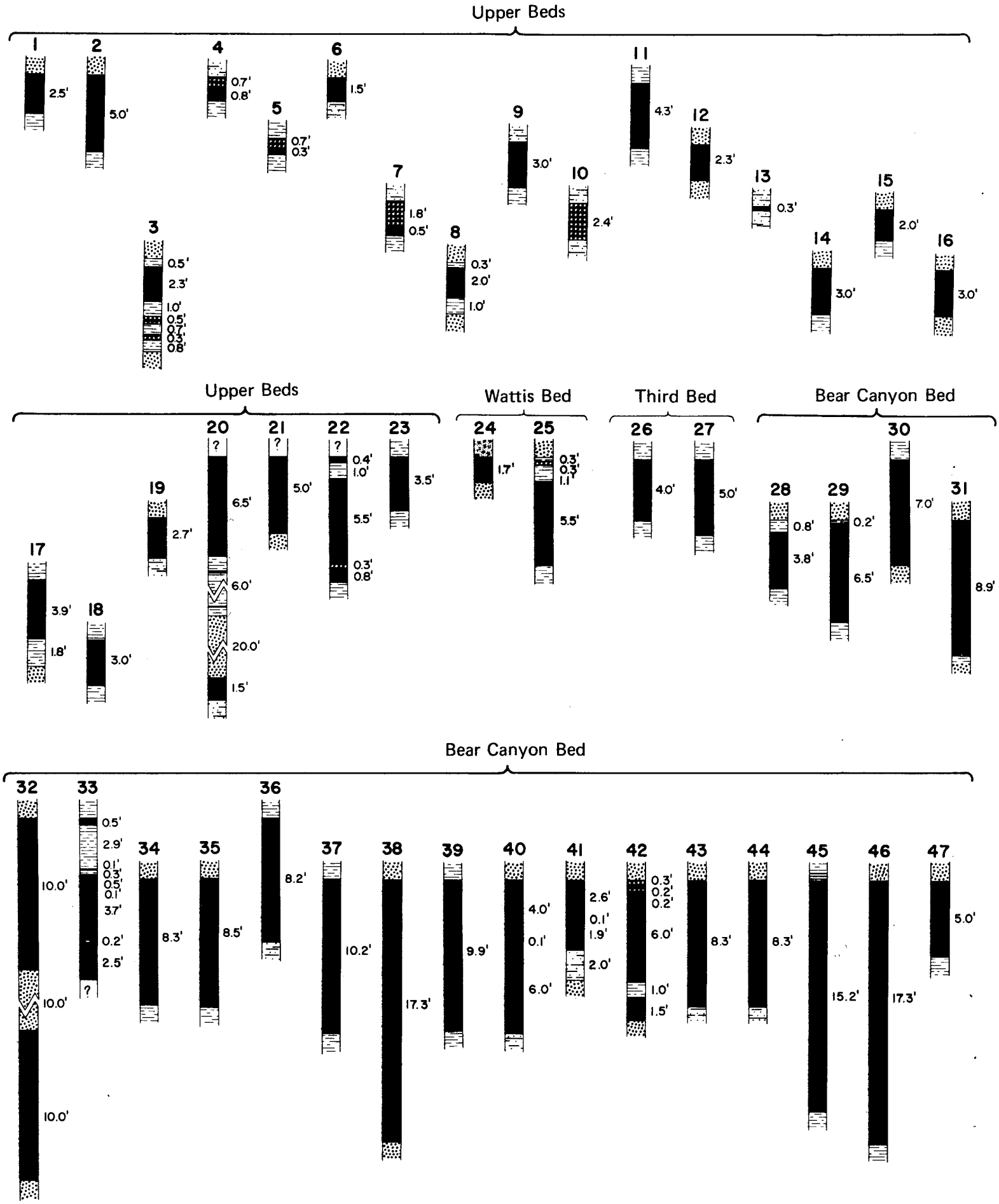


Figure 41. Coal sections of Hiawatha NE quadrangle (vertical scale: 1 inch = 8 feet).

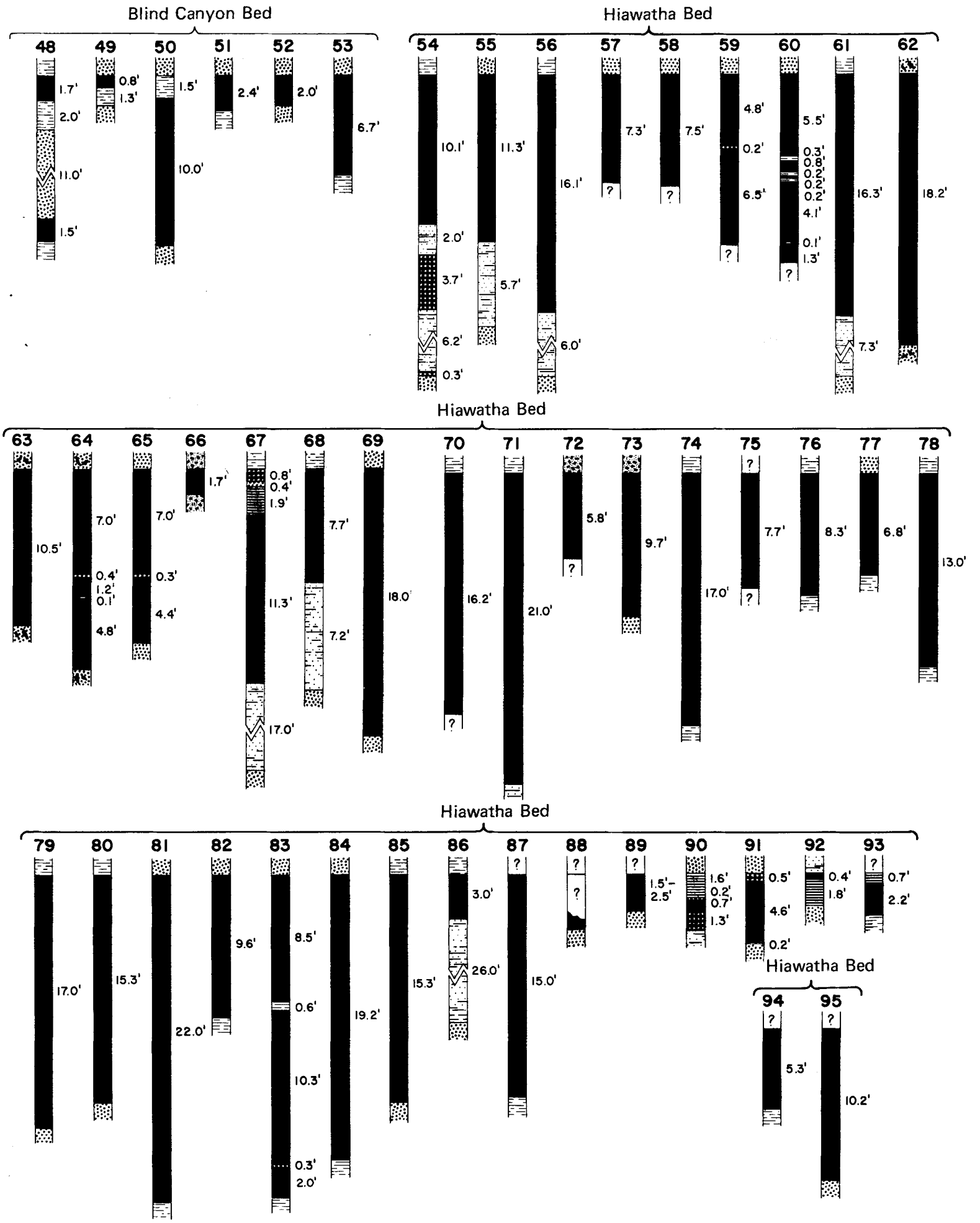


Figure 41. (continued)

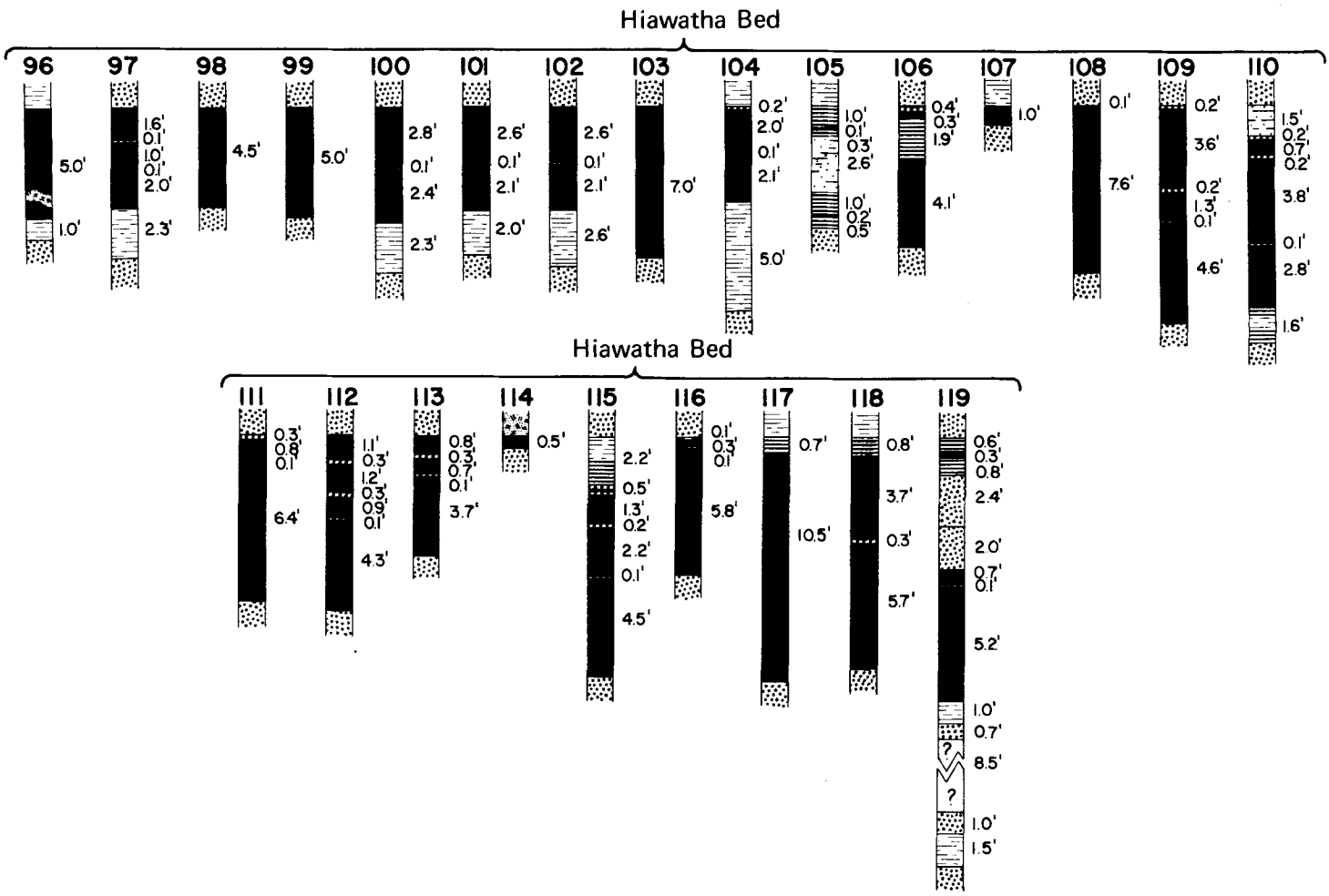


Figure 41. (continued)

to less than 4 feet. The 66 sections measured of the Hiawatha show seams to 22 feet thick compared to in-the-mine measurements to 28 feet. The bed contains partings in the vicinity of the Miller Creek Basin and thins between Chris Otteson Hollow and Upper Bear Creek Canyon. Spieker (1931, p. 116) observes the coal bed is replaced by sandstone or bone locally in the mines. He classifies these "wants" into three types: (1) "islands" of bone and dirty coal, formed at muddy places in the original swamp, (2) thin coal on the flanks of minor anticlines and synclines caused by local flexures and (3) old drainage channels cutting out the coal and replacing it with sand.

North of Hiawatha town in the Scofield SE quadrangle two beds, called Second and Third, achieve minable thickness. They are located 30 and 50 feet above the Hiawatha. They are missing near Hiawatha and to the south near Mohrland. In lower Huntington Canyon 40 to 60 feet above the Hiawatha is the Blind Canyon bed represented by six coal sections. It is best developed along the west edge of the map. Forty to 60 feet above the Blind Canyon bed is the Bear Canyon bed represented by 20 coal sections with individual seams greater than 17 feet. It is best developed in the southwest corner of the quadrangle. Possible thin bed extensions are found as far east as Chris Otteson Hollow. The Bear Canyon bed may correlate with the Wattis bed exposed north of Miller Creek Basin. The Wattis thins in the vicinity of Hiawatha and is not present at Mohrland.

Overlying the Bear Canyon and Wattis are several upper beds; most are thin, but locally exceed 4 feet thick. A 6-foot seam is located 335 feet above the base of the Blackhawk in Bear Canyon. Its extent is unknown.

Subsurface Information

No drill-hole information is available for the quadrangle. Extensive mining under Gentry Mountain reveals that the Hiawatha is continuous in the anticipated thicknesses. Least is known about the area in the northwest map corner. None of the coal lies at depths of more than 3,000 feet; 7.1 percent is covered with 2,000 to 3,000 feet of overburden, 52.6 percent 1,000 to 2,000 feet and 40.3 percent less than 1,000 feet. Most of the deep coal is under Gentry Mountain.

Quality of Coal

Three hundred and eighty-eight analyses demonstrate the quality of the coal in three beds (table 5). Most come from the U. S. Fuel Co.'s Hiawatha and Mohrland operations and the Bear Canyon, Co-op, Sea Gull and Tie Fork mines are represented. The majority of samples are from U. S. Fuel's operations and the Hiawatha bed. The Bear Canyon bed and Blind Canyon bed also are represented. Average analyses and ranges are given in table 34.

The coal in the three beds is similar. The Blind Canyon bed contains more ash; consequently the calorific value is lower. The U. S. Bureau of Mines (Walker and Hartner, 1966) subdivided the sulfur into sulfate, pyritic and organic (table 35).

Gomez, Landers and Boyd (1967, p. 9) calculated carbonization product yields for several mines on the quadrangle (table 36; end carbonization temperature 500° C).

The U. S. Fuel mine coal contains considerable resin and since about 1958 is concentrated to 55 percent as a part of the coal preparation process. Resins are used in high-quality lacquers and varnishes and in chewing gum. Production has been about two coal cars full weekly.

Mines and Development

The principal mines on the Hiawatha NE quadrangle are U. S. Fuel's King mines. Many portals to the King incorporate

Table 34. Average coal analyses, Hiawatha NE quadrangle.

	No. Analyses	As-received (percent) Average	Range
BEAR CANYON BED			
Moisture	6	6.8	4.5-10.9
Volatile matter	6	43.8	37.4-46.0
Fixed carbon	6	45.7	44.9-46.0
Ash	6	4.5	3.8- 5.8
Sulfur	6	0.53	0.5- 0.6
Btu/lb	6	13,014	10,840-13,530
BLIND CANYON BED			
Moisture	10	4.8	3.8- 5.3
Volatile matter	9	41.7	40.2-44.7
Fixed carbon	9	44.3	39.2-48.3
Ash	10	8.9	5.8-12.4
Sulfur	8	0.58	0.5- 0.6
Btu/lb	9	12,492	11,700-13,080
HIAWATHA BED			
Moisture	370	5.6	0.7 -11.0
Volatile matter	357	42.3	36.3 -46.4
Fixed carbon	357	45.7	38.3 -52.7
Ash	359	6.2	3.3 -11.2
Sulfur	330	0.61	0.29- 1.1
Btu/lb	365	12,719	11,521-13,600

Table 35. Sulfur-type determinations, Hiawatha NE quadrangle.

Mine	Bed	Percent Total Sulfur	Sulfate	Pyritic	Organic
King mine	Hiawatha	0.58	0.02	0.16	0.40
Co-op mine	Hiawatha	0.36	0.00	0.04	0.32
Sea Gull mine	Blind Canyon	0.50	0.01	0.04	0.45

Table 36. Carbonization product yields, Hiawatha NE quadrangle.

Mine	Carbonization yields wt. percent of maf coal Char	Water of decomposition	Tar plus light oil	Gas	Gas volume scf/lb maf coal	Heating value of gas Btu/scf
Co-op	69.5	4.7	21.0	3.8	.837	845
King	69.6	5.0	19.8	4.7	.907	808
Wattis No. 2	70.9	5.3	18.1	4.9	.952	792

older names, such as the Hiawatha, Blackhawk, Miller Canyon prospects and Mohrland mines. These and others on the quadrangle are listed with their locations (table 37).

The Bear Canyon mine enjoyed two periods of activity. Between 1896 and 1906 two seams of the mine were worked spasmodically. In 1906 twelve prospects in Bear Canyon produced about 8,000 tons. The mine operated steadily from 1938 to 1957 producing over 150,000 tons of coal.

Spieker (1931, p. 147) mentions a Community mine opened in Meetinghouse Canyon. Another Community mine was opened on the west side of Trail Canyon probably around 1921. The mine was abandoned because a major fault cut off the coal. Production in the Co-op mine began in 1938 and has been continuous to the present time. It is located on the east side of Trail Canyon. Total production is at least 600,000 tons.

The largest mine or group of mines owned by a single company is the King mine, including the Hiawatha, Blackhawk, Mohrland and Miller Canyon prospects. Operations started in the late 1890's but large production was achieved after 1910. The King mine is the largest producer of the Wasatch Plateau field. At the end of 1969 an estimated 51 million tons had been extracted. Spieker (1931, p. 118) noted that mining conditions were excellent and that 90 to 96 percent of the coal were removed. At a portal where a tramway lowers the coal 1½ miles to the railroad loading station, coal is moved 5 miles underground from the Blackhawk entranceway to the coal face.

Table 37. Mines and prospects, Hiawatha NE quadrangle.

Mine	Location	Remarks
Bear Canyon mine	SW.SW.24-16S-7E 4,362,200m.N. 492,000m.E.	Intermittently active 1896-1906; Active 1938-1957
Community mine	C.S.SW.NE.22-16S-7E 4,363,000m.N. 490,800m.E.	Active 1921
Co-op mine (Trail Gulch)	SE.SE.NE.22-16S-7E 4,363,000m.N. 491,040m.E.	Active 1938-1970
Hiawatha mine No. 1 No. 2	NE.SW.NW.29-15S-8E 4,371,425m.N. 495,175m.E. 4,371,520m.N. 495,175m.E.	Active 1905-1931
King mine (Blackhawk mine)	NE.NW.NW.NW.4-16S-8E 4,368,650m.N. 498,430m.E.	Active 1898-1970
Mohrland mine (King No. 2, Cedar Creek, Howard)	NE.NE.SE.SE.8-16S-8E 4,367,750m.N. 496,550m.E.	Active 1896-1938
Miller Canyon prospects	C.NW.32-15S-8E 4,369,900m.N. 295,350m.E.	Joins with King mines in subsurface
Reichert mine	S.SE.NW.SE.20-16S-8E 4,362,600m.N. 496,000m.E.	Active 1940's
Sea Gull mine (Beehive)	34-16S-7E 4,359,400m.N. 489,400m.E.	Active 1943-1956
Tie Fork prospect	34-15S-7E	Activity unknown

The Reichert mine was opened in the Hiawatha bed but production is unknown. Development work took place in the 1940's. The Sea Gull mine operated from 1943 to 1956; it opened on the Blind Canyon seam and produced more than 26,000 tons. Nothing is known about the activity of the Tie Fork prospects.

Total production for the quadrangle is estimated at 51,776,000 tons. Part of this coal was produced in the Scofield SE quadrangle but emerged from portals on Hiawatha NE.

Reserves

Spieker (1931, p. 204-205) calculated the reserves for the area by township and range. His reserves are modified to fit the Hiawatha NE quadrangle (table 38).

Table 38. Original reserves in the Hiawatha NE quadrangle (in short tons; beds 30 inches or more thick).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.15S. R.7E.	4,884	4.9	43,076,880	Hiawatha
	726	5.5	7,187,400	Blind Canyon bed
T.15S. R.8E.	2,727	9.5	46,631,700	Hiawatha
	2,430	4.1	18,000,000	Upper beds
T.16S. R.7E.	6,165	6.0	66,582,000	Hiawatha
	1,000	4.5	8,100,000	Blind Canyon bed
	3,088	10.0	55,584,000	Bear Canyon sec. 1-3, 10-12
	300	12.0	6,480,000	Bear Canyon sec. 27, 34
	392	7.0	5,000,000	Upper Bear Canyon sec. 24
	220	6.3	2,500,000	Bed 340 feet above Hiawatha
T.16S. R.8E.	4,233	14.4	110,000,000	Hiawatha upper 2 tiers of sections
	4,778	4.0	34,000,000	Hiawatha southern 4 tiers of secs.
	7,600	4.0	55,000,000	Upper beds
T.17S. R.7E.	314	7.0	3,956,400	Hiawatha
	200	9.3	3,348,000	Blind Canyon
	100	5.0	900,000	Bear Canyon
		Total coal	466,346,380	

It is impossible to determine the recoverability rate inasmuch as the exact mined-out acreage is unavailable. Mining conditions continue to be good in the U. S. Fuel mines and a minimum of 50 percent recoverability is expected. Using a 50 percent recoverability for the quadrangle, 233 million tons are recoverable; 51 million already have been mined leaving 182 million tons if all coal beds more than 4 feet average are mined.

PRINCIPAL WORK

Most of the work presented in this quadrangle report is from U. S. Geological Survey Bull. 819, published in 1931 by E. M. Spieker. Updating information has come from varied sources, mostly published and unpublished data of the U. S. Bureau of Mines.

Ruins in Winterquarter Canyon, near Scofield, after abandonment of the mines (Scofield NW quadrangle).

HIAWATHA NW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Hiawatha NW quadrangle is located west of the town of Huntington and includes three counties: Sanpete and Carbon counties to the north and Emery County to the south (figures 22 and 42). Along the west edge of the map is Upper Joes Valley and along the east edge is Huntington Canyon. East Mountain lies between and is underlain with coal. The only important road is in Huntington Canyon which joins Huntington to the east with Fairview to the west. Dirt access roads extend up some of the tributary canyons.

The area is mountainous; elevations range from 7,000 to 10,730 feet and the coal exposures from 7,500 to 8,500 feet above sea level.

STRATIGRAPHY

Seven consolidated stratigraphic units crop out on the quadrangle. The oldest is the Masuk Shale Member of the Mancos. It consists of yellow to blue-gray slope-forming sandy shale and is found only in the bottom of Huntington Canyon and for a short distance up tributary canyons. An oil well drilled in Flat Canyon (27-16S-6E) penetrated 1,300 feet of the marine unit.

The Star Point Sandstone overlies the Masuk and represents a change from offshore to nearshore and beach environments. Yellow-gray thick-bedded to massive cliff-forming sandstone rims the lower part of Huntington Canyon and its tributaries. The Flat Canyon well penetrated 245 feet of Star Point Sandstone. The unit thickens northward as attested by surface contours and appears 350 feet thick in Horse Canyon.

The important coal-bearing unit is the Blackhawk Formation, 625 feet thick in the southwest part of the quadrangle. Exposures make up the walls of Huntington Canyon and its tributaries and part of the escarpment produced by the Joes Valley fault. The Blackhawk consists of alternating sandstone, shale and coal in order of abundance. The better coal seams are located in the lower 400 feet.

Rimming East Mountain is the cliff-forming Castlegate Sandstone and the not-so-resistant Price River Formation. The lower unit is about 250 feet thick and the upper unit about 500 feet thick. Both consist of gray to white, coarse-grained, gritty sandstone interbedded with minor shale. The North Horn Formation (Tw) makes up most of the upper surface of East Mountain. Here it consists of 750 feet of variegated shales with interbedded subordinate sandstone and limestone. It is also exposed in Upper Joes Valley. The youngest unit, the Flagstaff Limestone, is exposed in isolated patches on East Mountain in the south part of the quadrangle.

STRUCTURE

Most of the area is a large block relatively free of faults. Two faults of the Pleasant Valley fault zone just enter the quadrangle in the southeast corner. The Joes Valley fault and the Joes Valley graben west of it lie along the west side of the map. The strata between the two fault zones are nearly horizontal; dips rarely exceed 3 degrees.

PROPERTY CONTROL

Ownership of the Hiawatha NW quadrangle is divided between the National Forest Service (83 percent) and private individuals or companies (17 percent). Coal underlies 91.3 percent of the land area of the quadrangle, excluding the eroded out area of Huntington Canyon and its tributaries.

More than 29 percent of these coal lands are held as such. The land is divided as follows and locations of these properties are given on figure 16 (January 1, 1970).

	Acres (approximate)	Type
Helco	80	Lease
Huntington Corp.	2,220	Fee
	1,712	Lease
Leamaster	40	Fee
	160	Lease
McKinnon	1,525	Fee
	1,123	Lease
Rilda Corp.	1,580	Lease
Swisher	160	Lease
Unassigned	1,160	Fee

COAL

Surface Information

Six beds of coal achieve minable thickness in the Hiawatha NW quadrangle. Two generalized columns are presented for the north and southeast ends of the area.

North	Feet	Southeast	Feet
Castlegate "A"	3-9		
Interval	65		
Fourth bed	0-6	Bear Canyon bed	0-16
Interval	55		40-60
Third bed	0-6		
Interval	25		
Blind Canyon bed	1-8		0-8
Interval	40-55		40-60
Hiawatha bed	1-5		6-14
Star Point Sandstone			

Twenty-eight coal sections were measured for the Hiawatha bed (figure 43). The bed is at least 6 feet thick over most of the south half of the quadrangle and becomes less important northward; little is known about it in the southwest map corner. The bed has been burned extensively along the outcrops creating large gaps. Thick sections occur south of Mill Fork and average 10 feet to the south map border.

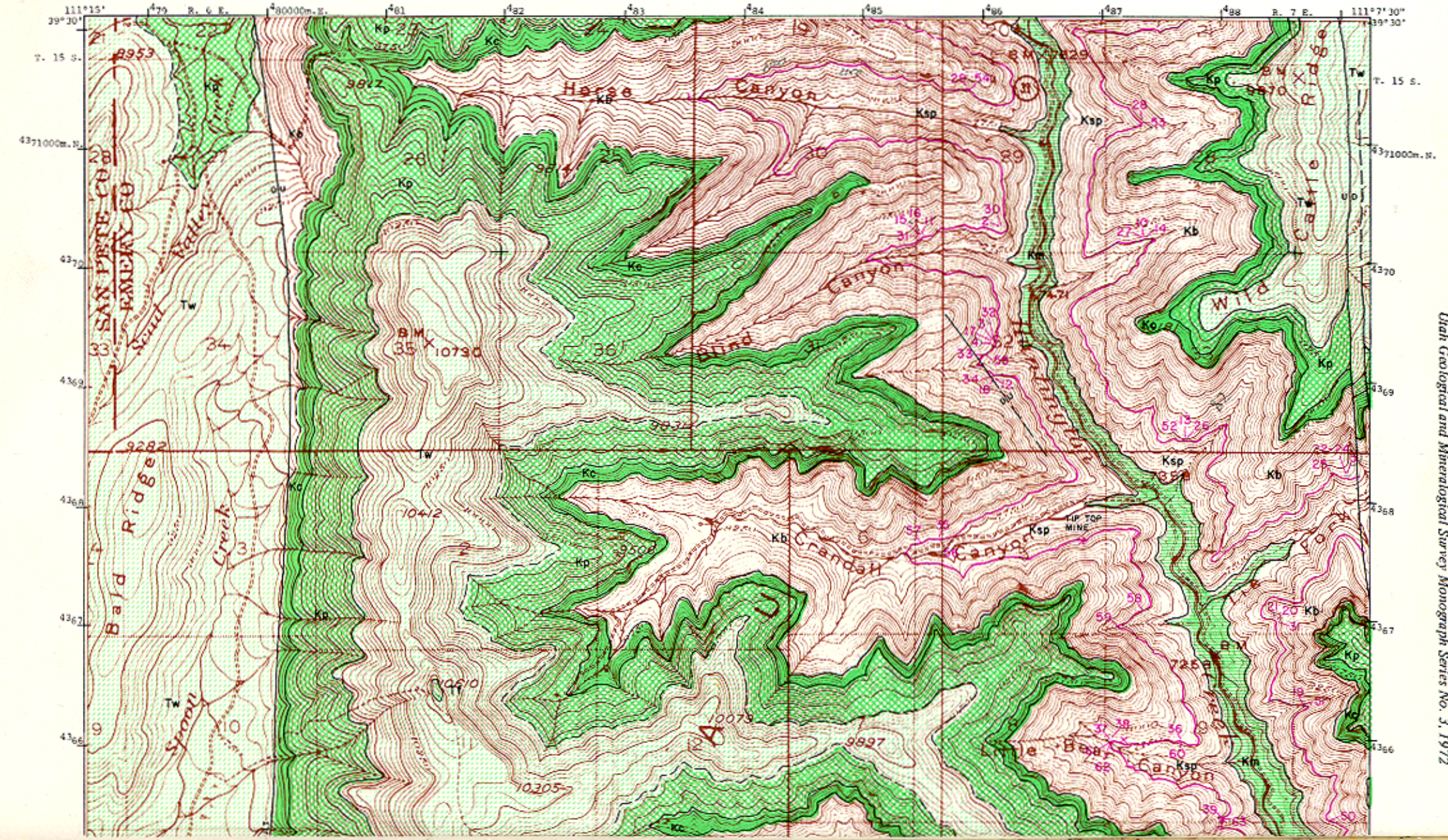
After the Hiawatha, the Blind Canyon bed is most important. Its type locality is in the north map area; twenty-one sections are available (figure 43). Insufficient evidence supports its presence in Crandall Canyon, but farther south it thickens again until south of Mill Fork where again it is of little value. In Blind Canyon a 6-foot thick bed 25 feet above the Blind Canyon bed is localized. It has been called the Third bed. Above the Third bed the Fourth bed also is localized. The thickest observed Fourth bed is 6 feet.

The Castlegate "A" is the uppermost valuable bed in the north part of the area. The farthest south of the four available sections is north of Crandall Canyon. The unit is unimportant farther south. The highest coal bed in the south area is the Bear Canyon bed about 100 feet above the base of the Blackhawk. It is well developed in the vicinity of Mill Fork Canyon with a 16-foot seam. It disappears north of Crandall Canyon and thins somewhat in Rilda Canyon.

Subsurface Information

No drill-hole data are available. The west third of the quadrangle is inferred as it is more than 1½ miles from a control point. The coal is expected to extend westward even under the Joes Valley graben. Of the total land, 21.9 percent are under 2,000 to 3,000 feet of cover, 39.8 percent 1,000 to 2,000 feet, 29.6 percent 0 to 1,000 feet, and the remaining 8.7 percent are noncoal land.

HIAWATHA, UTAH N.W.



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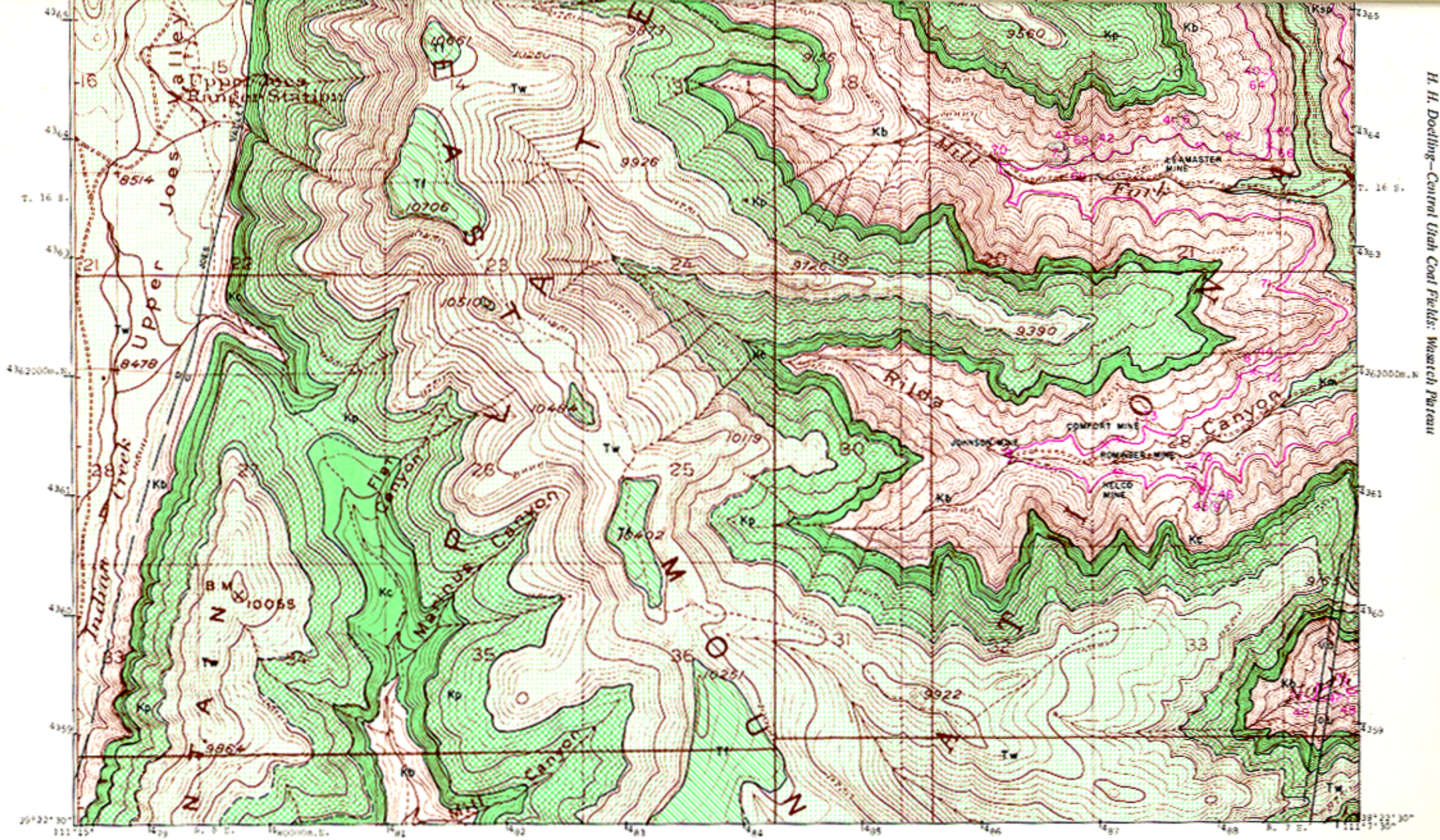


Figure 42. Coal and geology map, Hiawatha NW quadrangle (explanation pages 136-137).

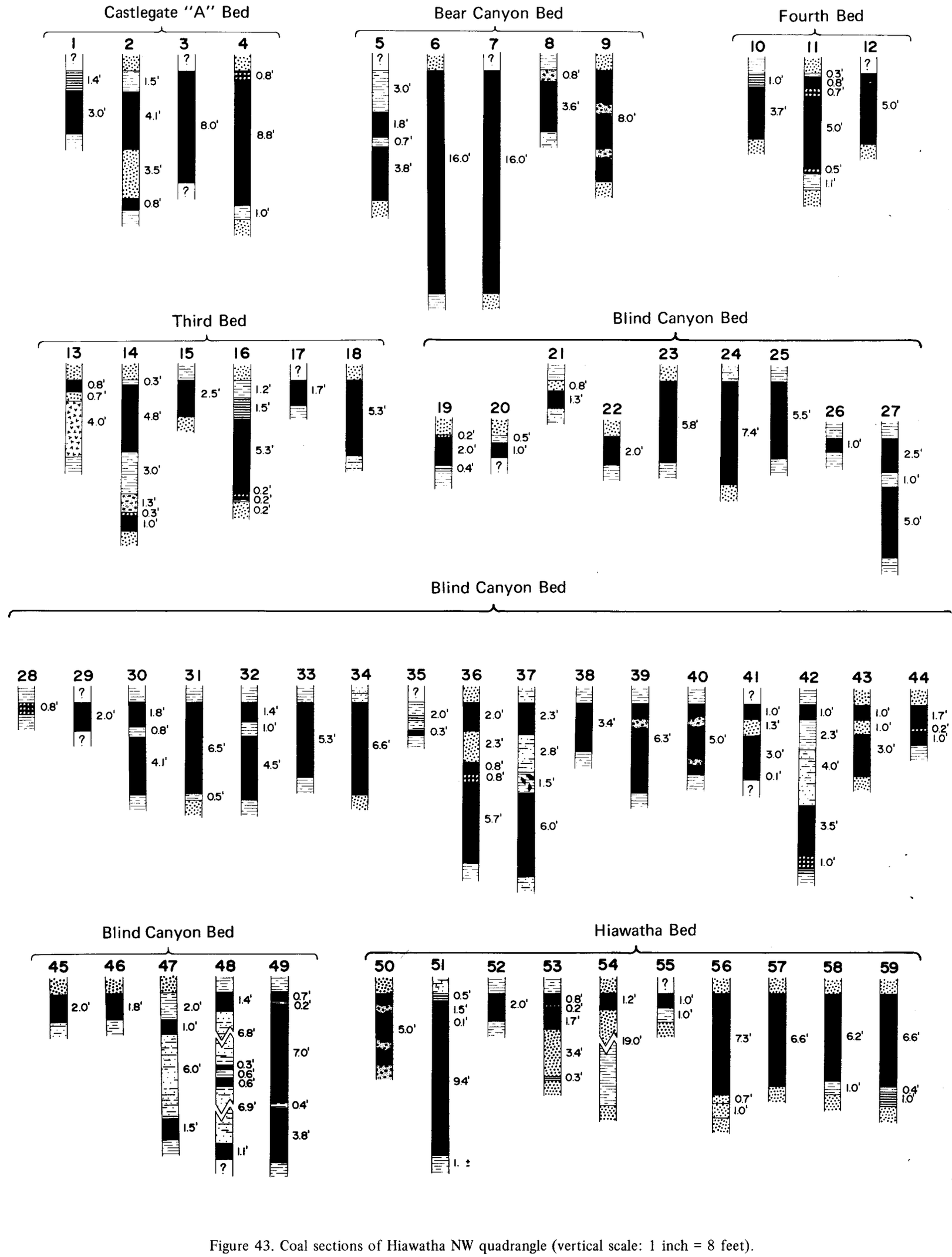


Figure 43. Coal sections of Hiawatha NW quadrangle (vertical scale: 1 inch = 8 feet).

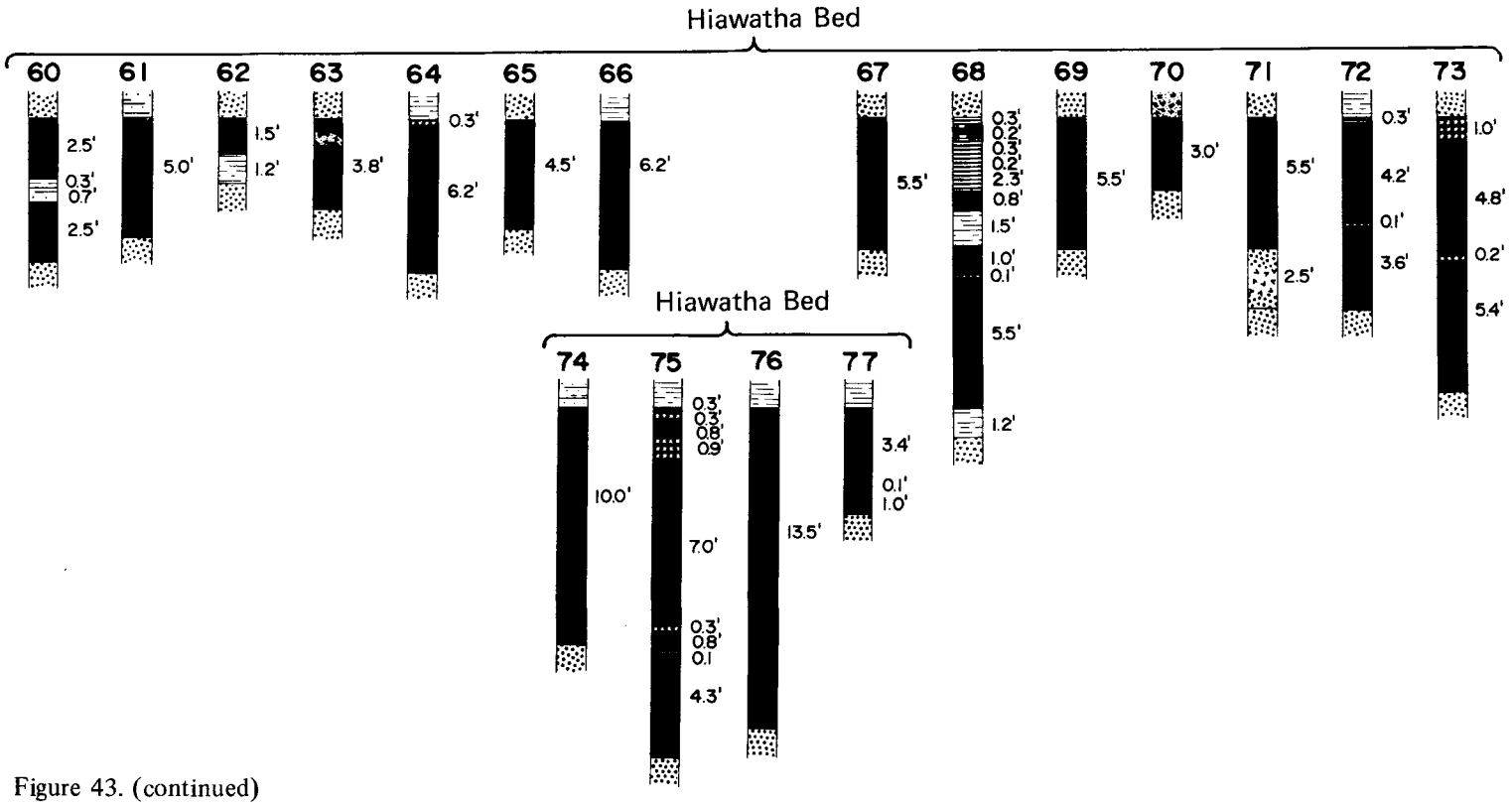


Figure 43. (continued)

Quality of Coal

Forty-one available analyses represent the Blind Canyon and Hiawatha seam (table 39). They are summarized together because the components making up the proximate analyses are similar. Table 40 lists sulfur-type determinations for the coal.

Table 39. Average coal analyses, Hiawatha NW quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	41	4.9	3.1 - 6.8
Volatile matter	35	43.4	40.4 -46.0
Fixed carbon	35	45.7	43.5 -51.1
Ash	41	6.0	2.8 -10.7
Sulfur	40	0.55	0.23- 0.80
Btu/lb	35	13,080	12,290-13,690

Table 40. Sulfur-type determinations, Hiawatha NW quadrangle (Walker and Hartner, 1966).

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Leamaster	Hiawatha	0.49	0.02	0.11	0.36
Rilda Canyon	Blind Canyon (?)	0.47	0.02	0.06	0.39
Comfort	Hiawatha	0.49	0.01	0.11	0.37
Rominger	Hiawatha	0.77	0.01	0.10	0.66
Tip Top	Hiawatha	0.50	0.01	0.07	0.42
Johnson	Hiawatha	0.38	0.01	0.05	0.32

Table 5 gives coal analyses by mines and prospects for the quadrangle.

Gomez, Landers and Boyd (1967, p. 9) calculated carbonization product yields for several mines on the quadrangle (table 41; end carbonization temperature 500° C).

Mines and Development

Several mines have been opened on the quadrangle mostly in the Hiawatha bed; a few have opened on the Blind Canyon (table 42).

Table 41. Carbonization product yields, Hiawatha NW quadrangle.

Mine	Carbonization yields wt. percent of maf coal				Gas volume scf/lb maf coal	Heating value of gas Btu/scf
	Char	Water of decomposition	Tar plus light oil	Gas		
Comfort	70.4	4.9	19.2	4.6	.906	812
Helco	70.6	4.6	20.8	3.7	.819	854
Johnson	70.2	4.8	20.0	4.2	.868	829
Leamaster	69.9	4.5	21.2	3.8	.820	851
Rominger	69.5	5.0	20.0	4.8	.911	806
Tip Top	69.6	4.7	21.0	4.0	.846	838

Table 42. Mines and their locations, Hiawatha NW quadrangle.

Mine	Location	Remarks
Comfort mine (Smith) adit 1 adit 2	W.SE.SE.NW.28-16S-7E 4,361,400m.N. 487,190m.E. 4,361,490m.N. 487,480m.E.	Active 1936-1954
Helco mine (Black Magic, Rilda Canyon)	S.NW.NW.SW.28-16S-7E 4,361,050m.N. 487,100m.E.	Active 1938-1969
Tip Top mine (Sam and Jim's, Jim Peterson)	SW.NW.SE.NE.5-16S-7E 4,367,760m.N. 386,800m.E.	Active 1939-1956
Johnson mine	29-16S-7E 4,361,250m.N. 486,250m.E.	Active 1943-195?
Leamaster mine (Mill Fork)	SE.SW.16-16S-7E 4,363,830m.N. 487,910m.E.	Active 1943-1964
Rominger mine	SE.SW.SW.NW.28-16S-7E 4,361,380m.N. 487,080m.E.	Intermittently active 1938-1954

The Comfort mine is believed opened on the Hiawatha bed in Rilda Canyon. The coal bed was reported 11 to 13 feet thick with an estimated production of almost 44,000 tons in 19 years. The Black Magic or Helco mine operates intermittently across the canyon from the Comfort mine. Its production has amounted to 32,000 tons.

The Tip Top is in Crandall Canyon in a 6½-foot section of the Hiawatha seam. Its production has been about 41,500 tons. The Johnson and Rominger mines in Rilda Canyon are in the Hiawatha in a bed 11 to 13 feet thick. They barely advanced beyond the prospect stage and some of the production accounted to them may have come from other mines in Rilda Canyon. Total production for these mines is estimated to be less than 3,000 tons.

The Leamaster mine is in Mill Fork to the north of Rilda Canyon. Coal analysts list both the Hiawatha and Blind Canyon as source beds. The lower Hiawatha is about 6 feet thick and the upper Blind Canyon bed is 5 to 14 feet thick. The interval between the beds is 60 feet. This mine has been the quadrangle's largest producer with almost 127,000 tons.

Many smaller prospects have operated, especially in pre-World War II days, in the Huntington Canyon area. Estimated combined tonnage is 29,000 tons. This makes the total coal removed from the Hiawatha NW quadrangle about 232,500 short tons.

Reserves

Reserves were estimated for the area east of Joes Valley fault by Spieker (1931, p. 204-205); they are modified to fit the quadrangle (table 43).

Table 43. Original reserves in the Hiawatha NW quadrangle (in short tons; beds 30 or more inches thick).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.15S. R.6E.	2,896	6.0	31,276,800	Castlegate "A"
T.15S. R.7E.	2,272	4.9	20,039,040	Hiawatha
	2,786	5.5	27,581,400	Blind Canyon
	1,352	7.5	18,252,000	3rd and 4th beds
	2,936	5.0	26,424,000	Castlegate "A"
T.16S. R.6E.	10,775	4.5	87,277,000	Hiawatha
	10,775	6.5	126,067,000	Blind Canyon
	1,745	5.0	15,705,000	Castlegate "A"
T.16S. R.7E.	10,441	6.0	112,762,800	Hiawatha
	6,163	4.5	49,920,300	Blind Canyon
	2,700	10.0	48,600,000	Bear Canyon sec. 3-10
	4,180	12.0	90,288,000	Bear Canyon sec. 29-35
	455	5.0	4,095,000	Castlegate "A"
T.17S. R.6E.	930	5.0	8,370,000	Hiawatha
T.17S. R.7E.	897	7.0	11,302,200	Hiawatha
	897	9.3	15,015,780	Blind Canyon
		Total coal	692,977,320	

West of the Joes Valley fault about 4,000 acres of land are Class III or inferred reserves. Using Spieker's averages for adjacent blocks the additional reserve is deduced (table 44).

Table 44. Additional reserve for land west of Joes Valley fault (Class III), Hiawatha NW quadrangle.

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.15S. R.6E.	1,430	6.0	15,444,000	Castlegate "A"
T.16S. R.6E.	2,637	4.5	21,359,700	Hiawatha
	2,637	6.5	30,852,900	Blind Canyon
	427	5.0	3,843,000	Castlegate "A"
		Total coal	71,499,600	

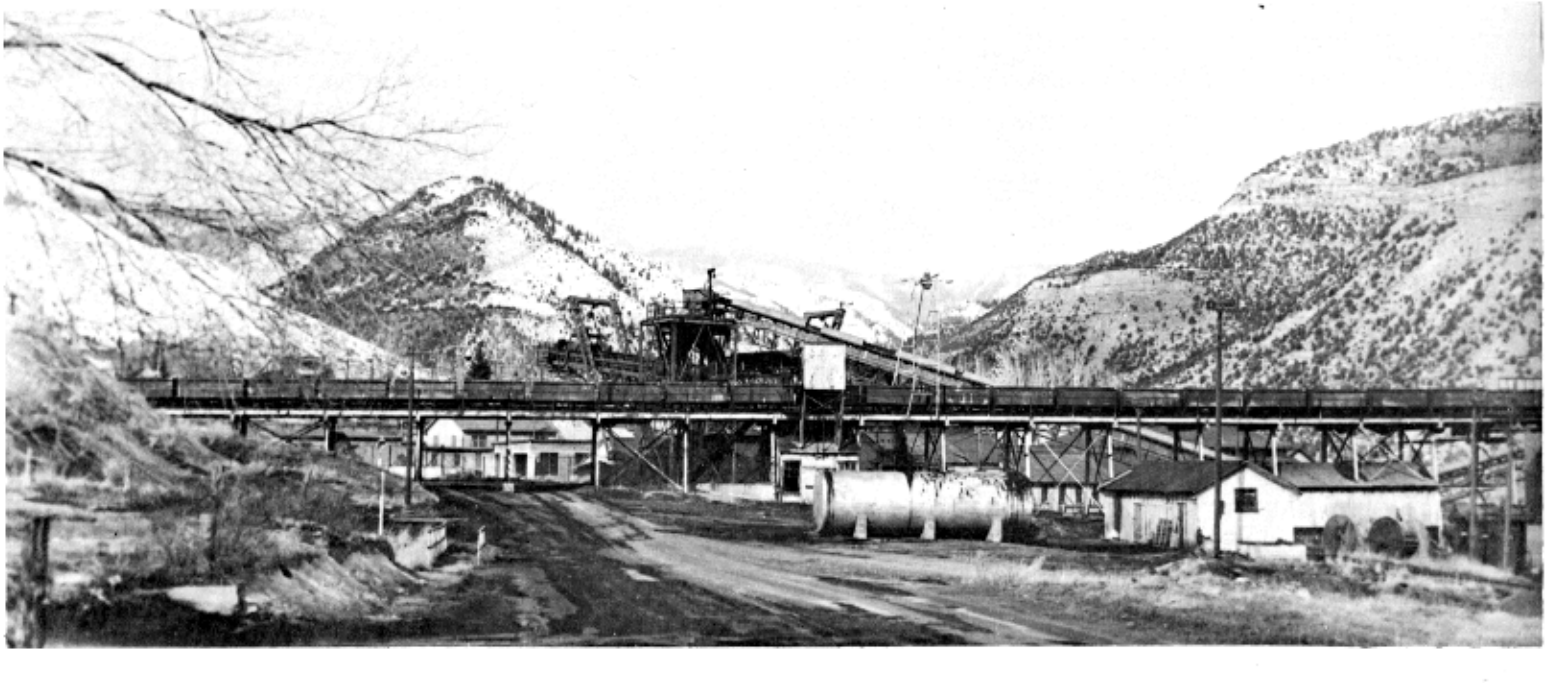
Spieker did not differentiate the reserve into classes. The west third of the quadrangle is more than 1½ miles from a control point and must be considered Class III or inferred; the remainder is Class II (estimated). Coal recoverability should be at least 50 percent in individual seams except in areas near faults or in case of unforeseen geologic hazards. Recoverability of all beds will more nearly approximate 33 1/3 percent.

The Wasatch Plateau coal field extends 4 to 8 miles farther to the west (South Tent Mountain quadrangle). On the west side of the Joes Valley graben the upper part of the Blackhawk is exposed. Nothing is known about the coal except that more than 1,000 to 3,000 feet of overburden bury the seams. On the far side of the Wasatch Plateau divide seams of minable thickness occur in the Mt. Pleasant coal field.

PRINCIPAL WORK

Most of the data presented in this quadrangle report are derived from Spieker's 1931 work on the Wasatch Plateau field. Other sources update and augment his information.

Below: U. S. Fuel Co. overpass and conveyors on road west into Hiawatha. Tram and mine portal to left (south) and tipple to right.



HIAWATHA SE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

Most of this quadrangle lies between Huntington and Cottonwood creeks directly west of the town of Huntington. The map area lies entirely within Emery County (figures 22 and 44). Elevations range from 5,800 feet to the southeast to 9,277 feet on a promontory along the west map edge. Much of the quadrangle is bench and gulley land making up the foothills to the Wasatch Plateau. Castle Valley parallels the east map edge and Red Point, an erosional salient, extends onto it from the west. The cliff near Red Point rises from 7,250 to 9,000 feet. The coal outcrops along the cliffs are between 7,500 and 8,250 feet above sea level.

Access roads connect Utah Highway 10 to the east. The best ones traverse Cottonwood Creek, Danish Bench and Huntington Canyon. Other gravel roads lead to the important mines. In relation to the Wasatch Plateau field the quadrangle lies along the east edge slightly north of the center line.

STRATIGRAPHY

Units from the Blue Gate Shale to the North Horn Formation are exposed. Members of the Mancos crop out in the bench and valley land below the cliffs. Mesaverde Group formations make up the cliff walls and the North Horn caps the upper surface.

The oldest unit on the map area is the Blue Gate Member of the Mancos Shale. Its outcrop makes up most of the Castle Valley surface. The rock is a pale blue-gray nodular and irregularly bedded marine mudstone and siltstone. It weathers into low rolling hills and badlands. A well drilled in 25-17S-7E penetrated a total of 3,100 feet of Emery and Blue Gate. The Emery is thought to be 250 to 350 feet thick in this area making a thick 2,750-foot Blue Gate. The Emery consists of alternating shale and sandstone tongues. Above the Emery is the Masuk Shale which is much like the Blue Gate except sandier. The Masuk is about 1,000 feet thick. Pediment benches have developed on these members of the Mancos and represent an old erosion surface now being dissected by the washes and gullies. The benches are covered with gravels up to 75 feet thick.

The Mesaverde Group is represented by the Star Point Sandstone, the Blackhawk Formation, the Castlegate Sandstone and the Price River Formation, in ascending order. The Star Point is below the coal, consists of massive sandstone beds interbedded with subordinate shale and is 500 feet thick. The Blackhawk consists of alternating resistant sandstone beds and nonresistant shale and coal. It is about 700 feet thick and the lower 200 to 300 feet contain all the valuable coal seams. Some of the coal seams have burned naturally along the outcrop, hence the name Red Point.

The Castlegate Sandstone and Price River formations are alike lithologically, basically gray to white gritty sandstone with some subordinate shale and conglomerate beds. The lower unit, however, is more resistant. The Castlegate is 300 feet thick and the Price River is about 250 feet thick on the quadrangle.

The North Horn Formation (Tw) with its variegated shales and subordinate conglomerate, sandstone and limestone lies atop the cliff in an incomplete section. Besides the bench gravels, alluvium fills the more important creek beds.

STRUCTURE

The strata of the Hiawatha SE quadrangle incline gently to the west. Dips are less than 5 degrees except locally adjacent to faults. The south end of the Pleasant Valley fault zone cuts the cliff at several places. Many have small displacements which hinder mining; others have large enough displacements to limit it.

PROPERTY CONTROL

Ownerships of lands of the Hiawatha SE quadrangle are approximately: Bureau of Land Management 63.7 percent, private property 14.7 percent, National Forest Service 13.5 percent and Utah state 8.1 percent.

All but 13 percent of the coal land belongs to the National Forest Service or is held as private property. Nearly 80 percent of the coal land are held by coal companies in fee land or government leases. An approximate breakdown of lands held is as follows (January 1, 1970):

	Acres	Type
Christensen	80	Lease
Kingston	100	Lease
LDS Church	1,160	Fee
	80	Lease
McKinnon	440	Fee
	256	Lease
Paramount Fuel	488	Fee
	400	Lease
Sentry Royalty (Peabody)	720	Lease

COAL

Surface Information

Available measured sections involve three, possibly four, valuable beds (figure 45). The position of the beds with respect to the Blackhawk Formation is generalized below:

	Feet
Upper bed of Grimes Wash	0-3
Interval	90
Bear Canyon bed	3-7
Interval	40-60
Blind Canyon bed	0-16
Interval	40-60
Hiawatha bed	4-15
Star Point Sandstone	

The most valuable bed is the well developed Hiawatha as attested by 23 measured sections. In Meetinghouse Canyon the bed is believed 5 to 6 feet thick but it thins in Deer Creek Canyon. The bed is heavily burned in Maple Gulch but one section shows the seam 11 feet thick. It is between 7½ and 13 feet from Maple Gulch to Red Point. Between Red Point and Grimes Wash the Hiawatha varies from 8 to 15 feet.

The Blind Canyon bed is up to 15 feet thick from Meetinghouse Canyon to Maple Gulch but disappears in sections farther east. It is present from the Deseret (LDS) mine westward but is not as thick as it is farther north.

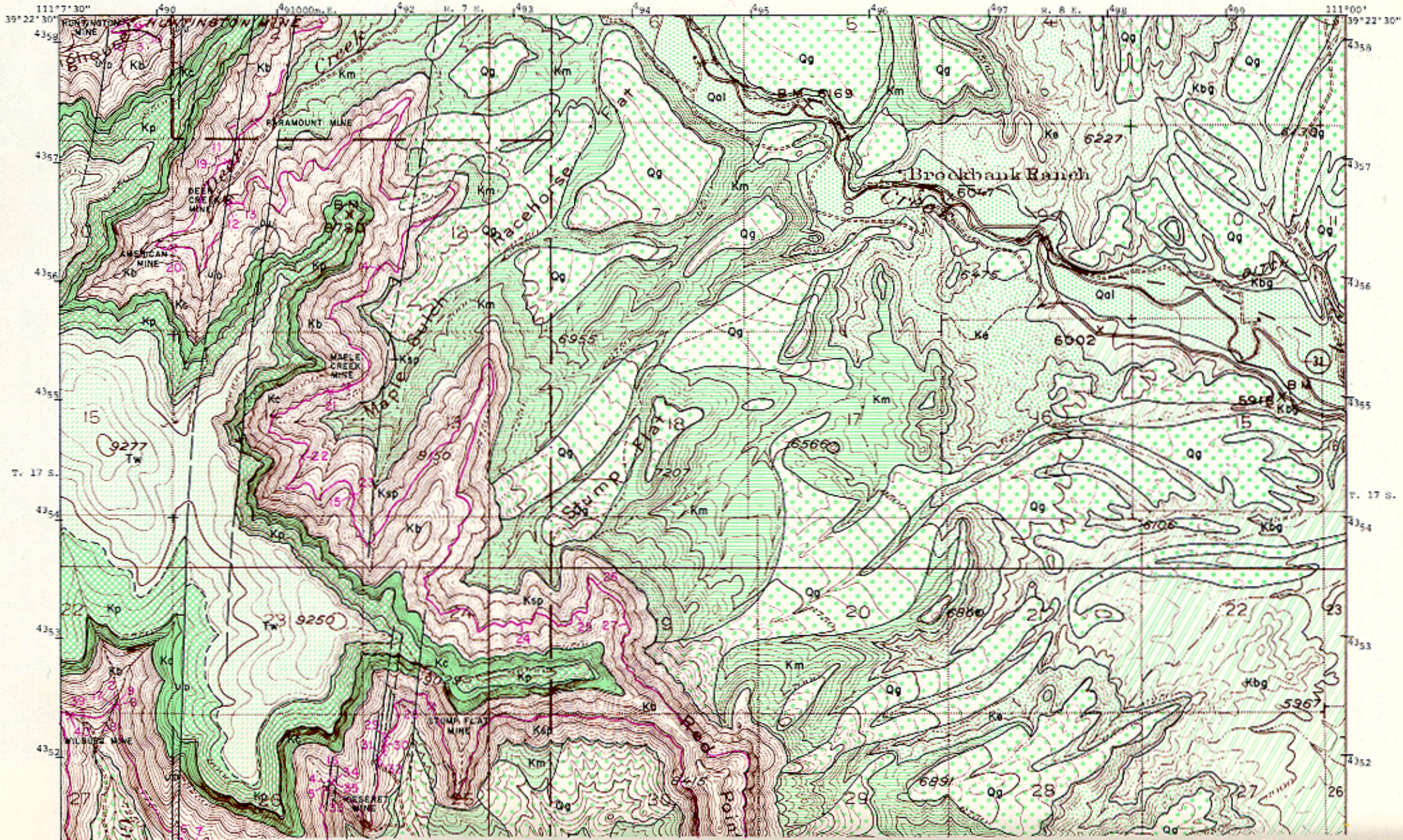
The Bear Canyon bed is present nearly everywhere but strongly burned so that a complete knowledge of its thickness is not available. The bed varies to more than 7 feet thick in the seven available sections.

The upper bed in Grimes Wash is less than 4 feet thick.

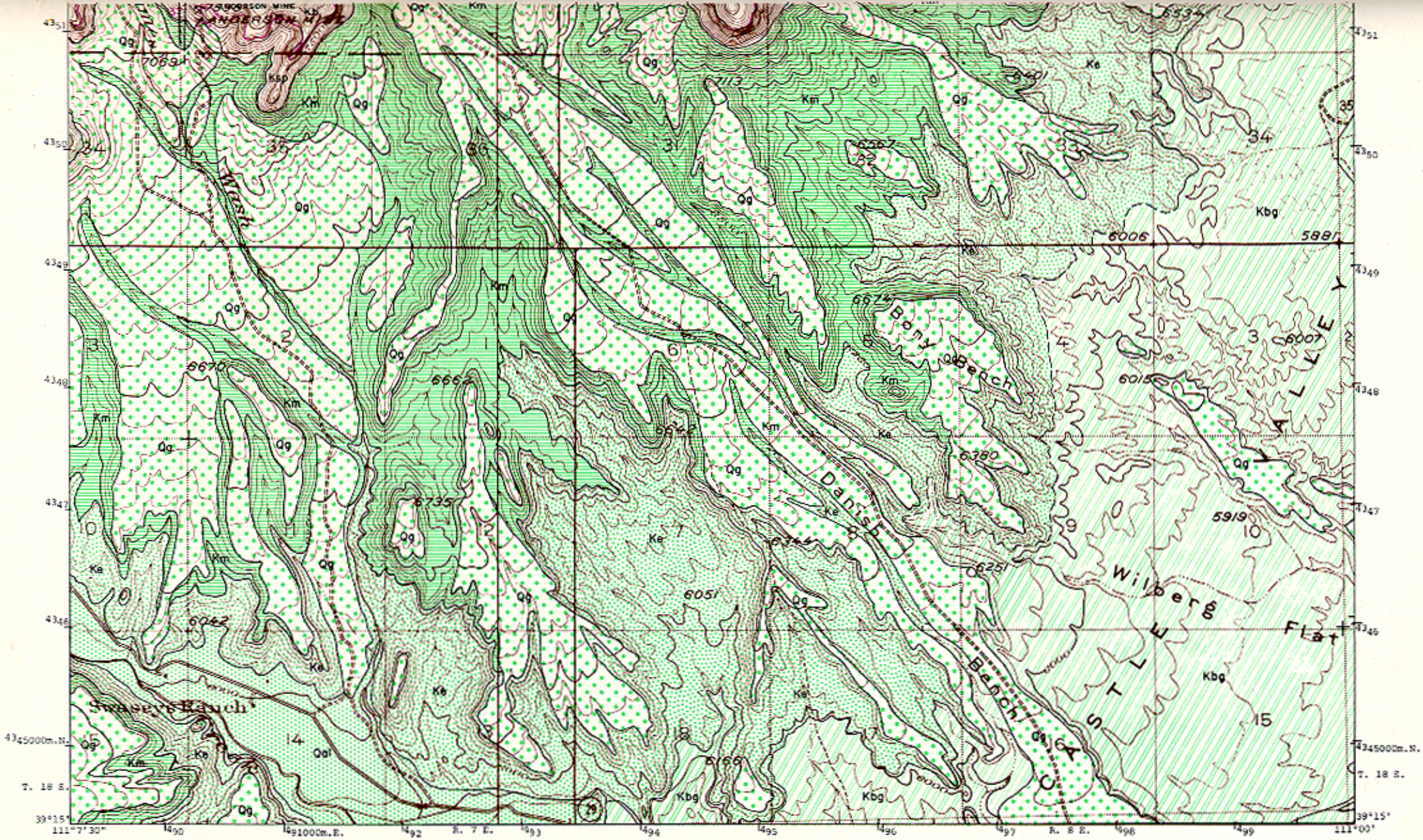
Subsurface Information

No drill-hole data are available for the Hiawatha SE quadrangle but all coal lands are within 1½ miles of a surface section. About 40 percent of the land are underlain by coal at depths more than 1,000 feet. None is deeper than 2,000 feet.

HIAWATHA, UTAH S.E.



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972



TOPOGRAPHY BY
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SCALE 1:42240

Geology and coal data by
E. M. Spieker, 1931, USGS

Figure 44. Coal and geology map, Hiawatha SE quadrangle (explanation pages 136-137).

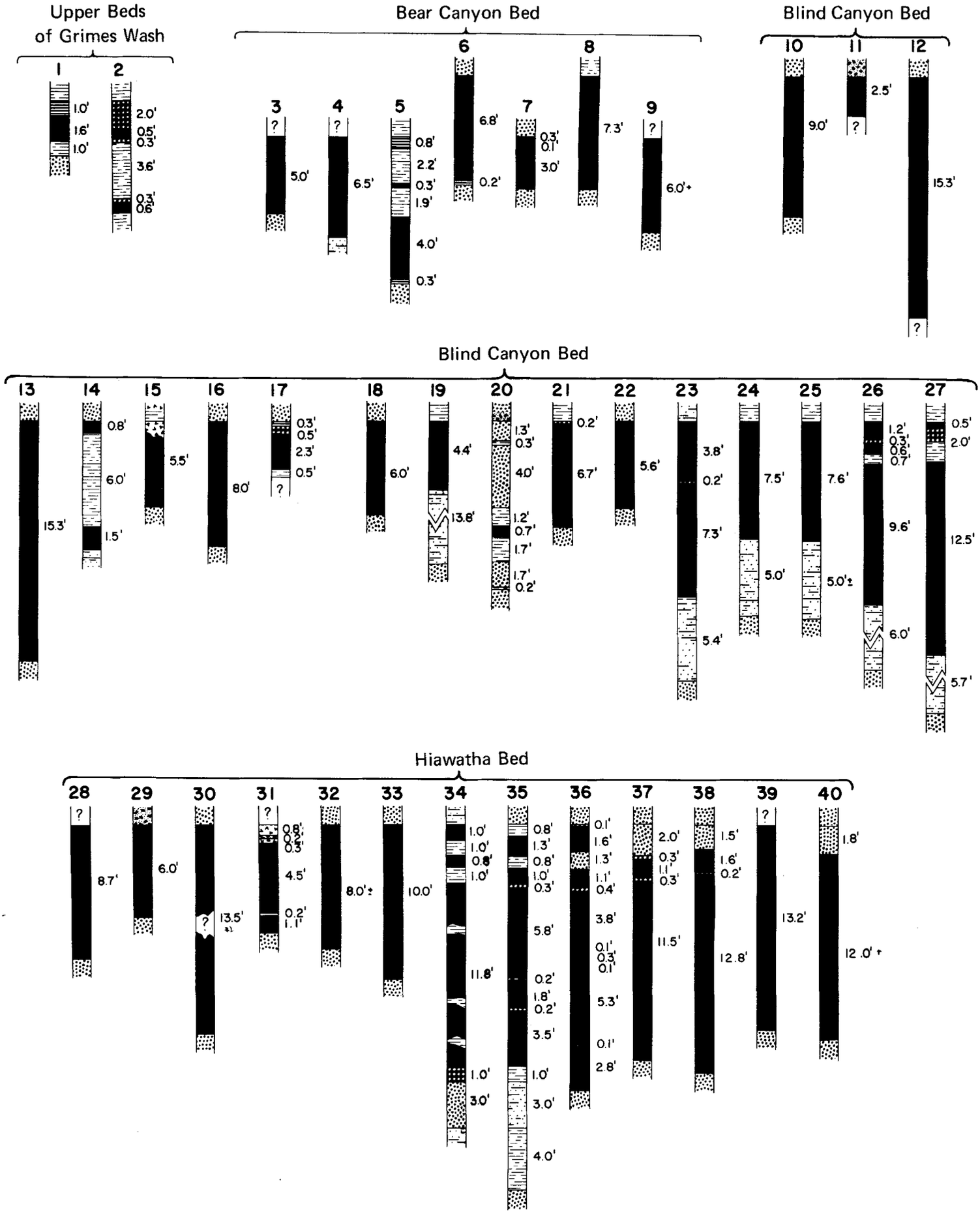


Figure 45. Coal sections of Hiawatha SE quadrangle (vertical scale: 1 inch = 8 feet).

Quality of Coal

More than 150 analyses of coal samples tabulated for the Hiawatha SE quadrangle represent two beds (table 5). The analyses come from several of the mines, some of which operate from both seams. About two-thirds of the analyses are from the Blind Canyon bed, the remainder from the Hiawatha. Table 45 gives averages of the analyses.

Table 45. Average coal analyses, Hiawatha SE quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
BLIND CANYON BED			
Moisture	108	5.1	1.2- 8.0
Volatile matter	100	42.5	38.5-45.6
Fixed carbon	100	44.8	37.5-48.4
Ash	104	7.4	4.0-18.3
Sulfur	93	0.52	0.4- 1.1
Btu/lb	104	12,803	10,800-13,353
HIAWATHA BED			
Moisture	46	5.5	2.0-11.4
Volatile matter	40	41.2	37.4-44.7
Fixed carbon	40	44.8	35.1-48.1
Ash	43	8.2	4.4-11.2
Sulfur	43	0.67	0.31- 1.50
Btu/lb	40	12,448	11,660-13,274

Slight differences characterize the coal in the area. Higher sulfur and ash content in the Hiawatha bed bring the calorific value down. Walker and Hartner (1966) subdivided the sulfur into sulfate, pyritic and organic (table 46).

Table 46. Sulfur-type determinations of coal, Hiawatha SE quadrangle.

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Castle Valley	Hiawatha	0.57	0.01	0.16	0.40
Deer Creek	Blind Canyon	0.72	0.02	0.11	0.59
Deer Creek	Blind Canyon	0.55	0.01	0.18	0.36
Meetinghouse	Hiawatha	0.54	0.02	0.11	0.41
Paramount	Blind Canyon	0.53	0.01	0.10	0.42
Stump Flat	Hiawatha	0.89	0.01	0.19	0.69

Buranek and Crawford (1952) report a high resin content in some mines opened in the Blind Canyon bed. In the Byron Howard mine in Deer Creek Canyon the bed carries 3 percent resin. According to the above authors:

> The resin seams in the coal strike N40°W. According to Mr. Howard, the present [1952?] output of the mine is roughly 200 tons per day of which approximately 10 percent is "bug dust". . .Some 200 pounds of "bug dust" were collected to be analyzed. Also a rough estimate of the fumes and "bug dust" contained in the dump was made. . .Samples analyzed for resin, benzene (Benzol) used as solvent are as follows:

	Percent resin	
	Howard mine	American Fuel
Selected lumps high grade	6.4	
"Bug dust" (coal fumes)	8.87	7.8
Machine drill across vein diagonally		3.2

> (Professor Kinney, analyst, University of Utah, Salt Lake City, Utah)

> The American Fuel mine. . .is several hundred yards to the southwest of the Howard mine and at an elevation some 250 feet above it . . . [the] quality of coal, percentage of resin contained therein and the geologic stratigraphic position of this mine is [sic] the same as the Howard mine. . .The occur-

Portal of new Deer Creek mine in Deer Creek Canyon. The mine will supply the Utah Power and Light power plant being constructed at the mouth of Huntington Canyon.

rence of the resin is similar in every respect to that described for the Howard mine, although it appeared that in the latter mine, the percentage of resin was slightly higher.

Fossil resins similar to commercial resins are used to prepare fine varnishes and lacquers. These resins have been imported from the East Indies.

Gomez, Landers and Boyd (1967, p. 9 and 12) calculated carbonization product yields for several mines on the quadrangle (table 47; end carbonization temperature 500° C).

Table 47. Carbonization product yields, Hiawatha SE quadrangle.

Mine	Carbonization yields wt. percent of maf coal				Gas volume scf/lb maf coal	Heating value of gas Btu/scf
	Char	Water of decomposition	Tar plus light oil	Gas		
Deer Creek	69.9	4.6	20.7	3.9	.844	841
Meeting-house	69.6	4.8	20.9	4.1	.856	832
Paramount	68.8	5.0	21.0	4.2	.874	831
Stump Flat	70.2	5.2	18.7	5.1	.954	791
Wilburg	96.5	5.3	19.8	4.9	.927	797
Wilburg prospect	69.6	5.7	18.7	5.2	.976	784

In a report of the Utah Conservation and Research Foundation (1939, p. 78) low-temperature carbonization of coal from the Deer Creek mine was tested and the results are repeated on table 48.

Mines and Development

A new mine was opened in Deer Creek Canyon in 1971 along the west edge of sec. 11-17S-7E eventually to supply a powerplant being built in Lower Huntington Canyon. Production undoubtedly will increase soon to build an initial stockpile. The production figure listed for the quadrangle is dated ending in 1970 and does not include production from the new mine.

The only other active mine on the quadrangle, the Deseret mine, produced 104,675 tons in 1969. Several other good mines were operative in the past (table 49).

Table 49. Mines and their locations, Hiawatha SE quadrangle.

Mine	Location	Remarks
American mine (American Fuel)	10 & 11-17S-7E ≃4,356,250m.N. 490,150m.E.	Active 1937-1966
Anderson mine	N.SW.SW.26-17S-7E 4,351,280m.N. 490,300m.E.	Active in 1922
Deer Creek mine	NW.SE.NW.11-17S-7E 4,356,650m.N. 490,600m.E.	Intermittently active 1896-1916 Active 1937-1956
Deseret mine (Beehive, Church, No. 1 Otterson) No. 2	N.SE.NE.26-17S-7E 4,351,800m.N. 491,525m.E. 4,351,920m.N. 491,530m.E.	Active 1909-1970
Huntington mine (Meetinghouse, Harrison, Leonard, Community)	SW.SW.SE.NE.3-17S-7E 4,358,000m.N. 489,810m.E.	Active 1921-1952
Maple Creek mine	N.NE.14-17S-7E ≃4,355,000m.N. 491,600m.E.	May be a prospect
Paramount mine	SE.SE.SE.SW.2-17S-7E ≃4,357,400m.N. 490,850m.E.	Active 1948-1956
Stump Flat mine	24-17S-7E ≃4,352,450m.N. 489,430m.E.	Intermittently active 1938-1960
Wilburg mine (Fox, Straight Canyon, Castle Valley, Crow Reed)	NE.NW.NW.NE.27-17S-7E 4,352,390m.N. 489,430m.E.	Intermittently active 1898-1936 Sustained 1937-1967

The Huntington mine located in Meetinghouse Canyon was opened in 1921 on a 6-foot section of the Hiawatha bed. According to analyses some of the production has come from the Blind Canyon bed. It is suspected that mining activity was slow until 1940, after which about 21,000 tons of coal were produced.

Table 48. Low-temperature carbonization product yields, Deer Creek mine, Hiawatha SE quadrangle.

		Vertical Retort										Rotary Retort			
		External Heating								Internal Heating		External Heating			
Carbonizing temperature °C (Products Weight Percent)		450	550	550	650	650	650	650	750	850	550	650	450	550	650	650
	Char	74.6	64.3	64.0	59.3	59.7	61.5	64.2	59.3	57.2	68.0	62.3	67.1	62.1	58.5	56.4
	Gas	1.6	4.8	4.5	8.6	9.2	8.2	9.7	9.6	11.5	2.0	3.9	4.2	7.9	9.2	–
	Tar	9.9	12.1	14.2	14.0	15.1	13.3	11.3	14.3	14.3	14.7	13.2	16.2	16.4	16.4	17.5
	Light oil	0.3	0.7	0.9	0.7	0.4	0.6	0.5	0.7	0.6	0.5	0.6	0.2	0.6	0.5	–
	CO_2	1.0	1.6	1.8	1.3	1.4	2.3	2.1	2.2	0.9	1.2	1.1	1.0	1.1	1.8	–
	Tar liquor	10.2	12.0	13.0	14.2	13.5	12.6	13.4	12.6	13.5	–	–	11.7	12.1	12.6	12.6
	Total	97.6	95.5	98.4	98.1	99.3	98.5	101.2	98.7	98.0	–	–	100.4	100.2	99.0	–
	Gas, cu. ft.	536	2,046	1,986	4,427	4,376	4,016	3,870	5,023	6,662	725	1,774	1,270	2,670	4,130	4,490
Yield/ton of coal	Tar, gallons	23.8	35.3	34.1	33.3	36.2	31.8	27.2	34.7	34.3	34.8	30.7	39.0	39.3	39.4	42.1
	Light oil, gallons	0.9	2.1	2.7	2.2	1.3	2.0	1.5	2.0	2.0	1.6	1.8	0.7	1.8	1.7	–
	$(NW_4)_2SO_4$ pounds total	3.5	7.7	10.6	12.9	6.4	9.8	7.1	14.5	13.5	8.9	7.4	4.1	4.9	5.2	–

Mines in Deer Creek Canyon include the American, Deer Creek and Paramount mines, all opened in the Blind Canyon bed. In the American mine the bed was reported between 12 and 18 feet thick and 1,727,700 tons were produced. In the Deer Creek mine the bed is 14 feet thick and production has been 461,600 tons. The Paramount operated on two seams of Blind Canyon coal, one 6 feet thick, the other 12. About 54,000 tons were produced.

Little is known about the Maple Creek mine except that it is developed on the Hiawatha bed. The Stump Flat mine is located in sec. 24-17S-7E on either side of the plateau promontory; its exact location is questioned. The coal bed is reported 12 to 14 feet thick but split by 1 foot of shale. The lower 8 feet were mined and about 8,000 tons were produced.

The Deseret mine, still active, is located in the first canyon east of Grimes Wash. Historically the mine operated on the Hiawatha bed but recently mining commenced on an upper seam, presumably the Blind Canyon or Bear Canyon bed. The mine was intermittently active from 1909 to 1940 when serious mining has continued steadily since. Total estimated production is 1.6 million tons.

The Wilburg mine and older mines incorporated into the later one are located in Grimes Wash near the west map edge. Total production from these mines has been 168,000 tons. Estimated total production from the quadrangle totals 4,040,300 tons.

Reserves

Reserves were calculated by Spieker (1931, p. 204-205) and are adjusted to fit the quadrangle (table 50).

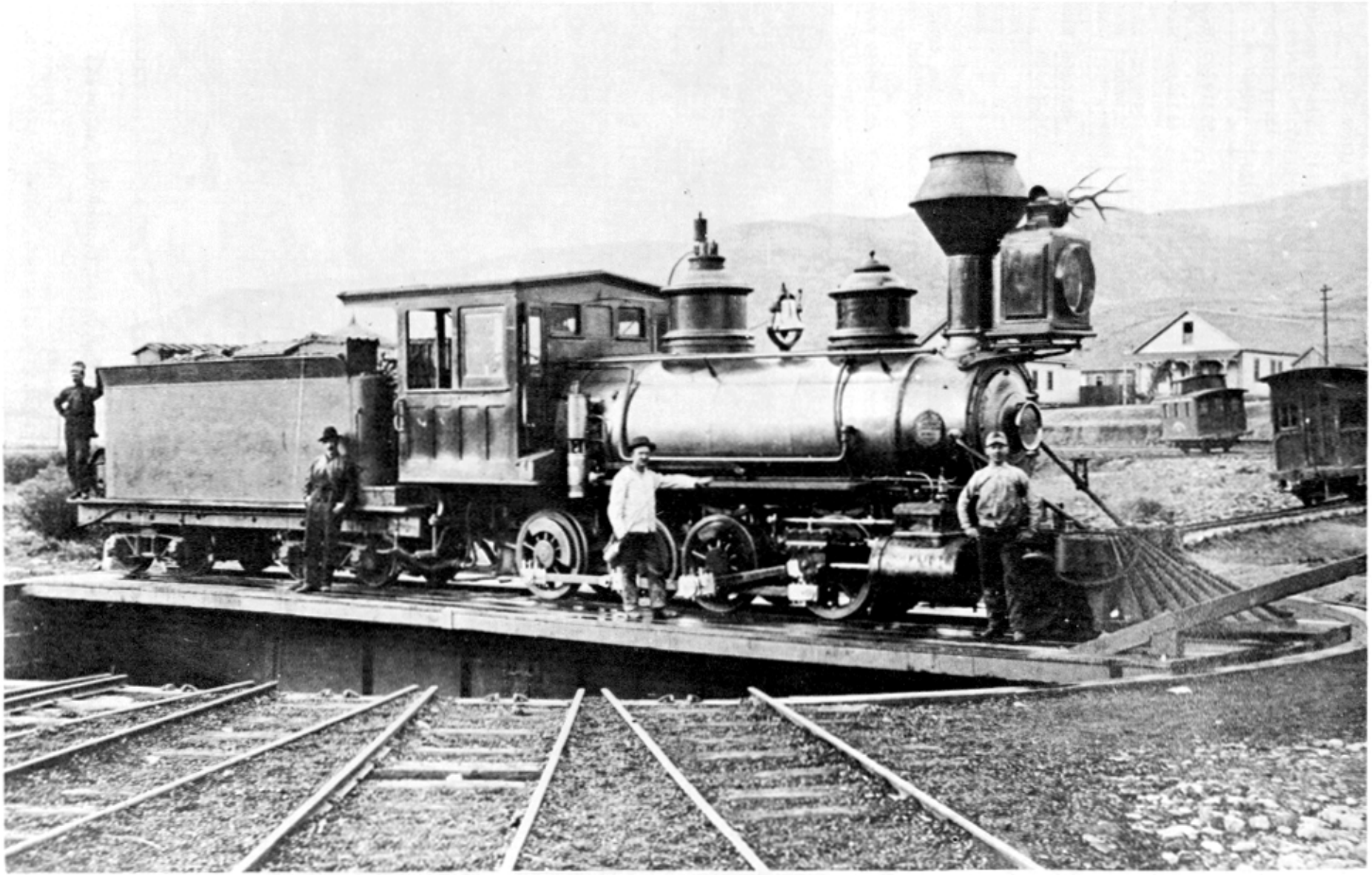
Table 50. Original reserves in the Hiawatha SE quadrangle (in short tons; beds 30 or more inches thick).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.17S. R.7E.	2,390	7.0	30,114,000	Hiawatha sec. 1-18
	2,062	13.0	48,250,800	Hiawatha secs. 19-36
	1,463	9.3	24,490,620	Blind Canyon
	300	5.0	2,700,000	Bear Canyon in Meetinghouse Canyon
T.17S. R.8E.	197	13.0	4,610,000	Hiawatha
		Total coal	110,165,420	

PRINCIPAL WORK

Most of the work presented in this quadrangle report is from Spieker (1931). Updating information has come from varied sources, mostly from published and unpublished data of the U. S. Bureau of Mines.

Upper mine portals, LDS Church mine; probably in the Blind Canyon bed, Cottonwood Canyon area.



Locomotive to pull coal from Helper to Soldier Summit, 1910 to 1930. Photo from Helper Mining Museum original.

HIAWATHA SW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

Hiawatha SW is located near the center of the Wasatch Plateau coal field (figures 22 and 46). Principal geographic features identifiable on the map area are Straight Canyon and Cottonwood Canyon. The nearest towns are Orangeville 4.4 miles east and Castle Dale about 7 miles east. Castle Dale is joined to Price by Utah Highway 10 and Utah Highway 29 cuts across the south part of the quadrangle joining Castle Dale to Ephraim in Sanpete Valley. It is about 25 miles from the west map edge to Ephraim.

The plateau is divided into three segments: East Mountain east of Cottonwood Creek, Trail Mountain between Cottonwood Creek and Straight Canyon and North Horn Mountain south of Straight Canyon. Elevations on the mountain tops are between 9,000 and 10,000 feet and in the canyon bottoms, 6,500 to 7,000 feet. The coal crops out between 6,500 and 7,750 feet.

STRATIGRAPHY

The upper two members of the Mancos Shale are exposed in the canyon and valley bottoms. The Emery Sandstone Member crops out along Cottonwood Creek. It is a yellow-gray massively bedded sandstone unit interbedded with subordinate gray shale. The upper shale member, the Masuk, is 1,300 feet thick on the Hiawatha SW quadrangle and consists of sandy slope-forming mostly dark gray shale.

The Mesaverde Group--the Star Point Sandstone, Blackhawk Formation, Castlegate Sandstone and Price River Formation--make up the walls of the canyons. Yellow-gray, thick-bedded to massive cliff-forming sandstone describes the 250- to 350-foot thick Star Point on the quadrangle. The lagoonal 625- to 800-foot thick Blackhawk bears the important coal seams. Mostly the unit consists of medium- to thick-bedded and even massive yellow-gray sandstones and intervening gray and carbonaceous shales. The better coal seams occur in the lower half of the formation.

Unconformably overlying the Blackhawk are coarse gritty sandstones of the Castlegate. The unconformity represents a change from the lagoonal and littoral environments of the Blackhawk to fluvial continental. The Castlegate (250 to 350 feet thick) appears as a massive cliff but in places is broken by partings of shale. The Price River above it carries the same lithology but is not massive appearing and less resistant.

The plateau top is capped by the North Horn and Flagstaff formations. Contours in sec. 29, T. 17 S., R. 7 E. indicate the North Horn, with its variegated shales, subordinate sandstone, conglomerate and freshwater limestone, to be about 1,000 feet thick. Atop East and Trail mountains is the Flagstaff Limestone, mostly dark yellow-gray to cream limestone, evenly bedded and resistant.

Unconsolidated rock includes alluvium and bench gravels. The alluvium makes up the floodplain of Cottonwood Creek and bench gravels to 75 feet thick have developed on the Masuk Shale Member of the Mancos Shale.

STRUCTURE

Except for one fault cutting through Meetinghouse Canyon in the northeast map corner little deformation of strata is evident. This fault represents the south end of the Pleasant Valley fault zone and trends north-south. The 250-foot displacement would limit mining. The regional dip is mainly westward to 7 degrees although it is generally more gentle.

The Joes Valley fault system occurs about a mile to the west (Joes Valley Reservoir quadrangle); the displacement of the east side fault is estimated between 1,500 and 2,000 feet.

PROPERTY CONTROL

The lands of the Hiawatha SW quadrangle are owned by government agencies and private interests. The breakdown in approximate percentages is as follows: National Forest Service 67.7 percent, private property 16.1 percent, Bureau of Land Management 12.7 percent and state of Utah 3.5 percent.

Total coal land amounts to about 82.6 percent of the quadrangle. Most of it is in the National Forest and in large tracts under private ownership, especially on East Mountain. About one-third of the state and BLM lands are underlain with coal.

Land held for coal by individuals and companies amounts to one-third of the coal land; it is concentrated mostly in the northeast quarter. The following acreages are approximate (January 1, 1970):

	Acres	Type
McKinnon	1,140	Fee
	4,826	Lease
Co-op Security Corp.	3,725	Lease
Sentry Royalty (Peabody)	272	Lease
E. J. Robertson	40	Lease

COAL

Surface Information

The important coal beds within the stratigraphic column are positioned in the lower part of the Blackhawk.

	Feet
Upper bed of Grimes Wash	0-3.5
Interval	69
Upper Bear Canyon bed	0.3.5
Interval	11-34
Bear Canyon bed	0-4
Interval	40-60
Blind Canyon bed	0-7
Interval	20-40
Cottonwood bed	0-5
(may be Upper Hiawatha)	
Interval	10
Upper Hiawatha bed	0-4.5
Interval	12-20
Hiawatha bed	0-9
Star Point Sandstone	

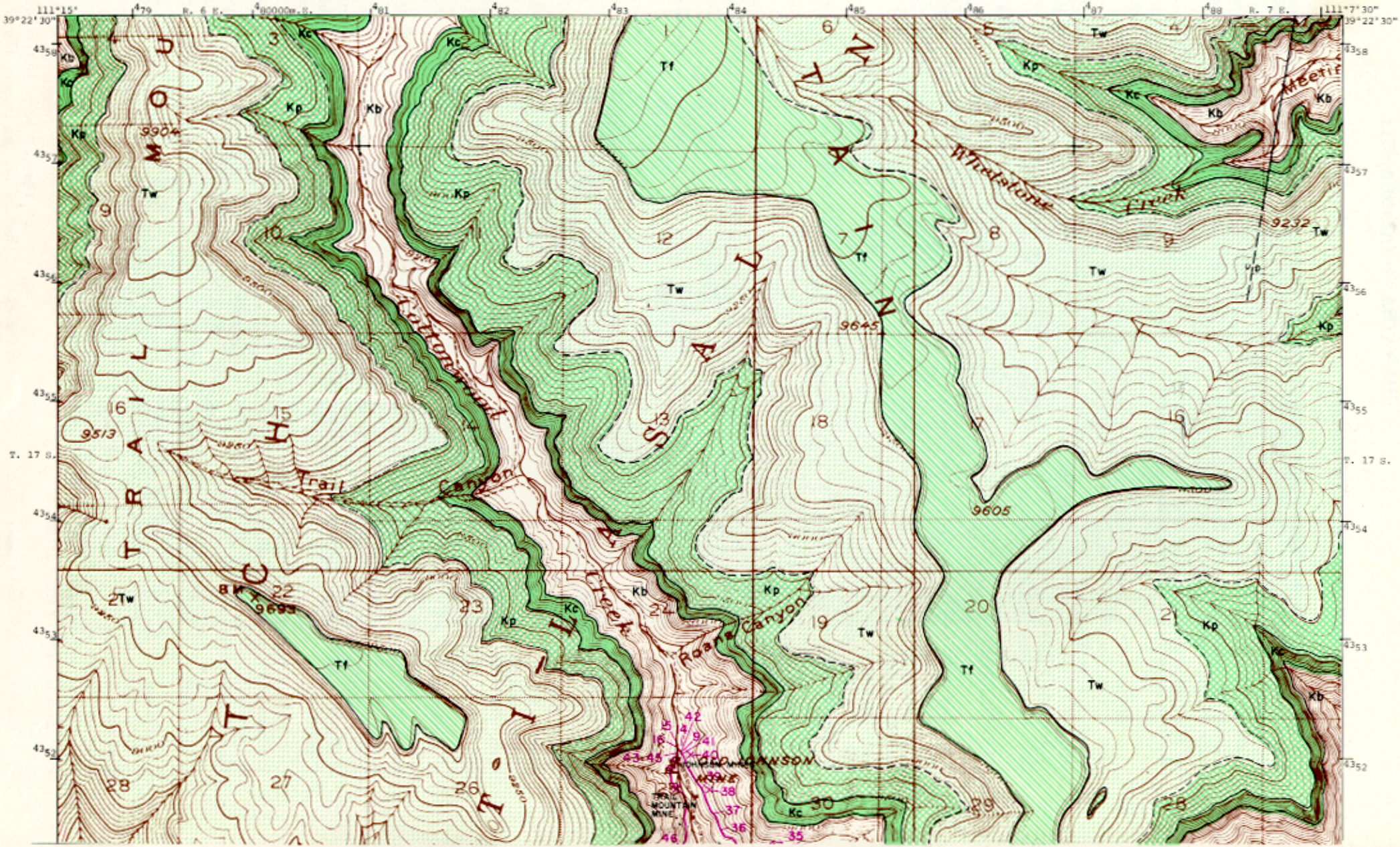
The most valuable bed is the Hiawatha with 49 measured sections (figure 47). The upper and lower seams are shown; the upper bed (8) is set somewhat higher on the coal section sheets. The Hiawatha is at least 6 feet thick with 8 and 9 feet dominating throughout T. 17 S. Farther south it thins and splits. On the north side of Straight Canyon the coal averages 5 feet but is believed to thin westward in the subsurface. All exposures farther south appear too thin and too badly split to mine.

The Upper Hiawatha is thickest in Straight Canyon between the Black Diamond and Oliphant mines where it is 2 to 6 feet thick. Elsewhere it is too thin or split too badly to be of value.

The Cottonwood is a lenticular bed exposed in sec. 30, T. 17 S., R. 7 E. between 3½ and 5 feet thick. Elsewhere its value is doubtful. The Blind Canyon is the next higher bed. All but one exposure measured is too thin. Measured section 21 reveals 7½ feet of coal with a 0.2-foot split. The bed thickens eastward.

The two Bear Canyon beds are best developed in the east half of the quadrangle. The thickest sections measured 4 feet of coal. The upper bed seems less continuous than the lower. A higher bed, termed the Upper bed of Grimes Wash, is isolated

HIAWATHA, UTAH S.W.



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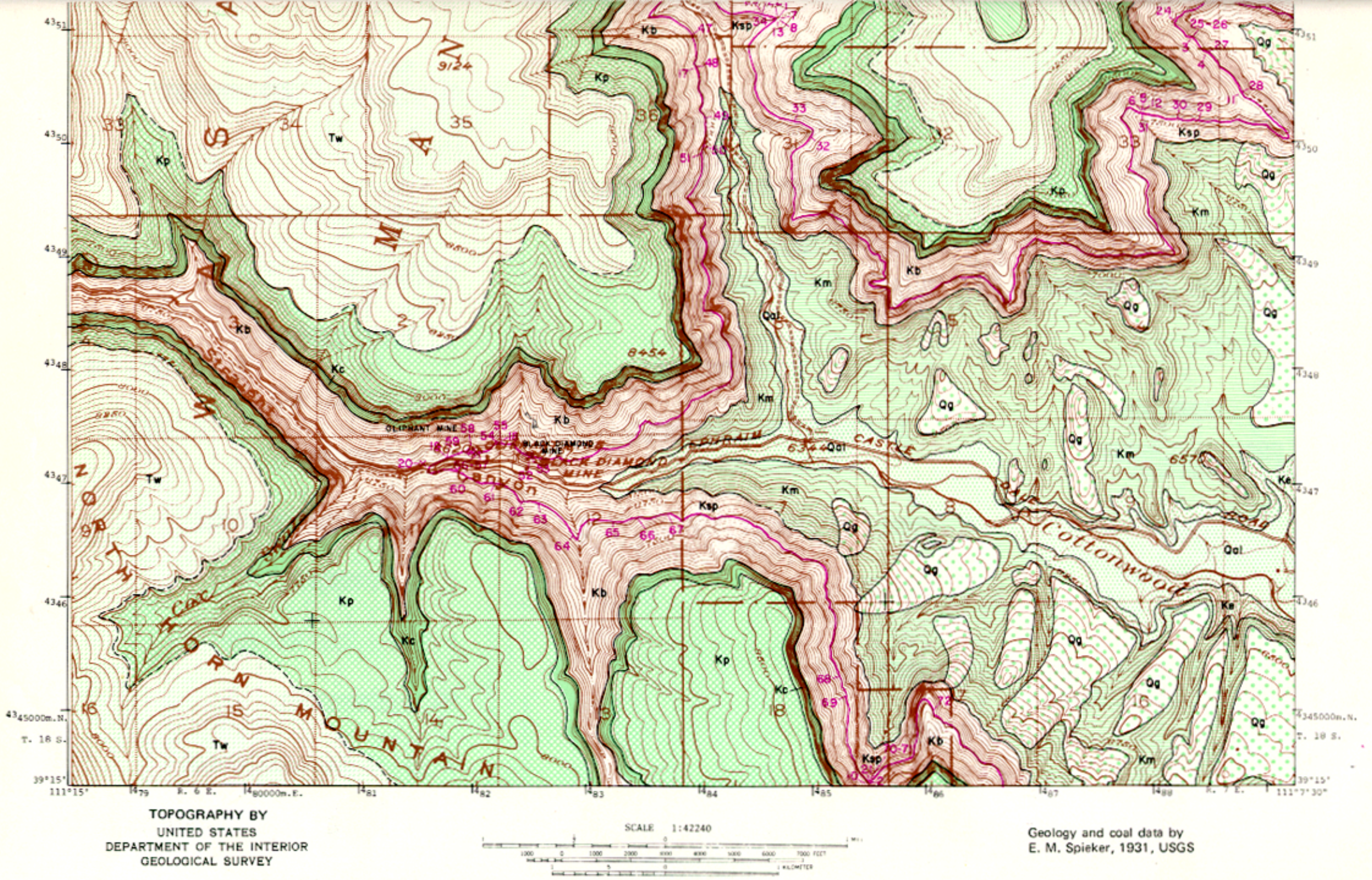


Figure 46. Coal and geology map, Hiawatha SW quadrangle (explanation pages 136-137).

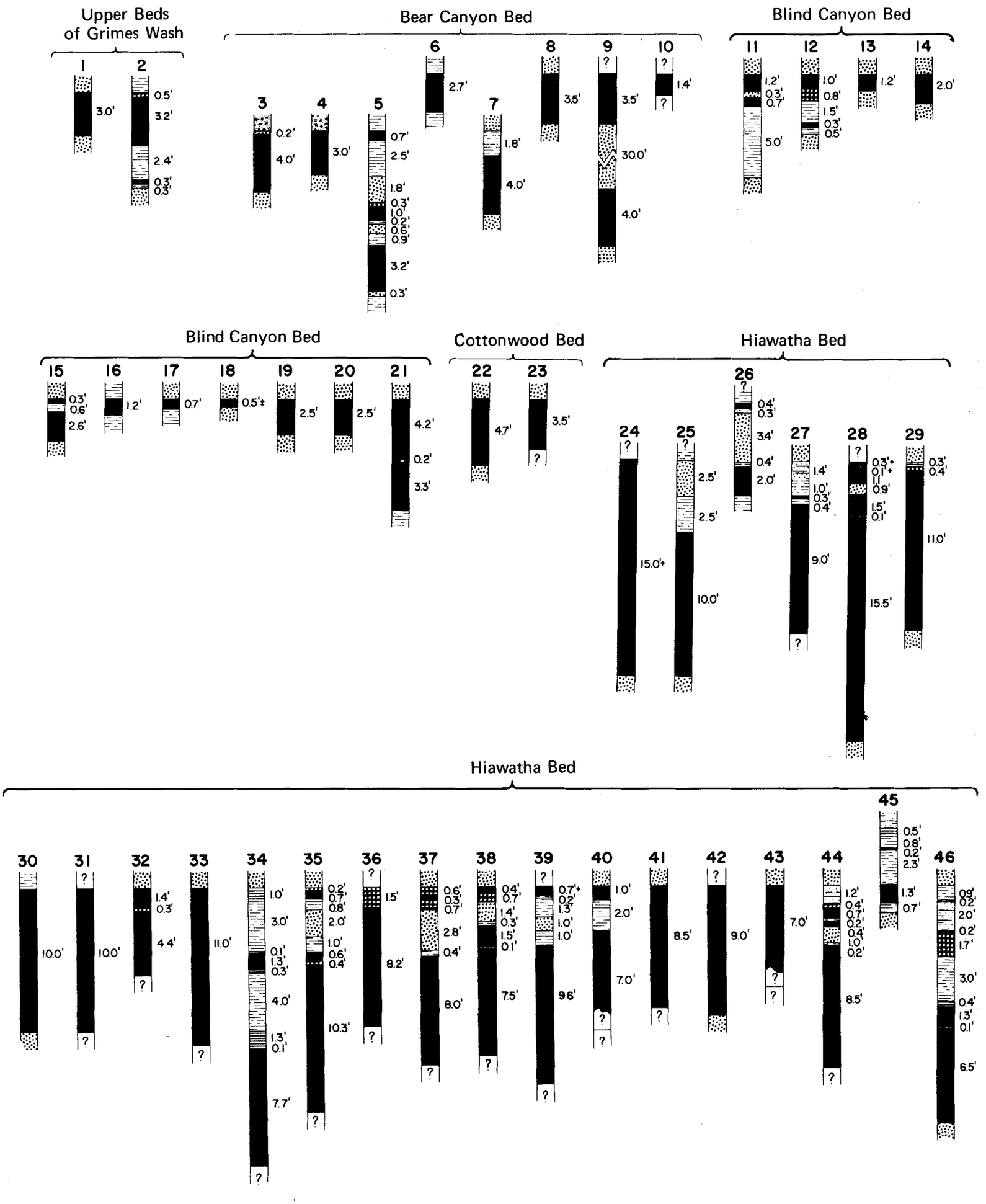


Figure 47. Coal sections of Hiawatha SW quadrangle (vertical scale: 1 inch = 8 feet).

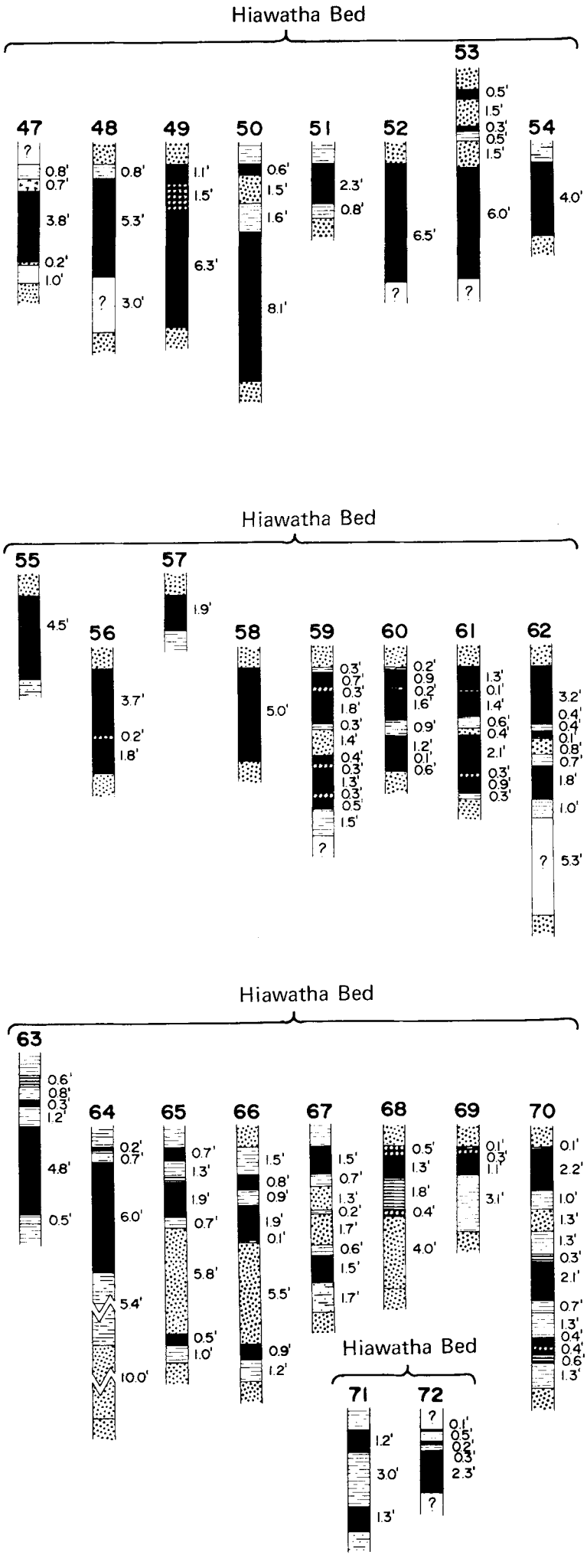


Figure 47. (continued)

north and south of Cottonwood Creek; both sections are too thin to be of importance.

Subsurface Information

No drill-hole information is available for the Hiawatha SW quadrangle; at least one-third of the map area mainly to the northwest and west falls in the Class III or inferred reserves because no control points fall within 1½ miles. Coal is buried under less than 1,000 feet in 12.5 percent of the area, 1,000 to 2,000 feet in more than 62.8 percent and more than 2,000 feet in the remaining 24.7 percent; maximum overburden is 2,600 feet.

Quality of Coal

All 27 analyses (table 5) are believed from the Hiawatha bed; the coal is similar to Wasatch Plateau coal in general. Table 51 lists averages and ranges for the area's coal.

Table 51. Average coal analyses, Hiawatha SW quadrangle.

	No. Analyses	Percent as-received	
		Average	Range
Moisture	27	4.7	1.5 -13.2
Volatile matter	16	41.6	37.9 -43.7
Fixed carbon	16	46.4	43.2 -48.7
Ash	20	6.5	4.2 - 8.8
Sulfur	18	0.57	0.38- 0.7
Btu/lb	23	12,905	11,376-13,452

The U. S. Bureau of Mines (Walker and Hartner, 1966) subdivided sulfur into sulfate, pyritic and organic (table 52).

Table 52. Sulfur-type determinations of coal, Hiawatha SW quadrangle.

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Oliphant	Hiawatha	0.61	0.01	0.13	0.47
Oliphant	Hiawatha	0.62	0.01	0.15	0.46
Trail Mountain	Hiawatha	0.51	0.01	0.05	0.45

Gomez, Landers and Boyd (1967, p. 9 and 12) calculated carbonization product yields for several of the mines (table 53; end carbonization temperature 500° C).

Table 53. Carbonization product yields, Hiawatha SW quadrangle.

Mine	Carbonization yields, wt. percent of maf coal				Gas volume scf/lb maf coal	Heating value of gas Btu/scf
	Char	Water of decomposition	Tar plus light oil	Gas		
Black Diamond	69.5	4.9	20.3	4.5	.891	816
Oliphant	71.1	5.0	18.6	4.7	.919	810
Trail Mtn.	70.3	5.1	19.0	5.0	.933	795
Trail Mtn. No. 2	72.3	4.8	17.8	4.6	.910	812

Mines and Development

Several mines have been opened on the quadrangle (table 54), notably in Cottonwood and Straight canyons. At present none are operating.

The Black Diamond mine east of the Oliphant and higher on Straight Canyon wall probably operated intermittently. The amount of coal mined is estimated to be about 10,000 tons. Coal in the Oliphant is from the Hiawatha seam which is 4 to 6 feet thick with a good sandstone roof. About 34,000 tons have been mined from the Oliphant.

Table 54. Mines and their locations, Hiawatha SW quadrangle.

Mine	Location	Remarks
Black Diamond mine (Fox)	SW.NE.NW.NW.12-18S-6E 4,347,220m.N. 482,520m.E.	1898-1950's (?)
Cottonwood Canyon prospects	NW.SW.SE.25-17S-6E 4,351,350m.N. 483,710m.E.	Active 1946-1948
	SE.SE.NE.31-17S-6E 4,350,190m.N. 485,300m.E.	
Johnson mines (Twin City, Shumway, Cottonwood)	SW.SW.NE.25-17S-6E 4,351,900m.N. 483,575m.E. 4,351,990m.N. 483,600m.E.	Active 1909-1948
Oliphant mine	SW.NE.NE.NE.11-18S-6E 4,347,265m.N. 482,010m.E.	Active 1906-1950's
Sitterud mine	Cottonwood Canyon, 10 miles NW or Orangeville, exact location unknown	Active 1946-1952
Straight Canyon prospect	NW.NE.11-18S-6E 4,347,300m.N. 481,720m.E.	Small hole on roadside
Trail Mountain mine		Active 1946-1967
No. 1	NW.SE.25-17S-6E 4,351,700m.N. 483,550m.E.	
No. 2	4,351,580m.N. 483,570m.E.	
No. 3	4,351,700m.N. 483,810m.E.	

The remaining important mines are in Cottonwood Canyon. Of these the Trail Mountain mine is the largest and has produced the most coal—an estimated 25,000 tons. An estimated 27,000 tons produced on other mines and prospects on the quadrangle make the total 96,000 tons.

Reserves

The following reserves include the Hiawatha SW quadrangle plus a narrow strip of land west to Joes Valley fault. Calculations are Spieker's (1931, p. 205) and are modified to fit the above dimensions (table 55).

Table 55. Original reserves in the Hiawatha SW quadrangle (in short tons; beds 30 or more inches thick).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.17S. R.6E.	15,287	5.0	137,583,000	Hiawatha
T.17S. R.7E.	4,776	7.0	60,117,600	Hiawatha secs. 1-18
	5,471	13.0	128,021,400	Hiawatha secs. 19-36
	700	4.0	5,000,000	Cottonwood bed
	200	5.0	1,800,000	Bear Canyon Meetinghouse Canyon
	7,320	4.0	40,000,000	Bear Canyon
	7,800	4.6	44,000,000	Upper Bear Canyon
T.18S. R.6E.	3,598	6.3	40,801,320	Hiawatha secs. 1-3, 10-12, 14
	4,477	4.5	36,263,700	Hiawatha secs. 4-9, 13, 15-18
	900	6.0	9,720,000	Blind Canyon
T.18S. R.7E.	290	9.0	5,000,000	Hiawatha secs. 4-6
	95	5.0	855,000	Hiawatha sec. 7
		Total coal	509,222,020	

PRINCIPAL WORK

The work taken from U. S. Geological Survey Bull. 819 by Spieker (1931) is updated from varied sources, mostly published and unpublished data of the U. S. Bureau of Mines.

Winterquarters tipple and conveyor, operated from 1878 to the 1940's. Photo was probably taken in the 1920's or 1930's. Photo from Helper Mining Museum original.

SCOFIELD NE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Scofield NE quadrangle bounds the east edge of the Book Cliffs coal field at the north end of the Wasatch Plateau field (figures 22 and 48). The center of the map lies about 15 miles west of Price. The greater part of the Gordon Creek area is represented. Presently (1970) there are no active communities on the quadrangle; Coal City, National and Consumers have been reduced to ghost towns. Access by Utah State Route 139 connects the area with U. S. Highway 50-6 near Helper. Route 139 is a well maintained gravel road over most of its length. Recent producers truck their coal to the Utah Coal Route (Utah Railway), 7 miles east of abandoned Coal City.

The area is mountainous and rugged. The main trend of the Wasatch Plateau cliff in the southeast map area aligns roughly northeast-southwest. North Gordon Creek, Bob Wright Canyon, Coal Canyon and Trail Canyon dissect the front. North of the front, Beaver Creek and Jump Creek flow northeasterly to the Price River in response to the regional dip. Elevations on the quadrangle range from 6,700 feet below the cliffs to more than 9,500 feet along the west edge of the map on top of the plateau. Coal seams are exposed between 7,750 and 8,750 feet above sea level.

STRATIGRAPHY

Cretaceous and Tertiary consolidated units are exposed on the quadrangle; some alluvial and gravel deposits of Quaternary age have been mapped. The oldest unit, the Emery Sandstone Member of the Mancos Shale, is a yellow-gray littoral sandstone with thick to massive bedding. Near Bob Wright Canyon it is 550 feet thick. It is overlain by the uppermost unit of the Mancos, the Masuk Shale. This gray shale unit becomes sandy toward the top. It forms a slope at the base of the cliffs and is at least 1,000 feet thick on the quadrangle.

The initial unit of the Mesaverde Group, the Star Point Sandstone, is the first or lower cliffy sandstone along the Wasatch Plateau escarpment. The unit is 440 feet thick in Coal Canyon and consists of massive tongues of yellow-gray littoral sandstone separated by Mancos-like shales which are probably tongues of that formation. The sandstone tongues named from bottom to top are Panther Tongue, Storrs Tongue and Spring Canyon Tongue.

The Star Point is overlain by the Blackhawk Formation which contains all the important coal seams. The Blackhawk consists of sandstone, shale and coal, varying between lagoonal and littoral sequences. The littoral sandstones are resistant, forming ledges and cliffs; the lagoonal shales and coal along with a substantial amount of shaley sandstone form intervening slopes. Eight hundred and seventy-five feet were measured in the southwest map area and structure contours north of Coal Canyon indicate the unit to be more than 900 feet thick at that location. The important coal beds lie in the lower 350 feet. Zones and beds well developed on the Scofield NE quadrangle include the Hiawatha bed, Castlegate "A" bed, Bob Wright coal zone and at least two other lenticular beds. The Blackhawk outcrop area covers most of the upper cliff surface of the plateau; younger beds cover it in the north.

In the Beaver Creek area the Blackhawk is successively covered by the Castlegate Sandstone, the Price River Formation and the North Horn (Wasatch). The Castlegate is coarse-grained, massive and a cliff former. The Price River continues with a similar lithology but is not as massive and somewhat less resistant. The lower unit is a little more than 500 feet thick and the upper unit less than 500 feet. In the northeast corner of the map area a few patches of North Horn Formation (Tw) consisting of variegated shale, sandstone and thin-bedded limestone crop out. At the most 200 to 300 feet are exposed.

Unconsolidated alluvium is confined to the valley floors of the important drainages; gravel is deposited on benches of Masuk Shale which are preserved from erosion by the coarse clastic material.

STRUCTURE

The most significant feature is the North Gordon fault zone. The faults are well described by Spieker (1931, p. 102):

> In the North Gordon area the coal-bearing rocks are broken by the network of faults that constitute the North Gordon fault zone. This fault zone is most complex and extensive in the valley of North Fork of Gordon Creek, where it is about 5 miles broad. Between the eastern border of the area and the head of North Fork of Gordon Creek there are at least 33 faults, 10 of which have displacements greater than 100 feet. Most of the larger faults trend nearly north, but many others extend in diverse directions, forming an irregular network within which the positions of the coal beds are somewhat complicated...The largest fault in the area is the Coal Canyon fault, on which the coal-bearing rocks have dropped from high positions in the cliffs east of Coal Canyon to positions near creek level on the west...The Coal Canyon fault decreases in throw northward, owing to the strong northeastward dip of the strata east of the fault...

The complexity of the faults in the area along with measured displacements by Spieker are illustrated in figure 49. To the north faulting is much less of a problem. Three faults in the northwest map area are about one-half mile apart. The displacements are large, as much as 1,000 feet in places. Three or four north-south trending faults occur within a half mile near the mouth of Bob Wright Canyon with displacements between 50 and 150 feet.

To the south coal beds are approximately horizontal. In the central map area the strata are inclined 2 degrees north. Locally, especially near faults, they may be higher. Dips to 4 degrees occur in the north part of the quadrangle.

PROPERTY CONTROL

More than 70 percent of the Scofield NE quadrangle is privately owned. An unknown amount of this land has coal reserved to the United States. Various governmental agencies own the remaining land: private property 70.2 percent, Bureau of Land Management 19.0 percent, state of Utah 6.5 percent and National Forest Service 4.3 percent.

Lands underlain with coal cover 65.1 percent of the quadrangle area. Roughly 25 percent of the National Forest, 56 percent of state lands, 38 percent of BLM lands and 76 percent of private lands are underlain with coal. Since most of the land is privately owned (some with coal reserved to the United States) it is difficult to ascertain how much is being held for coal development. At least four companies maintain coal lands totalling 2,400 acres–about 6.4 percent of the land area of the quadrangle or 10 percent of the coal lands. Another 1,700 acres are taxed by the state of Utah as coal land. Companies maintaining coal properties with approximate acreages are listed below:

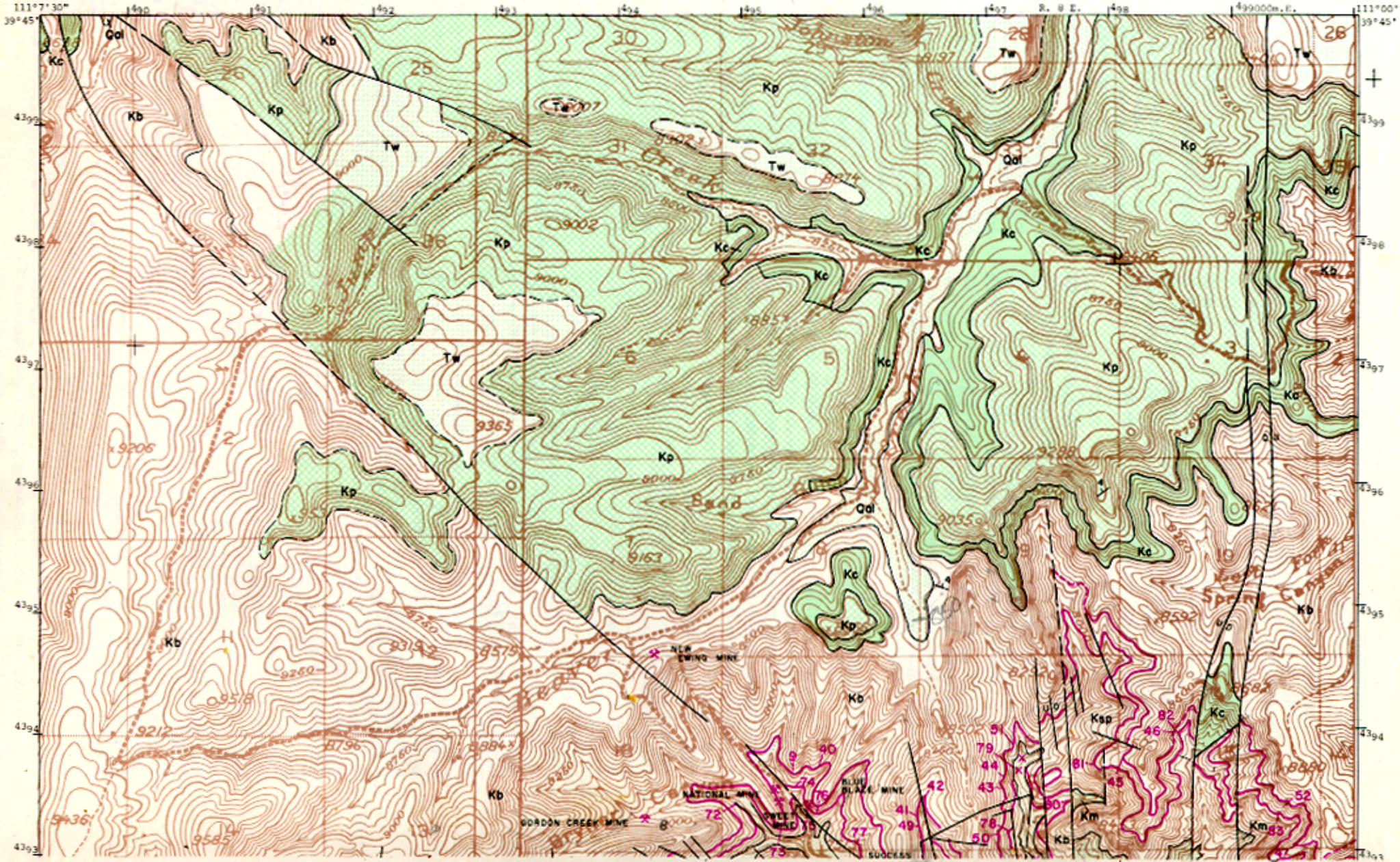
	Acres	Type
North American Coal Co.	360	Lease
Swisher Coal Co.	480	Fee
	400	Lease
Wasatch Coal Co.	640	Fee
	280	Lease
Western Fuel Co.	260	Lease
	2,420	

COAL

Surface Information

Coal-bearing sections for three outcrop localities are approximated in table 56: (1) to the southwest in the vicinity of Bob

SCOFIELD, UTAH N.E.



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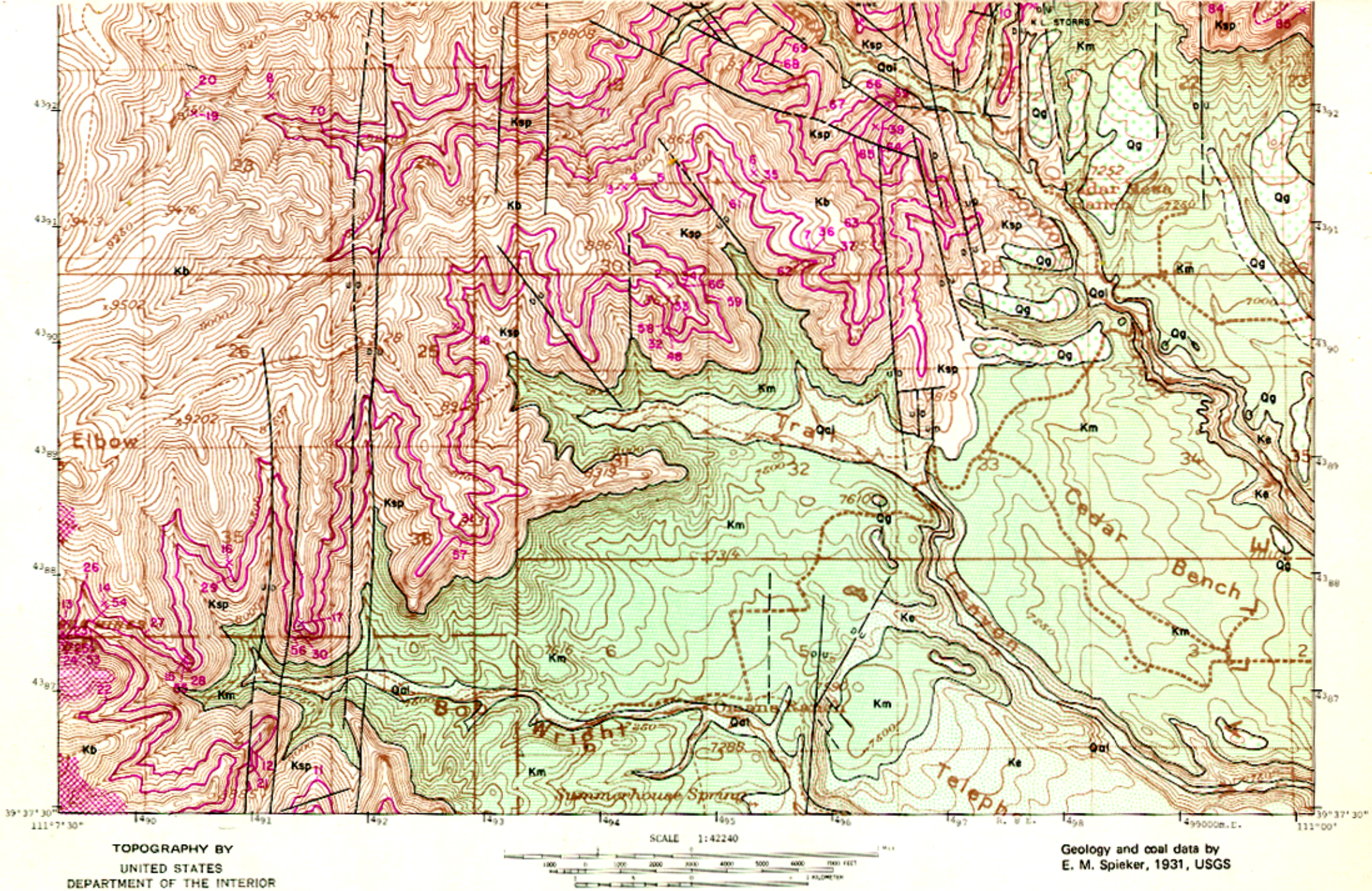


Figure 48. Coal and geology map, Scofield NE quadrangle (explanation pages 136-137).

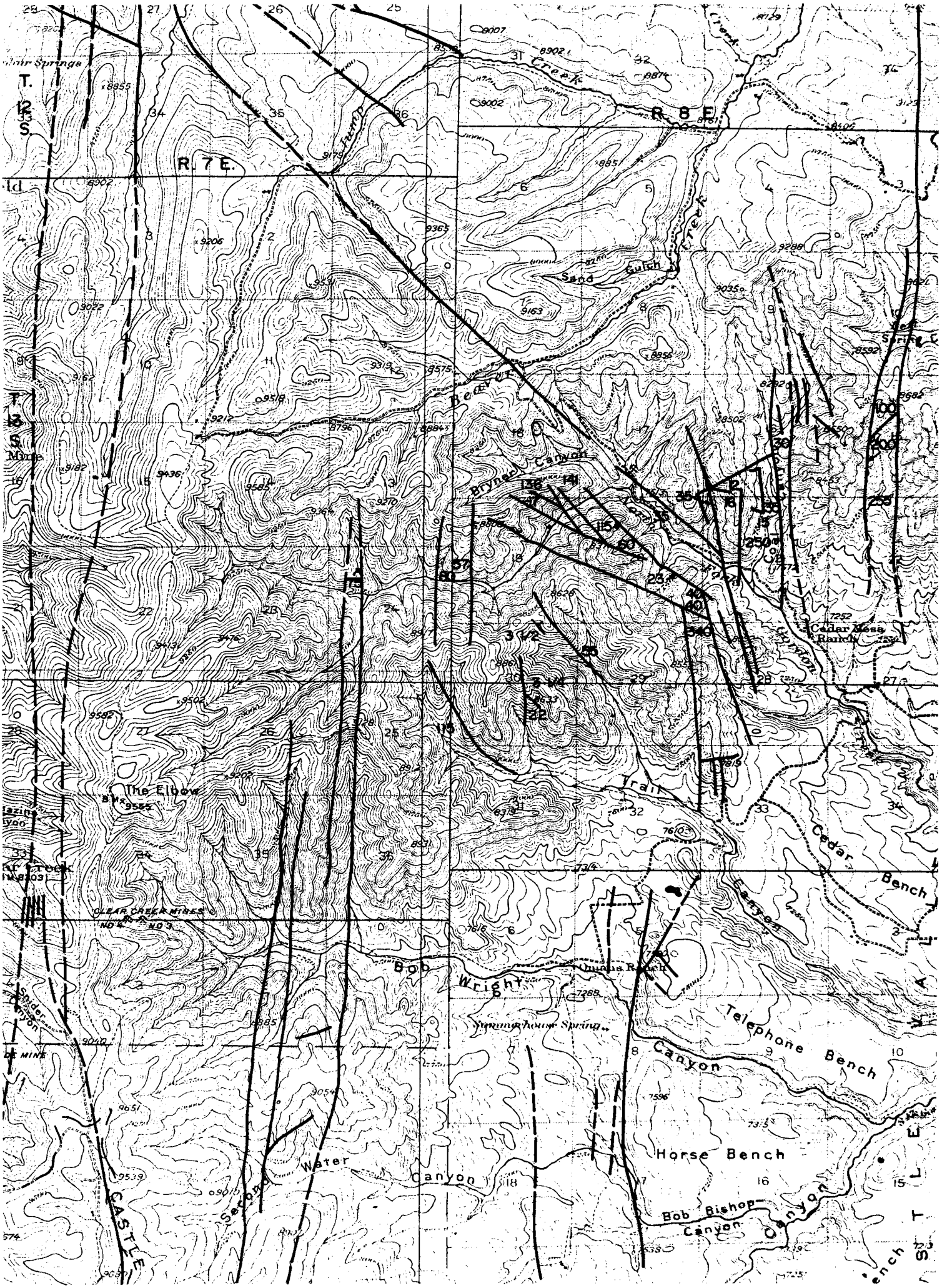


Figure 49. Map of North Gordon area showing displacements of faults (in feet).

Table 56. Coal-bearing sections for Bob Wright Canyon, West Spring Canyon and the north central outcrop localities.

Beds	Feet		
	Bob Wright Canyon	North Central	West Spring Canyon
Unnamed upper bed	0-4	–	–
Interval	40-65	–	–
Bob Wright zone			
Upper	0-4	Individual	Castlegate "D" 1-4
Interval	5-25	beds up to	70
Main	3-10	15	–
Interval	3-20		–
Lower	2-8		Castlegate "C" 1-5
Interval	25-35	90-130	90-100
Royal Blue (?) bed	0-6	–	–
Interval	50-70	–	–
Castlegate "A" bed	6-15	2-8	,2-14
Interval	160-200	60-120	90-125
Gordon bed	–	0-6	1-6
Interval	–	90-120	100
Hiawatha bed	0-3	3-10	upper split 2-6
Star Point Sandstone			

Wright Canyon, (2) just north of center near the Blue Blaze mine and (3) a generalization of west Spring Canyon, a part of the Book Cliffs field just east of the northeast map area.

The Hiawatha bed lies just above the base of the Blackhawk Formation on top of the Star Point Sandstone. Thirty-three sections have been measured along the outcrop (figure 50). In and around Bob Wright Canyon it is undeveloped; northward to Trail Canyon it is less than 4 feet thick. It thickens east of Trail Canyon to Coal Canyon averaging 6.9 feet and ranging from 5 to 10 feet. Thereafter it thins slightly ranging between 3.1 and 5.7 feet, averaging 4.3 feet. The Hiawatha is undeveloped in the Pleasant Valley area to the west. Most Hiawatha exposures are without splits but the thickest observed is ½ foot.

When present the Gordon bed overlies the Hiawatha about 100 feet. The four available sections are near Coal Canyon. Thicknesses more than 6 feet are badly split by shale or bone coal. Along the east margin of the map is a lenticular bed of coal 7 feet thick with a minor split near the top, 45 feet above the Hiawatha. According to Spieker (1931, p. 81-82) the Gordon bed may underlie Beaver Creek and may correlate with the Union Pacific bed in Pleasant Valley to the west. In sec. 30, T. 13 S., R. 8 E. it is reported to be 7½ feet thick and not broken by partings. The coal bed disappears in the vicinity of Bob Wright Canyon.

Approximately 200 feet above the Hiawatha atop the Aberdeen Sandstone Member of the Blackhawk is the Castlegate "A" seam. Twenty-seven sections attest to its condition. It is consistently present along outcrop but thins along the east margin of the map. The Castlegate "A" bed is believed well developed in Pleasant Valley and is probably continuous into the Gordon Creek area. The bed is probably too thin east of Beaver Creek to mine profitably. Thickness ranges to 10 feet but averages 5.6 feet excluding the area east of Coal Canyon.

Twenty measured sections of beds above the Castlegate "A" are more lenticular and more difficult to correlate. Some are grouped into the Bob Wright coal zone. The zone, well developed from Bob Wright Canyon to Trail Canyon, normally consists of three beds in intervals 45, 75 and 100 feet above the Castlegate "A". The lower two are thicker, the upper is usually less than 4 feet thick. Other upper beds range to 6 feet thick but little is known about their continuity and most are thin.

Subsurface Information

No useful drill-hole information is available but some underground data are available from experience in mines. In the Gordon Creek area two seams have been mined, the Hiawatha and the Castlegate "A". Near Bob Wright Canyon, mining in the Castlegate "A" bed and in the main Bob Wright seam has taken place. In the Gordon Creek area the Hiawatha has averaged 6 to 8 feet in all mines operating within it. The Castlegate "A" has averaged between 6 and 16 feet in the Gordon Creek and Bob Wright areas. Coal in the middle seam of the Bob Wright zone has averaged 6 to 10 feet.

Spieker (1931) mapped structural contours on top of the Star Point Sandstone or the Hiawatha coal. These are reproduced in part with cover lines indicating depth to the Hiawatha on figure 7.

About 42 percent of the coal are at depths less than 1,000 feet. These lands are located in a 1- to 3-mile strip parallel to the cliff front. Approximately 56 percent are under intermediate cover, 1,000 to 2,000 feet, and a few patches, 2 percent, located in the northeast part of the quadrangle are deeper.

Quality of Coal

About 48 analyses are available for the Scofield NE quadrangle (table 5), all but seven from the Hiawatha bed. No doubt samples collected from the Clear Creek mines with portals in Scofield NW are reported there. Exact locality within the mine is unknown. A summary is given in table 57.

Table 57. Average coal analyses, Scofield NE quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
HIAWATHA BED			
Moisture	40	7.2	3.2-12.6
Volatile matter	35	41.3	37.3-44.4
Fixed carbon	35	44.6	39.7-49.1
Ash	38	6.5	2.9-11.5
Sulfur	28	0.56	0.4- 0.87
Btu/lb	38	12,114	10,550-13,078
CASTLEGATE "A" BED			
Moisture	7	5.4	4.1 - 6.1
Volatile matter	5	43.7	42.2 -44.2
Fixed carbon	5	44.9	43.9 -45.9
Ash	7	5.9	4.7 - 7.0
Sulfur	7	0.45	0.39- 0.60
Btu/lb	5	12,686	12,330-12,840

Apparently the coal is low sulfur and high-volatile B bituminous in both seams. Samples have been run to determine kinds of sulfur by the U. S. Bureau of Mines; from the Clear Creek No. 3 located near the head of Bob Wright Canyon a sample contained 0.47 percent total sulfur–0.01 percent sulfate, 0.14 percent pyritic sulfur and 0.32 percent organic sulfur. The following is a breakdown of sulfur from various mines with portals in the Scofield NE quadrangle (table 58).

Table 58. Sulfur-type determinations, Scofield NE quadrangle (Walker and Hartner, 1966).

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
McGowan	Castlegate "A"	0.39	0.01	0.20	0.18
McGowan	Castlegate "A"	0.49	0.01	0.10	0.38
National	Hiawatha	0.49	0.02	0.27	0.20
Sweet	Hiawatha	0.52	0.01	0.14	0.37
Sweet	Hiawatha	0.46	0.03	0.12	0.31

Spieker (1931, p. 107) reported that the main Bob Wright seam is a highly resinous coal.

Gomez, Landers and Boyd (1967, p. 10) calculated carbonization product yields for several of the mines (table 59; end carbonization temperature 500° C).

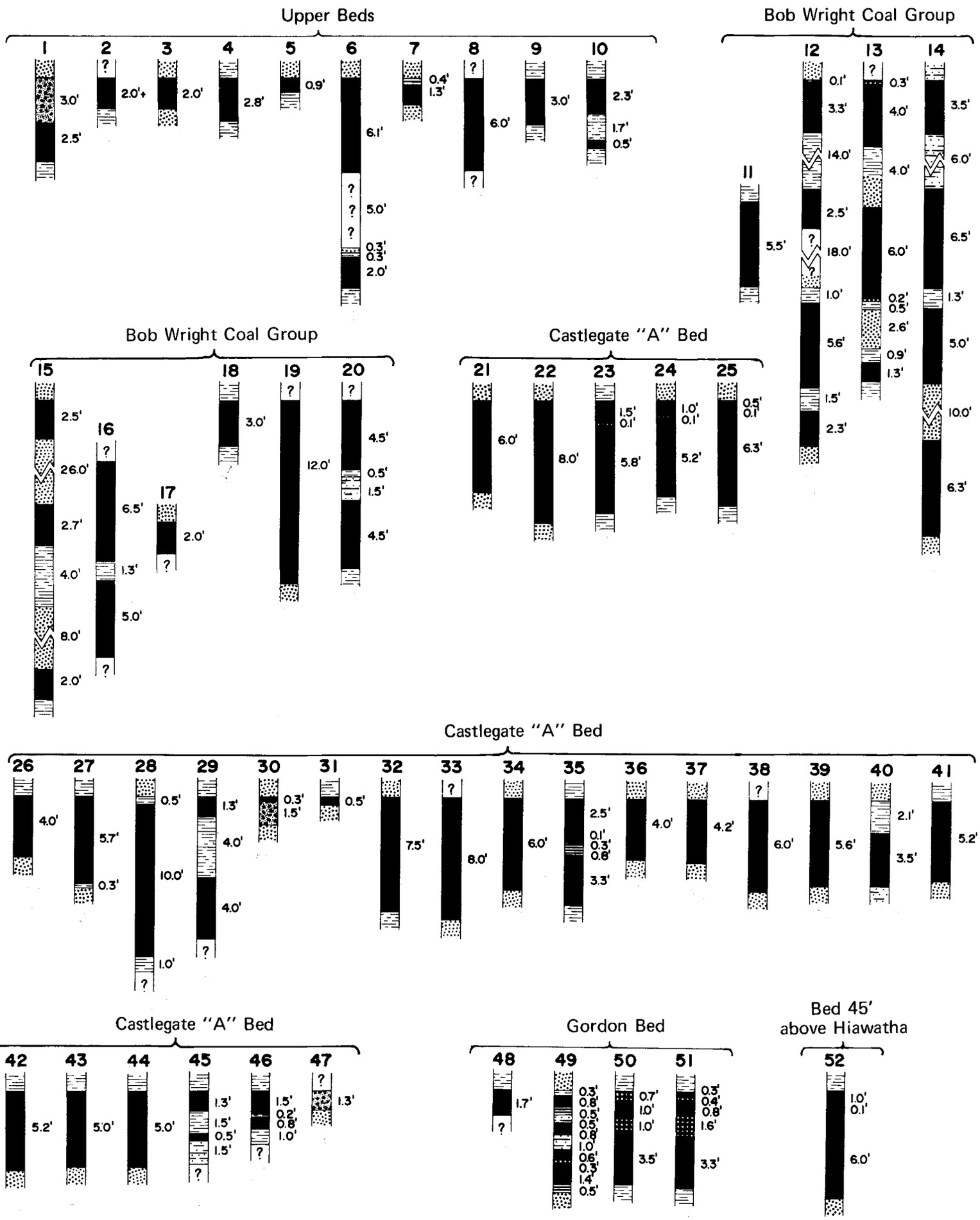


Figure 50. Coal sections of Scofield NE quadrangle (vertical scale: 1 inch = 8 feet).

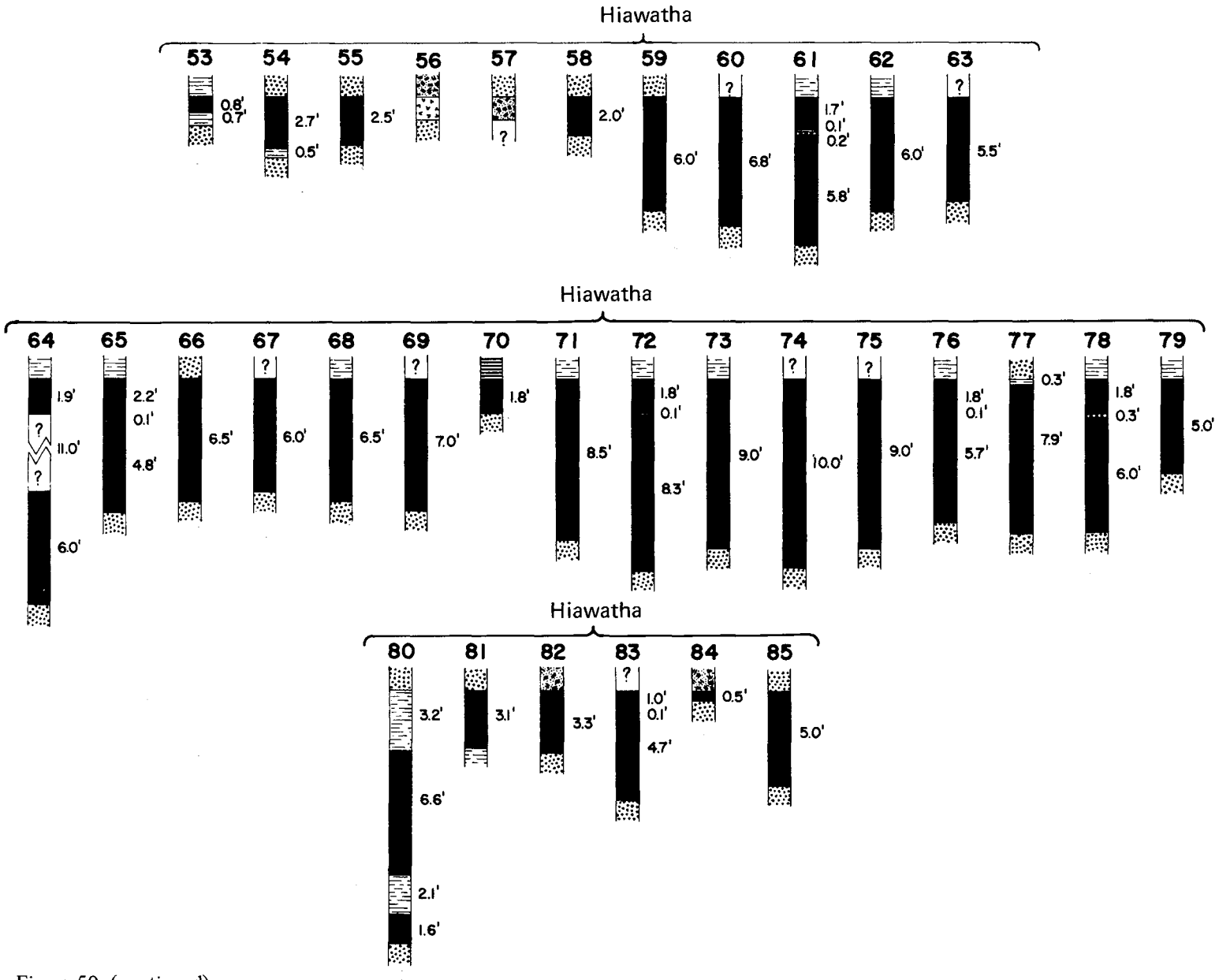


Figure 50. (continued)

Table 59. Carbonization product yields, Scofield NE quadrangle.

Mine	Carbonization yields, wt. percent of maf coal				Gas volume scf/lb maf coal	Heating value of gas Btu/scf
	Char	Water of decomposition	Tar plus light oil	Gas		
Blue Blaze	68.5	5.1	20.8	4.5	0:896	813
National	69.7	5.4	18.7	5.3	0.968	777
Sweet	69.2	6.5	16.9	6.5	1.100	717

Mines and Development

In the Gordon Creek area mining operations commenced in 1925 and continued to the middle 1940's. In 1967 Swisher Coal Co. reactivated the area; it is the only company operating at present (1970). Mining at the head of Bob Wright Canyon has taken place but the entry ways are at Clear Creek through the Pleasant Valley fault zone; this, the Clear Creek mine of the Utah Fuel and Independent Coal and Coke companies (North American), opened in 1899 and remained active until 1967 when it was shut down. Production is included in the Scofield NW quadrangle report. Other mining that progressed into the quadrangle from the east-lying Spring Canyon area of the Book Cliffs coal field is discussed in the Book Cliffs coal field report in the Castlegate–Kyune quadrangle.

At least nine mines have been opened in the Gordon Creek area; they are listed in table 60.

Table 60. Mines and their locations, Scofield NE quadrangle.

Mine	Location	Remarks
Blue Blaze mines (McGowan, Consumers)	SE.SE.NE.SW.17-13S-8E 4,393,330m.N. 495,540m.E.	1928-1952
Davis mine	≃ sec. 17,18,20,21, or 28 T. 13 S., R. 8 E.	Active 1946; Exact location unknown
Gordon Creek mines	NW.NW.SW.SE.18-13S-8E 4,393,250m.N. 494,250m.E.	Active 1927-30, 1941-1952, 1967-present
K. L. Storrs mine	NW.NE.NE.21-13S-8E ≃4,392,830m.N. 497,600m.E.	Active 1943
National mine	17-13S-8E ≃4,393,500m.N. 495,250m.E.	Active 1928-1938, 1950-1954
New Ewing mine	7, 18-13S-8E ≃4,394,590m.N. 494,270m.E.	No data
Success mine (Sheya)	NE.NE.20-13S-8E ≃4,392,700m.N. 496,100m.E.	Active 1945-1950
Sweet mine (Hudson)	C.E.SW.17-13S-8E ≃4,393,380m.N. 495,290m.E.	Active 1925-1940, interm. to 1952
Western mine	Unknown	Active 1948-1950

The following mines produced more than 500,000 tons: the Blue Blaze, Gordon Creek, National and Sweet mines. The Blue

Blaze is the largest producer with about 2.5 million tons followed by the Sweet mine with about 1.5 million tons. Total production from the Gordon Creek area ranges between 5.3 and 5.5 million.

Reserves

Total reserves for the area were calculated by Spieker (1931, p. 204) and modified to fit the quadrangle (table 61).

Table 61. Original reserves in the Scofield NE quadrangle (in short tons; beds 30 or more inches thick).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.12S. R.7E.	2,627	13	61,471,800	All beds
T.13S. R.7E.	8,528	16	245,606,400	All beds
T.14S. R.7E.	264	6.9	3,278,900	Castlegate "A"
	200	9.0	3,240,000	Bob Wright
T.12S. R.8E.	3,335	17	102,051,000	All beds
T.13S R.8E.	8,827	7.3	118,000,900	Hiawatha
	240	5	2,000,000	Bed 45 ft. above
	320	4	2,000,000	Gordon
	7,619	5.3	73,000,000	Castlegate "A"
		Total coal	610,649,000	

Most of the mining has taken place between the east edge of the North Gordon fault zone and the line between R. 7 and 8 E. and between the outcrops on the south and the first tier of sections in T. 13 S., R. 8 E. to the north. The area includes 4,245 acres, which, according to Spieker's criteria, involve 96 million tons of coal in the Hiawatha and Castlegate "A" seams. The most important bed has been the Hiawatha which by the same criteria should contain about 56 million tons. Mining experience has indicated only a 35 to 40 percent recoverability or 4,913 tons per acre. The problems of the field are illustrated by the statistics in table 62.

If all beds were mined–which is unlikely because of proximity to more important seams–the 609 million tons of Spieker's reserve with 35 percent recoverability would net 213.1 million tons. Not all areas are as complexly faulted as the vicinity of Gordon Creek and recoverability could conceivably be higher. Minability of other seams in the Gordon Creek area is questionable as mining of the Hiawatha may have made some inaccessible.

No work has differentiated the reserve into classes. Approximations from examination of the data in map form disclose about 363.4 million tons within 1½ miles of a known reference point and 245.4 million inferred. At least 15.7 million tons of total reserve can be eliminated because of past mining.

PRINCIPAL WORK

Most of the research presented here is from U. S. Geological Survey Bull. 819 published in 1931 by E. M. Spieker. Data from unpublished studies undertaken for this publication or donated by the Bureau of Mines, the local power company and consultants update the report.

Table 62. Recoverable reserves, Gordon Creek area, Scofield NE quadrangle.

Location	Mined		Measured and Indicated		Inferred		Nonminable[1]		Recoverable Minable Tons
	Acres	Tons	Acres	Tons	Acres	Tons	Acres	Tons	
7-13S-8E	270	1,326,510	370	1,817,810	–	–	–	–	1,817,810
8-13S-8E	20	98,260	–	–	620	3,046,060	–	–	3,046,060
9-13S-8E	–	–	–	–	640	3,144,320	–	–	3,144,320
16-13S-8E	–	–	–	–	400	1,965,200	200	982,600	1,965,200
17-13S-8E	440	2,161,720	–	–	–	–	200	982,600	–
18-13S-8E	320	1,572,160	320	1,572,160	–	–	–	–	1,572,160
19-13S-8E	–	–	–	–	500	2,456,500	–	–	2,456,500
20-13S-8E	65	319,345	–	–	–	–	–	–	–
21-13S-8E	–	–	–	–	200	982,600	–	–	982,600
Totals	1,115	5,477,995	690	3,389,970	2,360	11,594,680	400	1,965,200	14,984,650

[1] Lost by burned outcrop or by complex faulting.

SCOFIELD NW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The quadrangle is located at the north end of the Wasatch Plateau coal field (figures 22 and 51). Scofield and Clear Creek, originally coal towns, have converted to an area of summer cabins. To the north a large reservoir (Scofield) and recreational developments have been built. The mining area is one of the oldest in the Wasatch Plateau field and the most consistent. The large Clear Creek mines opened in 1899 and were finally closed in 1967. Mining started on the quadrangle in 1878 and in 1970 one mine remained active.

The area is mountainous and rugged. Elevations range from 7,500 feet above sea level at the north end of Pleasant Valley Creek to more than 10,000 feet on the ridge separating Pleasant Valley from Huntington Canyon. To the east and north all drainages are tributary to the north-flowing Pleasant Valley Creek and in the southwest corner they are tributary to the south-flowing Huntington Creek.

Three counties join on the quadrangle: Carbon to the east and Sanpete to the west with the panhandle of Emery County projecting between them in the south part of the map. A railroad spur extends to Clear Creek down Pleasant Valley from the main line of the D & RGW Railroad 20 miles to the north at Colton. Utah Highway 96 to Clear Creek is the only paved road. Gravelled Utah Highway 31 runs along Huntington Canyon from Fairview in Sanpete County to Huntington in Emery County. Dirt and gravel roads extend to the more accessible side canyons and a few cross the ridge to join Pleasant Valley with Huntington Canyon. No good roads extend directly eastward to Price from Pleasant Valley.

STRATIGRAPHY

The oldest formation exposed in and around Pleasant Valley is the Star Point Sandstone. The Star Point is considerably thicker here than in other parts of the field; on the west side of Pleasant Valley between Clear Creek and Scofield at least 1,000 feet of sandstone have been measured beneath the horizon of the Hiawatha coal bed (undeveloped in this quadrangle). The Mancos Shale is not exposed at the surface beneath the sandstone. The yellow-gray sandstone beds are mostly massive but occasionally broken by shale partings or partings of shaley sandstone. The amount of shale in the unit is also considerably less than to the east.

The coal-bearing Blackhawk Formation overlies the Star Point and makes up the surface of most of the quadrangle; the west and north edges of the map contain the younger units. Good exposures are lacking because of the deeper soil development. Even the more resistant sandstone beds often are covered. The Blackhawk consists of alternating sandstone, shale and coal. Several coal beds are developed including the U. P. bed, Castlegate "A" bed, Bob Wright coal zone and the Haley bed. The better coal seams are all located within 380 feet of the base of the 1,500-foot unit. Spieker (1931) indicates the Blackhawk to vary between 700 and 1,000 feet in the field, but according to his structural contours, in the west map area it is much thicker.

The Castlegate Sandstone and Price River Formation appear as exposed remnants in the north and west map area. They are not separated to the west probably because they are undifferentiated in this locality; there the Castlegate contains distinctive beds of exceedingly coarse grit, intermediate between sandstone and conglomerate. Both units probably total 750 feet in these exposures. Incomplete exposures of the North Horn Formation top the column. Important valleys are filled with Quaternary alluvium.

STRUCTURE

The dominant structural feature of the Scofield NW quadrangle is the Pleasant Valley fault zone. The zone is concentrated in the east half of the map area and contains normal faults of considerable displacement. The importance of faults has been well illustrated by Taff (1906, p. 343):

> The principal fault of the Pleasant Valley group is the westernmost one. It follows the west side of the valley in an almost due south course, crossing the foothills and spurs near the stream and passing through the west sides of Scofield and Clear Creek. North of Scofield it lies in a swampy valley and is not traceable. Whether there is a series of fractures or a single fault is not determinable. . .Near the head of the valley opposite Clear Creek the throw is nearly 1,000 feet. . .

Spieker (1931, p. 90) further states:

> The Pleasant Valley area contains the most complex and intricate faults of the Wasatch Plateau field and affords a good illustration of the effects of faults on mining, because all the mines of the area except one have passed through faulted zones, and most of the mining problems introduced by faults have been met and solved. Most of the faults crossed by the Pleasant Valley mines are of small displacements, and the only difficulty is that of grading entries between displaced blocks. Some of the mines, however, have encountered faults whose displacements are large enough to necessitate either making separate mining units of the faulted blocks or crossing them by means of rock tunnels and slopes to the coal beyond. . .The central down-dropped block of the fault zone, which constitutes the valley north of Scofield is of doubtful value for mining, both because the coal is very deep beneath the surface and because the rocks in this graben are broken by minor faults. . .

Two elongate faults parallel the ridge on the east side of Pleasant Valley. Their displacement is unknown; several parallelling subsidiary faults possibly occur between them.

The strata enclose a north-south trending anticline with an ill defined axis and an east side faulted by the Pleasant Valley zone. East of Pleasant Valley the beds are nearly horizontal dipping less than 2 degrees. To the west the beds dip 3 to 4 degrees northwesterly down the gentle limb of the anticline.

PROPERTY CONTROL

The National Forest Service (58.3 percent) and private interests (41.7 percent) own the lands of the Scofield NW quadrangle. The 18.1 percent that are not coal land fall mainly on private property so that the coal is nearly equally divided. Forest Service lands are to the west.

More than 40 percent of the land are held or maintained as coal land:

	Acres	Type
North American Coal	3,355	Fee
	550	Lease
Colombine Coal	680	Fee
Union Pacific Coal	1,000?	Fee
McAlpine mine	?	Fee
Monay mine	?	Fee
McKinnon	6,710	Lease
Unassigned	4,040	Fee

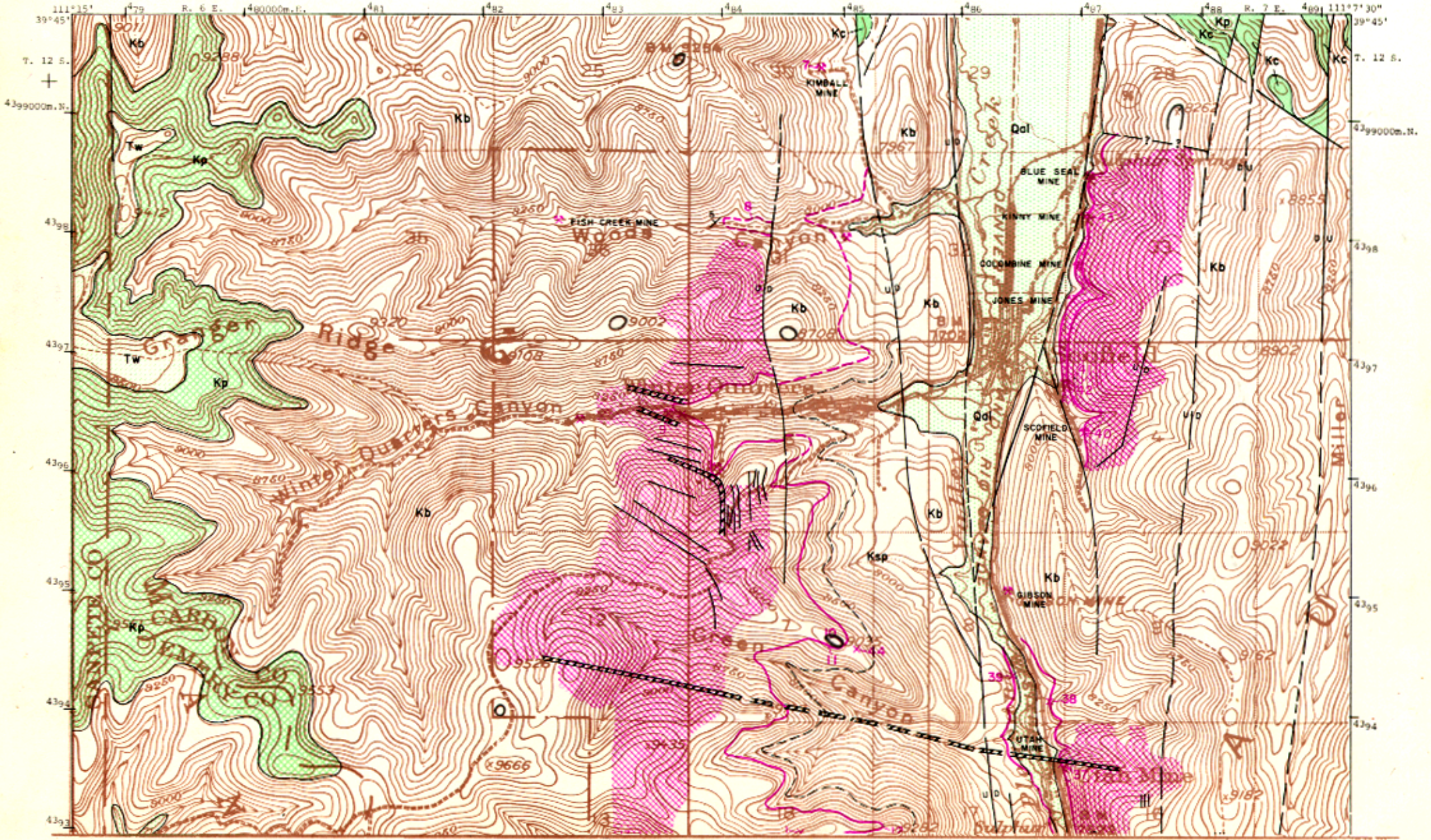
Locations of some of these holdings are shown on figure 17.

COAL

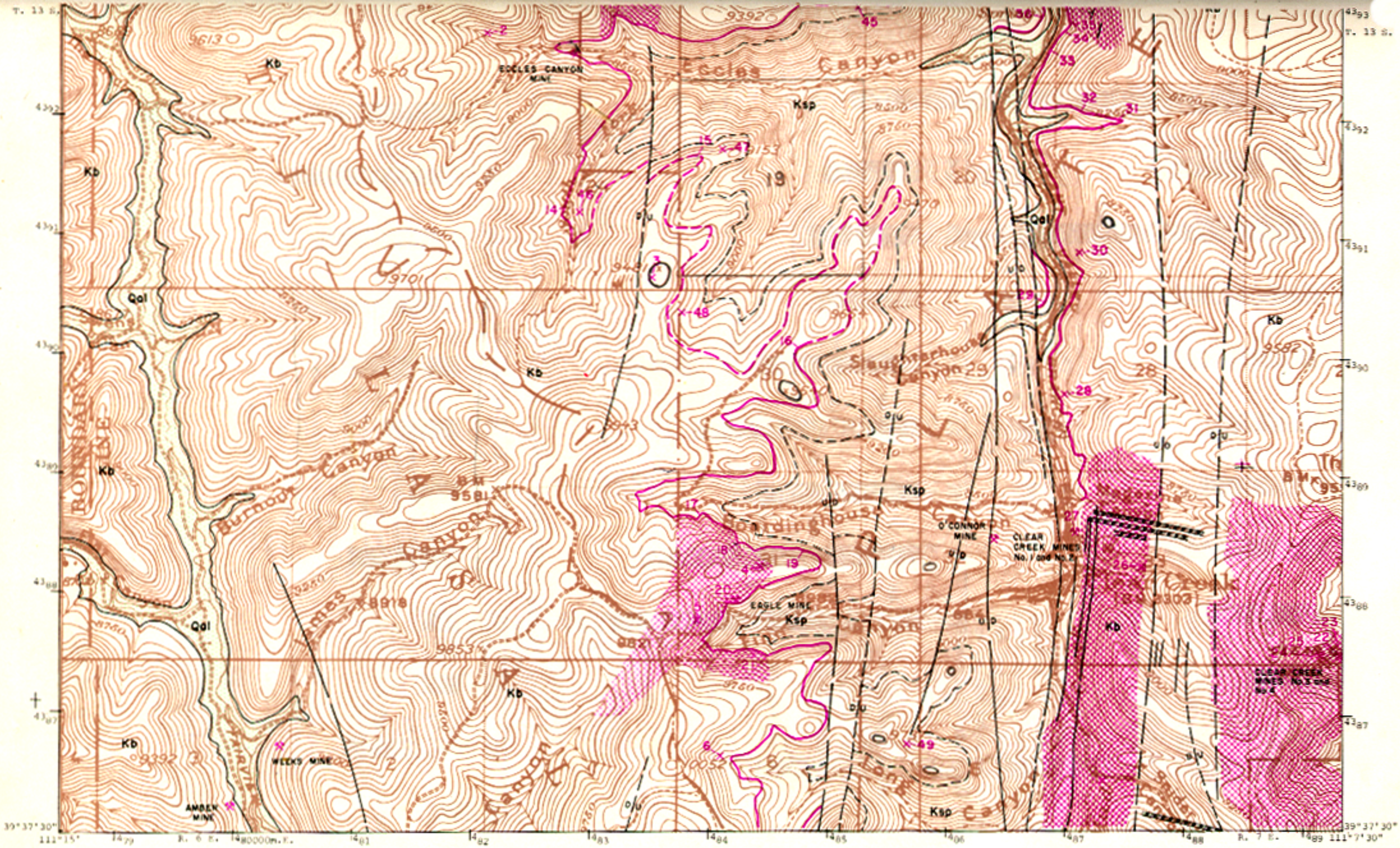
Surface Information

At least four beds or zones are recognized in the Pleasant Valley area and in Upper Huntington Canyon (figure 52). Approximate positions of these beds are given as follows.

SCOFIELD, UT. N. W.



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972



TOPOGRAPHY BY
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology and coal data by
E. M. Spieker, 1931, USGS

Figure 51. Coal and geology map, Scofield NW quadrangle (explanation pages 136-137).

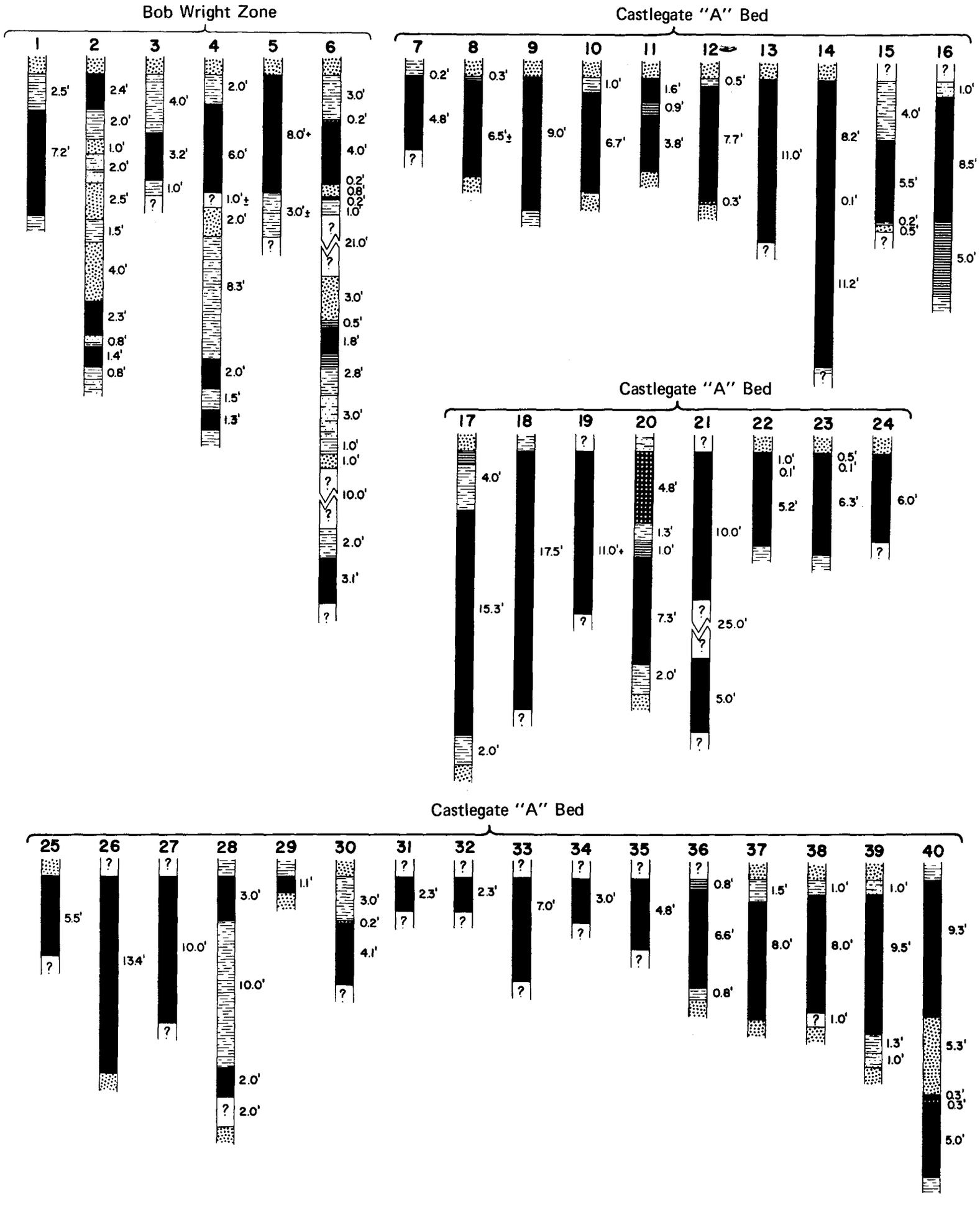


Figure 52. Coal sections of Scofield NW quadrangle (vertical scale: 1 inch = 8 feet).

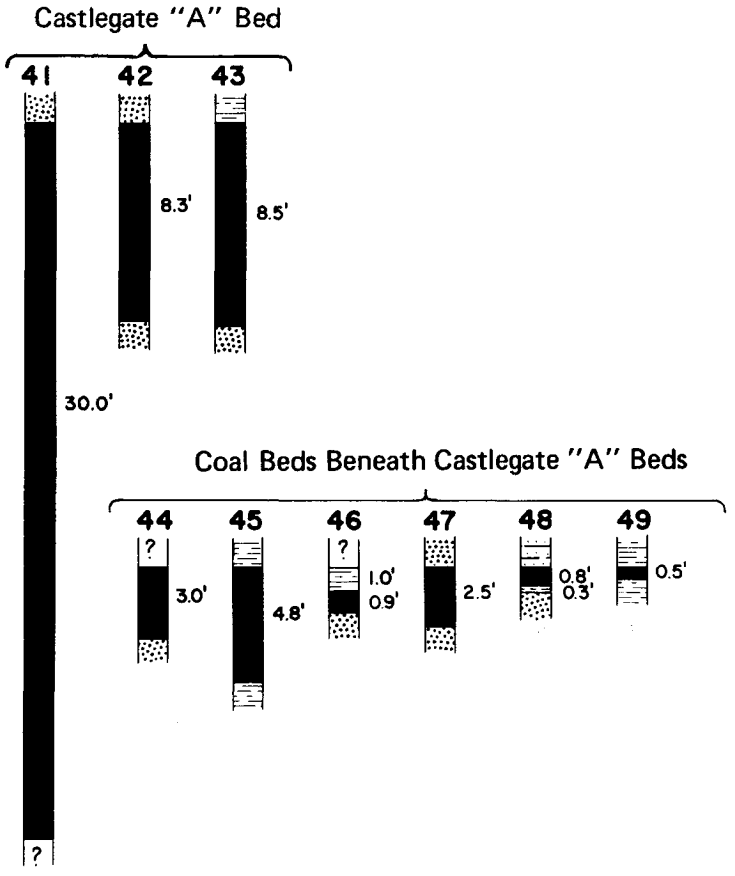


Figure 52. (continued)

Bed or zone	Pleasant Valley (feet)	Upper Huntington Canyon (feet)
Upper beds		0-7
Interval		105
Bob Wright	5-8	0-5
Interval	100-200	65
Candland	–	0-14
Interval	–	40-75
Castlegate "A"	6-19	3-11
Interval (local beds)	70-80	200?
Union Pacific bed (Gordon?)	0-30	–
Interval	1	–
Star Point Sandstone		

The lowest valuable bed is the Union Pacific bed which may be the same as the Gordon bed. According to Spieker (1931, p. 87):

> The U. P. coal bed. . .crops out in a relatively short stretch along the east side of Pleasant Valley near Scofield. For many years it has been worked at the Union Pacific mine, east of Scofield, and in parts of that mine it consists of 30 feet of clear coal. This unusual thickness, however, seems to be local, as the entire bed disappears west of Scofield, and north of the Union Pacific mine it thins materially and becomes split by partings of sandstone and shale. Its extent east of Pleasant Valley is not known, but it may be the same as the Gordon bed of North Gordon area, and it may underlie part of the land between Pleasant Valley and North Fork of Gordon Creek. South of Scofield little is known of the bed; it may be present underground at the Utah mine, but it seems definitely absent near Clear Creek.

Local beds between the U. P. bed and the Castlegate "A" near the Union Pacific mine and elsewhere range to 5 feet thick. Measured sections for the U. P. bed are not available but six sections were taken from beds beneath the Castlegate "A" located mostly on the west side of Pleasant Valley.

The Castlegate "A" is the most valuable bed of the area. Except locally it is continuous from 6 to 19 feet. North of Woods Canyon it thins out on the west side of Pleasant Valley and from Clear Creek northward for 2½ miles on the east side. Most of the large mines of the area have operated on this seam. In Upper Huntington Canyon about 1 mile south of the south boundary of the quadrangle it is 11 feet thick. Thirty-seven sections have been measured for the Castlegate "A" (figure 52).

The Candland bed lies in Upper Huntington Canyon 40 to 70 feet above the Castlegate "A"; it is unknown at Pleasant Valley. It thins north of the Amber mine and may not occur on this quadrangle. The next group of beds belong to the Bob Wright zone. Six sections measured on the west side of Pleasant Valley range to 7.2 feet thick. Up to three beds are present. They are also present on the east side of Huntington Canyon south of the map area, but are thinner. Continuity of the beds is unknown.

Higher beds have been discovered; no sections are available but they are reportedly thin.

Subsurface Information

No drill-hole data are available for the quadrangle and about one-third of the area, mostly on the west part of the map, falls more than 1½ miles from a control point. Most of the coal lies with less than 1,000 feet of cover (88.2 percent). The remaining area on the ridges in the northwest corner of the quadrangle is between 1,000 and 2,000 feet below the surface.

Quality of Coal

Ninety-three analyses are available for the quadrangle (table 5) and all but five test the Castlegate "A". The five are from the Clear Creek No. 4 mine in the main bed of the Bob Wright zone. Table 63 shows average analyses for the quadrangle.

Table 63. Average coal analyses, Scofield NW quadrangle.

	No. Analyses	Percent as-received	
		Average	Range
CASTLEGATE "A" BED			
Moisture	88	7.54	3.6-14.5
Volatile matter	81	41.11	35.3-54.3
Fixed carbon	81	44.91	28.3-53.5
Ash	86	6.24	3.8-13.5
Sulfur	65	0.61	0.4- 1.06
Btu/lb	76	12,042	10,250-13,650
BOB WRIGHT MAIN BED			
Moisture	5	6.15	2.8- 8.2
Volatile matter	5	44.90	42.0-46.1
Fixed carbon	5	45.00	44.1-46.9
Ash	5	3.94	3.1- 5.0
Sulfur	5	0.52	0.5- 0.6
Btu/lb	5	12,900	12,680-13,100

U. S. Bureau of Mines sulfur determinations reveal the following (table 64):

Table 64. Sulfur-type determinations of coal, Scofield NW quadrangle (Walker and Hartner, 1966).

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Clear Creek No. 1	Castlegate "A"	0.49	0.02	0.09	0.38
Clear Creek No. 1	Castlegate "A"	0.63	0.00	0.07	0.56
Clear Creek No. 3	Castlegate "A"	0.47	0.01	0.14	0.32
Eccles Canyon	Castlegate "A"	0.59	0.02	0.10	0.47

Spieker (1931, p. 107) also reports that the main Bob Wright bed is highly resinous.

Gomez, Landers and Boyd (1967, p. 10) calculated carbonization product yields for several of the mines (table 65; end carbonization temperature 500°C).

Table 65. Carbonization product yields, Scofield NW quadrangle.

Mine	Carbonization yields, wt. percent of maf coal: Char	Water of decomposition	Tar plus light oil	Gas	Gas volume scf/lb maf coal	Heating value of gas Btu/scf
Clear Creek No. 3	69.3	5.8	18.5	5.6	1.004	761
Eccles Canyon	69.3	5.6	18.3	5.6	1.001	764
Scofield	70.5	6.2	15.7	6.8	1.107	701
Standard-Colombine	70.5	5.5	18.0	5.6	.989	762

In a report of the Utah Conservation and Research Foundation (1939, p. 76) low-temperature carbonization of coal from the Clear Creek No. 3 mine was tested and the results are repeated on table 66.

Mines and Development

The list of mines (table 67) opened on the Scofield NW quadrangle was gleaned from several sources and locations were derived without field checking. Many older mines were incorporated in the later and larger mines. New owners often changed names and confusion resulted; names in parentheses indicate name changes.

Little is known about production history for the Amber and Blue Seal mines. Spieker (1931, p. 97) reported on the Clear Creek mines, one of the more important group of mines in the Pleasant Valley area:

> Nos. 1 and 2 mines are on the Castlegate "A" coal bed and are separated by a fault. No. 2 extends south of the main opening, and No. 1, the south end of which is east of No. 2, extends both north and south of the main opening. . .Mine No. 1 is limited on the east by a fault zone through which a rock tunnel has been driven to the coal on the east side of the ridge, and east of the fault zone two mines have been established, one on the Castlegate "A" bed and the other on the main bed of the Bob Wright group.

The mines started producing in 1899 and continued operations for 68 years when the mines were abandoned. Coal was mined in seams ranging from 7 to 14 feet thick producing 14,196,000 tons.

Table 67. Mines and their locations, Scofield NW quadrangle.

Mine	Location	Remarks
Amber mine	SE.SE.NW.3-14S-6E ≃4,386,160m.N. 480,050m.E.	Active 1877
Black Oaks mine	?	1898
Blue Seal mine (Utah-Wyoming)	C.NW.NW.33-12S-7E 4,398,440m.N. 487,060m.E.	Active intermittently 1921-1940's
Clear Creek mines (Pleasant Valley Coal Co., Utah Fuel Co., Independent Coal and Coke, North American Coal Corp.)		1899-1967
No. 1	NW.SE.SW.NW.33-13S-7E ≃4,388,470m.N. 487,050m.E.	West side of faults
No. 2	NW.SE.SW.NW.33-13S-7E 4,388,470m.N. 487,050m.E.	West side of faults
No. 3	SW.SW.SW.SW.SE.34-13S-7E 4,387,450m.N. 489,250m.E.	East side of faults
No. 4	SW.SE.SE.SE.SW.34-13S-7E 4,387,450m.N. 489,250m.E.	In Bob Wright bed
Colombine mine (Standard-Colombine, McAlpine, Olsen, Carbon, Fuel, Spring Creek, Rio Grande Colombo)	NW.NW.NW.SW.33-12S-7E 4,397,680m.N. 486,930m.E.	
Eagle mine (Jones)	SW.31-13S-7E ≃4,387,900m.N. 484,100m.E.	Intermittently Active 1923-1941
Eccles Canyon mine (Crandall)	SE.SW.13-13S-6E 4,392,450m.N. 482,630m.E.	Active intermittently 1899-1952
Fish Creek mine (Wood Canyon)	31-12S-7E(?) ≃4,398,090m.N. 484,800m.E.	Active 1908-1910
Gibson mine	NE.NW.SW.NE.8-13S-7E 4,394,950m.N. 486,340m.E.	Opened in 1922; now abandoned
Jones mine	NW.SW.SW.33-12S-7E 4,397,410m.N. 486,880m.E.	Abandoned

(continued on page 223)

Table 66. Carbonization product yields, Clear Creek No. 3 mine, Scofield NW quadrangle.

		Vertical Retort								Rotary Retort			
		External Heating						Internal Heating		External Heating			
Carbonizing Temperature °C (Products Weight Percent)		450	550	650	650	650	750	850	550	650	450	550	650	650
	Char	75.9	64.3	61.0	60.6	66.5	61.1	58.3	69.8	63.4	65.7	63.5	60.8	59.9
	Gas	1.4	5.7	9.3	9.7	7.2	11.5	12.2	2.2	4.9	4.8	–	7.9	4.6
	Tar	6.9	11.1	10.8	11.6	10.1	10.8	11.3	8.8	11.0	12.4	12.7	12.2	13.0
	Light oil	0.3	0.5	0.6	0.4	0.5	0.5	0.5	0.4	0.4	0.4	–	0.2	0.2
	CO_2	1.0	1.5	1.1	1.8	1.9	1.3	1.8	1.4	1.4	1.1	–	1.4	1.1
	Tar liquors	10.1	12.8	14.5	14.6	13.3	14.8	14.4	–	–	11.7	12.3	16.2	15.8
	Total	95.6	95.9	97.3	98.7	99.5	100.0	98.5	–	–	96.1	–	98.7	94.6
	Gas, cu ft	458	2,300	4,488	3,830	3,505	6,076	6,751	823	2,183	1,631	2,380	3,740	3,808
Yield/ton of coal	Tar, gallons	16.5	26.6	25.6	27.9	24.3	25.8	27.0	20.6	25.7	29.9	30.0	29.4	31.3
	Light oil, gallons	0.9	1.7	2.0	1.3	1.6	1.7	1.5	1.3	1.4	1.1	–	0.7	0.7
	$(NH_4)_2SO_4$ pounds total	1.7	5.6	13.3	7.7	9.1	13.5	10.0	7.9	12.8	3.3	–	7.2	9.7

Table 67. (continued)

Mine	Location	Remarks
Kimball mine	NW.NW.NW.SE.30-12S-7E 4,399,330m.N. 484,700m.E.	1885-1900
Kinney mine (Monay)	NE.SW.SW.NW.33-12S-7E 4,398,090m.N. 487,050m.E.	1920-1926 1946-1956
Lewellyn	In Mud Creek	1897-1898
O'Conner (Black Diamond)	SW.SW.NE.32-13S-7E 4,388,440m.N. 486,270m.E.	1956-1967
Scofield mine (Pleasant Valley, Union Pacific)	SW.SW.NW.NW.4-13S-7E 4,369,720m.N. 486,860m.E.	Intermittently active 1884-1936
Utah mine (Utah Central, Mud Creek)	SE.SE.NE.NE.17-13S-7E 4,393,520m.N. 486,820m.E.	Oldest mine in area; main activity 1910-1925
Utah Collieries (Smith and Nelson)	?	1909-1910
Weeks mine	SE.NE.3-13S-6E ≃4,386,670m.N. 480,250m.E.	1877
Williams mine	4 miles up Mud Creek	1897
Winter Quarters mines		1878-1895
No. 1	1-13S-6E ≃4,396,400m.N. 482,800m.E.	
No. 2	SE.NW.SW.6-13S-7E 4,396,000m.N. 483,960m.E.	1896-1940's
No. 3	6-13S-7E	
No. 4	C.SE.NE.1-13S-6E 4,396,440m.N. 183,550m.E.	
No. 5	1-13S-6E	
(Smith, Cox and Smith)		
No. 6	SW.SW.NE.31-12S-7E ≃4,397,920m.N. 486,030m.E.	

The Colombine mine began operations in 1960 and is presently active (1970); it may be the same as the older McAlpine mine or Olsen mine. The McAlpine operated from 1946 to 1960. Sixty-nine thousand tons of production are assigned to the Colombine mine.

The Eagle mine was probably active intermittently between 1923 and 1941. From four openings in the Castlegate "A" seam, it reportedly produced 116,000 tons of coal. It was later connected with the O'Conner mine.

Little is known about the Eccles Canyon mine or the Fish Creek mine supposedly located in Woods Canyon; Fish Creek mine may lie farther north. Production figures are incomplete but estimated to be small.

Spieker mentioned the Gibson mine opened in 1922 but little else is known about it. The Jones mine near the Colombine probably operated on the U. P. bed. The old Kimball mine on the west side of the valley was a wagon mine that yielded considerable coal (Spieker, 1931, p. 95); it had three openings. Most of Spieker's field work occurred in 1923.

The Kinney mine is located between the Blue Seal and Colombine mines; it operated between 1920 to 1926 producing 687,000 tons of coal probably on the Castlegate "A" bed. The mine was probably reopened as the Monay mine in 1946 and produced an additional 63,000 tons.

Production figures from the O'Conner mine (1956 to 1967) are incorporated with the Clear Creek mines. The Scofield mine, better known as the Union Pacific mine, was one of the more successful mines of Pleasant Valley area. It was intermittently active from 1884 to 1936 in coal to 30 feet thick. A lower mine operated on the thick U. P. bed and an upper mine probably on the Castlegate "A". Total production is estimated just short of 2 million tons.

The Utah mine is located between the Union Pacific and the Clear Creek mines on the east side of the valley. Spieker (1931, p. 96) calls it the oldest mine in the district but the main period of activity is believed to have been between 1910 and 1925. It operated on the Castlegate "A" and produced 713,800 tons.

One of the earliest large groups of mines is the Winter Quarters mines active from 1878 into the 1940's. Numerous faults and dikes were encountered. One igneous dike in a mine is more than 100 feet wide. Many of the faults cannot be detected on the surface. The mine has at least six openings; total production is estimated to have been 10.8 million tons.

Little is known about the remaining mines, most of which were opened prior to 1900. Their small production should not appreciably affect the total amount for the quadrangle. Total production from portals opening on the quadrangle is believed between 27.0 and 29.6 million tons.

Reserves

The reserves of the area are calculated by Spieker (1931, p. 204) and modified to fit the quadrangle (table 68).

Table 68. Original reserves in the Scofield NW quadrangle (in short tons; beds 30 or more inches thick).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.12S. R.6E.	3,482	5	31,388,000	Castlegate "A"
T.12S. R.7E.	2,784	13	65,145,600	All beds
T.13S. R.6E.	11,621	9	188,000,000	Castlegate "A"
	11,621	5	105,000,000	Bob Wright
T.13S. R.7E.	1,451	9	24,000,000	Castlegate "A"
	1,900	16	54,720,000	All beds east of fault
	1,985	21	75,033,000	All beds west of fault
T.14S. R.6E.	1,824	6	19,699,200	Castlegate "A"
	1,824	4	13,132,800	Upper beds
T.14S. R.7E.	277	6.9	3,440,340	Castlegate "A" east of fault
	550	7.4	7,326,000	Castlegate "A" west of fault
	277	9.0	4,487,400	Bob Wright east of fault
	450	5.0	4,050,000	Bob Wright west of fault
		Total coal	595,372,340	

Estimates of tons recovered per acre by various mining companies on the quadrangle applied to the remaining acreage in the holdings yield the following recoverable reserves:

	Tons	Acres
Class I and II Estimated Reserve	89,299,920	10,925
Class III Inferred Reserve	47,703,592	8,020
	137×10^6	

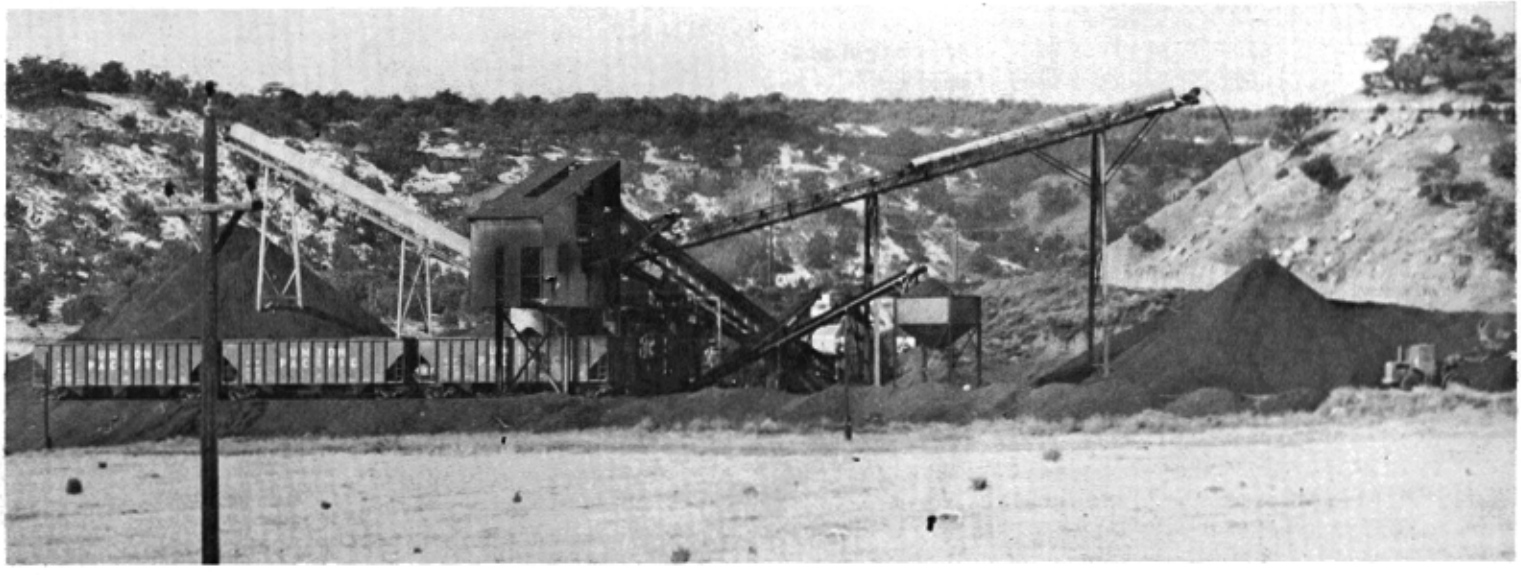
Application of the same method to Spieker's overall estimate indicates that 288 million tons of the 595-million-ton total reserve should be recoverable and that the recoverable rate is about 48 percent. About 56 million tons of total reserve already have been removed and/or are unretrievable as a result of mining. Economic

factors have not been considered and some of the beds listed by Spieker may never be mined; unforeseen geologic conditions also may prevent mining in parts of the reserve. No work was done by Spieker to differentiate the reserves into classes. Probably 20 percent fall into the inferred Class III. The inferred area is concentrated in the west portion of the quadrangle.

Coal undoubtedly extends westward into the Fairview Lakes quadrangle. At least 60 million potential tons that can be recovered are present on leased acreage (about 7,000 acres). Data for the west are lacking; the coal is subsurface with no known outcrops. A large north-south trending displacement fault is located about 2 miles west of the quadrangle boundary. West of the fault the block has dropped with the North Horn Formation at the surface indicating the coal measures are about 2,500 feet or more below the surface. The fault is the effective limit of the Wasatch Plateau coal field.

PRINCIPAL WORK

Most of the geologic work and coal data comes from Spieker (1931) and Taff (1906 and 1907) and published and unpublished U. S. Bureau of Mines reports.



Utah Coal Route loading facilities, Gordon Creek area, along Utah Highway 139.

Colombine mine, Pleasant Valley area.

SCOFIELD SE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Scofield SE quadrangle is located about 15 miles west and slightly south of Price, Utah, near the north end of the Wasatch Plateau (figures 22 and 53). The west edge of the quadrangle is marked by Castle Valley Ridge which divides the Huntington Creek drainages from those flowing eastward to the Price River and divides Carbon and Emery counties. East of the ridge are the cliffs; they are steep and close to the west map edge in T. 14 S. The low area below the cliffs, known as the Bob Wright embayment, is made up of benches being dissected by the principal drainages. In the south part of the quadrangle the cliffs extend eastward so that the Wasatch Plateau covers more of the map area.

Only the south cliffs are accessible by vehicle. Wattis, presently a ghost town, is joined to Price and Utah Highway 10 by Utah Highways 50 and 122. The Utah Railway (Utah Coal Route) passes along the south edge of the cliffs in the southeast map corner.

Elevations range from about 6,500 feet near the northeast map corner to 10,101 feet on Gentry Mountain to the southwest. Coal seams are exposed between 8,000 and 9,250 feet above sea level.

STRATIGRAPHY

The youngest consolidated unit on the quadrangle is the North Horn Formation (Tw) of Tertiary and Cretaceous age. All other consolidated units including the coal measures are Cretaceous. The oldest unit, Emery Sandstone Member of the Mancos, is 550 feet thick in the Bob Wright embayment. It forms step-like cliffs at the base of the Wasatch Plateau and consists of littoral, yellow-gray sandstones with some shaley partings.

Most of the floor of the Bob Wright embayment consists of outcrops of the Masuk Member, a gray marine shale that is sandy and more than 1,000 feet thick. The Star Point Sandstone is the first cliff former; it consists of massive yellow-gray and sometimes white sandstone members. The sandstones often are separated by thick gray shale beds, presumably tongues of the Masuk Shale. Type section of the unit and the name source originate in the Scofield SE quadrangle. To the north and east the Star Point has been divided into three members or tongues, from bottom to top, the Panther, Storrs and Spring Canyon. In a southward direction the shale tongues diminish in thickness and the tongues probably fuse. The Hiawatha coal bed, the first in the overlying Blackhawk Formation, lies atop the Spring Canyon Member.

The Blackhawk Formation is the most important unit because it contains the coal seams. It consists of alternating littoral and lagoonal sediments or alternating sandstone, shale and coal beds. The sandstone beds are usually yellow-gray to tan but are occasionally bleached white under more important coal seams. The unit is at least 1,000 feet thick but all the valuable coal seams lie in the lower 400 feet. The Blackhawk crops out along the cliff faces, producing a step-like cliff not as steep as that of the underlying Star Point.

The Castlegate Sandstone completes the cliff and is more resistant than the Blackhawk. It in turn is overlain by the Price River. Lithology is the same in both, coarse-grained, gray to brown fluvial sandstone with individual beds separated by hard sandy shale. The lower Castlegate is more massive and the upper Price River more slope forming. The two units are normally between 700 and 1,000 feet thick, but on Gentry Mountain seem to be thinner, less than 500 feet, probably the result of nondeposition.

The North Horn (Tw) caps the Price River on Gentry Mountain; about 600 feet of the variegated shales, sandstone and limestone are present. Unconsolidated bench gravels and alluvium were mapped.

STRUCTURE

Faults of the North Gordon zone affect the region occupied by the Scofield SE quadrangle. In the Bob Wright embayment the westernmost faults cut the seams along the spurs of cliffs. They increase in displacement toward the north and die out to the south. These faults just extend into the south part of the quadrangle (Hiawatha area). Most subside before passing through Star Point and the area farther south is not affected.

The nearly horizontal beds dip slightly everywhere. Rocks north of Corner Canyon dip 0 to 2 degrees northerly and to the south dip southerly as much as 8 degrees locally along the north-facing cliff of Gentry Mountain. Dips are shallow on Gentry Mountain itself.

PROPERTY CONTROL

Lands of the Scofield SE quadrangle are owned by government and private concerns: Forest Service 37.1 percent, private 25.2 percent, state of Utah 21.5 percent and Bureau of Land Management 16.2 percent.

Coal lands amount to about 36.4 percent of the total area. Most are in the National Forest, a percentage on private property and small acreage on state of Utah or BLM properties. Approximately 62 percent of the coal acreage is leased or held for coal exploitation. Three companies are involved and listed acreages are approximate (1970):

	Acres	Type
U. S. Fuel Co.	3,310	Fee
	790	Lease
Plateau Mining Co.	880	Fee
	2,560	Lease
North American Coal	270	Lease
Unassigned	280	

The state of Utah taxes the unassigned acreages as coal land. Locations of these holdings are shown on figure 17.

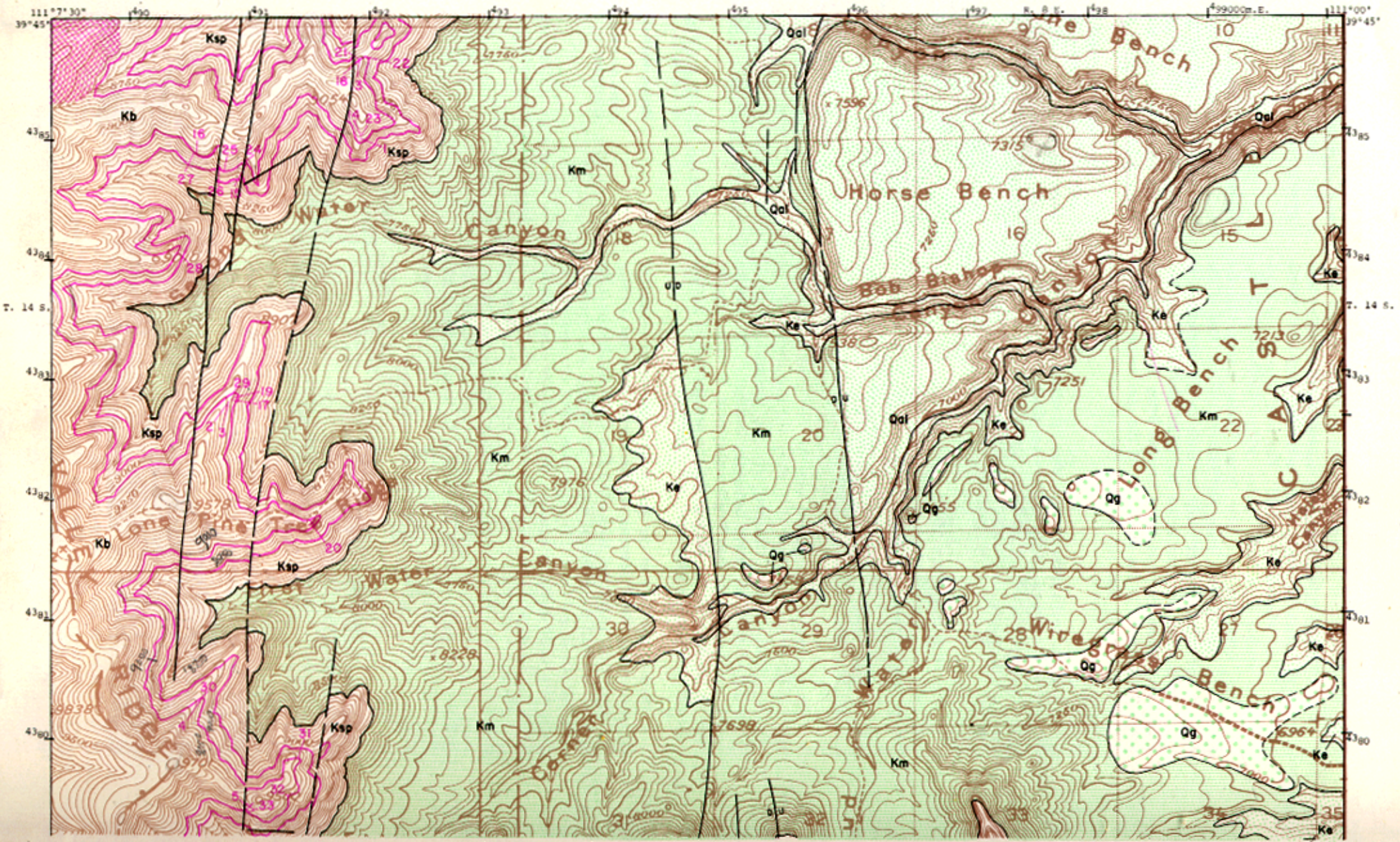
COAL

Surface Information

Eighty coal sections were measured on the Scofield SE quadrangle in nine beds or zones (figure 54). These beds and zones are best described by indicating their relative positions in the stratigraphic column. The first section is located in Bob Wright Canyon just north of the quadrangle and the second is from the Hiawatha area just south of the quadrangle.

Bob Wright Canyon		Hiawatha Area	
Bed or zone	Thickness (feet)	Bed or zone	Thickness (feet)
Upper bed	0-4		
Interval	40-65		
Bob Wright zone			
Upper bed	0-4		
Interval	5-25		
Main bed	3-10	Tank bed	0-6
Interval	3-20	Interval	200
Lower bed	2-8	Wattis bed	8-12
Interval	25-35	Interval	70
Royal Blue (?)	0-6	Third bed	0-9
Interval	50-70	Interval	20
Castlegate "A"	4-15	Second bed	0-7
Interval	160-200	Interval	30
Hiawatha	0-3	Hiawatha	5-20
Star Point Sandstone			

SCOFIELD, UTAH S.E.



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972

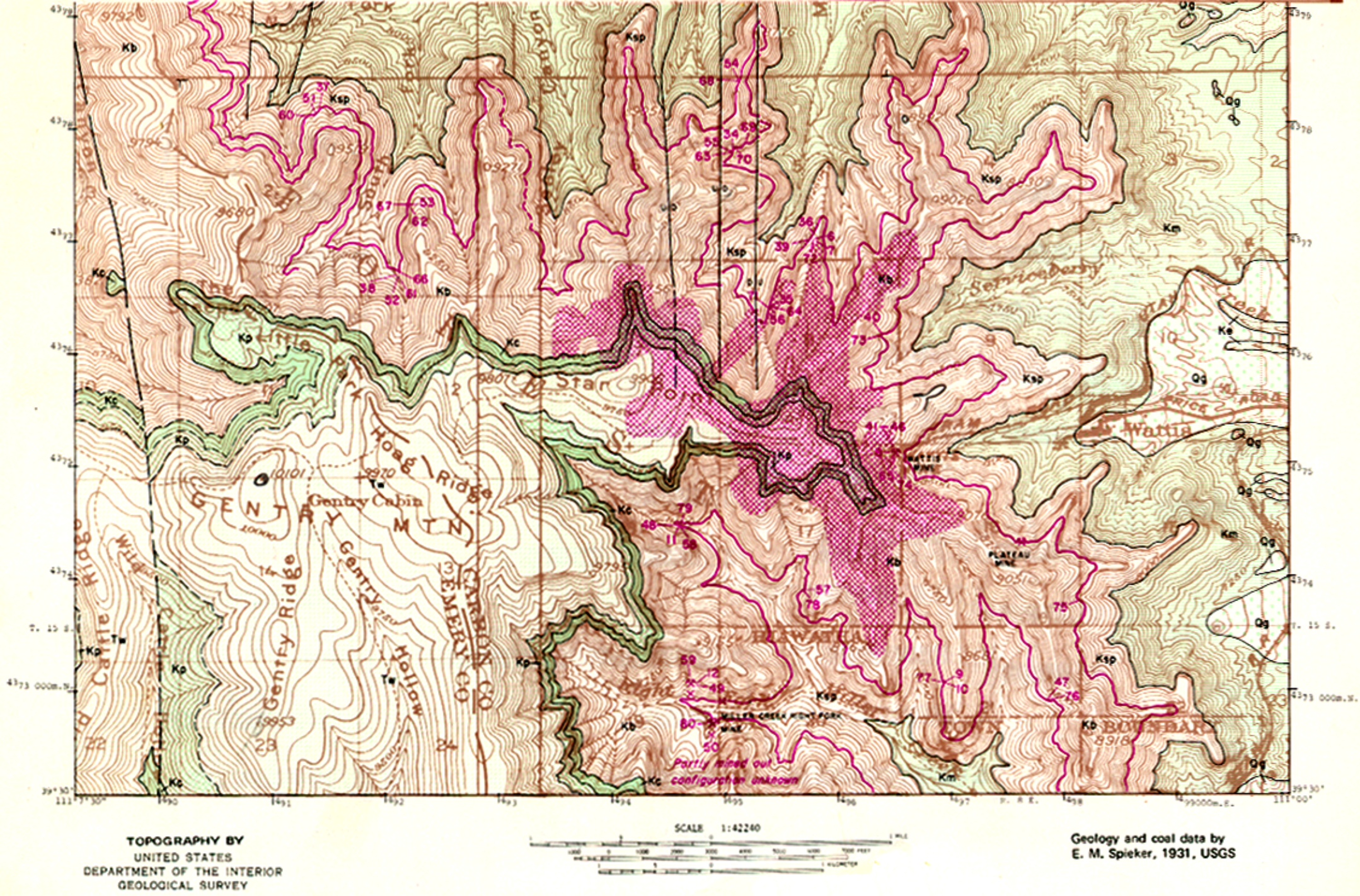


Figure 53. Coal and geology map, Scofield SE quadrangle (explanation pages 136-137).

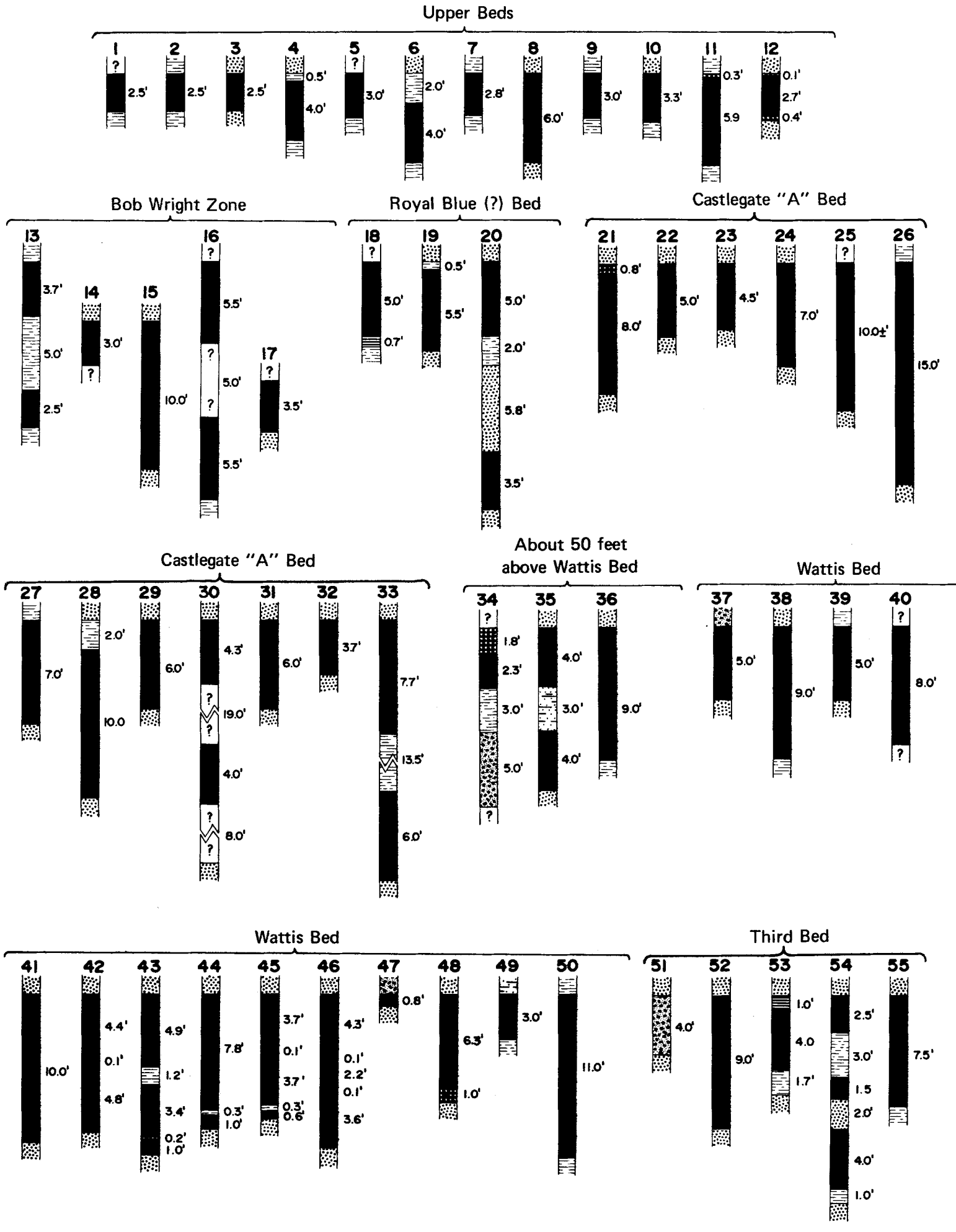


Figure 54. Coal sections of Scofield SE quadrangle (vertical scale: 1 inch = 8 feet).

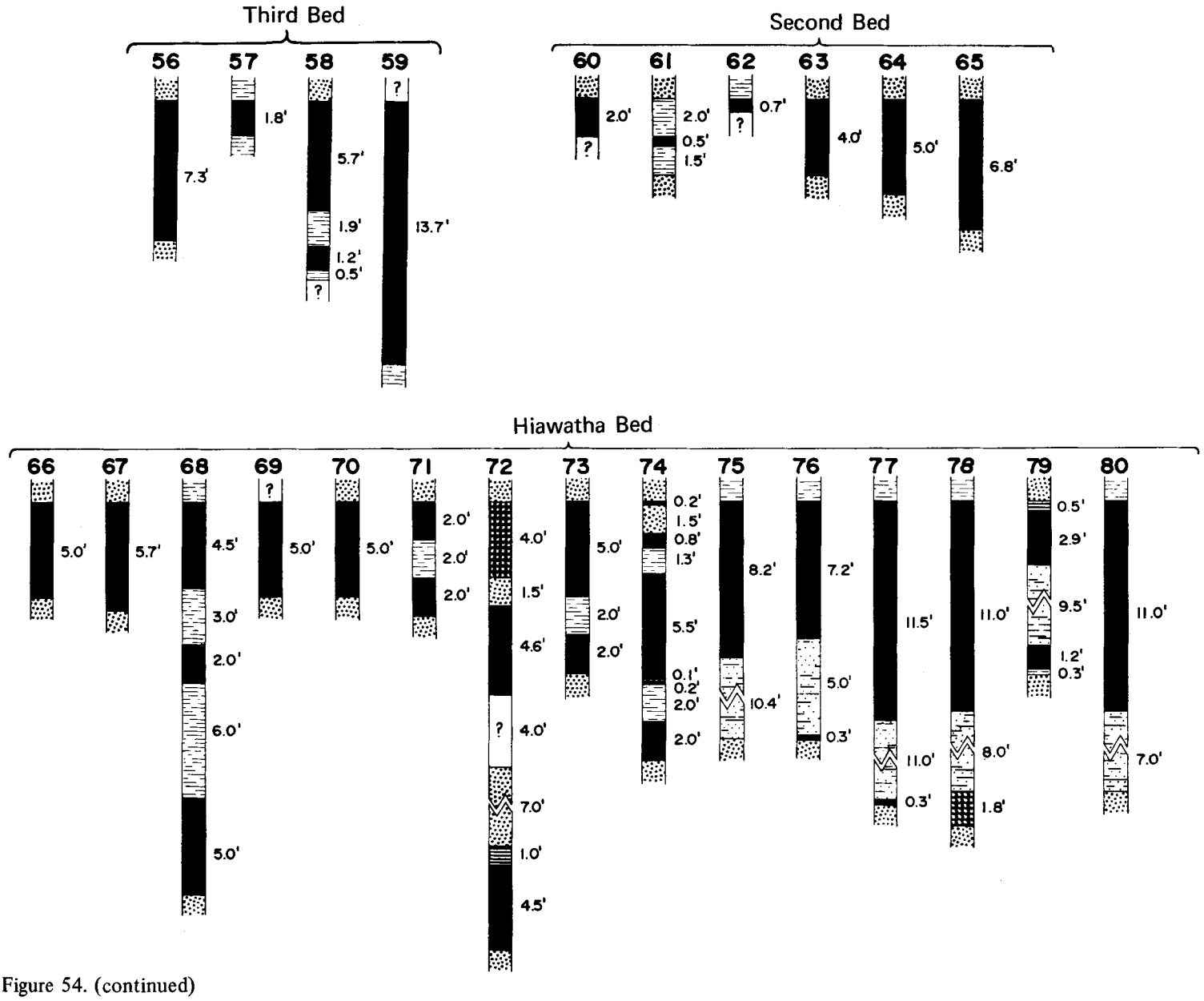


Figure 54. (continued)

Only the Hiawatha bed can be correlated. Sections 66 to 80 (15) are from this bed (figure 54) and all are located in the south part of the quadrangle. To the north the bed is of no value. Except for the thinner sections near the head of Mud Water Creek the coal maintains at least a 5-foot thickness around Gentry Mountain. It thickens southward to 11 feet at the map edge.

Thirty feet above the Hiawatha in the Hiawatha area is the Second bed varying to 7 feet thick. It is 5 or more feet thick between Mud Water and Wattis canyons. Twenty feet above the Second bed is the Third bed, 9 feet thick in Corner Canyon, absent at Wattis and as thick as 14 feet in the Right Fork of Miller Canyon. It is lenticular and developed better to the west.

The second most important bed in the south half of the quadrangle, after the Hiawatha, is the Wattis bed. It is represented by sections 37 to 50. Mined at Wattis it is workable for the most part between Corner Canyon and the center of the Miller Creek drainage and normally ranges between 8 and 12 feet. The bed occupies the same position as the Gordon bed to the north but is not known to be continuous with it. It pinches out a short distance south of the quadrangle.

The Castlegate "A" bed is of importance in the north half of the quadrangle where it ranges in thickness from 4 to 15 feet. It is the third most important bed on the map; Clear Creek No. 3 mine operated on it. South of Corner Creek the bed disappears. The bed occurs 160 to 200 feet above the Hiawatha; in the vicinity of Mud Water Canyon, another bed, 180 feet above the Hiawatha, has thick coal with one section of 9 feet. It may have been continuous with the Castlegate "A" prior to the erosion of the Bob Wright embayment.

Twenty sections have been measured in the upper beds which are mostly to the north. Locally the Royal Blue (?) averages 5 feet. The Bob Wright zone usually consists of at least three beds. The main bed is locally 10 feet thick and has been mined at the Clear Creek No. 4 mine. Other beds farther up in the column are generally thin; locally they reach 4 feet, however.

A single bed locally developed to the south, 196 feet above the Wattis bed, is known as the Tank bed. It is 6 feet thick in Wattis Canyon and has not been recognized elsewhere.

Subsurface Information

No drill-hole data are available for the quadrangle but most of the coal land is located within 1½ miles of a measured surface section. Mining has been extensive in some areas; perhaps the least known area falls southwest. None of the coal lies at depths greater than 2,000 feet below the surface; 36.8 percent are 1,000 to 2,000 feet below the surface and the remaining 63.2 percent are less than 1,000 feet below the surface.

Quality of Coal

All but one of the forty-nine available analyses (table 5) for the Scofield SE quadrangle are from the Wattis mine, Wattis and

perhaps the Hiawatha bed. Three mines of importance open in the map area; other portals of mines operating in the subsurface open in other quadrangles. An analyses from a prospect in sec. 23 or 24, T. 14 S., R. 7 E. is believed in the Castlegate "A" which is developed there. The sample contained 0.83 percent sulfur and 6.6 percent ash. Table 69 summarizes the analyses from the Wattis mine.

Table 69. Average coal analyses, Wattis mine, Scofield SE quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	49	6.5	2.7 -11.1
Volatile matter	44	40.8	37.3 -43.6
Fixed Carbon	44	46.0	39.8 -48.9
Ash	46	6.3	2.6 - 9.8
Sulfur	34	0.85	0.59- 1.2
Btu/lb	45	12,286	11,206-12,860

The U. S. Bureau of Mines divided the sulfur into sulfate, pyritic and organic. The high-volatile bituminous B coal of Wattis sampled 0.71 percent total sulfur with 0.01 percent sulfate, 0.13 percent pyrite and 0.57 percent organic sulfur. Another sample from the Hiawatha bed, presumably from the Plateau Mining Co. mine, contained a total of 0.85 percent sulfur: 0.02 percent sulfate, 0.25 percent pyritic and 0.58 percent organic. Spieker (1931, p. 107) observed that the Main Bob Wright seam is highly resinous.

Gomez, Landers and Boyd (1967, p. 9) calculated carbonization product yields for the Wattis No. 2 mine. Weight percent yields for maf coal show the following (end carbonzation temperature 500°C): char 70.9, water of decomposition 5.3, tar plus light oil 18.1 and gas 4.9. The gas volume for maf coal yields 0.952 scf/lb with a heat value of 792 Btu/scf.

In a report of the Utah Conservation and Research Foundation (1939, p. 77) low-temperature carbonization of coal from the Wattis No. 1 mine was tested and the results are repeated on table 70.

Mines and Development (table 71)

The principal mine with a portal on the quadrangle is the Wattis in the NE corner of sec. 17, T. 15 S., R. 8 E. The Wattis has operated in at least three seams: the Wattis, Hiawatha and an unknown bed. The Wattis was owned and operated by the Lion Coal Co. from 1917 to 1964 when the properties were taken over by the Plateau Mining Co. During those years between 7,737,000 to 7,784,150 tons were produced. The Plateau Mining Co. opened the area to mining in 1967 and an additional 317,000 tons have been mined. Other names for the Wattis mine include Plateau, Utah Chief and Star Point mine.

Table 71. Mines and their locations, Scofield SE quadrangle.

Mine	Location	Remarks
Miller Creek Right Fork mine	NE.NE.NE.SE.19-15S-8E 4,372,700m.N. 494,875m.E.	Activity unknown
Wattis No. 1	NE.NE.NE.NE.17-15S-8E 4,374,100m.N. 496,500m.E.	Active 1917-1964
Wattis No. 2 (Plateau mine)	NW.SE.16-15S-8E 4,374,300m.N. 497,640m.E.	Active 1966-1970

Nothing is known about the Miller Creek Right Fork mine except that it was probably incorporated into the holdings of U. S. Fuel at an early date; its production is included with the King mines to the south.

Reserves

Spieker (1931, p. 204-205) calculated reserves for the area and they are modified to fit the quadrangle (table 72).

Three large groups of mines have removed coal from the quadrangle: the Clear Creek mines in the Bob Wright area, Wattis mines and the U. S. Fuel Company mines at Hiawatha. The exact configuration of mining is not known. Mining tonnage for U. S. Fuel and Clear Creek is discussed in other quadrangle reports. Plateau Mining Co. and its predecessors have mined out 1,214 acres. Production has been 8,101,000 tons, calculating 6,700 tons per acre. With an average coal thickness of 7 feet, recovery was a little more than 50 percent. This means more than 16 million tons

Table 70. Carbonization product yields, Wattis No. 1 mine, Scofield SE quadrangle.

		Vertical Retort										Rotary Retort			
		External Heating									Internal Heating	External Heating			
Carbonizing Temperature °C (Products Weight Percent)		450	550	650	650	650	650	650	750	850	550	650	450	550	650	650
	Char	75.6	65.2	62.5	61.8	64.3	67.0	67.1	60.8	57.9	69.5	65.5	68.7	64.1	60.0	59.8
	Gas	1.3	4.7	8.6	8.2	6.5	8.3	7.9	8.7	12.1	2.1	4.9	4.1	–	9.0	8.9
	Tar	7.4	10.3	11.4	12.1	8.1	8.6	8.3	11.1	10.3	11.0	8.6	13.2	13.2	12.3	13.4
	Light oil	0.3	0.7	0.7	0.4	0.5	0.5	0.5	0.6	0.6	0.4	0.4	0.3	–	0.5	0.3
	CO_2	1.1	1.3	1.2	1.3	1.9	2.0	1.8	1.9	1.3	1.0	1.5	0.9	–	2.3	1.8
	Tar liquors	13.2	15.3	17.8	14.8	10.7	12.8	12.5	14.5	12.3	–	–	11.3	13.5	15.0	18.1
	Total	98.9	97.5	102.2	98.6	92.0	99.2	98.1	97.6	94.5	–	–	98.5	–	99.1	102.3
	Gas, cu ft	433	2,013	4,243	3,723	3,140	4,085	4,150	5,112	7,002	760	2,080	1,348	2,560	3,900	3,488
Yield/ton of coal	Tar, gallons	17.8	25.2	27.5	29.1	18.5	20.6	20.0	24.2	24.8	25.9	20.0	31.7	31.9	29.6	32.2
	Light oil, gallons	0.8	2.1	2.1	1.3	1.5	1.7	1.6	2.0	1.9	1.2	1.3	0.8	–	1.4	0.8
	$(NH_4)_2SO_4$ pounds total	2.9	6.5	10.4	9.4	6.1	11.8	10.0	12.3	6.1	6.0	9.2	3.1	–	8.7	10.8

Table 72. Original reserves in the Scofield SE quadrangle (in short tons; beds 30 or more inches thick).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.14S. R.7E.	1,878	6.9	23,324,760	Castlegate "A"
	1,466	9.0	23,755,680	Bob Wright
T.15S. R.7E.	4,998	4.9	44,082,360	Hiawatha
	3,766	5.5	37,283,400	Wattis
T.15S. R.8E.	3,482	6.8	43,000,000	Hiawatha N½
	1,200	9.5	20,520,000	Hiawatha S½
	2,240	8.5	34,000,000	2nd and 3rd
	4,523	7.0	58,000,000	Wattis
	640	6.4	7,000,000	Bed above Wattis
	1,600	4.3	12,000,000	Tank
		Total coal	302,966,200	

of coal have been removed from the available reserve figure. It is estimated that Plateau Mining Co. has 2,610 acres of Hiawatha coal remaining; with 6,700 tons recovery per acre about 17,487,000 tons are still recoverable from Plateau Mining Co. property. Calculations on the Wattis seam have not been made.

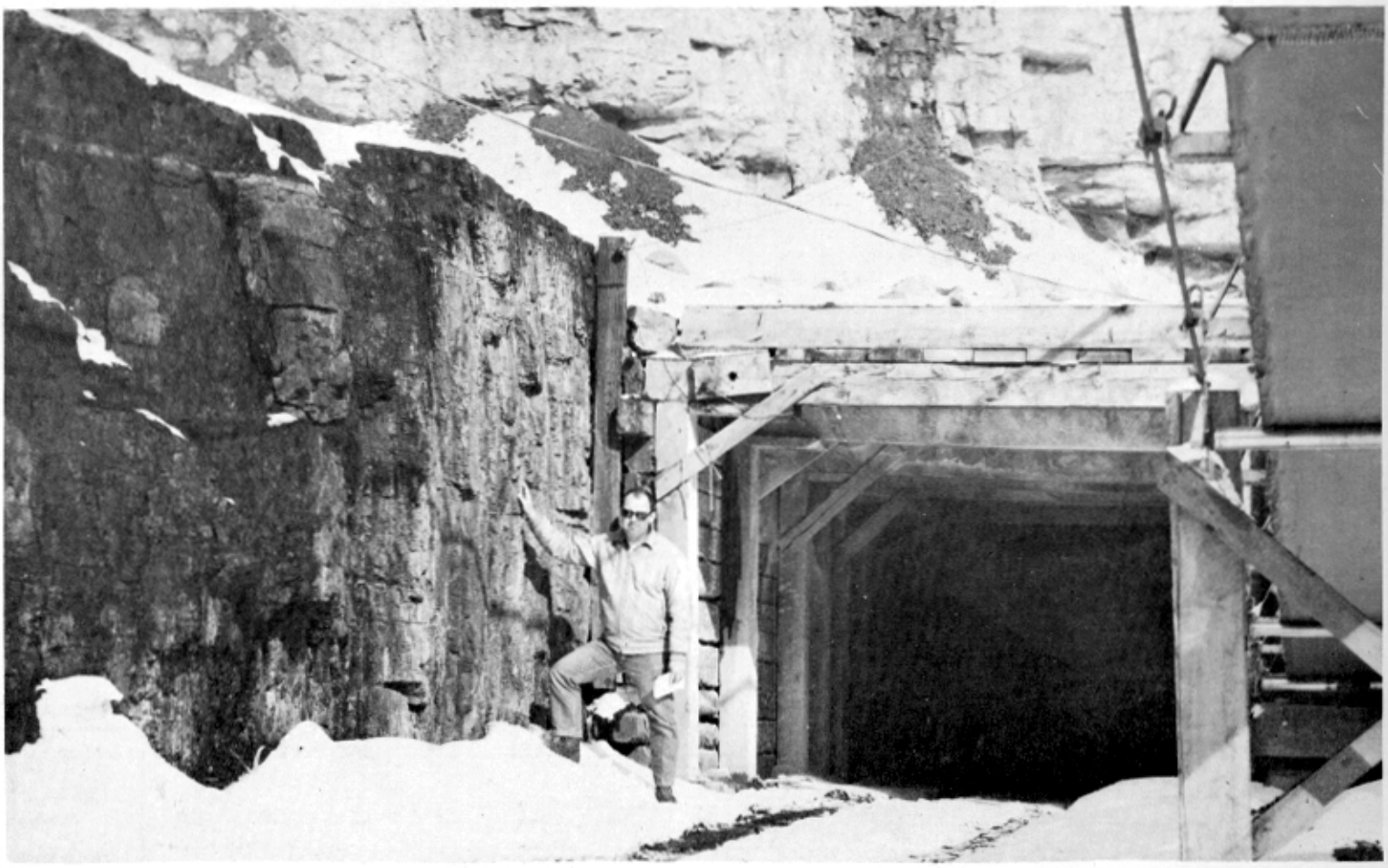
No work has been done to differentiate reserve figures into classes. Most fall into Class II reserve–measured or indicated; the areas in the southwest part of the quadrangle are considered inferred (Class III).

PRINCIPAL WORK

Most of the work presented in this quadrangle report is from Spieker (1931). Published and unpublished analytical data of the U. S. Bureau of Mines, consultants and the local power company update the report.

Load of coal from the Mohrland mine, Hiawatha area. Date of photo unknown, but prior to 1948. Photo from Helper Mining Museum original.

Portal to Hiawatha mine west of Hiawatha town, February 1972.



Portal for Swisher Coal Co. mine, Gordon Creek area. The coal seam is about 13 feet thick.

SCOFIELD SW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Scofield SW quadrangle is located in the north part of the Wasatch Plateau coal field near its west edge. Most of the area is in Emery County, but the northeast corner is in Carbon County and the west edge is in Sanpete County (figures 22 and 55). The area is mountainous and the drainages have cut deep canyons. The principal streams are the Left Fork of Huntington Creek and Huntington Creek. All other streams with the exception of the head of Pleasant Valley Creek are tributary to them. The Carbon-Emery County line marks the drainage divide. The Huntington Creek drainages flow southerly.

Elevations are high ranging from 7,400 feet (Huntington Canyon) to 10,443 feet (Monument Peak). At least seven prominences have elevations greater than 10,000 feet. The canyon walls are steep and access roads are few. Unpaved Utah Highway 31 is the principal access road joining Fairview with Huntington; it passes through Huntington Canyon. Elevations of surface exposures of coal seams range between 7,500 and 9,800 feet above sea level. In spite of the rugged high area, the first mine in the Wasatch Plateau coal field was developed here.

STRATIGRAPHY

Strata of the Masuk, Star Point, Blackhawk, Castlegate, Price River and North Horn formations are exposed. The upper part of the 1,000-foot thick Masuk Shale Member of the Mancos Shale is exposed near the bottom of Huntington Canyon; it is the oldest unit of the mapped area and consists of sandy gray shales. The bottom of Huntington Canyon is filled with unconsolidated alluvium.

The Star Point Sandstone also is exposed in Huntington Canyon and at the bottom of the Left Fork. The yellow-gray littoral sandstone unit is thought to be more than 1,000 feet thick to the north in Pleasant Valley. It thins southward; contours show it to be about 600 feet thick in the south part of the quadrangle.

Except in the downfaulted grabens, most of the remainder of the quadrangle surface exposes the coal-bearing Blackhawk Formation, which is about 1,200 feet thick. The unit consists of alternating sandstone, shale and coal, in order of abundance. It outcrops in a series of alternating ledges and slopes and is not as resistant as the cliff formers (Star Point and Castlegate) above and below. The better coal seams are located in the lower 400 feet.

The Castlegate and Price River formations on the prominences cap the Blackhawk or are preserved in the grabens. The gritty almost conglomeratic sandstone units have a combined thickness of about 400 feet to the east and thicken to the west. Near Bald Mountain a section of the Price River is 600 feet thick.

"Scabs" of the North Horn Formation (Tw) overlie Price River Formation in the downfaulted areas. The incomplete unit consists of variegated shales, with subordinate sandstone, conglomerate and freshwater limestone. Some igneous dikes thought to be basic lamprophyres cut the strata in the north part of the quadrangle.

STRUCTURE

The quadrangle can be divided roughly into three structural divisions: to the east, faults and grabens of the Pleasant Valley fault zone, in the center, little disturbed rocks and along the west edge, faults of the Joes Valley fault zone.

The westernmost fault of the Pleasant Valley zone is the Pleasant Valley fault and the easternmost one follows Woodward Canyon. Distance between them ranges between 1 and 1½ miles. Except near the faults to the north near the Fireside mine, the rocks between are unaffected and strata dip gently. The displacement of the Pleasant Valley fault near the head of South Hughes Canyon is 750 feet and is downthrown to the east. That of the Woodward Canyon fault is 350 feet downthrown to the west.

Between the Pleasant Valley and the Valentine faults an area of relatively undisturbed strata 2 to 6 miles wide tapers to the north. The beds are nearly horizontal. At Valentines Gulch the Valentine fault has a displacement of 800 feet which probably decreases to the north and south; where it crosses Left Fork of Huntington Creek, it is 100 feet. The downthrown block is to the west.

The Valentine fault marks the east limit of the Joes Valley fault zone in this area. The next major fault to the west is Joes Valley fault, the easternmost fault farther south, which decreases in displacement to the north. Except at the Left Fork the ½- to 1-mile interval between the faults is little disturbed. The Joes Valley fault zone dies out north of Bear Canyon. To the south the Joes Valley fault has a minimum displacement of 600 feet. The strata within the Joes Valley graben are nearly horizontal or dip gently.

PROPERTY CONTROL

National Forest Service dominates land ownership on the Scofield SW quadrangle (80 percent). Most of the remainder located to the west and north is private property. About 80 acres of Utah state land are located along the west map edge (figure 16).

About 80.5 percent of the land area are considered coal land; bottoms of the major canyons are eliminated. None of the coal is believed more than 3,000 feet below the surface. Approximately 8,175 acres or 27.7 percent of the coal land are held privately as coal land or as leased coal land. Locations of the holdings are shown on figure 17.

	Acres (approx.)	Type
McKinnon	234	Lease
Kemmerer Coal Co.	2,320	Fee
Larsen-Rigby	160	Lease
Colombo Coal Co.	1,909	Lease
Sanders	160	Lease
North American Coal	1,720	Fee
	472	Lease
Unassigned	200	Fee

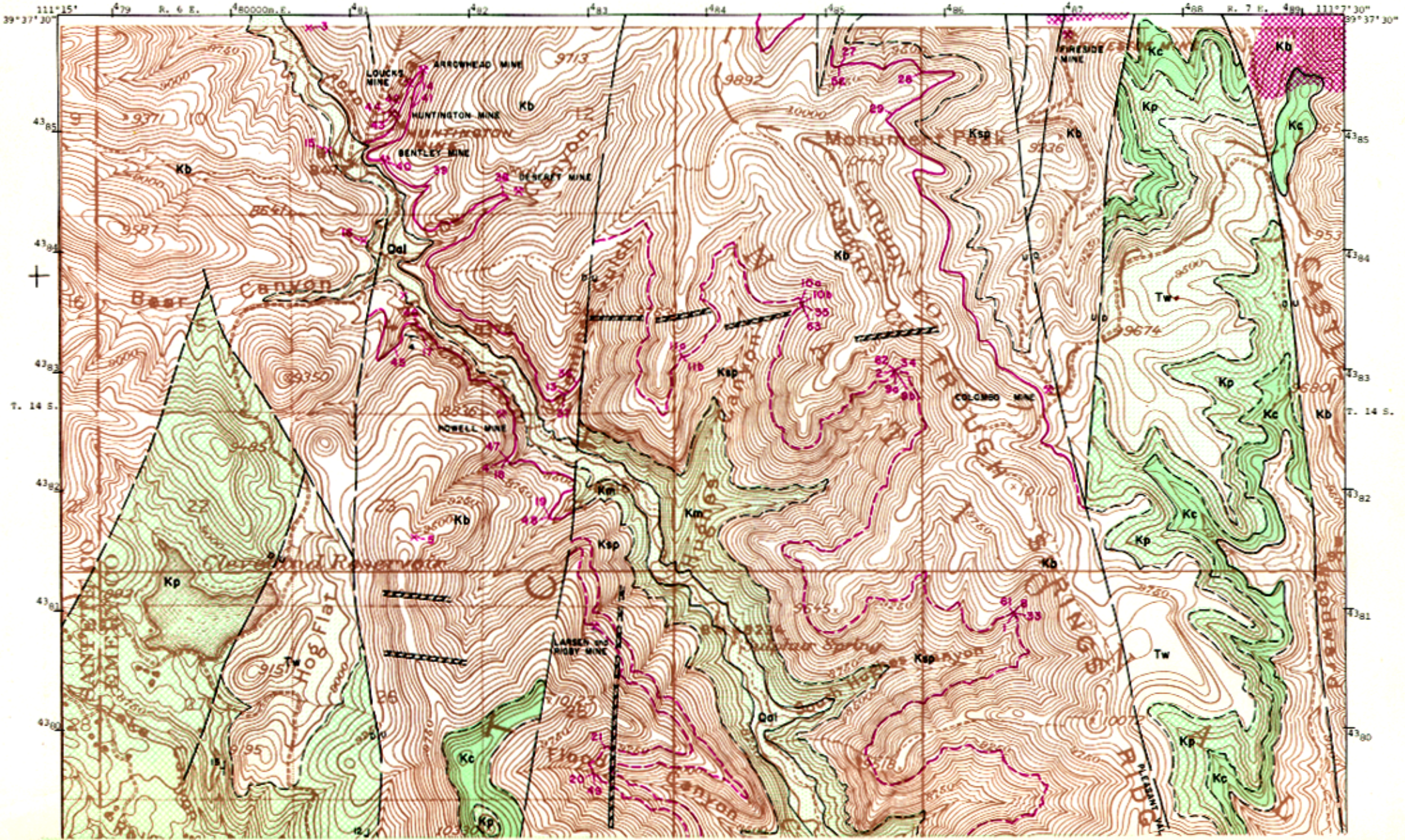
COAL

Surface Information

Six beds or zones are recognized on the Scofield SW quadrangle. Their positions in the Blackhawk Formation are indicated by the following listing for the Upper Huntington Canyon area.

	Feet (approx.)	
Upper beds	0-7	
Interval	105	
Bob Wright zone	0-5	(contains several beds–interval 35 feet)
Interval	65	
Candland bed	0-16	
Interval	40-75	
Castlegate "A"	3-15	
Interval	145	(may contain thin coal beds)
Blind Canyon bed	0-4	
Interval	40-55	
Hiawatha	0-3.5	
Star Point Sandstone		

SCOFIELD, UT. S.W.



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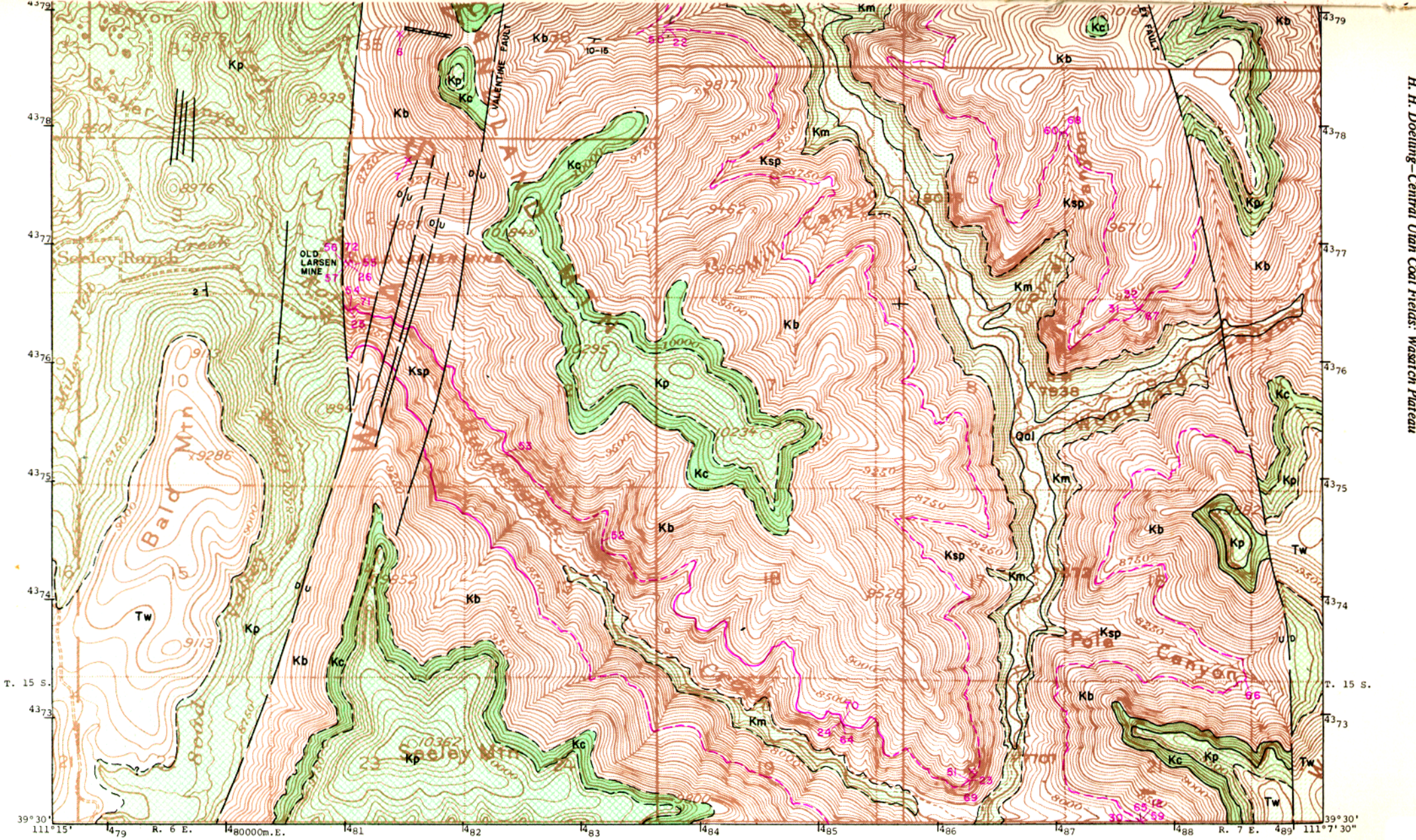


Figure 55. Coal and geology map, Scofield SW quadrangle (explanation pages 136-137).

The Hiawatha bed is represented by eight sections (figure 56) all located in the south half of the quadrangle; it is missing in the Pleasant Valley area to the north. All sections represent thin coal and average about 2 feet. The Blind Canyon bed is about 50 feet above the Hiawatha. It thins northward; its six representative sections show a maximum thickness of 3.9 feet. It is missing in Pleasant Valley and considered unimportant on this quadrangle. Just north of Monument Peak a section of coal 3.8 feet thick lies on a bed between Blind Canyon and Castlegate "A" beds.

The Castlegate "A" is the most valuable bed and is present in thick sections almost everywhere in the area; a locality of thin seams stretches from the south edge of the map to Hughes Canyon on the east side of Huntington Canyon. This probably reflects a thinning trend to the east. In the Hiawatha area and in the vicinity of Wattis, the Castlegate "A" disappears. To the north it is well developed in most sections to more than 10 feet thick. In Left Fork Canyon it varies between 6 and 8 feet.

The next higher coal bed is the Candland bed named for its exposures around Candland Mountain in the center of the map area. The fifteen sections (figure 56) are thick around the mountain averaging about 6 feet and thinning from Bear Canyon northward and east. At the south end of the mountain in section 23 the bed is 4.4 feet thick and in the southeast map corner 1 foot thick, also thinning in that direction.

The remaining Bob Wright zone and upper beds are usually thin but thicken locally. The Bob Wright beds are prominent to the northeast and sections in that part of the quadrangle indicate coal thicker than 4 feet. No trends can be established for beds higher than the Bob Wright although it is assumed they are highly lenticular and unreliable.

Subsurface Information

No drill-hole data are available for this study. Most of the coal land lies within 1½ miles of a control point except lands within part of Joes Valley graben. Even so coal is expected to be thick to the west but little is known about the extent of subsidiary faulting within the graben. Of the coal land 67.2 percent are under less than 1,000 feet of cover; 26.3 percent have 1,000 to 2,000 feet of cover and the remaining 6.5 percent lie under more than 2,000 feet but less than 3,000 feet of cover. The deep areas occur under Bald Mountain and Hog Flat in the Joes Valley graben.

Quality of Coal

Twenty-two analyses (table 5) are available for the Scofield SW quadrangle and all are presumed from the Castlegate "A" seam. Averages are presented in table 73.

Table 73. Average coal analyses, Scofield SW quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	22	7.21	4.9 -11.0
Volatile matter	18	41.78	37.7 -45.1
Fixed Carbon	18	45.93	42.8 -48.0
Ash	22	4.95	2.8 -11.2
Sulfur	21	0.62	0.31- 1.6
Btu/lb	15	12,459	11,640-13,350

The U. S. Bureau of Mines (Walker and Hartner, 1966) determined types of sulfur (table 74).

Table 74. Sulfur-type determinations of coal, Scofield SW quadrangle.

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Arrowhead mine	Castlegate "A"	0.52	0.01	0.09	0.42
Larsen and Rigby	Castlegate "A"	0.45	0.01	0.06	0.38
Larsen and Rigby		0.46	0.01	0.08	0.37

In 1876 some of the coal was converted to coke. An analysis by Morton (1877) appeared in an article:

> The following analyses of the coal and coke . . . have been recently made by Mr. J. Blodget Britton of Philadelphia. This coal cokes exceedingly well, and produces an article which, selling at $25 per ton, is taking the place of Connellsville coke, which now costs $28 a ton at the smelting works of the Territory.

	Coal	Coke
Volatile matter	49.61	2.70
Fixed carbon	48.21	94.05
Ash	1.88	3.25

> The coal contained sulphur 0.547; phosphorous, a trace; the coke contained, sulphur 0.356; and phosphorous, a trace.

The enterprise failed because of the haulage distance; later work indicated the coke was a devolatilized coal.

Gomez, Landers and Boyd (1967, p. 9) calculated the carbonization product yields for two of the mines (table 75; end carbonization temperature 500° C).

Table 75. Carbonization product yields, Scofield SW quadrangle.

Mine	Carbonization yield, wt. percent of maf coal				Gas volume scf/lb maf coal	Heating value of gas Btu/scf
	Char	Water of decomposition	Tar plus light oil	Gas		
Christensen No. 3	68.3	5.7	19.6	5.6	0.990	758
Larsen and Rigby	68.2	5.7	19.5	5.8	0.994	755

Mines and Development

The following mines have been opened on the Scofield SW quadrangle (table 76):

Table 76. Mines and their locations, Scofield SW quadrangle.

Mine	Location	Remarks
Arrowhead mine (Sanders)	NE.11-14S-6E 4,385,450m.N. 481,540m.E.	1940's?
Bentley mine	NW.NW.SE.11-14S-6E 4,384,700m.N. 481,230m.E.	1874-1877
Colombo mine (prospect)	17, 20, 21-14S-7E ~4,382,770m.N. 486,800m.E.	No recorded production
Deseret mine	SW.SW.12-14S-6E ~4,384,450m.N. 482,330m.E.	Active 1896-1910
Huntington mine (Fairview, Bell, Connellsville, New York, Bear Gulch, Christensen, New York and Howell, Tompkins)	SW.SW.SW.NE.11-14S-6E 4,385,110m.N. 481,320m.E.	Active intermittently, 1875-1940's
Fireside mine	NW.NW.NW.NW.9-14S-7E 4,385,250m.N. 481,320m.E.	Never produced
Larsen mine	NE.SE.SW.2-15S-6E 4,376,860m.N. 481,050m.E.	Active 1906-1915
Larsen and Rigby mine	NW.25-14S-6E ~4,380,800m.N. 482,950m.E.	1937-1970 Still active
Loucks mine	NE.11-14S-6E ~4,385,350m.N. 481,400m.E.	1874-1877

Included in the first mines opened in 1874 in Huntington Canyon were the Bentley, Huntington and Loucks. Of these only the Huntington became a significant producer. Attempts to produce coke were uneconomical. The mines closed after 1877, but the ruins of the coke ovens can still be seen. The Huntington mine reopened prior to 1895 operating five to six months a year; it never produced a large amount of coal. From 1875 to 1877 eleven coke ovens produced 1,000 tons of coke. Between 1895 and 1921 almost 34,000 tons and in the late 1930's and early

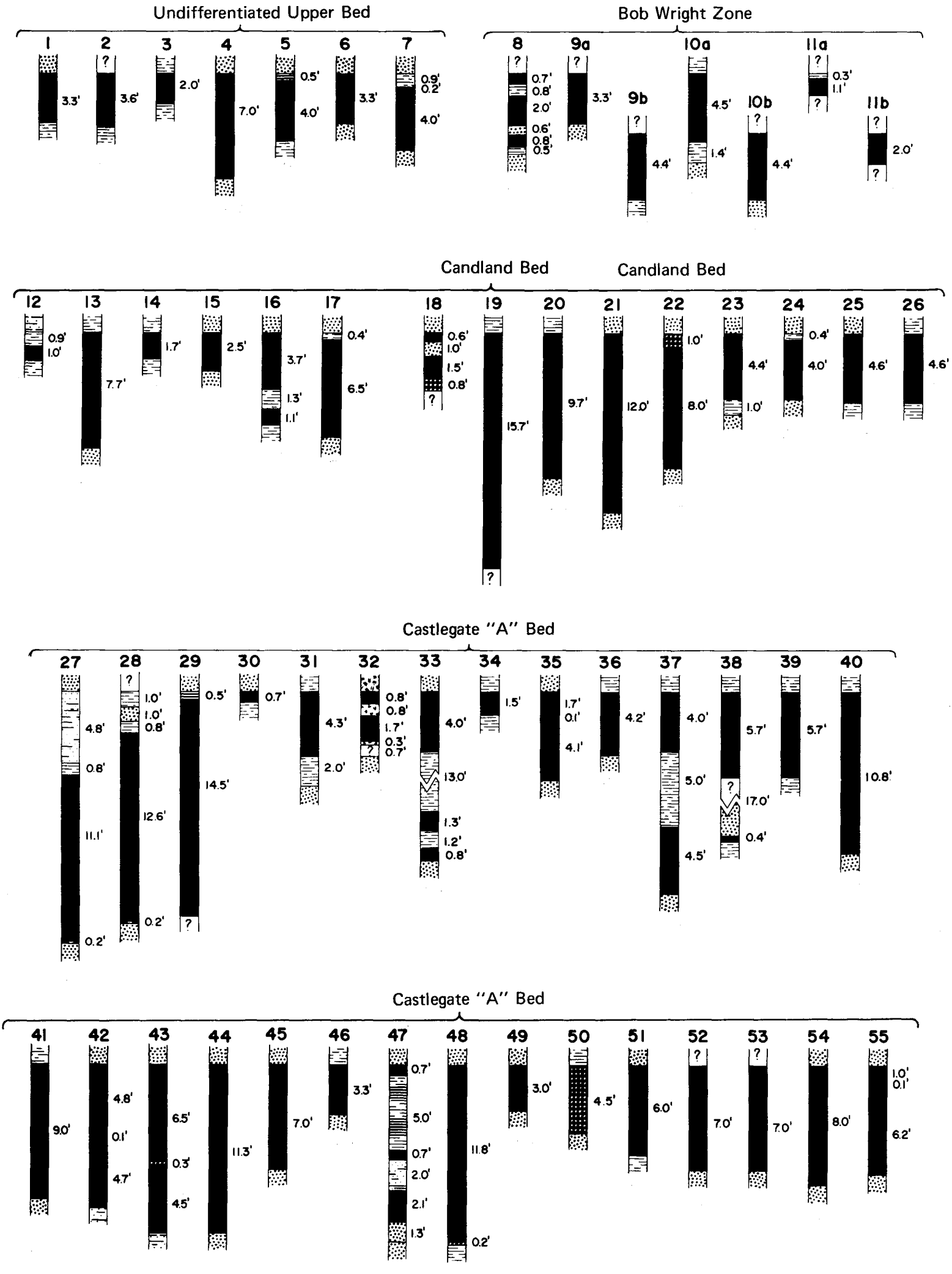


Figure 56. Coal sections of Scofield SW quadrangle (vertical scale: 1 inch = 8 feet).

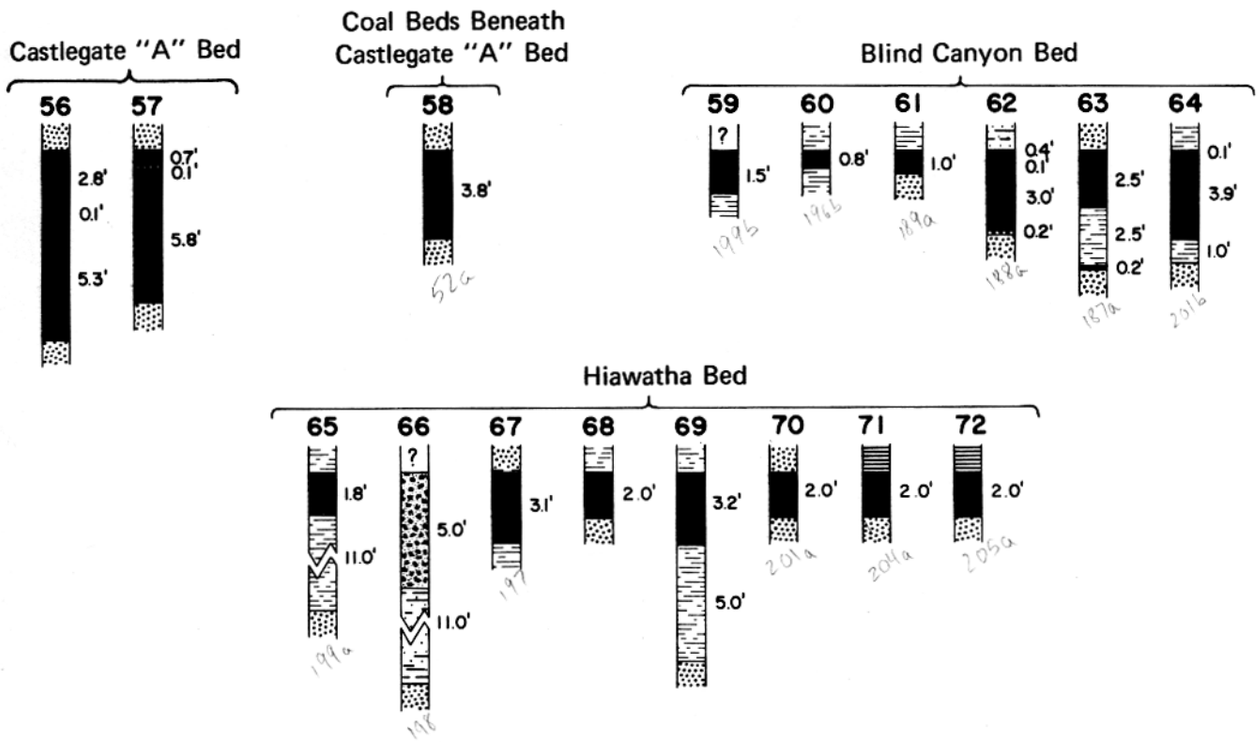


Figure 56. (continued)

1940's another 20,000 tons of coal were produced. Excellent mining conditions prevailed with the coal bed ranging between 10 and 11 feet thick.

Little is known about the later Arrowhead and Fireside mines. The Colombo is located on currently held properties (federal lease) where coal is close to the surface near Monument Peak; it may possibly be surface-mined here.

The Larsen and Deseret mines worked between 1896 and 1915. Total known production of 20,000 tons for the two small operations supplied local needs in Sanpete Valley. The only presently active mine on the quadrangle, the Larsen and Rigby, has supplied Sanpete Valley residents with coal since 1937. It operates part of the year and has produced about 150,000 tons. Part of the Clear Creek mines extends under the northeast corner of the area. This production is reported on the Scofield NW quadrangle. Total production of coal from portals opening on the Scofield NW quadrangle is estimated to be 230,000 tons.

Reserves

The reserves of the area have been calculated by Spieker (1931, p. 204) and modified to fit the quadrangle (table 77). Beds averaging less than 4 feet are eliminated.

The approximately 5,800 acres west of the Joes Valley fault are not counted. The reserve is classed as inferred. From Spieker's averages for adjacent blocks the following is deduced:

Acres	Average thickness (feet)	Tons	Bed or zone
5,800	6.0	62,640,000	Castlegate "A"
5,800	4.0	41,760,000	Candland
	Total Coal	104,400,000	

No work has differentiated the reserve into classes. Most of the area of the quadrangle falls within 1½ miles of a measured outcrop; none falls into a doubtful reserve classification (Class IV).

Table 77. Original reserves in the Scofield SW quadrangle (in short tons).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.14S. R.6E.	4,296	6.0	46,300,000	Castlegate "A"
	4,840	6.0	52,000,000	Candland
	3,616	4.0	25,867,200	Upper beds
T.41S. R.7E.	725	6.9	9,004,500	Castlegate "A" east of fault
	3,182	7.4	42,674,000	Castlegate "A" west of fault
	502	9.0	8,132,400	Bob Wright east of fault
	1,707	5.0	15,950,000	Bob Wright west of fault
T.15S. R.6E.	3,550	6.0	38,340,000	Castlegate "A"
	3,290	4.0	24,000,000	Candland
T.15S. R.7E.	2,140	4.9	21,256,000	Hiawatha
	5,280	5.0	47,520,000	Castlegate "A"
	4,100	4.0	30,000,000	Candland
		Total coal	361,044,100	

The Wasatch Plateau coal field extends westward another 4 miles into the Huntington Reservoir quadrangle. The surface is mainly North Horn Formation indicating the coal is more than 2,000 feet below. Several north-south faults disrupt the area. The upper part of the the Blackhawk Formation crops out about 3 miles farther west beyond the coal field boundary on the west side of the Wasatch Plateau. Drilling in this area (Mt. Pleasant coal field) reveals seams to 6 feet thick indicating continuity. Coal in this inbetween area is regarded as a Class IV reserve.

PRINCIPAL WORK

Most of the geology and coal data presented here are derived from Spieker's 1931 account of the field. Published and unpublished Bureau of Mines sources update and augment the study.

SOLDIER SUMMIT SE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Soldier Summit SE quadrangle is located at the north tip of the Wasatch Plateau field; the east edge of the map is about 20 miles northwest of Price on U. S. Highway 50-6 (figures 22 and 57). The highway lies in the northeast map corner along with the main line of the Denver and Rio Grande Western Railway. A railroad junction at Colton sends a spur line through the canyon of the Price River to Clear Creek on the Scofield quadrangle. Utah Highway 96 branches from U. S. Highway 50-6 through Spring Canyon to provide access to Scofield and Clear Creek. Dirt roads provide access to other parts of the quadrangle.

The area is rugged and mountainous; elevations range from 7,000 feet along the Price River to almost 9,200 on a peak in the southwest map corner. Coal outcrops between 7,500 and 7,800 feet above sea level. The north half of the area is in Utah County and the south half in Carbon County.

STRATIGRAPHY

The upper part of the stratigraphic column is exposed. The Blackhawk is the oldest formation on the quadrangle; it outcrops along the Price River to the southwest. Regional dip is to the north and northeast so that the succeedingly younger beds lie to the northeast. The youngest unit is the Green River Formation. The units are described on figure 5 and in the general discussion of the units for the field. The important coal seams occur in the lower part of the Blackhawk Formation. Estimated thicknesses of each unit are listed below:

	Feet
Green River Formation	Incomplete
Colton Formation	1,500
Flagstaff Limestone	500
North Horn Formation	600
Price River Formation	550
Castlegate Sandstone	200- 500
Blackhawk Formation	1,500-1,600

STRUCTURE

The principal structural feature of the Soldier Summit SE quadrangle is the northeastward-dipping flank of the Clear Creek anticline. The inclination is as much as 15 degrees in places. Several faults along the west map edge represent the north end of the Pleasant Valley fault zone. The easternmost fault of the North Gordon fault zone extends into the area along the west map edge. This fault, called the Forge Mountain fault, may continue as far north as Colton and marks the east edge of the Wasatch Plateau field. There is plenty of room between faults for mining; the difficult problem is the moderate to steep dip and resultant increase in cover to the north and east.

PROPERTY CONTROL

More than 92 percent of the land are private property; the remainder is almost equally shared by the Bureau of Land Management and the state of Utah. Thick coal beds lie to the south of the quadrangle both to the east and west and these beds may be inferred to extend under the Soldier Summit SE quadrangle. To the northwest, however, coal is too deep to be mined profitably and must be excluded from the coal lands, which amount to a little more than 75 percent of the quadrangle area.

None of the government land is currently leased or permitted for coal. Sunnybrook Coal and Coke Co. (800 acres) and the Kearns Corp. (160 acres) hold lands that are taxed as such by the Utah State Tax Commission.

COAL

Surface Information

The only bed of value exposed at the surface (Price River Canyon) is the Haley bed (figure 58; Spieker, 1931, p. 89 calls the canyon Fish Creek Canyon). The bed is 4 to 6 feet thick at its east outcrops, but near the Scofield Reservoir it becomes thin and dirty. The exact stratigraphic position of the Haley and lower beds is unknown. The Castlegate Sandstone is 900 feet above the Haley bed and if Spieker's structure contours for the Hiawatha bed are correct the Hiawatha is 700 feet below the Haley. The Blackhawk should be at least 1,600 feet thick at this location.

Subsurface Information

No drill-hole information is available for the Soldier Summit SE quadrangle. Overburden on the Hiawatha and coal beds of value, such as the Castlegate "A", is great in most areas. The only area with less than 1,000 feet of cover (5 percent) lies in the west part of Price River Canyon; 17 percent underlie 1,000 to 2,000 feet, 55 percent 2,000 to 3,000 feet and 23 percent more than 3,000 feet. These estimates are not based on reliable information and deep burial may occur farther south than shown on the overburden map for the field.

Condition of the better and deeper coal beds is speculative. The following section taken from the south in the Gordon Creek area exemplifies the beds:

	Feet
Castlegate "A" bed	2- 8
Interval	60-120
Gordon bed	0- 6
Interval	90-120
Hiawatha coal bed	3- 10
Star Point Sandstone	

To the southwest in the Pleasant Valley area the position and condition of the coal are as follows:

	Feet
Bob Wright coal zone	5- 8
Interval	100-200
Castlegate "A"	6- 19
Interval	70- 80
Union Pacific bed (Gordon?)	0- 30
Interval	100
Star Point Sandstone	

Quality of Coal

No analyses are available for the Soldier Summit SE quadrangle.

Mines and Development

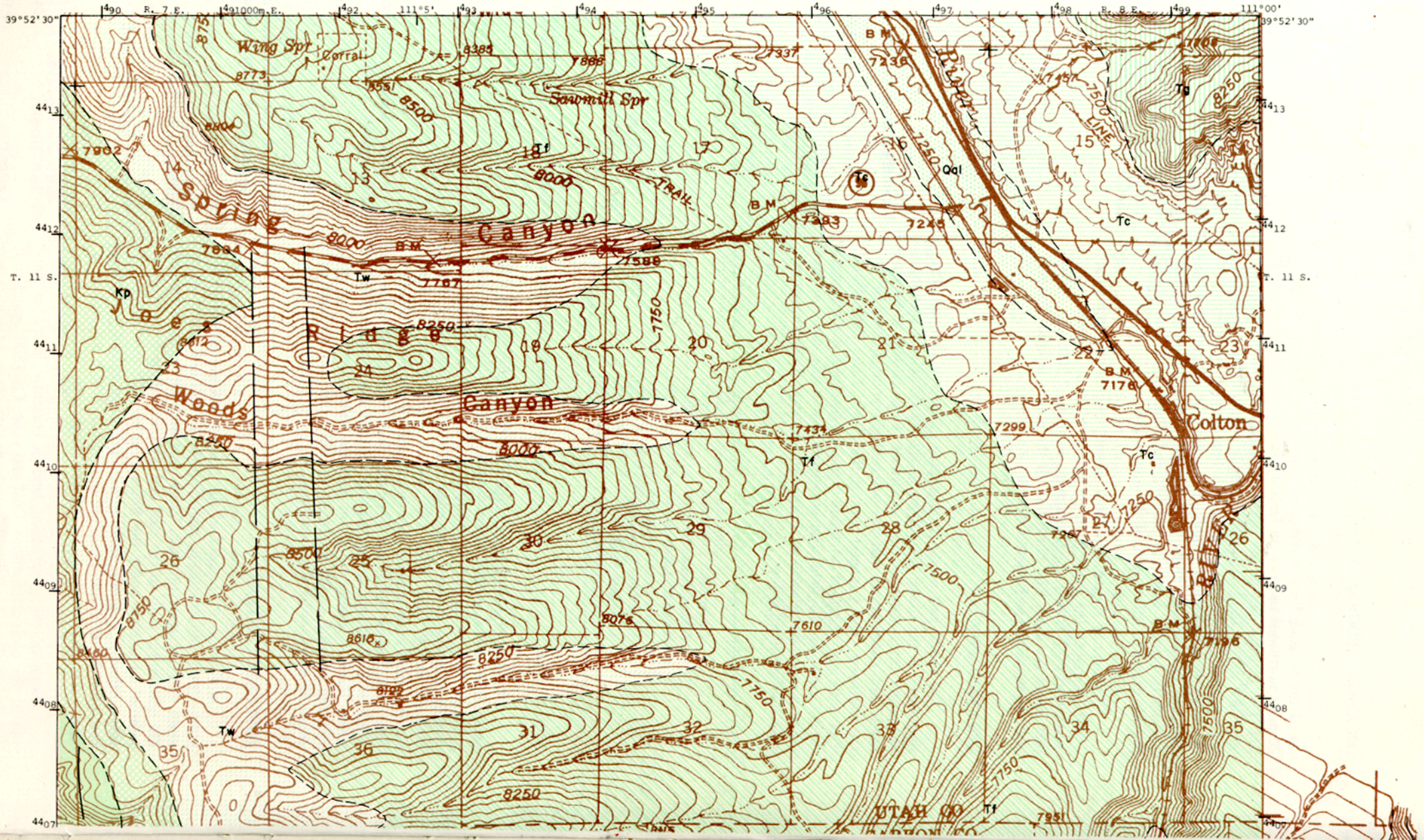
Presently no mines are active on the quadrangle. Spieker (1931, p. 95) noted that all mines and prospect pits (table 78) along the Price River Canyon had been abandoned in 1923.

The bed at People's Coal and Coke is 4 feet thick in the Haley bed; the Carbon Dale mine is the same. Estimated total production for both mines is 6,000 tons.

Table 78. Mines and their locations, Soldier Summit SE quadrangle.

Mine	Location	Remarks
People's Coal and Coke (Haley, Hales)	SE.11-12S-7E 4,404,230m.N. 490,130m.E.	Active 1907-1909
Carbon Dale (Sunshine, Sunnybrook)	NW.13-12S-7E 4,403,250m.N. 491,860m.E.	Active 1900-1908

SOLDIER SUMMIT S.E., UTAH



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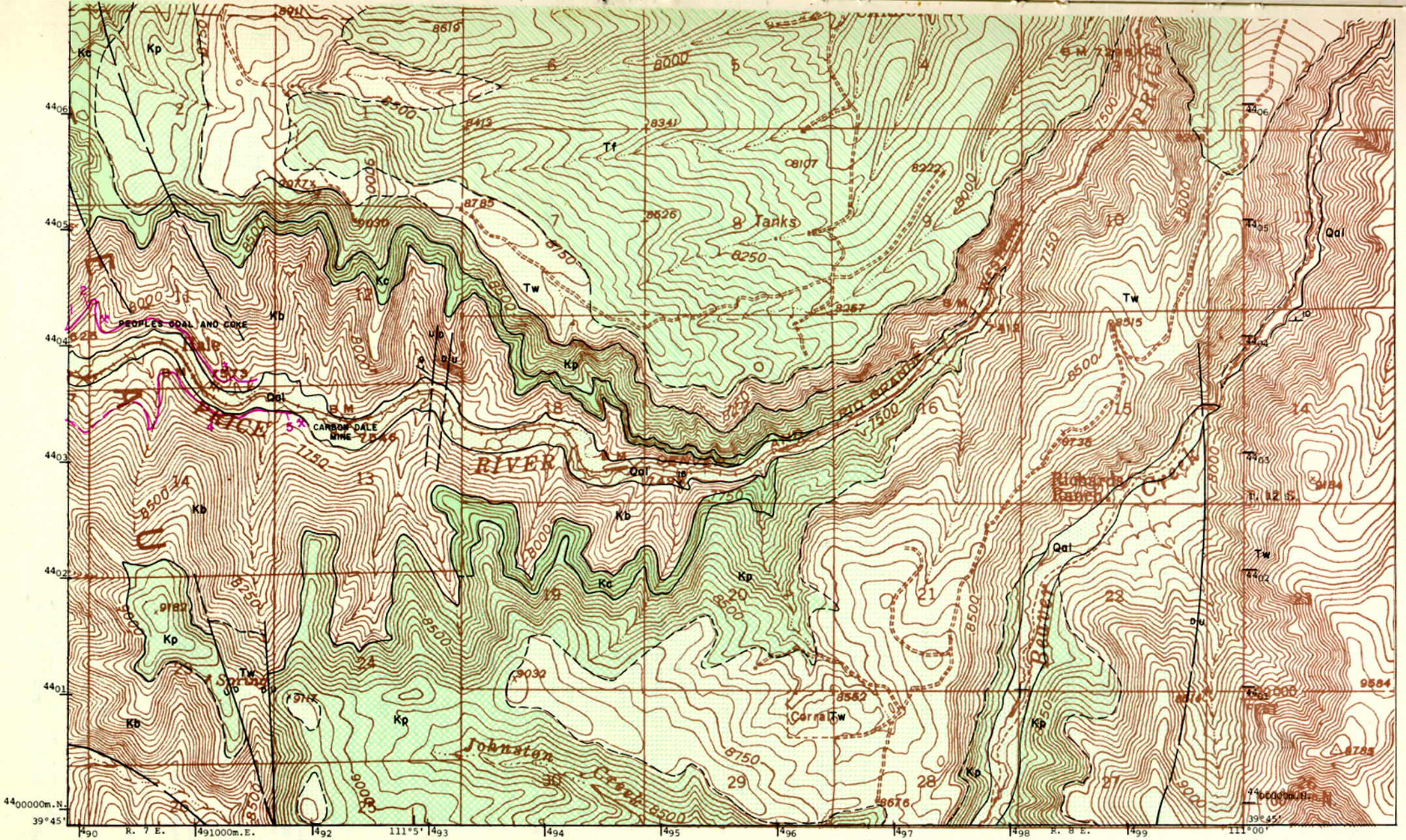

TOPOGRAPHY BY
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology and coal data by
E. M. Spieker, 1931, USGS

Figure 57. Coal and geology map, Soldier Summit SE quadrangle (explanation pages 136-137).

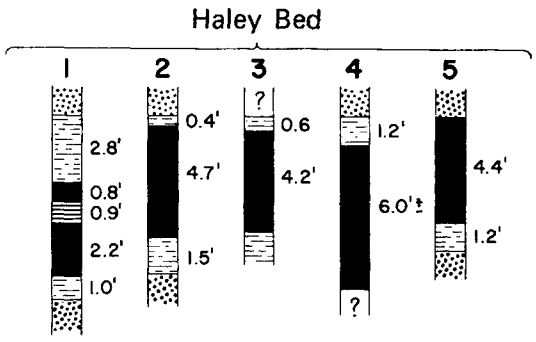

Figure 58. Coal sections of Soldier Summit SE quadrangle (vertical scale: 1 inch = 8 feet).

Reserves

Spieker (1931, p. 204) calculated reserves (table 79) from projections from the south and limits the reserves to the south half of the quadrangle (T. 12 S.).

Table 79. Original reserves in the Soldier Summit SE quadrangle (in short tons).

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.12S. R.7E.	1,814	13.0	42,447,600	All beds, secs. 1-3, 12, 13, 22-27
	2,885	10.0	51,930,000	All beds, secs. 2-3, 10-15, 22, 23
T.12S. R.8E.	12,025	17.0	367,965,000	All beds
		Total coal	462,342,600	

PRINCIPAL WORK

Most of the data presented for this quadrangle are derived from Spieker (1931).

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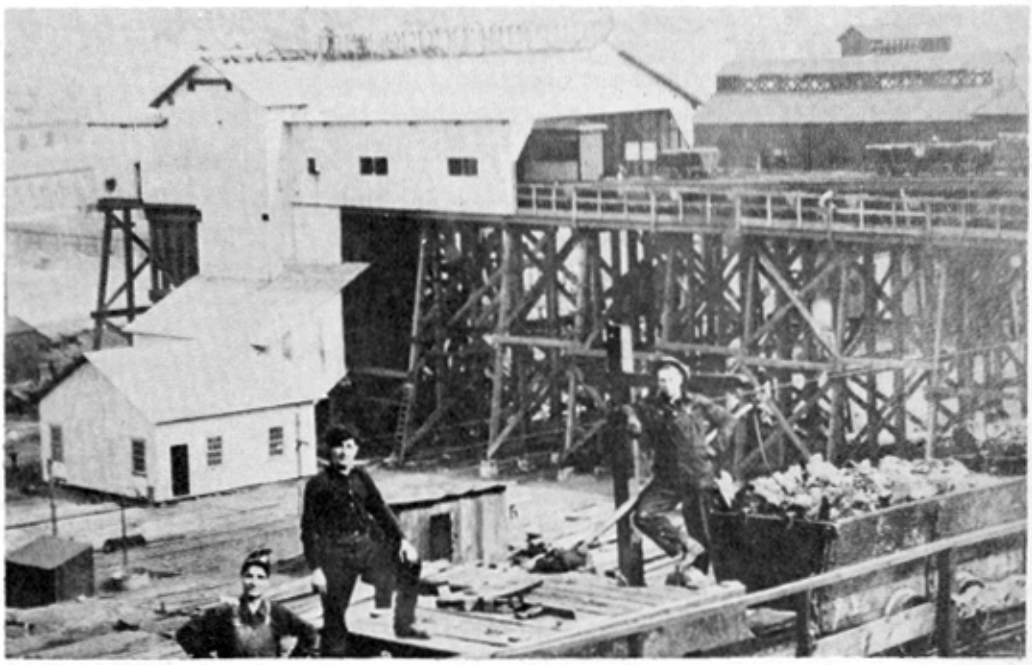
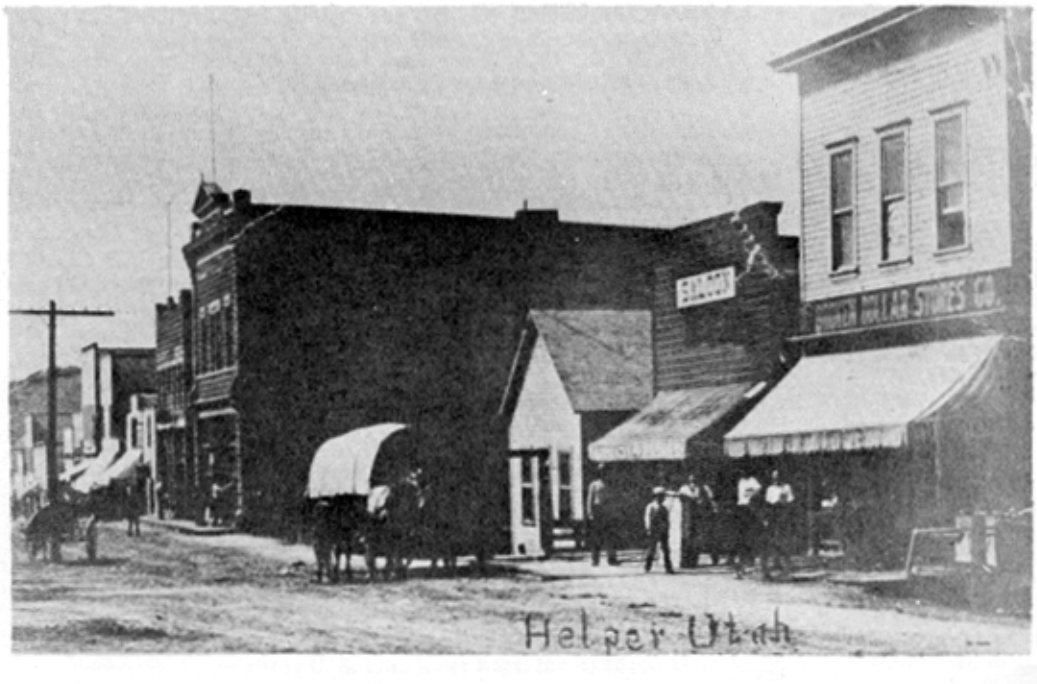
Sunnyside complex, early day photo. Copied from Helper Mining Museum original.



Old tipple at Sunnyside, pre-1930. Copied from Helper Mining Museum original.



Main street, Helper, Utah, before 1920. Photo from Helper Mining Museum original.

BOOK CLIFFS COAL FIELD

by

H. H. Doelling[1]

INTRODUCTION

Location and Extent

The Book Cliffs form the south boundary of the Uinta Basin and extend from Grand Junction, Colorado, to Spring Canyon, Utah. The length of the sinuous feature is about 185 miles with coal seams along the entire length. This report concerns itself with the west 70 miles of outcrop from Spring Canyon, where the Book Cliffs join with the Wasatch Plateau, to the canyon of the Green River (Gray Canyon). The east boundary of the field then becomes the Green River, the north or northeast boundary is the mining limit in that direction in the foreseeable future, the west boundary is the easternmost fault of the North Gordon fault zone and the south or southwest boundary is the escarpment of the Book Cliffs. The north-northeast boundary is placed a little beyond the 3,000-foot coverline. That good coal is present in this area plus advancing technology in the field of deep mining will probably push back the boundaries as the need for the resource increases. The area of the field as shown on maps in this report is 645 square miles. Considering the 3,000-foot limit reduces the field width to 4 miles and the area to 280 square miles.

The Book Cliffs coal field lies slightly east of the central part of Utah (Preface, figure 1a and figure 1). The west end of the field is about 120 miles southeast of Salt Lake City. The north and west parts of the field are in Carbon County and the south part is in Emery County.

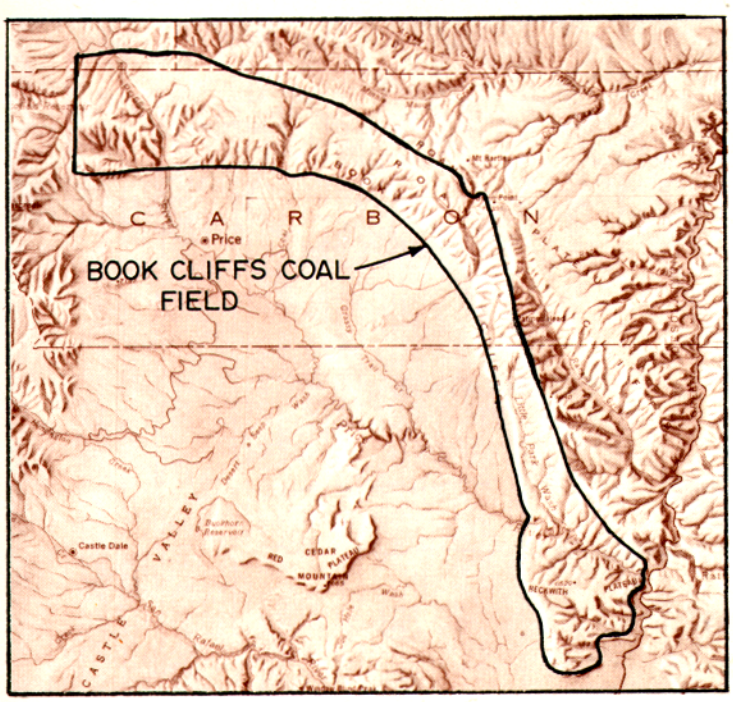


Figure 1. Relief map of east central Utah showing the approximate location of the Book Cliffs coal field.

Topography and Drainage

The physiographic feature which lends its name to the coal field is the most imposing and dominating along its entire length (figure 2). The 70-mile cliff line has its base at 5,000 feet near the Green River, 6,000 feet near Sunnyside, and at 7,000 feet from Soldier Canyon westward. The top of the steep part of the cliff is at 8,500 feet in the Castlegate area, about 8,400 feet near Soldier Canyon, climbs to almost 9,000 feet at Sunnyside, drops to 6,500 feet near Woodside and is a little more than 6,000 feet at the south end of the field. As such the relief varies between 1,000 and 2,000 feet. Behind the cliffs are mountains with more gentle slopes. Some of the more important prominences include Forge Mountain (9,785 feet), Mt. Bartles (10,047 feet), Bruin Point (10,285 feet), Patmos Mountain (9,845 feet) and Buckhorn Mountain (about 6,500 feet).

The coal outcrops are located along the cliffs and in the canyons which indent them. They are exposed between 6,000 and 8,500 feet in the Castlegate area, between 6,500 and 7,600 feet in the Soldier Canyon and Sunnyside areas and between 5,000 and 6,000 feet in the Woodside area.

Only two important drainages occur along the 70-mile length of cliffs at each end of the field. The Price River originates in the Wasatch Plateau to the west and flows southeasterly through the Book Cliffs in a deep canyon, emerging near the town of Helper. It continues southeasterly separating Castle Valley to the southwest from Clark Valley to the northeast. It cuts across the north end of the San Rafael Swell and emerges near Woodside. At Woodside the river cuts a canyon through the south end of the Book Cliffs and finally flows into the Green River. The Green River marks the east boundary of the field and is the second of the two important drainages. The two rivers cut off a segment of the Book Cliffs called the Beckwith Plateau.

Other drainages cutting canyons into the Book Cliffs are mainly tributaries of the Price River. The amount of water carried by them is small, often intermittent and unreliable. The more important include Spring Canyon, Willow, Coal, Soldier, Dugout, Whitmore Canyon and Horse Canyon creeks.

In the north and west part of the field a level area has developed along the contact of the Flagstaff Limestone and the Colton Formation. The Flagstaff is resistant and its gentle dip slope is responsible for the development of flat surfaces locally called parks, such as Emma and Whitmore parks. Another set of cliffs north and northeast of the parks is known as the Roan Cliffs.

Population, Industries and Transportation

The sparsely populated Books Cliffs area has three nodes. The Price-Helper area is the area of greatest population. The second most populated area is the Dragerton-Sunnyside area.The town of Green River in Emery County, 1960 population, 1,975 and 1,033 in 1970, is the least important center. Essentially no other towns exist and scattered ranchhouses make up a rural population. The only exception is Woodside that had a population of 25 in 1960 and 10 in 1970.

[1] Economic geologist, Utah Geological and Mineralogical Survey.

EXPLANATION

PRIMARY ROADS

SECONDARY ROADS

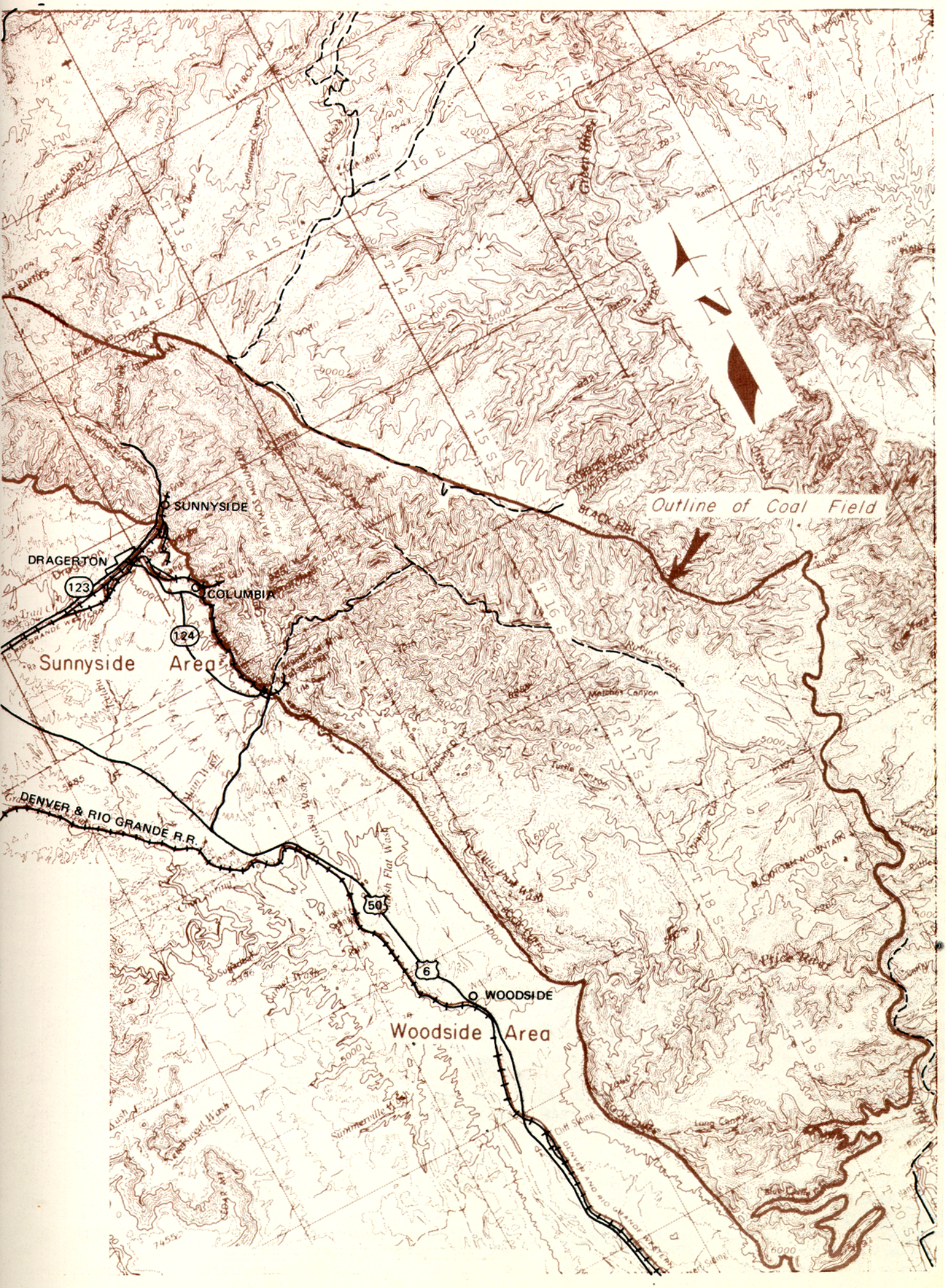
U.S. HIGHWAY 50

UTAH STATE HIGHWAY 10

1:250,000

0 5 10 Miles

Figure 2. Topography and roads map, Book Cliffs coal field.


N
Outline of Coal Field
SUNNYSIDE
DRAGERTON
COLUMBIA
123
124
Sunnyside Area
DENVER & RIO GRANDE R.R.
50
6
WOODSIDE
Woodside Area
R 14 E
R 15 E
R 16 E
R 17 E
T 14 S
T 15 S
T 16 S
T 17 S
T 18 S
T 19 S
BLACK HILL
Matches Canyon
Tuttle Canyon
Price River
BLOOMING MOUNTAIN
Long Canyon
Rock Canyon

In 1970 about 13,600 people lived in the communities below the Book Cliffs (table 1):

Table 1. Towns and population figures, 1960 and 1970, Book Cliffs coal field.

	Population	
	1960	1970
Price-Helper area		
Carbonville	–	500
Castlegate	321	205
Farnham	9	–
Helper	2,459	1,964
Kenilworth	879	500
Mutual	213	–
Price	6,802	6,218
Rains	100	–
Royal	250	–
Spring Canyon	691	–
Spring Glen	400	700
Wellington	1,066	922
	13,190	11,009
Dragerton-Sunnyside area		
Columbia	500	500?
Dragerton	2,959	1,614
Sunnyside	1,740	485
	5,199	2,599

Since 1960 the population of Carbon County has decreased from 21,135 to 15,647. Towns like Mutual, Spring Canyon and Royal have almost completely disappeared. The drop in population is attributed to a decline in the number of miners required by the coal mining industry.

Coal mining is still the principal industry. Other industries are agriculture, government, service and sales. A much smaller work force is employed by transportation companies or the tourist trade. Price is the most diversified of the communities. Most of the government offices, stores and shops, motels and restaurants of the region are located there. Wellington, Woodside and Green River are farm and ranch communities and practically all the rest are strictly coal-mining camps. Helper originated as a transportation center to help move the coal westward over the Wasatch Plateau. The railroad yards are located there still but activity is much reduced when compared to the heyday of the steam locomotive. Distribution of the work force is approximately as follows: government 30 percent, mining and construction 25 percent, farming and ranching 17 percent, trade 16 percent, service, banking, miscellaneous 10 percent, transportation 9 percent and manufacturing 2 percent.

The Denver and Rio Grande Western Railway parallels the Book Cliffs from Green River to Helper and them climbs the Wasatch Plateau through the Price River Canyon. The main line extends from Denver, Colorado, to Salt Lake City. At least three spur lines were built to haul coal. The first leaves the main line at Mounds at the north end of the San Rafael Swell and cuts across Clark Valley easterly to Sunnyside and continues south to Horse Canyon. The other two extend east and west from Helper to Spring Canyon and Kenilworth. A unit train operates on the Sunnyside line and transports coal to the Fontana steel plant at Fontana, California. The unit train operates on a 96-hour cycle, moves the coal 806 miles (round trip distance 1,612 miles) carrying 8,400 tons at a time. The entire load is placed in the railroad cars in less than one hour. A similar arrangement feeds coal from the Geneva mine to the U. S. Steel plant in Utah County.

The major highway serving the area is U. S. Highway 50-6 (figure 2), which, like the railroad, joins Denver, Colorado, with Salt Lake City. It parallels the railroad for the most part below the Book Cliffs and utilizes the same canyon beyond Helper to Colton on the Wasatch Plateau. Along the entire distance between Green River and Colton three roads of importance extend northeasterly. Utah Highway 123, a dead-end road, provides access to the Sunnyside area and the mines at Horse Canyon. Utah Highway 53 extends from 2 miles east of Wellington through Soldier Canyon, parallels Minnie Maud Creek and crosses the Uinta Basin to Myton in Duchesne County, a distance of 71 miles. The highway is paved only to the mouth of Soldier Canyon. Utah Highway 33 extends northward from Castlegate up Willow Creek Canyon to Duchesne, 45 miles distant. Several gravelled roads provide access to the base of the cliffs. They usually lead to abandoned coal mines and the best are presently maintained as service roads for ranchers and hunters. The Book Cliffs are steep with few natural accessways to the top. Most of the canyons that indent the front are much too steep to allow for inexpensive road construction. Both Green River and Price maintain good airports.

Climate

The Book Cliffs coal field is located in a mid-latitude steppe climate and part of the lands below the cliffs approach desert conditions. Precipitation ranges from 5 inches to a maximum of 20 inches annually (figure 3), the difference largely controlled by elevation. The Forge Mountain area northwest of Helper and Bruin Point north of Sunnyside are the only parts of the Book Cliffs that receive more than 20 inches. For the most part along the coal outcrops, 10 to 12 inches of rain are expected. Price receives 9 inches annually and Green River almost 6 inches. The heaviest rainfall can be expected in August, September and October. The summer precipitation is convectional, torrential and does much damage to dirt roads as an initiator of flash floods. During the other months an average of 0.5 inches is expected at Price and an average of 0.38 inches at Green River either as snow or light rain due to cyclonic storms. The driest month is June. As is typical of steppe climates, the rainfall is unreliable; no rain may fall one month and 4 inches may fall in the next.

Temperatures are also a function of altitude. At the base of the cliffs the temperature ranges from a July average of about 75 degrees to a January average of 25 degrees. The average July maximum is more than 90 degrees and the average January minimum is 11 degrees. Compare Price with Green River (figure 4). Green River lies 1,500 feet below Price, is much drier and hotter in the summertime and colder in wintertime. In July or August 100-degree temperatures are common and in January a 20-degree below zero reading is not unusual. The average climatic conditions are shown on the isohyetal map of the area and the climographs of Price and Green River (figures 3 and 4).

HISTORICAL OUTLINE

Coal was discovered in the Wasatch Plateau in 1874 and the Winterquarters mine in Pleasant Valley was opened in 1878. Exploration for coal spread to the Book Cliffs. The Castle Gate mine was opened in 1889 and the small sizes of coal were crushed into dust and made into coke. The coke was not of good quality but had geographical advantage to west markets. In 1890, eighty 8-foot beehive ovens were erected and by 1900 an additional one hundred and twenty-four were built. Continued exploration of the field revealed that coal in the Sunnyside area was of superior quality for coking. The Sunnyside coking coal was discovered in 1898 and eventually coking operations shifted there. In 1919 the Sunnyside coke plant was the largest single beehive in operation in the United States with eight hundred and nineteen 12- to 13-foot ovens. Originally the coal was hauled to Castlegate for coking, but in 1903 the process was started near the mine. Production continued to increase in the Castlegate area as the coal was extremely hard, kindled easily and burned brightly. The coal was much sought after and regarded as having no equal west of the Mississippi River for domestic or steam purposes.

The coal was usually discovered away from settled areas and companies built towns for employees. Immigrants were brought in and by 1909 they made up over half the labor force. Production from mines generally increased until 1920 when 6 million tons

Figure 3. Rainfall map, Book Cliffs coal field (isohyetals in inches).

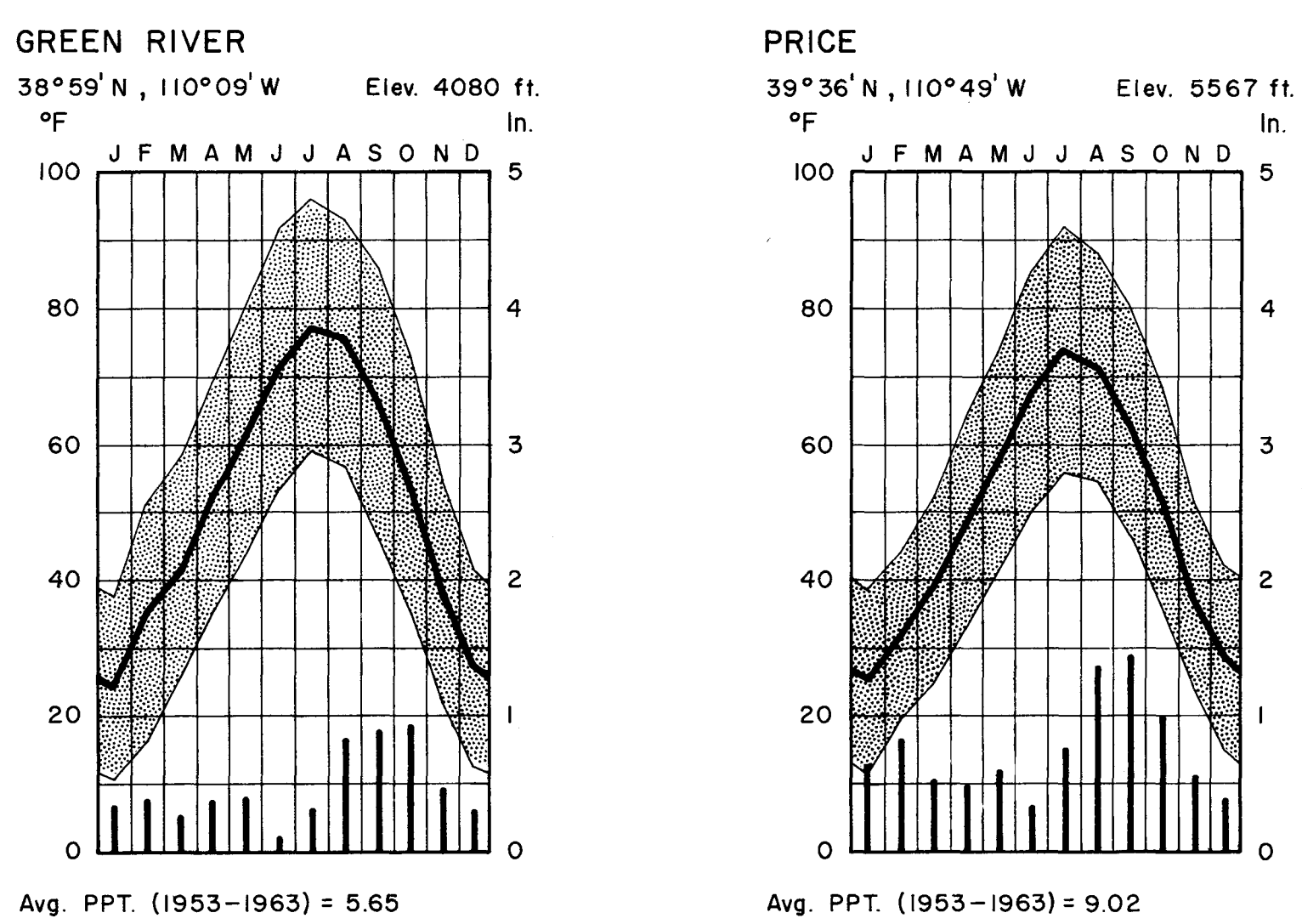


Figure 4. Climographs of weather stations near the Book Cliffs coal field (based on U. S. Weather Bureau data, 1953 to 1963).

were produced in Utah, mostly from Carbon County. The industry declined during the 1920's and 1930's as the competition of petroleum fuels and natural gas increased. In spite of this, Utah coal competed successfully for the remaining market with other western mines and at the end of the 1930's had some of the best equipped mines, highest paid workers and best safety conditions in the U. S.

World War II brought Utah production back to 6 million tons and the mines enjoyed a golden age until 1957 when production again declined. Rising costs, competition with foreign countries for foreign markets and further incursions by competitive fuels all added to the problem. The mines of the Book Cliffs up to the present have produced 75 percent of Utah's coal annually, primarily from the Castlegate and Sunnyside areas. At present the outlook for coal is believed on the upswing as the country's power needs increase and reserves of competitive fuels fail to increase accordingly.

In 80 years of concentrated coal mining, more than 200 million short tons have been extracted from the coal measures of the Book Cliffs field. Although much coal remains, the more cheaply mined reserves are rapidly being depleted.

GEOLOGIC SETTING (figure 5)

Stratigraphy

Rocks exposed on the quadrangles in this report range in age from the lowermost Upper Cretaceous to Early Tertiary (figure 6). The commercial coal seams, however, are in a single unit, the Cretaceous Blackhawk Formation. A short discussion of all units should aid in unit recognition, in understanding the geologic history and in explaining some of the phenomena associated with the coal. Older Cretaceous units, the Dakota Sandstone and the Mancos Shale, occur in Clark Valley and extend to the foot of the cliffs. Here the shales are terminated by the initial sandstones of the Mesaverde Group.

Even where the sandstone is thin it serves as a protecting cap to the buttes, and in many places the underlying clay marl stands in perpendicular columnar walls 100 feet or more in height. The soft layers in the marl weather out in parallel bands in the cliffs leaving the hard layers as projecting ledges. Thus the cliffs simulate rows of gigantic books (Taff, 1906, p. 290).

The Mesaverde Group, consisting of the Star Point Sandstone, Blackhawk Formation, Castlegate Sandstone and Price River Formation, makes up the steep part of the cliff and Tertiary units primarily make up the uppermost surfaces, ledges and cliffs. These ledges comprise the outer south edge of the Uinta Basin and are named Badland Cliffs, Roan Cliffs, etc.

Dakota Sandstone

The Dakota in this area is regarded as lowermost Upper Cretaceous. It is a thin, resistant, cuesta-making, heterogeneous formation that rests upon the Lower Cretaceous Cedar Mountain Formation. The Cedar Mountain was previously considered a part of the Jurassic Morrison shown to be otherwise by Stokes (1944). The Dakota overlies the Cedar Mountain unconformably, although it appears as if the contact is otherwise in many places, and consists of alternating quartzitic sandstone, conglomerate and shale. The sandstone is calcareously cemented, grades from a hard black quartzite to a light gray friable rock. Varicolored conglomeratic pebbles to 4 inches in diameter have been located. The shales range from a light greenish gray to dark gray.

System	Series	Stratigraphic unit	Thickness (feet)	Description
TERTIARY	Eocene	Green River Formation	–	Greenish gray and white claystone and shale, also contains fine-grained and thin-bedded sandstone. Shales often dark brown containing carbonaceous matter. Full thickness not exposed.
		Colton Formation	300-2,000	Colton consists of brown to dark red lenticular sandstone, shale and siltstone, thins westwardly and considered a tongue of the Wasatch.
		Wasatch Formation	3,000	Wasatch predominantly sandstone with interbedded red and green shales with basal conglomerate. Found in east part of field and equivalent to Colton and Flagstaff in west.
	Paleocene	Flagstaff Limestone	0- 500	Flagstaff mainly light gray and cream colored limestones, variegated shale, and fine-grained, reddish brown, calcareous sandstone.
		North Horn Formation	350-2,500	Gray to gray green calcareous and silty shale, tan to yellow-gray fine-grained sandstone and minor conglomerate. Unit thickens to west.
		MINOR COAL		
	Danian	Tuscher Formation	0- 200	Light gray to cream-white friable massive sandstone and subordinate buff to gray shale that exhibits light greenish cast. Contains minor conglomerate and probably represents lower part of North Horn, only present in east part of field.
	Maestrichthian	Mesaverde Group: Price River Formation *MINOR COAL*	500-1,500	Yellow-gray to white, medium-grained sandstone and shaley sandstone with gray to olive green shale. Contains carbonaceous shale with minor coal and thickens along east edge of field.
		Castlegate Sandstone *MINOR COAL*	100- 500	White to gray, fine- to medium-grained, argillaceous massive resistant sandstone thinning eastwardly with subordinate shale. Carbonaceous east of Horse Canyon but coal is thin and lignitic.
	Campanian	Blackhawk Formation *MAJOR COAL SEAMS*	600-1,100	Cyclical littoral and lagoonal deposits with six major cycles. Littoral deposits mainly thick-bedded to massive cliff-forming yellow-gray fine- to medium-grained sandstone, individual beds separated by gray shale. Lagoonal facies consist of thin- to thick-bedded yellow-gray sandstones, shaley sandstones, shale and coal. Coal beds form basis of Book Cliffs coal field. Unit thins eastward grading into the Mancos Shale.
		Star Point Sandstone	0- 580	Yellow-gray massive medium- to fine-grained littoral sandstone tongues projecting easterly separated by gray marine shale tongues projecting westerly.
CRETACEOUS		Masuk Tongue Mancos Shale	4,300-5,050	Gray marine shale, locally heavily charged with carbonaceous material, slightly calcareous and gypsiferous, nonresistant forming flat desert surfaces and rounded hills and badlands. Separated mainly to the west into tongues by westward projecting littoral sandstone which eventually grade into shale. Sandstones are fine- to medium-grained, yellow-gray to tan and medium-bedded to massive and cliff forming.
		Emery Sandstone		
	Santonian	Garley Canyon Sandstone		
	Coniacian	Blue Gate Shale		
	Turonian	Ferron Sandstone *MINOR COAL*		
		Tununk Shale		
	Cenomanian	Dakota Sandstone	2- 126	Heterogeneous sandstone, conglomerate and shale, thin resistant cuesta former.

Figure 5. Generalized section of rock formations, Book Cliffs coal field.

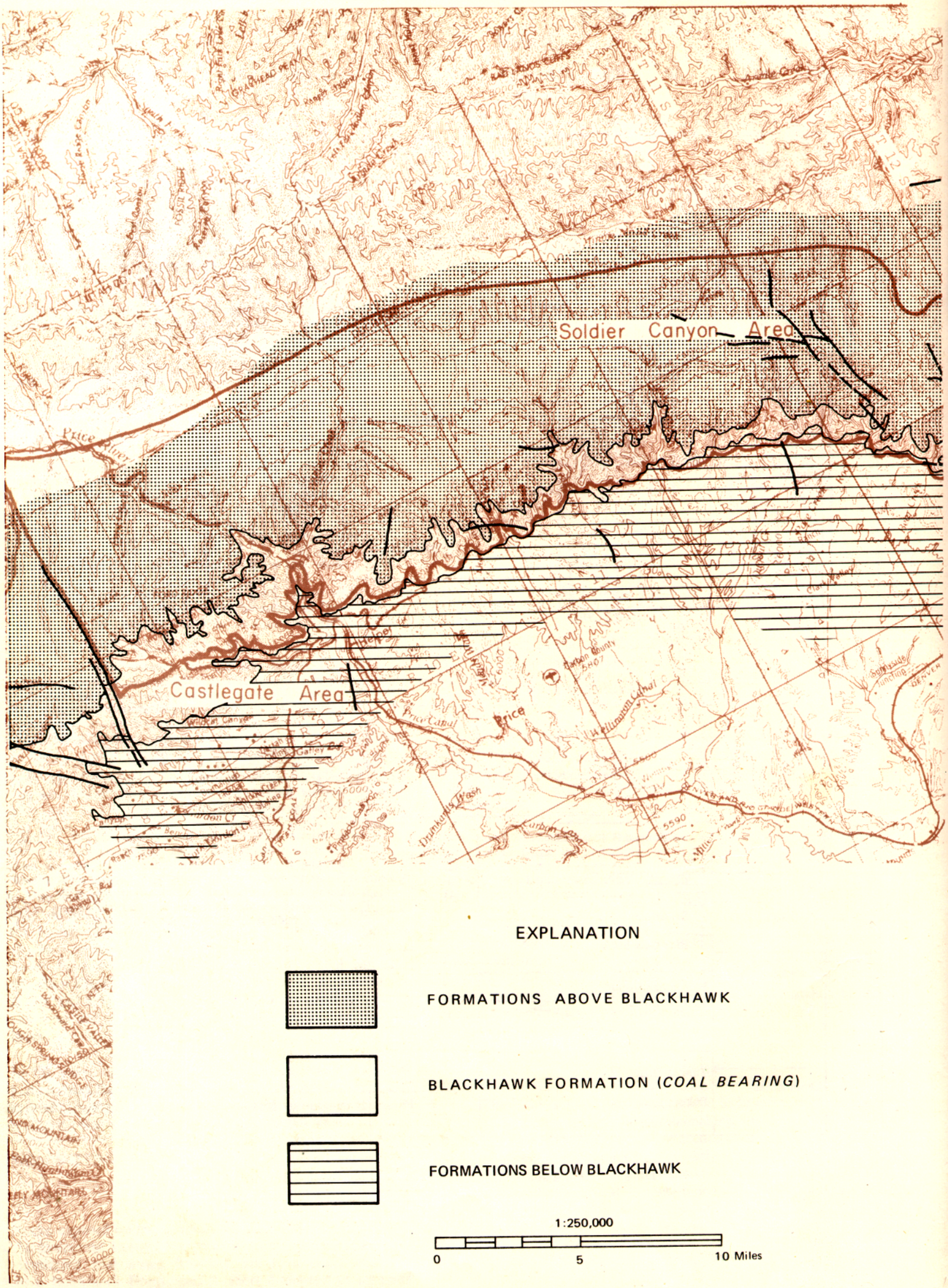


Figure 6. Generalized geology map, Book Cliffs coal field.

R 15 E
R 16 E
R 17 E
T 13 S
T 14 S
T 15 S
N
Outline of Coal Field
Sunnyside Area
Woodside Area
Grassy Trail Creek

The outcrop area of the Dakota surrounds the north end of the San Rafael Swell, 4 to 12 miles south or west of the Book Cliffs. In some areas of Utah the Dakota is coaliferous, but none has been reported from this area. In the Farnham anticline, a structure which extends northward into Clark Valley as an extension of the San Rafael Swell, the unit is 15 feet thick. It fluctuates in thickness with an apparent thickening eastward. The State Geologic Map of Utah, SE quarter (Hintze and Stokes, 1964), shows it pinching out on the east flank of the swell and Fisher (1936, p. 10) indicates the thickness ranges from 2 to 126 feet. His studies, however, extend to the Colorado border and the Dakota may not achieve that thickness between the Green River and the Farnham anticline.

Mancos Shale

The Mancos is a thick (4,300 to 5,050 feet) unit in its exposures below the Book Cliffs of this area. Most of the Mancos is a shale of varying shades and hues of gray, locally heavily charged with carbonaceous material. The material ranges from a fine clay to siltstone. Rather than being shaley it is nodular or massive in its fresh surface appearance. It is often calcareous and gypsiferous. The dominantly marine unit is nonresistant and forms flat desert surfaces or low rounded hills. Where protected by an overlying sandstone unit it forms badland cliffs. Impervious to water infiltration it supports little vegetation. Water falling on it produces a layer of mud at the surface which dissolves chemical matter from the shale. Later, as the mud dries, it forms white patches or efflorescences of alkali. Flash floods crossing Clark Valley cut into the soft unit creating deep gullies with almost vertical walls that cannot be crossed easily. Nevertheless, farming is carried out in Clark and Castle valleys in areas where enough unconsolidated material has mixed with the clay soil to change its texture.

Sandstone tongues project into the Mancos Shale at intervals and, in the west part of the field, divide members. These are littoral to lagoonal in nature and some may contain thin coal beds or carbonaceous units. The sandstone beds immediately above the Mancos (Star Point and Blackhawk) are littoral units as well. These littoral sandstone beds thin toward the east and often pinch out. Part of the Mancos thus becomes younger and transgresses time lines from west to east.

The lowermost sandstone tongue of the Mancos is called the Ferron Sandstone. It is the most extensive of the Mancos tongues and parallels the Book Cliffs in outcrop along the entire length of the field. The Ferron lies 400 to 800 feet above the Dakota contact. The shale member below the Ferron is termed the Tununk Shale. The Ferron is 25 to 30 feet thick in the Farnham area and probably varies from 25 to 150 feet, thickening to the south and west. To the southwest, south of the town of Ferron in Emery County, it is coaliferous and contains the thick beds of the Emery coal field and Henry Mountains coal field. It is basically a yellow-gray calcareous sandstone, interbedded with thin gray shales. Individual sandstone beds are thin- to thick-bedded and the unit forms a prominent cuesta. The Ferron south of the Book Cliffs outcrops is mostly littoral and devoid of coal. A large acreage of state land coal leases are held southwest of Price behind the Ferron outcrops and possibly thick coal may be present in the subsurface there. The Ferron coal is discussed in the Emery coal field report.

The next sandstone tongue is that of the Garley Canyon Member. According to Clark (1928, p. 112):

> It extends in outcrop from the bench north of Price westward to Garley Canyon, and thence southward to sec. 10, T. 15 S., R. 9 E., where it thins out and disappears, merging with the enclosing shale of the Mancos Formation. The sandstone is a lens in the cross section represented by exposures of it, but it probably represents a peninsula of sandy beaches extending out into the Mancos sea from the mainland on the west. Its eastern limit is somewhere under the bench north of Price. . . The Garley Canyon Sandstone consists uniformly of two beds of massive sandstone separated by a layer of shale.

The massive sandstones are cliff formers, yellow-gray in color and probably thicken westward in the subsurface. The Garley Canyon Member is about 1,800 feet above the Ferron.

The next sandstone member within the Mancos is the Emery, 400 feet above the Garley Canyon. It too is limited in its outcrops in the area of the Book Cliffs. It is first recognized in the bench north of Price and gradually thickens westward and southward. It consists of at least three separate sandstone beds near Helper, each separated by 50 feet of shale. The lower bed is 25 feet, the next 15 feet and the upper bed 5 feet thick. The Emery does not crop out in the east part of the field. The first sandstone units of the Mesaverde Group occur about 800 feet above the Emery near Price River Canyon.

Star Point Sandstone

This formation is only present in the west portion of the field and pinches out in the middle of the Soldier Canyon area. The unit consists of three sandstone tongues (in ascending order): the Panther, Storrs and Spring Canyon. The Spring Canyon Tongue is traceable westward from Soldier Canyon and at this east location consists of impure limestone concretions and thin beds of sandy shale and sandstone. It forms a cliff in the Kenilworth-Spring Canyon area where it attains a thickness of 100 to 125 feet. Individual beds are in 1- to 10-foot thicknesses with the thinner beds near the bottom.

About 150 feet higher is the Storrs Tongue, the middle interval consisting of Mancos-like shale. It disappears a few miles east of Kenilworth and thickens westward. At Storrs in Spring Canyon the member is 30 feet thick. Both Spieker (1931) and Clark (1928) placed the Spring Canyon Tongue in the Star Point Sandstone so that the initial coal unit was also the initial unit of the Blackhawk Formation. Young (1955) notes six cycles in the Blackhawk and that the Spring Canyon starts the first. He, however, notes that the change of the upper boundary is impractical to the west and south in the Wasatch Plateau where the three members unite. Since the tongues extend only 20 to 30 miles eastward, all three tongues are maintained as Star Point units in this report. The Spring Canyon Tongue is 150 feet thick in Spring Canyon, thins eastward and pinches near Soldier Canyon. The shale interval between the Storrs and Spring Canyon varies but averages about 100 to 125 feet.

Blackhawk Formation

By virtue of the coal it bears, this formation is the most important unit in the coal field. The best analysis of the unit originates with Young (1955, p. 183-186) and many of his findings are reiterated here. In his discussion he includes the Spring Canyon Tongue, here carried with the Star Point Sandstone, with the Blackhawk. With this tongue he includes six prominent littoral marine sandstone tongues with several minor ones projecting eastward into the Mancos Shale. These sandstone tongues in their eastward extension grade into shale and thus lose their identity (figures 7 and 8). The interval between each tongue consists of lagoonal deposits of sandstone, shale and coal. The top sandstone ledge below the lagoonal deposits is invariably bleached white. The six members from the highest to the lowest include: Desert, Grassy, Sunnyside, Kenilworth, Aberdeen and Spring Canyon members.

These members can be subdivided only where the littoral sandstone tongues are present and each is limited in extent. As a general rule the lower members are more easily identifiable to the west and the upper members are more easily identifiable to the east.

The lowest member, the Spring Canyon, consists of 60 to 100 feet of coal-bearing shales and sandstones. The coal beds in the member thin out eastward and are replaced by two massive offshore bar sandstones near Helper which mark the east limits of

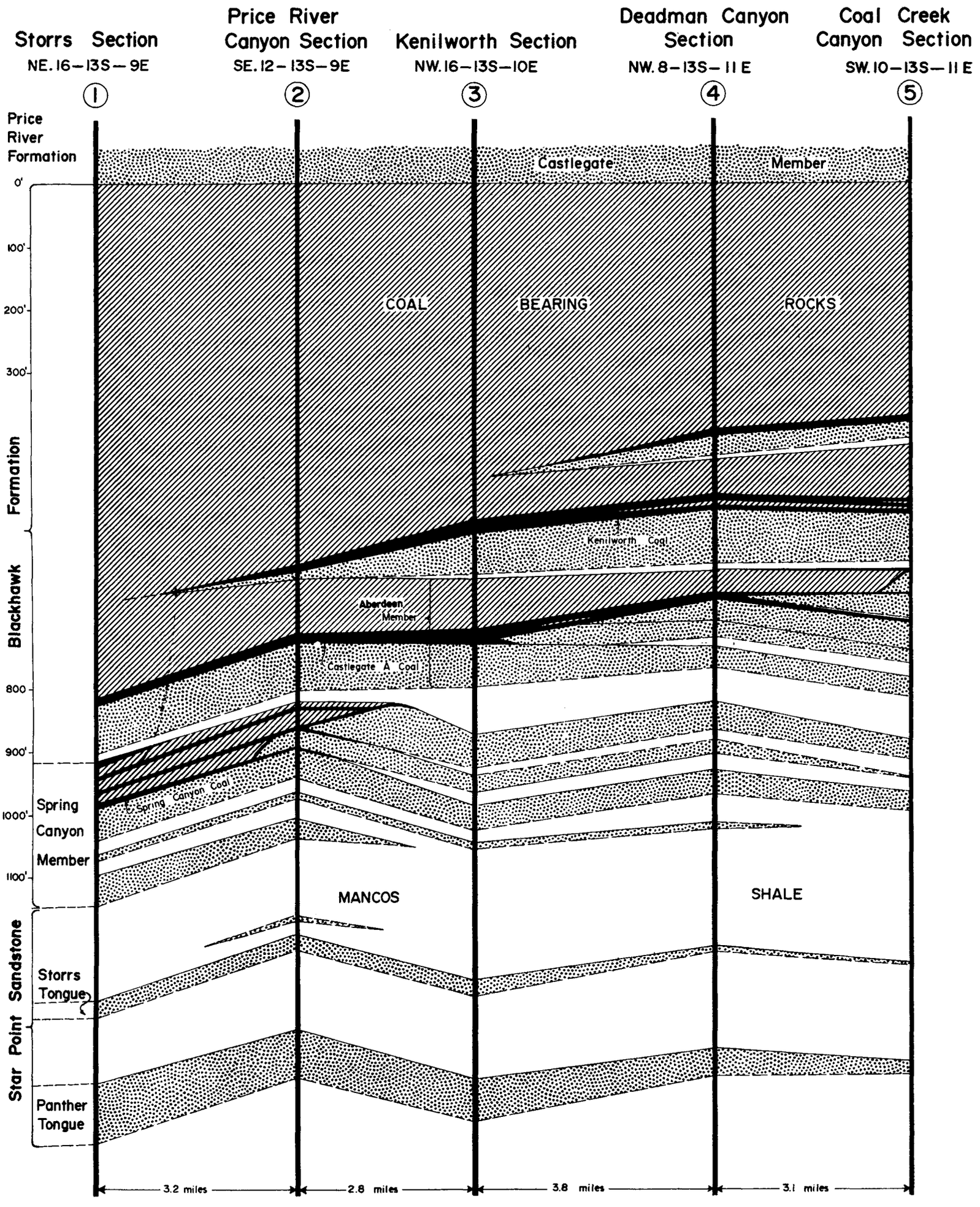


Figure 7. Stratigraphic diagram showing details of intertonguing in the Book Cliffs coal field (after Young, 1955).

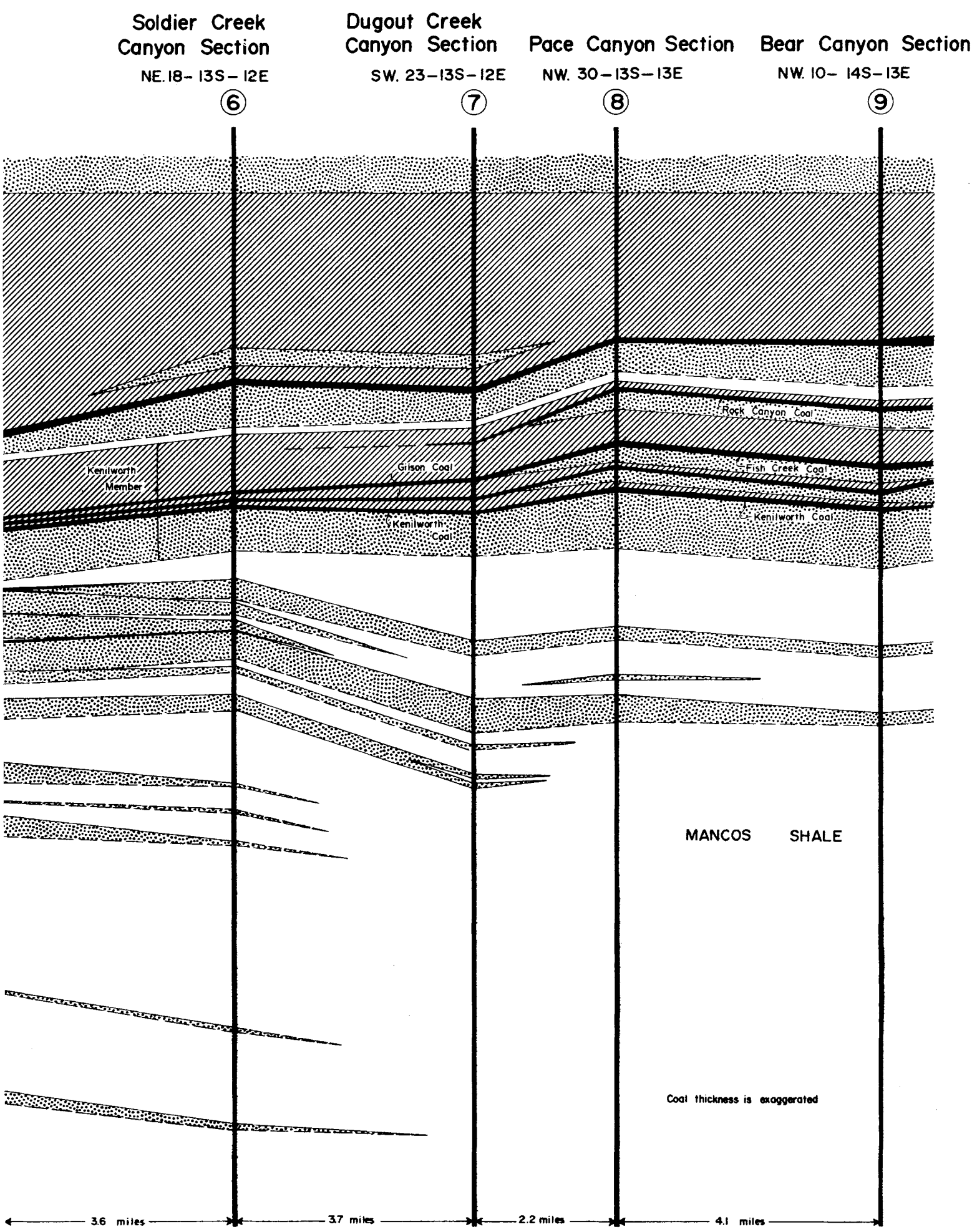
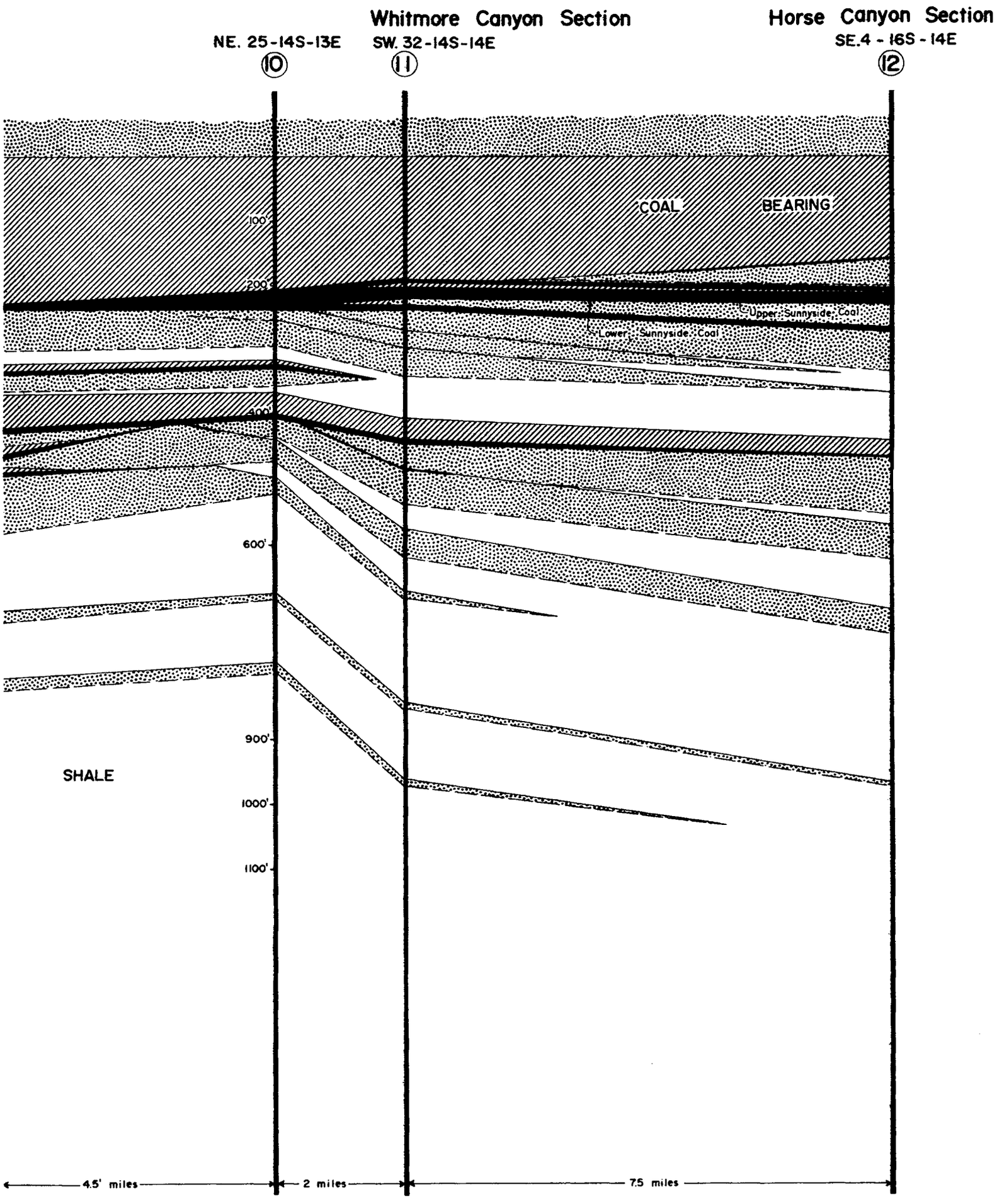


Figure 7. (continued)



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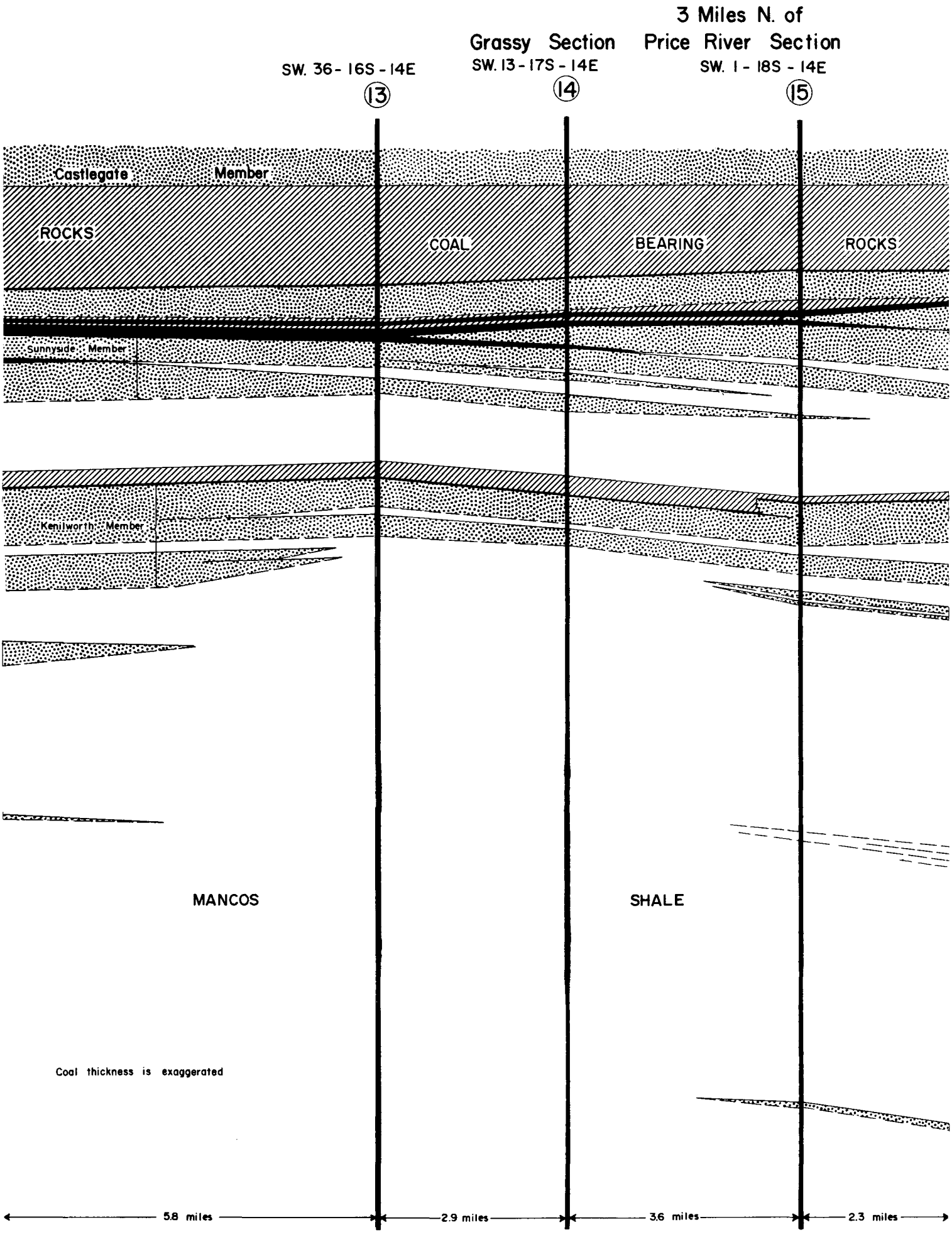

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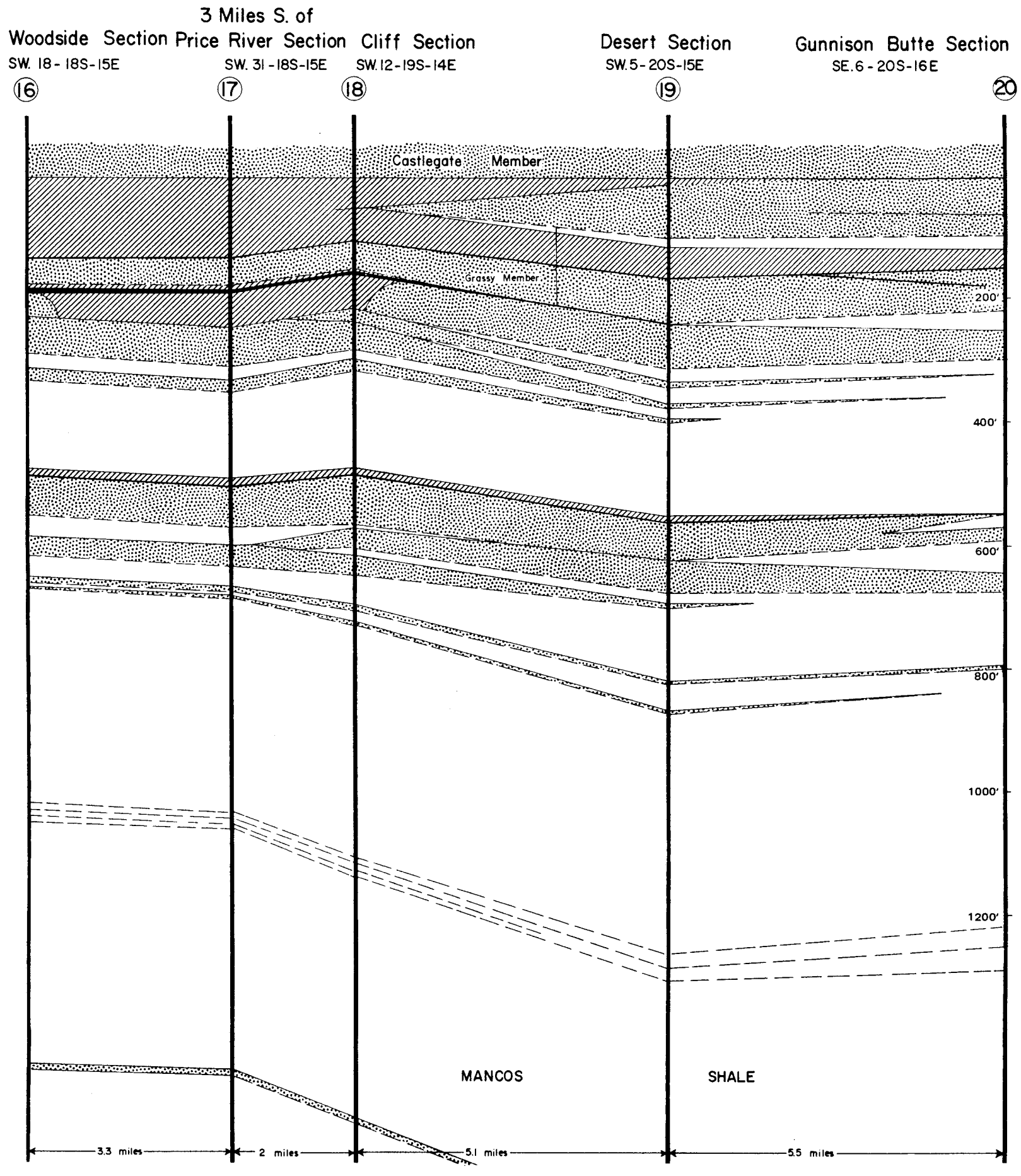

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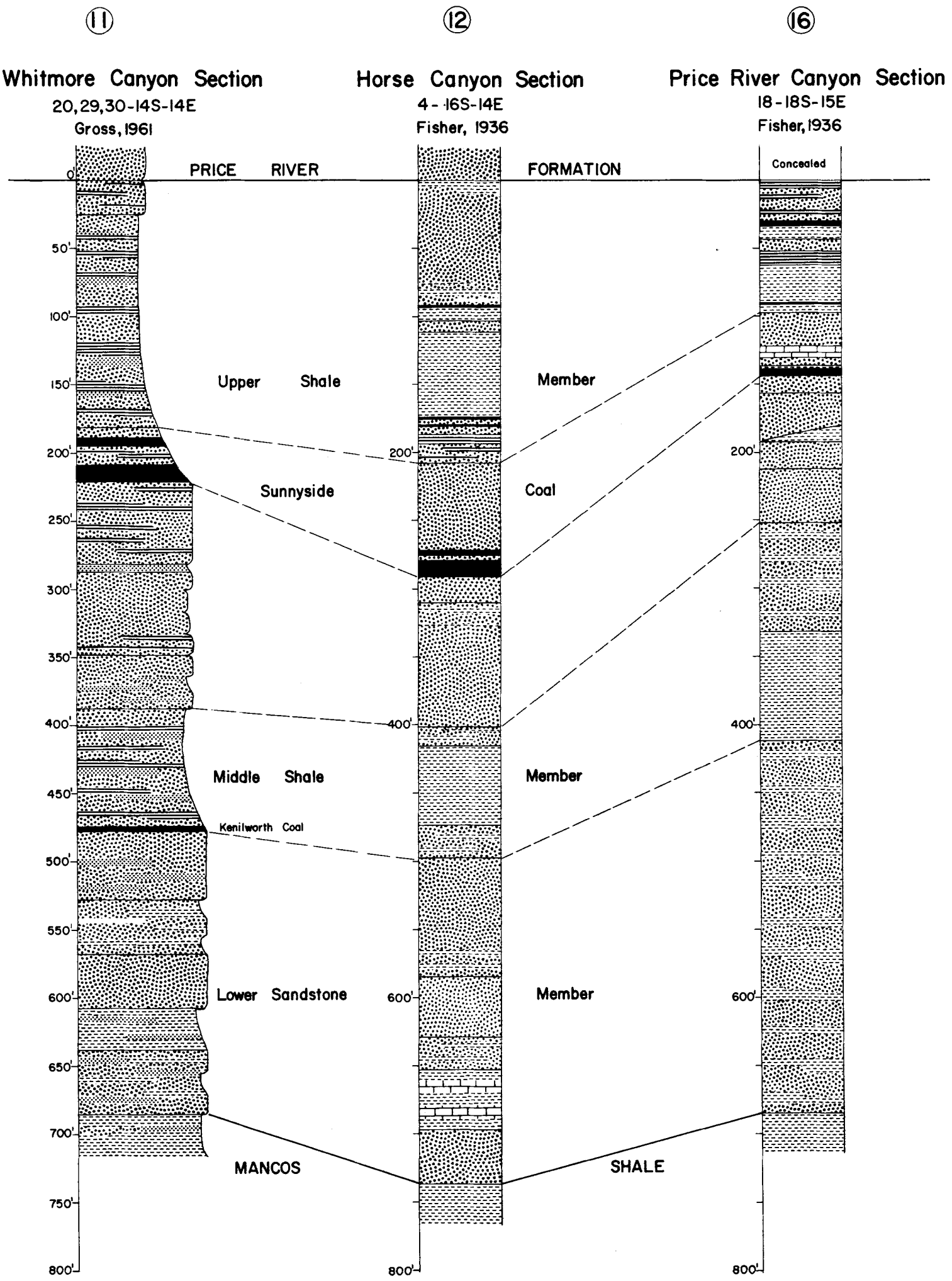


Figure 8. Supplemental sections of the Blackhawk Formation (see figure 7).

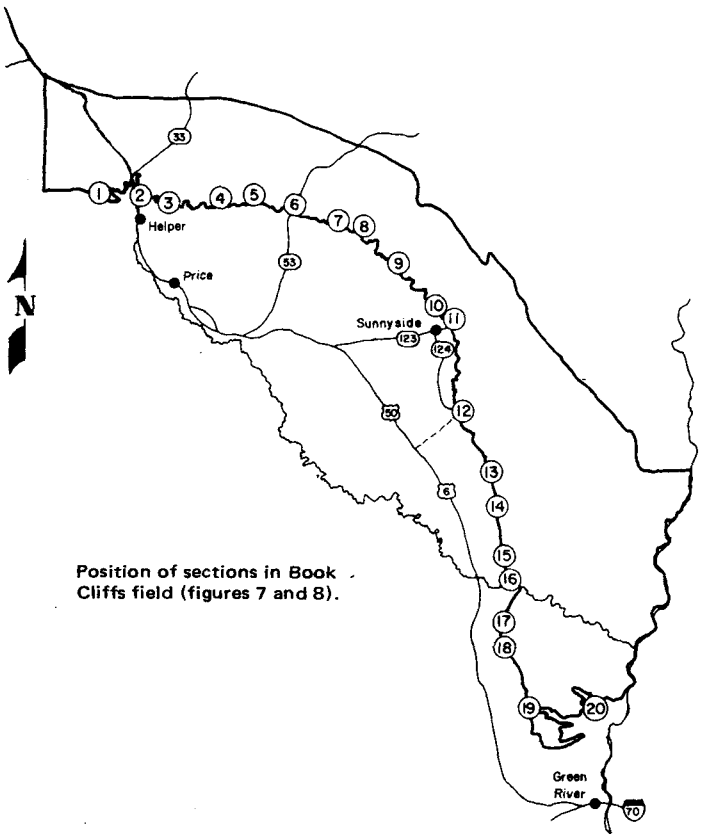


Figure 8. (continued)

coal-producing swamps in that sequence. The next member, the Aberdeen, consists of 88 feet of sandstone topped by 100 feet of shale, sandstone and coal near Kenilworth. The Aberdeen Sandstone first appears in the west part of the field and may be recognizable in the Gordon Creek area of the Wasatch Plateau field. It extends eastward to Dugout Canyon a few miles east of Soldier Canyon where it grades into the Mancos. The coal beds are replaced by five bar sandstones between Kenilworth and Coal Creek Canyon that are consequently replaced by Mancos-like shale. The Kenilworth Member has a lower sandstone which reaches a maximum of 85 feet thick and disappears eastward near Sunnyside. The coal-bearing beds become important near the west end of the field, thicken and extend eastward only to thin east of Cordingly Canyon. Farther eastward the beds grade into Mancos-like shale and eventually become a part of that formation. Thin coal is recognized as far east as the Beckwith Plateau. Four minable beds are known in the Kenilworth Member. The interval of sand, shale and coal reaches a maximum thickness of 160 feet.

The next member, the Sunnyside, has its sandstone bed reaching a maximum of 50 feet at Pace Canyon. It first appears near Kenilworth, extends eastward by splitting into two tongues and finally gives way to the Mancos near Horse Canyon. The lagoonal rocks are relatively thin, 25 feet, which are replaced east of Sunnyside. These beds contain two important coal beds, however. The Grassy Member is 110 feet thick near the Grassy siding of the D&RGW Railroad 6 miles north of Woodside. The lower sandstone, 60 feet thick, first appears at Sunnyside but grades into the Mancos on the east side of the Green River Canyon. Only a few thin coal beds are present in the upper 50 feet. The final member first appears near the Desert siding of D&RGW Railroad 12 miles south of Woodside at the south end of the coal field. The sandstone reaches a maximum of 70 feet and gives way to the Mancos eastward at Saleratus Canyon east of the Green River. The entire Blackhawk finally disappears in that direction. Fifty feet of coal-bearing rocks present at Desert thin rapidly eastward. At Green River the overlying Castlegate Sandstone rests directly on the sandstone beds of the Desert Member. The lagoonal beds contain many thin, unminable lenses of coal. Young's beds are not easily recognizable south of Sunnyside and Fisher's subdivisions are more easily recognized. The Kenilworth is a lower sandstone, followed by a middle shale. The Sunnyside cliff-forming sandstone (middle sandstone) follows with its coal beds near the top. The lagoonal sequence that follows, including thicker sandstone beds, is called the upper shale or Beckwith zone.

In the Castlegate area the Blackhawk ranges from 900 to 1,300 feet thick; the upper members are not definable. Better coal beds are assembled in the lower 500 feet because the coals are best developed above thick sandstone members. In the Soldier Canyon and Sunnyside areas the Blackhawk has thinned to 500 to 1,000 feet of rock and to the south it thins farther. Near the south end of the Beckwith Plateau 170 to 475 feet of Sunnyside, Grassy and Desert members are underlain by 100 to 260 feet of Mancos-like shale, followed by a littoral sandstone tongue 150 to 170 feet thick. This lower tongue (Kenilworth Sandstone) quickly disappears east of Green River.

Each sandstone tongue is usually medium-grained yellow-gray sandstone, bleached white at the top. Most are thick-bedded to massive at the top and gradually become more thin-bedded near the bottom. Near their eastward terminus they become finer-grained, eventually reverting to siltstone and finally into Mancos Shale. The lagoonal sandstones are medium- to fine-grained, yellow-gray to brown, shaley to thick-bedded. The shales contain varying amounts of carbonaceous matter which determines their color. The coal beds are more fully discussed in the Coal Seams section.

Castlegate Sandstone

The Castlegate Sandstone is a mappable, fine- to medium-grained, argillaceous to slightly calcareous, normally massively bedded unit found disconformably above the Blackhawk in the west part of the field. The sand grains are usually subangular quartz often with abundant coal particles. A lagoonal facies appears near Horse Canyon which extends eastward across the boundaries of the field. In the lagoonal facies carbonaceous shale and siltstone are common. Any coal beds present are thin and lignitic. Thus the unit is fluvial to the west and becomes lagoonal to the east; still farther east near Thompson, it reverts to a littoral sandstone only to grade into the Mancos a short distance east of the Utah-Colorado line.

The thickness of the Castlegate ranges from 500 feet near Helper to less than 100 feet near Green River. The unit thickens to the north and west. It is an easily recognizable cliff former and marker bed in most places. It takes its name from a gate-like passage in the Price River Canyon formed by a vertical cliff of this sandstone.

Price River Formation

Conformably overlying the Castlegate is a series of beds made up of sandstone, shale and sandy shale. Some of the individual sandstone beds, as much as 100 feet thick, are much like those of the Castlegate. The shales are mostly gray in color but in some areas become olive green. West of Woodside the unit is considered fluvial in origin and contains no coal. East of Woodside, coal-bearing rocks begin to appear at stratigraphically higher levels. The thickness of the Price River is 950 to 1,000 feet near the west edge of the coal field, thins to 516 feet near Sunnyside but then thickens to more than 1,700 feet near Thompson, 25 miles east of the Green River, where it contains important coal seams. The coal beds west of the Green River are too thin to be mined. In the Thompson area the Price River is subdivided into members: the Buck Tongue of the Mancos, the Sego Sandstone Member, the Neslen Member and the Farrer Member. Some of the members are identifiable in the Beckwith Plateau north of Green River.

Tuscher and North Horn Formations

Dependent on location, the Price River is overlain by the Tuscher or North Horn Formation. Fisher (1936, p. 20) named

the Tuscher after a canyon just east of the Green River. The rock involved is a series of nonfossiliferous light gray sandstones separated by thin beds of shale. He noted that the upper and lower contacts were obscure and that no pronounced erosional unconformity was seen at either the top or bottom of the unit. Fisher's description follows:

The Tuscher Formation is largely quartz sandstone but contains buff to gray shales that in many places show a very light greenish cast. The sandstone is typically massive, cross-bedded, friable, and light-gray to creamy white and weathers to rounded surfaces. Rare layers are conglomeratic, carrying a few pebbles of quartz and black chert as much as 1 inch in diameter. The presence of conglomerate and the fact that the sandstones closely resemble those of the Wasatch (North Horn-Flagstaff-Colton) favor assignment of these beds to the Tertiary.

Young (1955, p. 192) notes that the Tuscher is a light-colored, conglomeratic sandstone about 200 feet thick resting unconformably on the Price River beds. The disconformity is not recognized west of the Green River. Gross (1961, p. 30) indicates the sandstones of the Tuscher are often conglomeratic and coarser than underlying beds and contain black, gray or brightly colored chert or quartz. The Tuscher occurs in the east part of the Book Cliffs field, first appearing near Horse Canyon.

To the west the Price River beds are overlain by the North Horn Formation. The North Horn is a series of shale, sandstone, minor conglomerate and freshwater limestone. The shales are mostly gray or gray-green and are usually calcareous and silty. The sands are fine-grained with a tan to yellow-gray color. The limestones increase in the upper part of the unit. A few thin coal beds outcrop in the unit in Price River Canyon. The North Horn represents fluvial and lacustrine environments of deposition and grades imperceptibly down into the Price River and up into the Flagstaff. It has been noted that the basal part of the unit is probably equivalent to the Tuscher. The North Horn is 2,500 feet thick in the northwest corner of the Book Cliffs field and thins to 400 feet at Sunnyside. At Grande Mesa in Colorado the North Horn is only 200 feet thick (Young, 1955, p. 192).

In the lower part of the North Horn, Upper Cretaceous fossils were located and in the upper part, Tertiary fossils were identified. The unit therefore straddles the time line. In the east part of the field the Mesozoic-Cenozoic line probably also lies in the Tuscher-North Horn sequence, but the position is not known. It may be in the Tuscher or in the North Horn part of the sequence.

Flagstaff Limestone

Clark (1928) did not differentiate the Wasatch in his study of the Sunnyside to the Castlegate part of the field. He grouped the North Horn, Flagstaff and Colton into the Wasatch Formation. The Flagstaff is the product of a lacustrine environment and consists of thin-bedded limestones, shales and sandstones. The shales are varicolored and interbedded with the microcrystalline limestone. The less abundant sandstones are calcareous, fine- to medium-grained and reddish brown. The Flagstaff thins from west to east, being 500 feet thick in Price River Canyon and 140 feet thick at Sunnyside, disappearing completely farther east. The contacts are gradational and the unit is dated as Paleocene-Eocene.

Colton-Wasatch Formations

The Colton Formation overlies the Flagstaff in the north and west parts of the field and the Wasatch overlies the North Horn in the east and south parts. Gross (1961, p. 35-37) summarized the relationships; excerpts from his dissertation are repeated here:

The Colton Formation is a fluviatile deposit in the northern part of the Wasatch Plateau. It consists of lenticular sandstone, shale and siltstone. The colors of the various lithologies are predominantly brown and dark red with some yellow. The Colton has a maximum thickness of approximately 2,000 feet along the Green River, but thins westward by intertonguing with, and grading into, the Green River Formation ... Near the Green River the Wasatch Formation is approximately 3,000 feet thick and is predominantly sandstone with interbedded red and green shales and a conglomerate at the base. . .East of Sunnyside, Utah, the Colton Formation is equivalent to approximately two-thirds of the Wasatch Formation. . .The Colton is apparently a tongue of the Wasatch Formation which may be both Wasatch and Flagstaff in age. . .

Spieker (1931) notes that the Colton in the Wasatch Plateau area ranges from 300 to 1,500 feet thick. The Colton thins westward by grading into the overlying Green River Formation. The age of both Wasatch and Colton is probably Eocene.

Green River Formation

The uppermost consolidated unit exposed in the mapped areas of the Book Cliffs field is the Green River Formation. The unit is thick and extensive with outcrops covering one-third of the Uinta Basin. It is gradational with the underlying Wasatch or Colton and forms the crest and dip slope at the south end of the basin. The basal part of the unit exposed in the mapped areas is made up of pale greenish gray mudstone and thin-bedded shale of lacustrine origin interbedded with fluvial sandstone. Also subordinate thin-bedded hard limestone occurs. Fossil leaves and other plant remains are common in the unit. The Green River often contains oil shales and in the Sunnyside area the sand beds as well as the underlying Colton-Wasatch beds are saturated with bitumen.

Surficial Deposits

The most common unconsolidated deposits are the gravel benches on mesas of Mancos Shale in Clark Valley. The Mancos was apparently buried beneath sheets of gravel, at times reaching a temporary base level. Later the situation changed and new vigorous erosion cut the gravel surface and all that remains presently are the benches. The gravel varies to 50 feet thick and is made up of former constituents of the Mesaverde Group formations.

The major stream channels and many of the minor drainageways are filled with alluvium. In addition along the cliff sides are landslides, mudflows and similar deposits. Only the largest surficial deposits were mapped.

Structure

Basically the Book Cliffs are a homocline dipping into the Uinta Basin with the cliff front roughly paralleling the strike of the feature. Except for some medium-displacement faults near Sunnyside, faulting is local and of minor displacement (figure 9).

Folds

East of the Price River the coal-bearing rocks of this (Castlegate) quadrangle strike east and dip 4°-5° N. West of Price River there is a local anticlinal nose with an accompanying synclinal reentrant, and west of this small flexure the strike swings to the northwest. In the vicinity of Castlegate the rocks dip about 6° N., but elsewhere they dip north and northeast from 4° to 5° . . .(Clark, 1928, p. 120).

The rocks in these quadrangles (Wellington and Sunnyside) form a part of the northern and northeastern flanks of the San Rafael Swell and dip east, northeast and north. . .The coal-bearing rocks strike north from the south boundary of the Sunnyside quadrangle to Sunnyside, where the strike is abruptly deflected to the northwest. It holds this trend to Rock Canyon, where another deflection swings the strike due west. The surface rocks dip 12° NE at Sunnyside, but the dip gradually decreases in all directions, being about 3° E at the south edge of the Sunnyside quadrangle, 4° N at the west edge of the Wellington quadrangle and 2° NE at the northeast corner of the Sunnyside quadrangle. The abrupt change in strike at Sunnyside produced several faults or displacements in the surface rocks (Clark, 1928, p. 23).

South of the Sunnyside quadrangle the rocks continue to strike north until just before reaching the south end of the Beckwith Plateau. Dips range from 3 to 12 degrees. The strike swings to the northwest and finally east-west at the Green River.

Faults

Examination of a geologic map shows an occasional fault cutting the coal measures which, for the most part, are unimpor-

tant or of small displacement. The most serious group of faults lies in the area of Sunnyside where two steeply dipping fault sets occur; the first trends north-northwest, the second east-northeast. The maximum separation is 200 feet but on most faults is much less. Although a hindrance to mining, they fortunately are not too closely spaced. A major fault with about 4,000 feet of displacement located in the subsurface southwest of Sunnyside does not affect the coal (Osterwald and Dunrud, 1966, p. 99).

Unconformities

No prominent unconformities exist in the Book Cliffs coal field. A few disconformities not easily found by investigators may not be continuous throughout the area. Since they do not affect the coal, discussion of them is omitted here. Katich (1954), Young (1955) and Gross (1961), however, deal with them.

GEOLOGIC AND TECTONIC HISTORY

During the Triassic and Jurassic periods, the area of the Book Cliffs was relatively stable but gradually subsiding and receiving sediments. The area is assumed to have been a relatively flat lowland experiencing mostly continental conditions. Occasionally a shallow sea spread over the area but the duration of its existence was usually short geologically. A thick redbed sequence suggests tropical conditions and great thicknesses of sand accumulation suggest arid conditions. The sediments probably came from all directions during the Triassic, but during the Jurassic the major source areas lay to the west and south. The surface picture of the Book Cliffs area commences with the Dakota Sandstone.

At the beginning of the Cretaceous a trough developed in the area of the present-day Colorado Rockies and the sea invaded that area. Gradually the sea crept westward as the trough continued to subside and reached the east edge of the Colorado Plateau by the beginning of the Upper Cretaceous. The movement was spasmodic. The transgression of the Cretaceous sea is well described by Young (1966):

> The sea did not advance westward continuously. Instead, it apparently advanced rapidly westward for a few miles, probably in response to a distinct pulse of basinal subsidence, then remained stationary for a period of time. During this lull a beach formed at the shoreline and began to grow seaward as a relatively thin body of sand, grading downward and seaward into nearshore marine mud. Longshore currents added successive offlapping layers to the sand body producing a thin diachronous sheet and causing a minor regression of the sea. While this beach was forming at the shoreline, swamps or marshes formed behind it along the low-lying shore.
>
> Later another basinal subsidence occurred and the sea again advanced rapidly westward to a new shoreline, farther west than the preceding one, and began anew to form a beach. Not only did the shoreline shift with these landward and seaward movements of the sea, but the boundaries between offshore marine and nearshore marine, nearshore marine and littoral, littoral and paludal, and paludal and floodplain environments shifted also.

The westward transgression of the sea saw the Dakota Sandstone deposited and extended westward eventually into central Utah in Sanpete County. This occurred during Cenomanian time during which the Tununk Member of the marine Mancos was deposited over the present San Rafael Swell and in the Book Cliffs area the sea remained in this westerly position until Campanian time, but the exact shoreline fluctuated as orogenic pulses elevated the lands to the west. Each pulse sent a flood of clastics toward the sea filling the basin faster than it could subside, extending the shoreline eastward. Then, as the activity subsided, the incoming sediments diminished and the sea encroached westward once more. With each such pulse the boundaries of the depositional environments moved eastward and then returned westward. The sandstone tongues projecting into the Mancos were deposited at these times (Ferron, Garley Canyon and Emery).

The regression of the Cretaceous sea began in Campanian time as the orogenic activity in the west began to migrate eastward. According to Young (1966, p. 10):

> This overwhelming volume of sediment, perhaps coupled with a decreasing rate of overall subsidence, forced the sea to become more restricted and ultimately to withdraw from the geosyncline. The regression of the sea was not continuous but was punctuated by numerous relatively short landward transgressions resulting from pulses of basinal subsidence or possibly from temporary deficiencies of sediment.

Temporary deficiencies of sediment indicate a lull in the tectonic activity (mountain building) to the west. As the seas moved eastward so did the environments and the Mesaverde Group was deposited. The degree of subsidence varied from place to place; some areas received thicker sediments than others. Gross (1961) reports a thickening of the Blackhawk centered north of Sunnyside with the isopachs roughly paralleling the present cliff front (figure 10). This probably indicates that the formation of structures which have shaped the present physiographic features began at least as early as Mesaverde time. The eastward regression of the sea caused the littoral sandstone-marine Mancos Shale contact to rise 2,700 feet between Castlegate and Palisade in Colorado.

Although the sea retreated, the area continued to receive sediments under continental environments. This condition is known to have continued well into Eocene time, alternating between fluvial and lacustrine conditions. In Oligocene time the area began to rise in earnest and erosion commenced to attack the previously deposited formations. Here and there deposits were laid down, especially flanking the newly formed mountain ranges and cliff fronts. Basically the condition has persisted until the present.

Correlation with Surrounding Areas

Figure 11 gives one interpretation of the stratigraphic relationships between the Book Cliffs and adjacent coal fields. Figure 12 explains how each formation or facies changes from place to place.

North Central Utah

Two coal fields of significance lie north and west of the Book Cliffs. The first is located almost 40 miles north of Helper across the Uinta Basin with stratigraphic units connected in the subsurface. This coal field (Tabby Mountain) is centered near Red Creek on the south flank of the Uinta Mountains. The coal occurs in two formations, the Frontier Sandstone and the Mesaverde Formation, undivided. The correlation is visualized in the diagram A-D (figure 12). The Ferron becomes the Frontier and the Emery-Star Point-Blackhawk are evidently the Mesaverde at Tabby Mountain.

The second field, Coalville, is located across the Uinta Mountains upfold. The rocks are not continuous. The 85-mile distance from Helper shows radical facies changes. The Frontier Formation at Coalville contains the important coal seams. The formation is greatly expanded at Coalville, extending from Albian through Coniacian time and including at least ten members, three of which contain coal. The Ferron Sandstone of the Book Cliffs is the correlative of only part of this Frontier. The Blackhawk corresponds to part of the Echo Canyon Conglomerate at Coalville and is fluvial in origin rather than lagoonal. The Echo Canyon is barren of coal.

Central Utah

This correlation relates the Book Cliffs to points west and is visualized in section A′ to B′ (figure 12). The rocks and coal of the west part of the field are contiguous with those of the north part of the Wasatch Plateau coal field with little apparent difference. Farther west in the subsurface, sandstone tongues projecting into the Mancos become more numerous and eventually become conglomeratic in the Indianola Group of Sanpete County. The Blackhawk is finally cut out by a post-Blackhawk erosional surface and the overlying Price River-Castlegate sequence becomes conglomeratic. The Blackhawk is present and recognizable as far west as the west side of the Wasatch Plateau, 5 miles east of Mt. Pleasant.

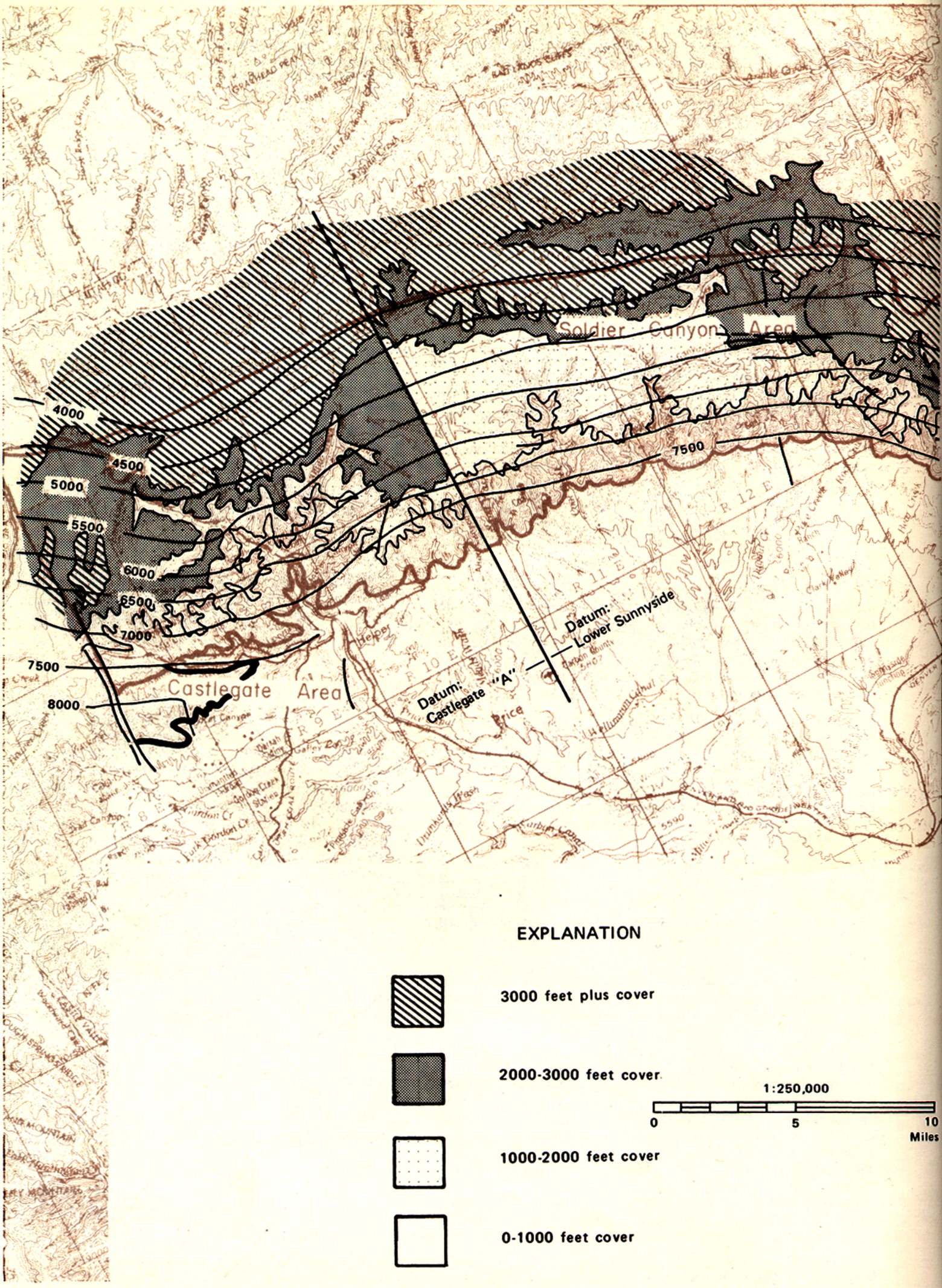
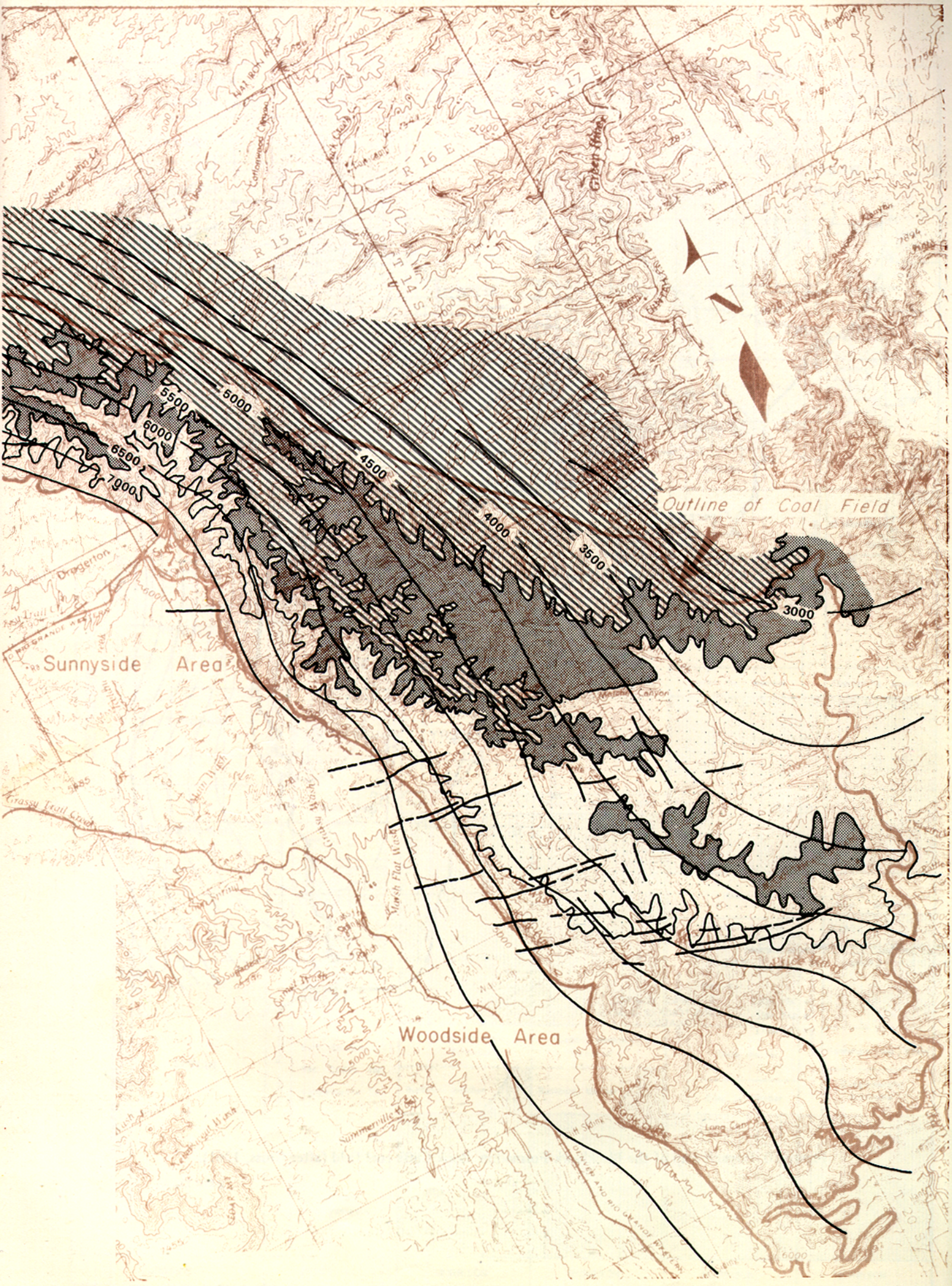


Figure 9. Structure and overburden map, Book Cliffs coal field.


5500
6000
6500
7000
5000
4500
4000
3500
3000
Outline of Coal Field
Sunnyside Area
Woodside Area
N
R 15 E
R 16 E
R 17 E
T 14 S
Dragerton
Grassy Trail Creek
Green River
Book Cliffs

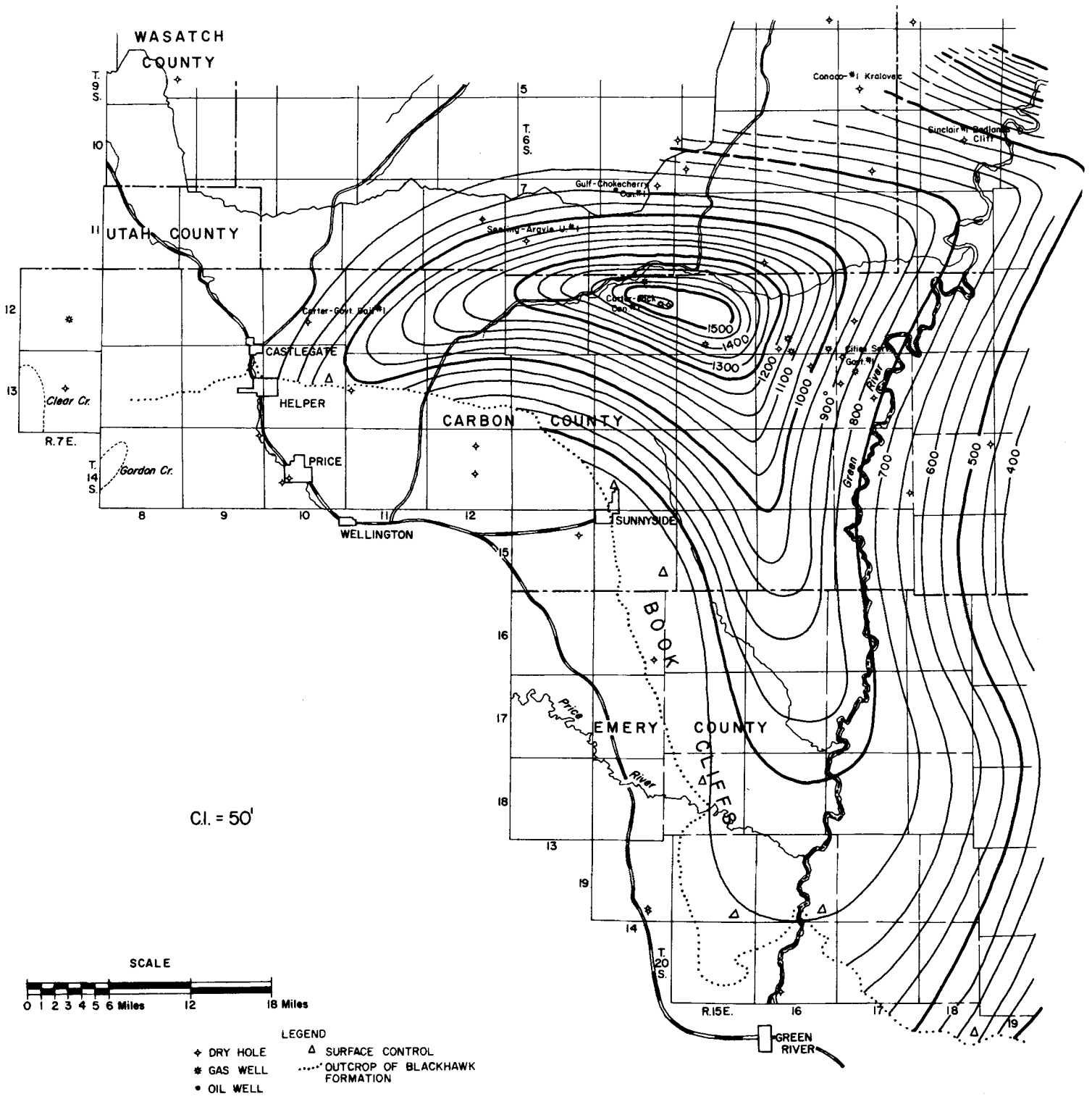


Figure 10. Isopach map of the Blackhawk Formation, Book Cliffs coal field (after Gross, 1961).

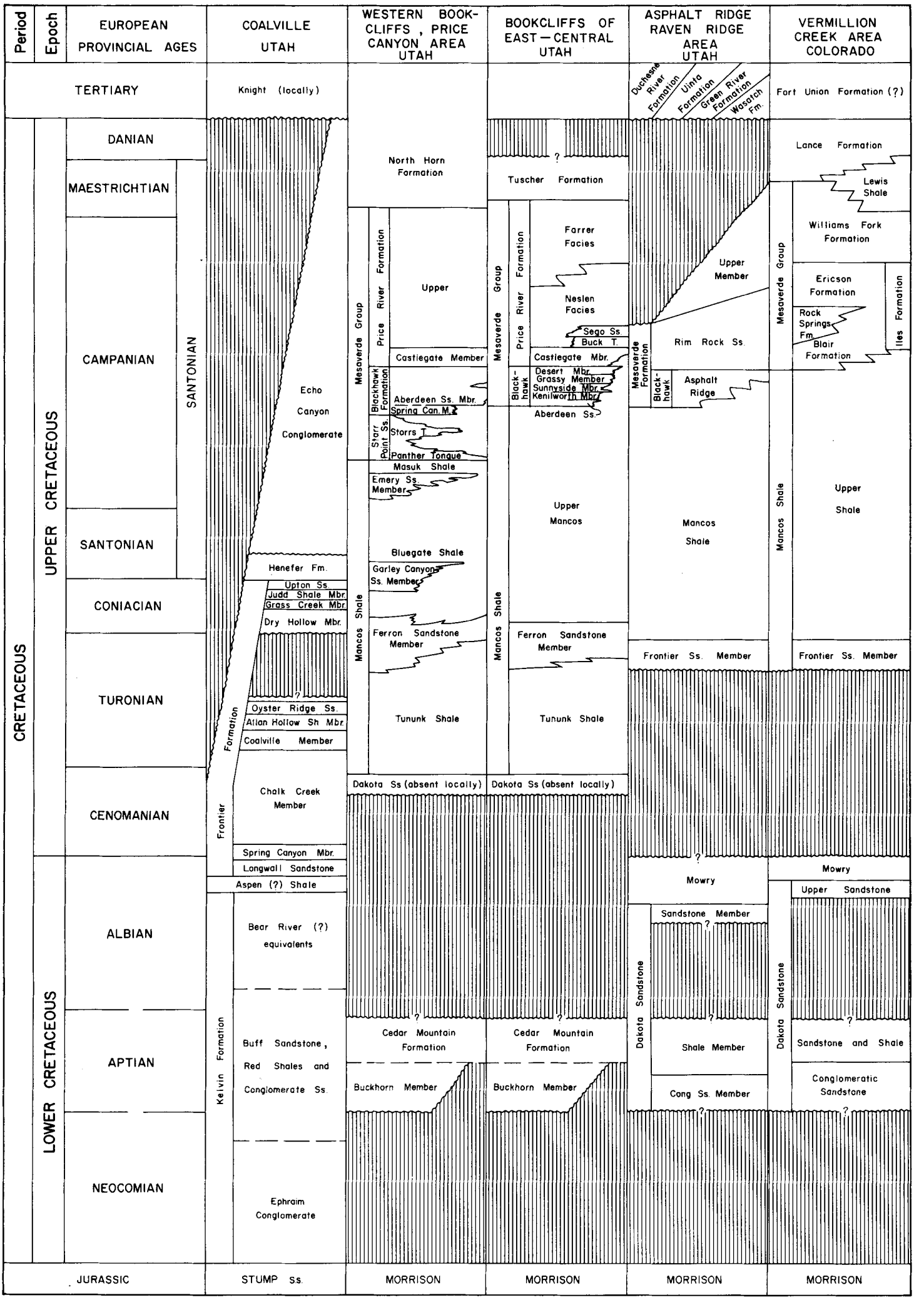


Figure 11. Correlations of Cretaceous formations adjoining Book Cliffs coal field.

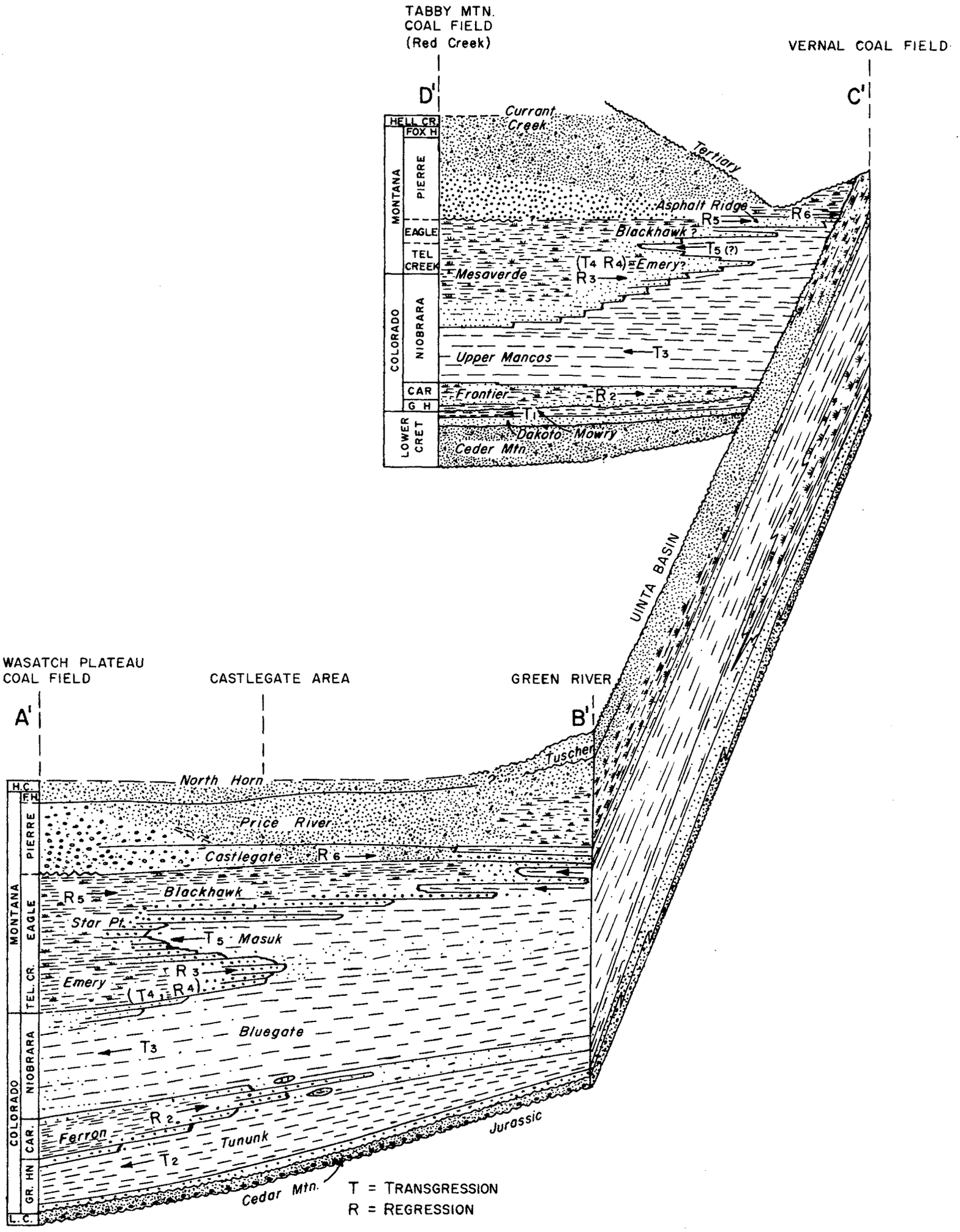


Figure 12. Correlation of beds between the Wasatch Plateau, Book Cliffs, Vernal and Tabby Mountain coal fields (after Hale and Van de Graaff, 1964).

East and Northeast Utah

Stratigraphic relationships are clarified by section B-C (figure 12). As already alluded the Mancos Shale transgresses time lines toward the east. A little east of the Green River the Blackhawk pinches completely out. Not only does the Mancos transgress time lines to the east but also the lagoonal facies progressing upward in the column. In the Thompson area the coal seams are in the Neslen Member of the Price River Formation. The Vernal coal field is located across the Uinta Basin and the rocks are continuous in the subsurface. The Vernal field is about 70 miles northwest of Sunnyside. The coal occurs in the Frontier Sandstone and in the upper member of the Mesaverde Formation. The better coal at Vernal is in the Frontier which correlates with the Ferron Sandstone Member of the Mancos Shale. Very lenticular and lignitic coal outcrops in the Upper Mesaverde, which correlates with the Price River Formation. The Blackhawk disappears east of Vernal; at Asphalt Ridge just west of the town, the barren Asphalt Ridge Member of the Mesaverde is all that is left of the Blackhawk.

South Utah

The coal fields of south Utah are based mainly on coal beds below the Mesaverde. The interval that corresponds to the Mesaverde is either eroded off or is of continental origin and devoid of coal. Coal-bearing Mesaverde rocks appear again in the San Juan Basin of New Mexico, 135 to 150 miles to the southeast, but source areas of sediments and tectonic events that produced the units there were quite different, making attempts at correlation meaningless.

COAL DEPOSITS

Status of Information

The Castlegate and Sunnyside areas of the Book Cliffs coal field were opened to mining in 1889 and 1898, respectively, and shortly thereafter gained prominence as the leading coal producers in Utah. Geologic reports and commentaries, published reports of the U. S. Bureau of Mines and U. S. Geological Survey and university theses soon followed describing the coal beds and the rocks containing them. Two geologic references stand out as being most valuable, the work of Clark (1928) and Fisher (1936). Together they cover the entire field presenting a comprehensive work on the stratigraphy, structure and coal deposits.

Clark's subsurface data are adequate in all respects; to update his work, analytical, drill-hole, mine and production data were added. Fisher's work was of a reconnaissance nature, but for the most part is adequate with respect to surface information. Fisher's portion of the Book Cliffs extends from Columbia southward where the cliffs are less easily climbed. He confined his efforts to the immediate area of the cliffs so further mapping is still necessary where the coal crops out on the plateau surfaces. Because of inaccessibility, measurements were made by alidade and some coal sections are spaced rather far apart.

Subsurface data for areas of coal under 2,000 and 3,000 feet of overburden are lacking in all parts of the field. More analytical and geological prospecting is necessary in the south part of the field.

All principal and supporting work thought applicable to the geology of the coal resources in the Book Cliffs field are in the References section.

Mines, Prospects and Production

Mines and prospects have been opened in the Book Cliffs coal field since 1889; most are located in the Castlegate and Sunnyside areas (figure 13). The area first developed was closer to historic markets and superimposed on the major transportation routes. The Sunnyside area owes its early development to the metallurgical quality product there. Prospecting activity rose in 1906 in the inbetween areas, but poorer quality seams, and competition from the other two areas, i.e., location and quality, hampered its development even to the present time. About 108 million tons of coal have been extracted from the Castlegate area (Spring Canyon, Castlegate and Kenilworth districts) and 100 million tons have been extracted from the Sunnyside area (Sunnyside, Columbia and Horse Canyon). In 1969 the following mines were active and producing coal:

	Tons
Carbon Fuel mine (Castlegate-Kyune)	356,882
Geneva mine (Woodside NE)	843,362
Kenilworth mine (Castlegate-Matts Summit)	627,423
Soldier Canyon mine (Wellington NE)	143,093
Spring Canyon mine (Castlegate-Kyune)	218,281
Sunnyside No. 1 (Sunnyside SW)	959,730
Sunnyside No. 2 (Sunnyside SE)	116,443
Sunnyside No. 3 (Sunnyside SE)	115,129
	3,380,343

Table 2 lists all mines with information on location, quadrangle and period of activity. The estimated total production for the field is 208.8 million tons of coal through January 1, 1970. The production figures are subdivided by mines in the Mines and Development sections of the quadrangle reports and by quadrangle under the general field Coal Deposits section.

Table 2. Mines and prospects in the Book Cliffs coal field.

Quadrangle	Location	Remarks
Castlegate-Kyune		
Bills and Kilgore (Castlegate, Rains, Mutual)		Active 1941-1948
Cameron mine (Royal mine)	NE.NE.NW.35-12S-9E 4,399,040m.N. 510,460m.E.	Active 1912-1962
Carbon Fuel mine (Hardscrabble Canyon, Carbon King)		Active 1896-1970
No. 1	C.N.SE.SW.3-13S-9E 4,396,570m.N. 508,360m.E.	
(Lolly mine) No. 2	NW.NW.NW.NE.10-13S-9E 4,396,110m.N. 508,390m.E.	
(Helper Coal Co., Martin, Blaze mine) No. 3	SW.SW.SW.NE.10-13S-9E 4,395,660m.N. 508,690m.E.	
Liberty mines		Active 1919-1967; abandoned
No. 1	SW.NE.SE.7-13S-8E 4,395,060m.N. 503,750m.E.	
(Maple Creek) No. 3	NE.NE.SE.18-13S-9E 4,393,750m.N. 503,460m.E.	
(Greek mine) No. 4	NE.SW.SW.17-13S-9E 4,393,790m.N. 505,840m.E.	
No. 5	NE.NE.SW.18-13S-9E 4,393,750m.N. 503,690m.E.	
MacLean mine (Western)	SE.NE.SW.7-13S-8E 4,395,000m.N. 503,480m.E.	Active 1922-1966; abandoned
Mutual mine	NW.SE.NE.12-13S-8E 4,395,660m.N. 502,540m.E.	Active 1921-1938; abandoned
Peerless mine		Active 1915-1954; abandoned
No. 1	C.W.SW.SW.10-13S-9E 4,394,710m.N. 507,900m.E.	
No. 2	E.NW.NW.NW.15-13S-9E 4,394,470m.N. 508,070m.E.	
No. 3	E.SW.NW.NW.15-13S-9E 4,394,230m.N. 508,050m.E.	
Spring Canyon mines (Spring Canyon-Royal, Storrs, Rhodes)		Active 1900-1970
No. 1	NE.NE.SW.9-13S-9E 4,395,180m.N. 506,930m.E.	

(continued on page 272)

EXPLANATION

1. VULCAN MINE
2. MUTUAL MINE
3. UTA-CARBON MINE
4. LIBERTY MINES
5. STANDARD MINES
6. SPRING CANYON MINES
7. PEERLESS MINES
8. CARBON FUEL MINES
9. ROYAL MINE (CAMERON)
10. CASTLEGATE MINES
11. PANTHER MINE
12. KENILWORTH MINE
13. ABERDEEN MINE
14. ZION MINE
15. RIO GRANDE MINE
16. SUTTON MINE
17. COAL CANYON MINE
18. SOLDIER CANYON MINE
19. DUGOUT MINE
20. PACE CANYON MINE
21. ROCK CANYON MINE
22. SUNNYSIDE MINES
23. COLUMBIA MINE
24. GENEVA MINE (HORSE CANYON)
25. BOOK CLIFFS MINE

1:250,000

0 5 10 Miles

Figure 13. Coal seams and mines map, Book Cliffs coal field.

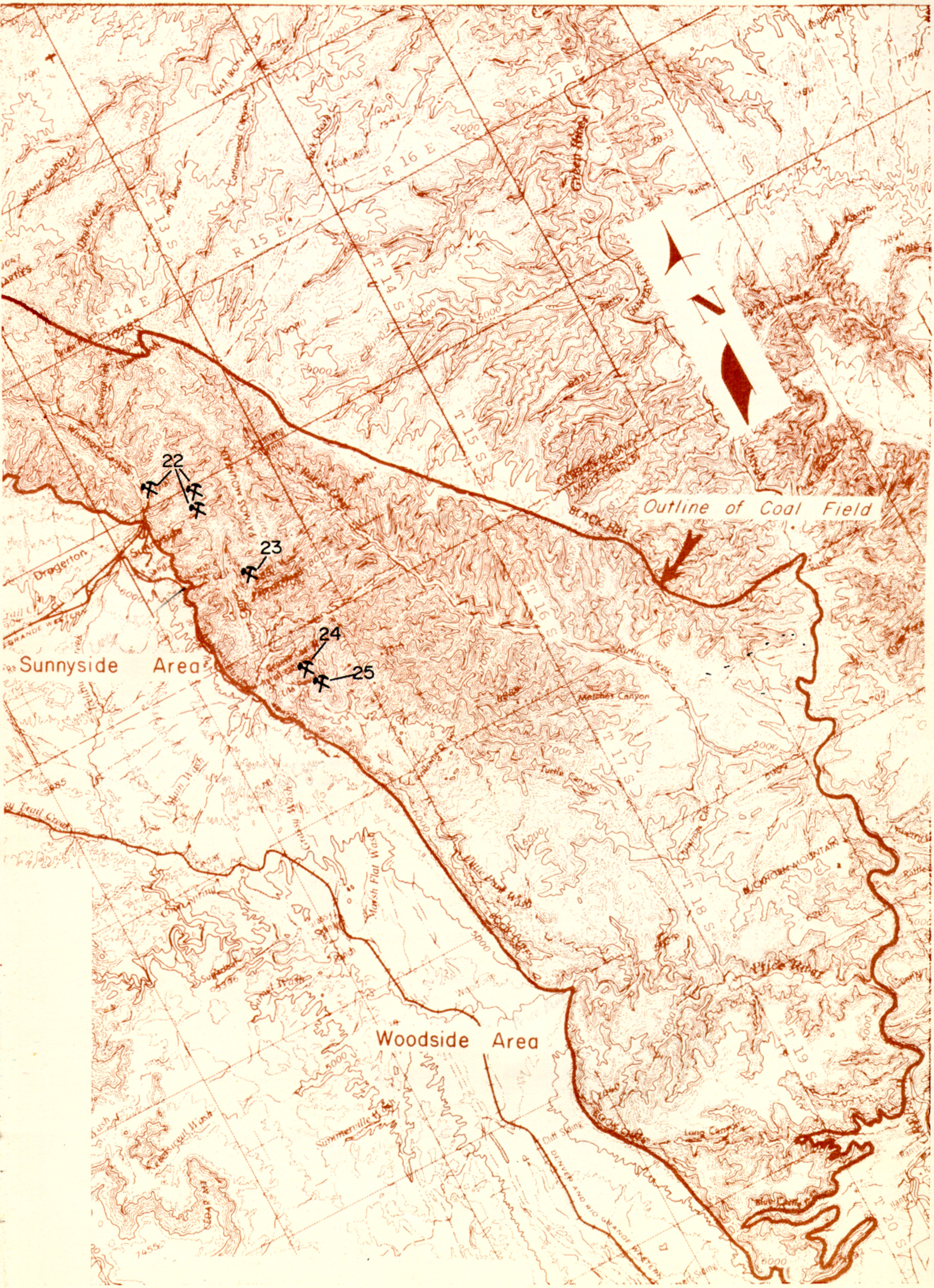

Outline of Coal Field
Sunnyside Area
Woodside Area
22
23
24
25
N
Dragerton
Metzes Canyon
Turtle Canyon
Price River
R 14 E
R 15 E
R 16 E
R 17 E
T 14 S
T 15 S
T 16 S
T 17 S
T 18 S
T 19 S
T 20 S

Table 2. (continued)

Quadrangle	Location	Remarks
No. 2	SW.SE.NW.9-13S-9E 4,395,400m.N. 506,680m.E.	
No. 2½	SE.SW.NW.9-13S-9E 4,395,370m.N. 506,490m.E.	
(Pratt mine) No. 3	SE.NE.NW.NW.9-13S-9E 4,395,480m.N. 506,530m.E.	
No. 4	NW.NW.SE.NW.9-13S-9E 4,395,720m.N. 506,700m.E.	
No. 5	C.W.SE.SW.4-13S-9E 4,396,340m.N. 506,680m.E.	
No. 7	SW.SW.SW.SW.4-13S-9E 4,396,200m.N. 506,210m.E.	
No. 8	C.SW.NW.NW.9-13S-9E 4,395,840m.N. 506,400m.E.	
Standard mines		Active 1913-1954
No. 1	NE.SE.NW.8-13S-9E 4,395,660m.N. 505,300m.E.	
No. 2	SW.SW.NE.8-13S-9E 4,395,340m.N. 505,480m.E.	
No. 2½	NE.NW.SE.8-13S-9E 4,395,280m.N. 505,670m.E.	
No. 3	SE.SW.SW.NE.8-13S-9E 4,395,450m.N. 505,600m.E.	
Uta-Carbon mine (Rains, Hi-Heat mine)		Active 1914-1956; abandoned
No. 1	NW.NW.NE.7-13S-9E 4,396,050m.N. 503,850m.E.	
No. 2	SW.NW.NE.7-13S-9E 4,395,880m.N. 503,850m.E.	
No. 3	7-13S-9E	
Vulcan mine	NW.NW.SE.12-13S-8E 4,395,310m.N. 502,450m.E.	Active 1944-1957; abandoned
Castlegate-Matts Summit		
Aberdeen (Bollinger, Price Trading Co)	SE.SW.10-13S-10E 4,394,810m.N. 518,190m.E.	Active 1898-1916; portal abandoned
Bull Canyon prospect	C.S.½-9-13S-10E	
Peacock mine (Castlegate mine)	NE.SW.SW.NE.1-13S-9E 4,397,760m.N. 510,900m.E.	Old
Cordingly Canyon prospect	C.NW.14-13S-10E	
Kenilworth mine Rock Tunnel (Independent, Four Points, Wade and Lowley)	SE.NE.SW.NW.16-13S-10E NW.NE.SW.16-13S-10E 4,394,110m.N. 516,190m.E.	Active 1906-1970
Castlegate mine (Peacock, Ketchum)		Active 1890-1970
No. 1	NW.NW.NW.NW.1-13S-9E 4,397,050m.N. 511,980m.E.	
No. 2	SE.SW.SW.SW.SW.31-12S-10E 4,397,810m.N. 512,550m.E.	
No. 3	SE.NW.NE.35-12S-9E	
No. 4	SE.SE.SE.SE.36-12S-9E 4,397,820m.N. 512,495m.E.	
Milburn mine (Arronco, Cordingly Canyon)	NE.SW.SW.11-13S-10E 4,394,910m.N. 519,440m.E.	Active 1936-1949
Ketchum mine (Castlegate mine)	NE.NE.NE.NW.1-13S-9E 4,397,050m.N. 511,980m.E.	Active 1911-1916
Panther mine (Heiner, U. S. Fuels)	NE.SE.SE.1-13S-9E 4,396,650m.N. 512,400m.E.	Active 1913-1938
Sunnyside NW		
Bear Canyon mine	N ½. 10-14S-13E 4,386,260m.N. 547,220m.E.	
Rock Canyon mine	SE.NE.32-13S-13E 4,388,960m.N. 544,950m.E.	Prospected 1906; active 1952-1960
Sunnyside SE		
Columbia mine (U. S. Steel mine)	NW.NW.NW.21-15S-14E 4,373,250m.N. 556,090m.E.	Active 1922-1967

Table 2. (continued)

Quadrangle	Location	Remarks
Sunnyside mine (Kaiser mine)		Active 1899-1970
No. 1	SE.NE.SE.SW.32-14S-14E 4,378,650m.N. 555,140m.E.	
No. 2	NW.NE.5-15S-14E 4,378,210m.N. 555,360m.E.	
No. 3	NW.NE.5-15S-14E 4,378,210m.N. 555,360m.E.	
Wellington NE		
Dugout Canyon mine (ESO, Branch Bros., Knight-Ideal)	SE.SE.NW.23-13S-12E 4,392,320m.N. 539,080m.E.	Active 1906, 1920-1953
Pace Canyon mine (Snow mine)	NW.NW.30-13S-13E 4,391,060m.N. 542,150m.E.	Active 1906, 1932-1940
Soldier Canyon mine (Premium mine)	NW.NE.18-13S-12E 4,394,480m.N. 533,220m.E.	1906 prospecting
Spring Canyon mine	NE.NW.21-13S-12E 4,392,900m.N. 535,980m.E.	Active 1906-1910
Wellington-Minnie Maud W		
Knight-Ideal mine	E ½.NW.10-13S-11E 4,396,090m.N. 527,790m.E.	1906, 1940-1965 closed
	C.E.NE.9-13S-11E 4,395,830m.N. 527,250m.E.	
Olson prospect	SE.NE.13-13S-10E 4,393,910m.N. 523,400m.E.	
Rio Grande mine (Olson mine)	W.NW.SW.SE.7-13S-11E 4,394,950m.N. 523,400m.E.	Opened 1925 as Rio Grande; 1900's prospects; 1940-1956 closed
Sutton mine (Blue Flame, Star Point, Crandall mine)	NE.SE.NE.18-13S-11E 4,394,270m.N. 523,940m.E.	1945-1964; abandoned
Zion mine (Zion Securities, Jesse Knight)	SE.SW.7-13S-11E 4,395,000m.N. 523,100m.E.	1906 prospected; 1925-1948 closed
Woodside NE		
Book Cliffs mine (Prentiss, Utah Blue Diamond, Blue Diamond, Heiner)	SW.SW.SW.NW.10-16S-14E 4,366,540m.N. 555,390m.E.	Intermittently active 1938-1948; active 1949-1966
Calkins prospect	SE.10-16S-14E 4,365,600m.N. 556,610m.E.	Activity unknown
Geneva mine (U. S. Steel) Adit 1	NW.SW.3-16S-14E 4,368,200m.N. 555,500m.E.	Active 1941-1970
Adit 2	4,368,100m.N. 555,550m.E.	
Lila Canyon prospect	C.N.15-16S-14E 4,365,420m.N. 556,110m.E.	Activity unknown
Prentiss prospect	SE.9-16S-14E 4,366,180m.N. 555,250m.E.	Activity unknown
Woodside SE		
Peterson prospect	NW.19-18S-15E 4,345,500m.N. 562,000m.E.	Activity before 1905

Land Ownership

The lands and coal of the Book Cliffs coal field are owned by federal and state government agencies, by private corporations, companies and individuals (figure 14). With coal lands and fringe lands adjacent to the coal, the Bureau of Land Management is the largest land holder with 55.2 percent. Private property follows with individuals and corporations holding 36.2 percent of the land. The state of Utah holds the remaining 8.6 percent. To the north and west large parcels of coal lands are privately owned. The spaces between are owned mainly by the BLM. Only an occasional

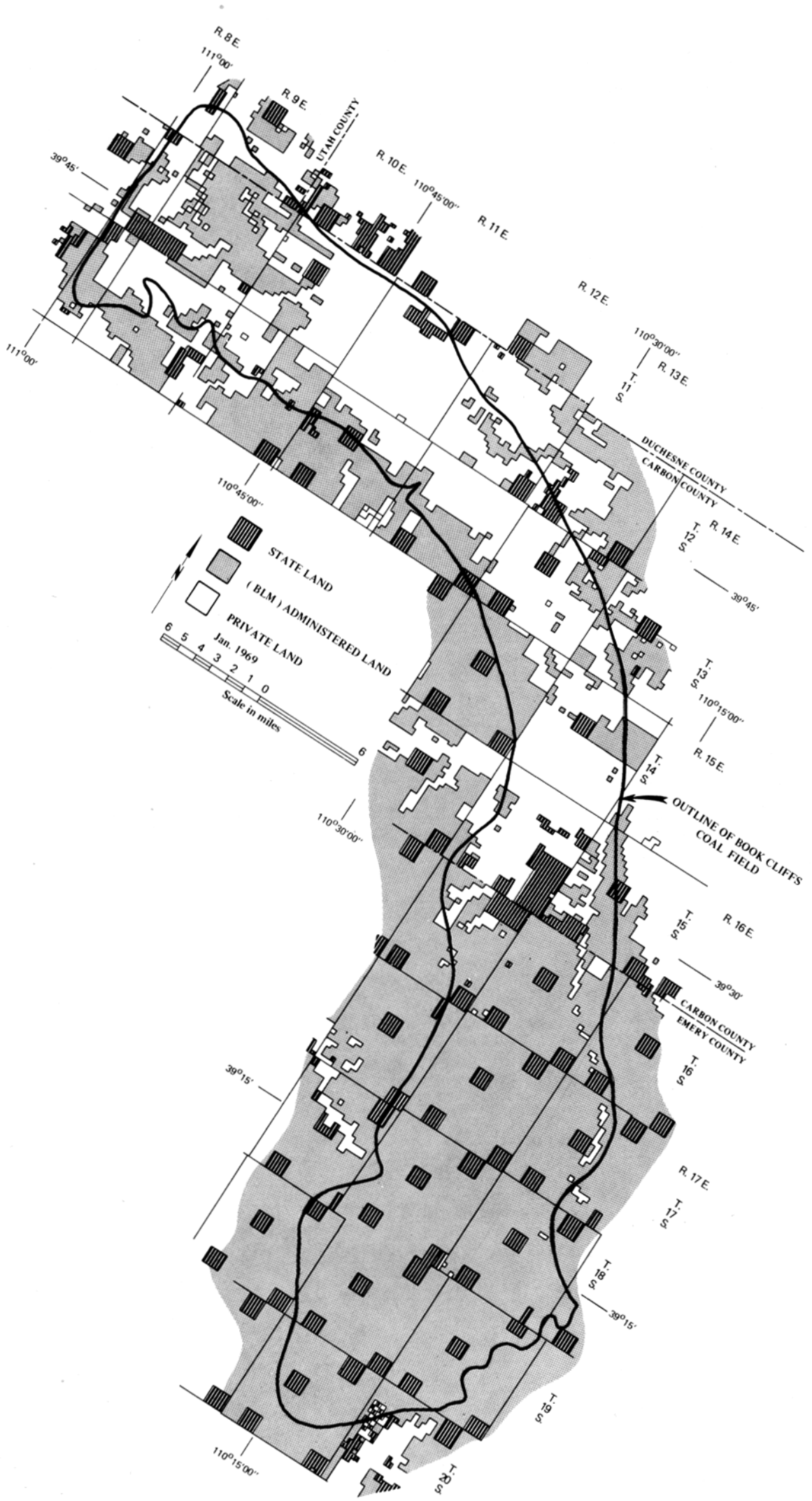


Figure 14. Land ownership map, Book Cliffs coal field.

state section is coal land. Some private properties with the coal, however, are reserved to the United States. South of the Geneva mine no private property is superimposed on coal lands; most is BLM land with an occasional state section.

No coal permits exist for prospecting in the Book Cliffs field; the coal land is either held as private property or is leased. Acreages held by various companies and individuals are indicated in the quadrangle reports and summarized in table 3. The acreages are approximate and rounded off and are given to show the type of activity in the Book Cliffs at a point in time (January 1, 1970); locations of the holdings are shown on figure 15. A direct relationship exists between the percentage of land an agency (BLM, state or private) owns and the acreage leased.

The total acreage held as coal land amounts to about 124 square miles. If the minable width of the 70-mile field is 4 miles, then the field has an area of 280 square miles and more than 44 percent are leased or held as private coal land. The only large area of open land is to the southeast where the coal reserves are expected to be small.

Quality of Coal

Nearly 1,300 analyses were incorporated to determine the quality of the coal (table 4); the greatest amount of sampling is representative of the Castlegate area (875). No dramatic differences mark the coal throughout the field. The only differences noted in quality between individual seams is an occasional local seam higher in ash and/or sulfur than its neighbor. These differences are discussed with the quadrangle reports. No analyses were available from the Beckwith Peak NE, SE and Gunnison Butte W quadrangles and the one analysis from the Woodside NE quadrangle does not demonstrate coal quality there. The results from the other quadrangles give a fairly good index.

Table 3. Coal land holdings in the Book Cliffs coal field (leased or fee acreage).

Name	State	Federal	Private	Total
Bank of America	120	–	–	120
Bertola, C.	–	–	40	40
Book Cliffs Coal	–	320	–	320
Cannon, G. N.	–	280	–	280
Carbon School district (Unassigned)	–	–	3,140	3,140
Carbon Development	640	640	880	2,160
Carbon-Emery Bank	575	–	224	799
Crandall, R. B.	–	40	–	40
Duvels, Inc.	–	–	40	40
Hawthorne, L.	–	–	640	640
Heiner (Island Creek)	1,616	–	–	1,616
Island Creek Coal	–	5,852	–	5,852
Kaiser Steel Corp.	480	14,536	10,145	25,161
Kennecott Coal	–	2,736	1,157	3,893
Liberty Fuel	667	640	–	1,307
Mathis, W.	–	–	160	160
North American Coal	–	5,765	4,470	10,235
Peperakis, J.	–	–	400	400
Premium Coal	–	1,548	–	1,548
Royal Coal	–	4,421	440	4,861
Spring Canyon Coal	–	?	2,030	2,030
Sutton, L. D.	–	2,042	–	2,042
U. S. Steel	2,036	4,392	5,320	11,748
Western Coal	–	277	–	277
White, J. R.	340	–	–	340
Zion's Securities	–	–	205	205
Total Acreage	6,474	43,489	29,291	79,254

Table 4. Quality of coal data, Book Cliffs coal field.

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
	CASTLEGATE–KYUNE QUADRANGLE																	
1	Bills & Kilgore mine Castlegate bed "A"	13S–9E	A	4.4	–	–	8.0	.54	–	–	–	–	–	–	–	–		88
2	Blaze mine Sub. 1, 3, or "A"	SW.SW.SW.NE.10–13S–9E 4395660mN 508690mE	A	5.3	–	–	5.2	.66	–	–	–	–	–	–	–	–		88
3	Carbon Fuel mine Castlegate B bed	C.N.SE.SW.3–13S–9E 4396570mN 508360mE	A	4.7	43.6	45.2	6.6	.3	–	–	–	–	12,820	2,270	–	–	D	87
			C	–	45.7	47.4	6.9	–	–	–	–	–	13,450	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
4	Carbon Fuel mine Castlegate B bed		A	4.7	43.5	45.1	6.8	.3	–	–	–	–	12,780	–	–	–	D	87
			C	–	45.6	47.3	7.1	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
5	Carbon Fuel mine Castlegate B bed		A	5.0	44.0	44.7	6.3	.3	–	–	–	–	12,850	2,260	–	–	D	87
			C	–	46.3	47.1	6.6	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–	–		
6	Carbon Fuel mine Castlegate B bed		A	5.0	43.8	44.7	6.5	.3	–	–	–	–	12,820	–	–	–	D	87
			C	–	46.1	47.1	6.8	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
7	Carbon Fuel mine Castlegate B bed		A	5.2	43.2	45.1	6.4	.3	–	–	–	–	12,770	2,240	–	–	D	87
			C	–	45.6	47.6	6.8	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
8	Carbon Fuel mine Castlegate B bed		A	4.5	43.3	45.4	6.8	.3	–	–	–	–	12,770	–	–	–	D	87
			C	–	45.3	47.6	7.1	–	–	–	–	–	13,370	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
9	Day mine Castlegate Sub. no. 1 bed	NW.SE.NE.12–13S–8E 4395660mN 502540mE	A	3.6	46.2	43.9	6.4	1.9	–	–	–	–	13,070	–	–	–	T	11
			C	–	47.9	45.5	6.6	–	–	–	–	–	13,550	–	–	–		
10	Day mine Castlegate Sub. no. 1 bed		A	3.4	46.2	44.4	6.0	1.4	–	–	–	–	13,170	–	–	44	T	11
			C	–	47.8	46.0	6.2	–	–	–	–	–	13,630	–	–	–		
11	Day mine Castlegate Sub. no. 1 bed		A	3.7	46.4	44.2	5.7	1.3	–	–	–	–	13,110	–	–	–	T	11
			C	–	48.2	45.9	5.9	–	–	–	–	–	13,600	–	–	–		
12	Day mine Castlegate Sub. no. 1 bed		A	3.6	–	–	6.6	1.26	–	–	–	–	–	–	–	–		88

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
				AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
13	Day mine Castlegate Sub. no. 1 bed		A C	3.5 –	45.7 47.4	44.5 46.1	6.3 6.5	1.6 –	5.9 –	74.7 –	1.5 –	9.8 –	13,160 13,640	– –	– –	– –		10
14	Day mine Castlegate Sub. no. 1 bed		A C	3.9 –	43.1 44.9	45.6 47.4	7.4 7.7	1.7 –	– –	– –	– –	– –	13,040 13,560	– –	– –	46 –		10
15	Hardscrabble mine Castlegate B bed	C.N.SE.SW.3–13S–9E 4396570mN 508360mE	A C	3.7 –	42.7 44.3	48.6 50.5	5.0 5.2	.4 –	– –	– –	– –	– –	13,190 13,690	– –	– –	– –	T	16
16	Hardscrabble mine Castlegate B bed		A C	3.8 –	42.7 44.4	48.9 50.8	4.6 4.8	.4 –	– –	– –	– –	– –	13,320 13,840	– –	– –	– –	T	16
17	Hardscrabble mine Castlegate B bed		A C	3.7 –	42.9 44.5	46.6 48.4	6.8 7.1	.3 –	– –	– –	– –	– –	12,900 13,390	– –	– –	– –	T	16
18	Hardscrabble mine Castlegate B bed		A C	4.4 –	43.0 45.0	45.9 48.0	6.7 7.0	.3 –	– –	– –	– –	– –	12,800 13,400	– –	– –	– –	D	16
19	Hardscrabble mine Castlegate B bed		A C	4.3 –	43.3 45.2	46.1 48.2	6.3 6.6	.4 –	– –	– –	– –	– –	12,950 13,520	– –	– –	– –	T	16
20	Hardscrabble mine Castlegate B bed		A C	5.7 –	43.5 46.1	45.5 48.2	5.4 5.7	.4 –	– –	– –	– –	– –	12,820 13,590	– –	– –	– –	T	16
21	Hardscrabble mine Castlegate B bed		A C	3.4 –	43.5 45.0	46.4 48.0	6.8 7.0	.3 –	– –	– –	– –	– –	12,830 13,290	– –	– –	– –	D	19
22	Hardscrabble mine Castlegate B bed		A C	3.0 –	44.8 46.2	45.7 47.1	6.5 6.7	.4 –	– –	– –	– –	– –	13,030 13,440	– –	– –	– –	D	19
23	Hardscrabble mine Castlegate B bed		A C	4.4 –	42.7 44.7	46.4 48.5	6.5 6.8	.3 –	– –	– –	– –	– –	12,800 13,390	– –	– –	– –	D	19
24	Hardscrabble mine Castlegate B bed		A C	4.5 –	43.7 45.8	45.2 47.3	6.6 6.9	.3 –	– –	– –	– –	– –	12,870 13,480	– –	– –	– –	D	21
25	Hardscrabble mine Castlegate B bed		A C	4.7 –	43.6 45.7	45.2 47.4	6.6 6.9	.3 –	– –	– –	– –	– –	12,810 13,450	– –	– –	– –	D	21
26	Hardscrabble mine Castlegate B bed		A C	4.7 –	43.5 45.6	45.1 47.3	6.8 7.1	.3 –	– –	– –	– –	– –	12,780 13,410	– –	– –	– –	D	21
27	Hardscrabble mine Castlegate B bed		A C	2.8 –	43.4 44.7	47.7 49.1	6.0 6.2	.3 –	– –	– –	– –	– –	13,190 13,570	– –	– –	– –	D	14
28	Hardscrabble mine Castlegate B bed		A C	4.1 –	43.3 45.1	46.8 48.8	5.9 6.1	.3 –	– –	– –	– –	– –	12,970 13,520	– –	– –	– –	D	14
29	Hardscrabble mine Castlegate B bed		A C	4.5 –	43.3 45.3	45.3 47.4	7.0 7.3	.3 –	– –	– –	– –	– –	12,720 13,320	– –	– –	– –	D	20
30	Hardscrabble mine Castlegate B bed		A C	4.8 –	42.8 45.0	45.1 47.4	7.2 7.6	.3 –	– –	– –	– –	– –	12,640 13,280	– –	– –	– –	D	20
31	Hardscrabble mine Castlegate B bed		A C	3.3 –	42.4 43.8	46.3 47.9	6.1 6.3	.4 –	– –	– –	– –	– –	12,020 13,470	– –	– –	– –	D	17
32	Hardscrabble mine Castlegate B bed		A C	4.5 –	43.8 45.9	45.8 48.0	5.8 6.1	.3 –	– –	– –	– –	– –	12,950 13,580	– –	– –	– –	D	17
33	Hardscrabble mine Castlegate B bed		A C	4.3 –	41.4 43.3	48.6 50.8	5.6 5.9	.3 –	– –	– –	– –	– –	12,960 13,540	– –	– –	– –	T	15
34	Hardscrabble mine Castlegate B bed		A C	2.7 –	43.8 45.0	46.0 47.3	7.5 7.7	.3 –	– –	– –	– –	– –	12,740 13,100	– –	– –	– –	D	15
35	Hardscrabble mine Castlegate B bed		A C	3.9 –	43.4 45.2	46.8 48.7	5.9 6.1	.3 –	– –	– –	– –	– –	12,960 13,480	– –	– –	– –	T	15
36	Hardscrabble mine Castlegate B bed		A C	4.4 –	43.5 45.5	46.2 48.3	5.9 6.2	.3 –	– –	– –	– –	– –	12,900 13,500	– –	– –	– –	D	15
37	Hardscrabble mine Castlegate B bed		A C	6.2 –	45.6 48.6	43.1 46.0	5.1 5.4	.3 –	– –	– –	– –	– –	12,820 13,670	– –	– –	– –	T	15
38	Hardscrabble mine Castlegate B bed		A C	4.4 –	42.8 44.8	46.7 48.8	6.1 6.4	.3 –	– –	– –	– –	– –	12,810 13,400	– –	– –	– –		12
39	Hardscrabble mine Castlegate B bed		A C	3.3 –	40.7 42.1	50.5 52.2	5.5 5.7	.4 –	– –	– –	– –	– –	13,240 13,700	– –	– –	– –	T	13
40	Hardscrabble mine Castlegate B bed		A C	3.6 –	42.8 44.4	47.3 49.1	6.3 6.5	.3 –	– –	– –	– –	– –	12,950 13,430	– –	– –	– –	T	13
41	Hardscrabble mine Castlegate B bed		A C	3.3 –	43.1 44.6	46.7 48.3	6.9 7.1	.3 –	– –	– –	– –	– –	12,760 13,200	– –	– –	– –	T	13
42	Hardscrabble mine Castlegate B bed		A C	3.6 –	42.5 44.1	47.6 49.4	6.3 6.5	.3 –	– –	– –	– –	– –	12,920 13,400	– –	– –	– –	T	13
43	Hardscrabble mine Castlegate B bed		A C	3.7 –	43.0 44.6	47.4 49.2	6.0 6.2	.3 –	– –	– –	– –	– –	12,990 13,490	– –	– –	– –	D	13

(continued on page 278)

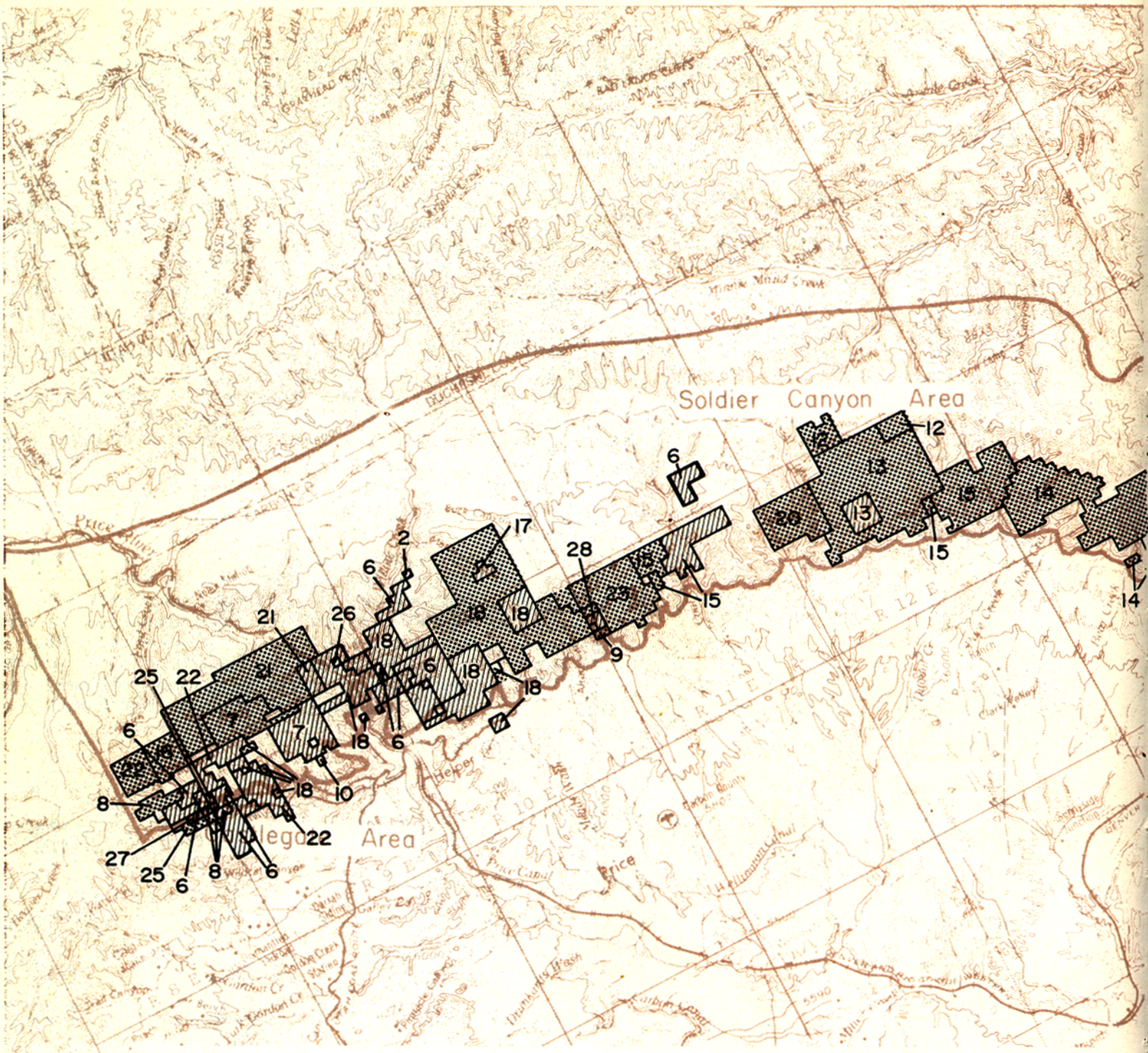


Figure 15. Leases and permits map, Book Cliffs coal field.

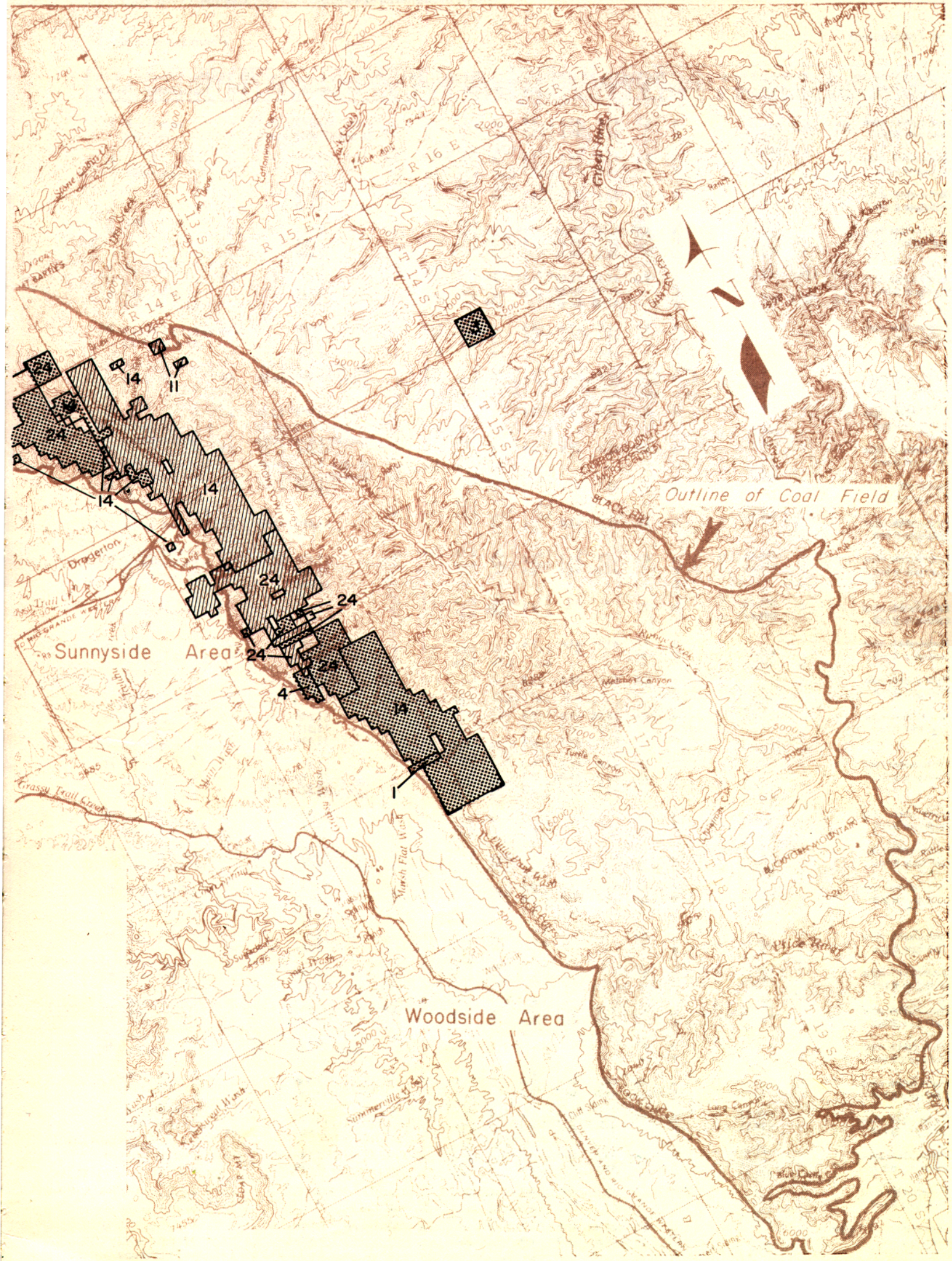

Outline of Coal Field
Sunnyside Area
Woodside Area
Dragerton
Grassy Trail Creek
Tuscher Canyon
Turtle Canyon
Cottonwood Canyon
Gilson Mtns
Book Cliffs
Roan Cliffs
Range Creek
Desert Mtn
Bryson Canyon
Willow Creek
Kenilworth Mountain
Clear Creek
Lazy Canyon
Summerville Wash
Cottonwood Wash
Willow Creek Wash
Marsh Flat Wash
Grassy Trail Wash
Rock Creek
Stone Cabin Wash
Dooly Draw
Bear Canyon
Nine Mile Canyon
Denver and Rio Grande Western RR
Utah Railway
Black Hill
T 15 S
T 14 S
R 14 E
R 15 E
R 16 E
N
24
14
11
4
1

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
44	Hardscrabble mine Castlegate B bed		A C	6.2 –	43.4 46.3	45.5 48.5	4.9 5.2	.4 –	– –	– –	– –	– –	12,790 13,640	– –	– –	– –	T	13
45	Hardscrabble mine Castlegate B bed		A C	4.8 –	42.7 44.8	46.7 49.1	5.8 6.1	.4 –	5.5 –	74.7 –	1.4 –	11.9 –	12,750 13,400	– –	– –	48 –	T	11
46	Hardscrabble mine Castlegate B bed		A C	4.3 –	42.4 44.3	47.2 49.3	6.1 6.4	.3 –	– –	– –	– –	– –	12,840 13,420	– –	– –	– –	D	11
47	Hardscrabble mine Castlegate B bed		A C D	4.58 – –	43.27 45.35 49.21	44.66 46.80 50.79	7.49 7.85 –	.76 .80 .87	– – –	– – –	– – –	– – –	12,713 13,324 14,459	– – –	2.2 – –	– – –		38
48	Hardscrabble mine Castlegate B bed		A C D	4.08 – –	41.33 43.09 47.40	45.87 47.82 52.60	8.72 9.09 –	.69 .72 .79	– – –	– – –	– – –	– – –	12,578 13,113 14,425	– – –	1.8 – –	– – –		38
49	Hardscrabble mine Castlegate B bed		A C D	4.9 – –	41.9 44.0 46.6	47.9 50.4 53.4	5.3 5.6 –	.5 .5 .5	5.8 5.5 5.9	72.2 75.9 80.4	1.3 1.4 1.5	14.9 11.1 11.7	12,950 13,610 14,420	– – –	2.6 – –	– – –		39
50	Hardscrabble mine Castlegate B bed		A	5.7	41.4	47.5	5.4	.5	–	–	–	–	12,890	2,220	3.3	–		39
51	Hardscrabble mine Castlegate B bed		A	4.6	41.6	48.2	5.6	.5	–	–	–	–	12,980	2,220	2.1	–		39
52	Hardscrabble mine Castlegate B bed		A	4.9	42.4	47.9	4.8	.4	–	–	–	–	13,050	2,220	2.4	–		39
53	Hardscrabble mine Castlegate B bed		A	4.7	42.7	47.0	5.6	.5	–	–	–	–	13,020	2,240	2.8	–		39
54	Hardscrabble mine Castlegate B bed		A	4.5	41.6	47.8	6.1	.5	–	–	–	–	12,850	2,240	2.5	–		39
55	Hardscrabble mine Castlegate B bed		A C D	4.5 – –	43.7 45.8 –	45.2 47.3 –	6.6 6.9 –	.3 – –	– – –	– – –	– – –	– – –	12,870 13,480 14,480	2,260 – –	– – –	– – –	D	87
56	Hardscrabble mine Castlegate B bed		A	5.1	–	–	4.6	.66	–	–	–	–	–	–	–	–		88
57	Hardscrabble mine Castlegate B bed		A C	7.5 –	43.7 –	41.4 –	7.4 –	– –	– –	– –	– –	– –	12,250 13,260	– –	– –	– –		86
58	Hardscrabble mine Castlegate B bed		A C	5.5 –	42.3 –	39.4 –	12.8 –	– –	– –	– –	– –	– –	11,700 12,400	– –	– –	– –		86
59	Hardscrabble mine Castlegate B bed		A B D	7.4 1.7 –	38.96 41.3 42.1	45.8 48.6 49.4	7.9 8.4 8.5	– – –	– – –	– – –	– – –	– – –	11,608 12,317 12,534	– – –	– – –	– – –		86
60	Hardscrabble mine Castlegate B bed		A B C	3.9 1.0 –	41.6 42.8 43.3	45.6 46.96 47.4	9.0 9.2 9.3	– – –	– – –	– – –	– – –	– – –	11,847 12,198 12,325	– – –	1.12 – –	– – –		86
61	Hardscrabble mine Castlegate B bed		A B	3.0 –	– –	– –	– –	– –	– –	– –	– –	– –	12,840 13,237	– –	– –	– –		86
62	Hardscrabble mine Castlegate B bed		A C	2.9 –	– –	– –	– –	– –	– –	– –	– –	– –	12,705 13,084	– –	– –	– –		86
63	Hardscrabble mine Castlegate B bed		A B D	4.9 1.8 –	40.9 42.3 43.1	48.7 50.3 51.2	5.4 5.6 5.7	– – –	– – –	– – –	– – –	– – –	13,027 13,459 13,700	– – –	2.7 – –	– – –		86
64	Hardscrabble mine Castlegate B bed		A B	2.2 –	– –	– –	– –	– –	– –	– –	– –	– –	12,977 13,269	– –	– –	– –		86
65	Hardscrabble mine Castlegate B bed		A B	0.9 –	– –	– –	– –	– –	– –	– –	– –	– –	13,262 13,382	– –	– –	– –		86
66	Hardscrabble mine Castlegate B bed		A C	4.6 –	42.9 45.0	46.5 48.7	6.0 6.3	.4 –	5.5 –	75.2 –	1.4 –	11.2 –	12,870 13,480	– –	– –	49 –		10
67	Hardscrabble mine Castlegate B bed		A B	4.7 –	– –	– –	– –	– –	– –	– –	– –	– –	12,565 13,190	– –	– –	– –		86
68	Hardscrabble mine Castlegate B bed		A C	2.9 –	44.7 46.0	44.9 46.2	7.6 7.8	.3 –	– –	– –	– –	– –	13,000 13,390	– –	– –	– –		18
69	Hardscrabble mine Castlegate B bed		A C	2.8 –	44.0 45.3	46.3 47.6	6.9 7.1	.3 –	– –	– –	– –	– –	13,080 13,460	– –	– –	– –		18
70	Hardscrabble mine Castlegate B bed		A C	4.4 –	43.5 45.5	45.4 47.5	6.7 7.0	.3 –	– –	– –	– –	– –	12,820 13,430	– –	– –	– –		18
71	Hardscrabble mine Castlegate B bed		A C	4.4 –	43.1 45.1	45.6 47.7	6.9 7.2	.3 –	– –	– –	– –	– –	12,790 13,380	– –	– –	– –		18
72	Hardscrabble no. 1 mine Sub 2 bed		A C	4.1 –	42.8 44.6	47.0 49.0	6.1 6.4	.7 –	5.7 –	74.6 –	1.6 –	11.0 –	13,120 13,670	– –	– –	– –	T	9
73	Hardscrabble no. 1 mine Sub 2 bed		A C	4.7 –	42.3 44.4	46.7 49.0	6.3 6.6	1.0 –	– –	– –	– –	– –	13,050 13,690	– –	– –	– –	T	9

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
74	Helper mine Sub 1 bed	SW.SW.SW.NE.10–13S–9E 4395660mN 508690mE	A B C	4.6 2.5 –	43.3 44.2 45.4	44.6 45.7 46.7	7.5 7.6 7.9	.8 .78 .8	– – –	– – –	– – –	– – –	12,710 12,990 13,320	2,360 – –	2.2 – –	– – –		38
75	Helper mine		A B D	4.1 2.3 –	41.3 42.1 43.1	45.9 46.7 47.8	8.7 8.9 9.1	.7 .7 .7	– – –	– – –	– – –	– – –	12,580 12,810 13,120	2,260 – –	1.8 – –	– – –		38
76	Helper mine		A C D	4.9 – –	41.9 43.1 46.3	47.6 50.0 53.7	6.5 6.9 –	.7 .7 .8	5.7 5.4 5.8	70.3 74.0 79.4	1.5 1.6 1.7	15.3 11.4 12.3	12,600 13,260 14,230	– – –	2.8 – –	– – –		39
77	Helper mine		A	4.2	42.1	47.1	6.6	.8	–	–	–	–	12,870	2,450	2.3	–		39
78	Helper mine Castlegate A bed		A	5.8	39.8	47.9	6.5	.6	–	–	–	–	12,250	2,130	3.4	–		39
79	Lamph & Johansen mine Castlegate A bed	13S–9E	A	4.4	–	–	6.0	.60	–	–	–	–	–	–	–	–		88
80	Liberty mine no. 3 Sub 3 bed	SW.NE.SE.7–13S–8E 4395060mN 503750mE	A B C D	4.48 2.67 – –	42.19 42.99 44.17 47.80	45.14 46.00 47.26 52.20	8.19 8.34 8.57 –	.71 .73 .75 –	5.98 5.89 5.74 –	68.60 70.91 72.86 –	1.42 1.45 1.49 –	14.10 12.68 10.59 –	12,671 12,912 13,266 13,918	– – – –	– – – –	– – – –		85
81	Liberty mine no. 5 Castlegate B bed	NE.NE.SW.18–13S–9E 4393750mN 503690mE	A C	7.0 –	40.6 43.7	47.2 50.8	5.1 5.5	.4 –	– –	– –	– –	– –	12,500 13,430	– –	– –	– –	T	14
82	Liberty mine no. 5 Castlegate B bed	NE.NE.SW.18–13S–9E 4393750mN 503690mE	A C	6.3 –	42.2 45.0	46.3 49.4	5.2 5.6	.7 –	– –	– –	– –	– –	12,730 13,590	– –	– –	– –	D	14
83	Liberty mine 1-5 Castlegate B bed & Liberty bed		A C	5.5 –	45.1 47.7	45.1 47.7	4.3 4.6	.9 –	– –	– –	– –	– –	13,070 13,830	– –	– –	– –	T	20
84	Liberty mine 1-5 Castlegate B bed & Liberty bed		A C	5.3 –	45.2 47.4	45.7 48.3	4.1 4.3	.9 –	– –	– –	– –	– –	13,090 13,830	– –	– –	– –	T	20
85	Liberty mine 1-5 Castlegate B bed & Liberty bed		A C	5.5 –	43.9 46.5	44.0 46.6	6.5 6.9	1.0 –	– –	– –	– –	– –	12,730 13,480	– –	– –	– –	T	20
86	Liberty mine 1-5 Castlegate B bed & Liberty bed		A C	6.3 –	42.4 45.2	44.2 47.2	7.1 7.6	.9 –	– –	– –	– –	– –	12,450 13,290	– –	– –	– –	T	20
87	Liberty mine 1-5 Castlegate B bed & Liberty bed		A C	6.1 –	44.3 47.2	43.5 46.3	6.1 6.5	1.0 –	– –	– –	– –	– –	12,630 13,440	– –	– –	– –	T	20
88	Liberty mine 1-5 Liberty bed		A C	5.4 –	44.3 46.8	45.2 47.8	5.1 5.4	.9 –	– –	– –	– –	– –	12,930 13,660	– –	– –	– –		12
89	Liberty mine no. 5 Castlegate B bed	NE.NE.SW.18–13S–9E 4393750mN 503690mE	A C	7.2 –	38.9 41.9	46.3 49.9	7.6 8.2	.4 –	5.1 –	72.9 –	1.5 –	11.9 –	12,020 12,960	– –	– –	– –		12
90	Liberty mine 1-5 Castlegate A bed		A C	5.2 –	43.6 46.0	43.1 45.5	6.2 6.5	.6 –	5.7 –	76.0 –	1.5 –	9.7 –	12,910 13,620	– –	– –	– –		12
91	Liberty mine no. 3 Liberty Sub 3 bed	NE.NE.SE.18–13S–9E 4393750mN 503460mE	A C	3.8 –	44.8 46.6	45.6 47.4	5.8 6.0	.7 –	– –	– –	– –	– –	13,150 13,670	– –	– –	– –		73
92	Liberty mine no. 3 Liberty Sub 3 bed		A C	4.9 –	43.3 45.5	44.3 46.6	7.5 7.9	.8 –	– –	– –	– –	– –	12,610 13,260	– –	– –	– –		73
93	Liberty mine 1-5 Liberty bed		A C	4.6 –	45.3 47.5	45.5 47.7	4.6 4.8	1.0 –	– –	– –	– –	– –	13,270 13,900	– –	– –	– –	T	7
94	Liberty mine 1-5 Liberty bed		A C	4.6 –	44.9 47.1	44.8 47.0	5.6 5.9	1.1 –	– –	– –	– –	– –	13,130 13,760	– –	– –	– –	T	7
95	Liberty mine 1-5 Liberty bed		A C	6.1 –	43.9 46.8	43.9 46.8	6.0 6.4	1.0 –	– –	– –	– –	– –	12,760 13,580	– –	– –	– –	T	7
96	Liberty mine no. 5 Castlegate B bed	NE.NE.SW.18–13S–9E 4393750mN 503690mE	A	4.9	–	–	5.4	.84	–	–	–	–	–	–	–	–	T	88
97	Liberty mine 1-5 Liberty bed		A	5.0	–	–	4.9	.58	–	–	–	–	–	–	–	–	T	88
98	Liberty mine 1-5 Liberty bed		A C	4.95 –	45.4 –	40.3 –	9.3 –	– –	– –	– –	– –	– –	12,250 12,890	– –	– –	– –		86
99	Liberty mine 1-5 Liberty bed		A B C	5.0 3.1 –	42.1 42.98 44.4	44.8 45.7 47.2	8.0 8.2 8.45	– – –	– – –	– – –	– – –	– – –	12,476 12,727 13,138	– – –	– – –	– – –		86
100	Liberty mine 1-5 Liberty bed		A B C	4.8 2.5 –	38.96 39.9 40.9	47.2 48.3 49.5	9.1 9.3 9.6	– – –	– – –	– – –	– – –	– – –	12,252 12,543 12,867	– – –	– – –	– – –		86
101	Liberty mine 1-5 Liberty bed		A B C	4.6 2.6 –	40.96 41.8 42.95	46.4 47.4 48.7	7.99 8.2 8.4	– – –	– – –	– – –	– – –	– – –	12,532 12,803 13,142	– – –	– – –	– – –		86

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
102	Liberty mine 1-5		A	5.0	44.2	43.99	7.8	–	–	–	–	–	12,594	–	–	–		86
	Liberty bed		B	3.4	44.9	43.7	7.96	–	–	–	–	–	12,813	–	–	–		
			C	–	46.5	45.3	8.2	–	–	–	–	–	13,258	–	–	–		
103	Liberty mine 1-5		A	6.7	35.8	47.0	10.5	–	–	–	–	–	12,243	–	–	–		86
	Liberty bed		B	3.2	37.2	48.8	10.9	–	–	–	–	–	12,698	–	–	–		
			C	–	38.4	50.4	11.2	–	–	–	–	–	13,115	–	–	–		
104	Liberty mine 1-5		A	3.8	42.2	43.0	11.0	–	–	–	–	–	12,310	–	–	–		86
			B	2.6	42.9	43.4	11.2	–	–	–	–	–	12,520	–	–	–		
			D	–	43.8	44.8	11.4	–	–	–	–	–	12,800	–	–	–		
105	Liberty mine 1-5		A	3.4	42.1	47.98	6.5	–	–	–	–	–	13,000	–	–	–		86
			B	2.4	42.6	48.4	6.6	–	–	–	–	–	13,191	–	–	–		
			C	–	43.5	49.8	6.7	–	–	–	–	–	13,480	–	–	–		
106	Liberty mine 1-5		A	6.2	42.4	44.6	6.8	–	–	–	–	–	12,593	–	3.8	–		86
			B	2.1	44.2	46.6	7.1	–	–	–	–	–	13,152	–	–	–		
			C	–	45.2	47.6	7.3	–	–	–	–	–	13,430	–	–	–		
107	Liberty mine 1-5		A	1.4	–	–	–	–	–	–	–	–	13,164	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,346	–	–	–		
108	Liberty mine 1-5		A	3.0	–	–	–	–	–	–	–	–	13,040	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,449	–	–	–		
109	Liberty mine 1-5		A	5.5	–	–	–	–	–	–	–	–	12,302	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,024	–	–	–		
110	Liberty mine 1-5		A	3.6	–	–	–	–	–	–	–	–	12,028	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	12,473	–	–	–		
111	Liberty mine 1-5		A	4.9	–	–	–	–	–	–	–	–	12,642	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,288	–	–	–		
112	Liberty mine 1-5		A	6.1	44.8	42.4	6.8	.49	–	–	–	–	12,434	–	–	–		86
			B	1.5	46.98	44.5	7.1	.51	–	–	–	–	13,039	–	–	–		
			C	–	47.7	45.1	7.2	.52	–	–	–	–	13,235	–	–	–		
113	Liberty Fuel mine		A	8.6	41.7	44.7	5.0	–	–	–	–	–	–	–	–	–		59
			D	–	48.3	51.7	–	.8	5.8	79.1	1.7	12.6	14,210	–	–	–		
114	MacLean mine	SW.NE.SW.7–13S–8E	A	4.3	43.8	46.3	5.6	.9	5.9	72.3	1.4	13.9	12,040	2,110	2.2	–		39
	Sub 1 bed	4395000mN 503480mE	C	–	45.8	48.3	5.9	.9	5.7	75.5	1.5	10.5	13,620	–	–	–		
			D	–	48.6	51.4	–	1.0	6.0	80.2	1.6	11.2	14,470	–	–	–		
115	Martin mine	SW.SW.SW.NE.10–13S–9E	A	7.1	40.5	44.6	7.8	.6	–	–	–	–	12,360	2,260	5.1	–		39
	Sub 2 bed	4395660mN 508690mE																
116	Martin mine		A	4.2	41.3	46.6	7.9	.7	–	–	–	–	12,730	2,280	2.6	–		39
	Sub 2 bed																	
117	Martin mine		A	5.8	41.4	45.1	7.7	.7	5.8	69.5	1.4	14.3	12,540	–	3.8	–		39
	Sub 2 bed		C	–	43.9	47.9	8.2	.7	5.5	73.8	1.5	10.3	13,310	–	–	–		
			D	–	47.8	52.2	–	.8	6.0	80.4	1.6	11.2	14,500	–	–	–		
118	Mutual mine	NW.SE.NE.12–13S–8E	A	4.4	41.3	47.7	6.6	.8	–	–	–	–	12,820	2,240	2.5	–		39
	Sub 2 bed	4395660mN 502540mE																
119	Mutual mine		A	4.1	41.4	45.1	9.4	.7	–	–	–	–	12,430	2,200	2.2	–		39
	Sub 2 bed																	
120	Mutual bed		A	4.4	41.4	46.3	7.9	.8	5.8	70.8	1.4	13.3	12,640	–	2.3	–		39
	Sub 2 bed		C	–	43.3	48.4	8.3	.8	5.5	74.1	1.5	9.8	13,210	–	–	–		
			D	–	47.2	52.8	–	.9	6.0	80.8	1.6	10.7	14,410	–	–	–		
121	Peerless mine no. 1	C.W.SW.SW.10–13S–9E	A	4.3	41.9	47.0	6.8	.6	–	–	–	–	12,910	–	–	–		7
	Castlegate A	4394710mN 507900mE	C	–	43.8	49.1	7.1	–	–	–	–	–	13,490	–	–	–		
122	Peerless mine		A	4.1	42.4	47.1	6.4	.6	–	–	–	–	12,950	–	–	–		7
	Castlegate A		C	–	44.2	49.1	6.7	–	–	–	–	–	13,490	–	–	–		
123	Peerless mine		A	4.0	43.1	46.5	6.4	.7	–	–	–	–	12,940	–	–	–		7
	Castlegate A		C	–	44.9	48.4	6.7	–	–	–	–	–	13,480	–	–	–		
124	Peerless mine		A	4.6	42.2	47.1	6.1	.7	–	–	–	–	12,930	–	–	–		7
	Castlegate A		C	–	44.2	49.4	6.4	–	–	–	–	–	13,560	–	–	–		
125	Peerless mine		A	4.5	41.1	48.1	5.8	.8	–	–	–	–	12,830	–	–	–		7
	Castlegate A		C	–	43.0	50.4	6.6	–	–	–	–	–	13,440	–	–	–		
126	Peerless mine		A	6.7	41.0	47.2	5.1	.8	–	–	–	–	12,650	–	–	–		7
	Castlegate A		C	–	43.9	50.6	5.5	–	–	–	–	–	13,560	–	–	–		
127	Peerless mine		A	5.2	41.0	48.6	5.2	.5	5.9	71.6	1.3	15.5	12,890	–	4.0	–		39
	Castlegate A		C	–	43.3	51.2	5.5	.5	5.6	75.6	1.4	11.4	13,610	–	–	–		
			D	–	45.8	54.2	–	.6	5.9	79.9	1.5	12.1	14,390	–	–	–		
128	Peerless mine		A	5.7	40.4	49.1	4.8	.5	–	–	–	–	12,950	2,240	4.2	–		39
	Castlegate A																	
129	Peerless mine		A	5.8	41.1	48.0	5.1	.6	–	–	–	–	12,850	2,220	4.3	–		39
	Castlegate A																	
130	Peerless mine		A	4.9	43.1	46.8	5.2	.4	–	–	–	–	12,920	2,200	3.7	–		39
	Castlegate A																	

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
131	Peerless mine Castlegate A		A	5.0	41.0	48.2	5.8	.4	–	–	–	–	12,760	2,200	3.8	–		39
132	Peerless mine Castlegate A		A	4.0	42.10	46.95	6.95	–	–	–	–	–	12,820	–	–	–		86
			B	2.59	42.98	47.35	7.08	–	–	–	–	–	13,097	–	–	–		
			C	–	43.90	48.86	7.24	–	–	–	–	–	13,380	–	–	–		
133	Peerless mine Castlegate A		A	4.7	47.5	42.7	5.1	–	–	–	–	–	13,210	–	–	–		86
			C	–	–	–	–	–	–	–	–	–	13,950	–	–	–		
134	Peerless mine Castlegate A		A	3.9	–	–	6.6	–	–	–	–	–	12,830	–	–	–		86
			B	2.5	–	–	6.7	–	–	–	–	–	13,024	–	–	–		
			C	–	–	–	6.8	–	–	–	–	–	13,355	–	–	–		
135	Peerless mine Castlegate A		A	4.4	–	–	6.4	–	–	–	–	–	12,760	–	–	–		86
			B	2.7	–	–	6.5	–	–	–	–	–	12,996	–	–	–		
			C	–	–	–	6.7	–	–	–	–	–	13,350	–	–	–		
136	Peerless mine Castlegate A		A	4.5	42.3	47.2	5.96	–	–	–	–	–	12,872	–	–	–		86
			B	3.2	42.9	47.9	6.0	–	–	–	–	–	13,043	–	–	–		
			C	–	44.3	49.5	6.2	–	–	–	–	–	13,477	–	–	–		
137	Peerless mine Castlegate A		A	5.4	40.1	46.3	8.2	–	–	–	–	–	12,616	–	–	–		86
			B	3.2	41.1	47.4	8.4	–	–	–	–	–	12,918	–	–	–		
			C	–	42.4	48.9	8.7	–	–	–	–	–	13,338	–	–	–		
138	Peerless mine Castlegate A		A	5.3	40.3	47.4	6.96	–	–	–	–	–	12,307	–	–	–		86
			B	2.1	41.7	49.1	7.2	–	–	–	–	–	12,731	–	–	–		
			C	–	42.6	50.1	7.4	–	–	–	–	–	12,997	–	–	–		
139	Peerless mine Castlegate A		A	4.6	–	–	5.6	.62	–	–	–	–	–	–	–	–		88
140	Peerless mine Castlegate A		A	6.7	–	–	5.2	.77	–	–	–	–	–	–	–	–		88
141	Peerless mine Castlegate A		A	4.2	42.2	47.1	6.5	.67	–	–	–	–	12,661	–	–	–		86
			B	2.8	42.8	47.8	6.6	.68	–	–	–	–	12,856	–	–	–		
			C	–	44.0	49.2	6.8	.70	–	–	–	–	13,222	–	–	–		
142	Peerless mine Castlegate A		A	5.9	40.2	46.7	6.3	.81	–	–	–	–	12,661	–	–	–		86
			B	2.98	41.5	48.2	6.5	.84	–	–	–	–	13,060	–	–	–		
			C	–	42.78	49.7	6.7	.86	–	–	–	–	13,461	–	–	–		
143	Peerless mine Castlegate A		A	3.6	40.95	48.4	7.06	.93	–	–	–	–	13,143	–	–	–		86
			B	1.6	41.8	49.4	7.2	.95	–	–	–	–	13,414	–	–	–		
			C	–	42.5	50.2	7.3	.96	–	–	–	–	13,632	–	–	–		
144	Rains mine Castlegate A, Sub 2	NE.7–13S–9E	A	3.67	44.41	49.17	6.42	.48	–	–	–	–	13,012	–	–	–		72
			C	–	–	–	–	–	–	–	–	–	13,508	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,435	–	–	–		
145	Rains mine Castlegate A, Sub 2		A	3.2	–	–	–	–	–	–	–	–	12,510	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	12,918	–	–	–		
146	Rains mine Castlegate A, Sub 2		A	1.78	–	–	–	–	–	–	–	–	12,866	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,099	–	–	–		
147	Rains mine Castlegate A, Sub 2		A	3.6	–	–	–	–	–	–	–	–	12,036	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	12,485	–	–	–		
148	Rains mine Castlegate A, Sub 2		A	9.2	41.2	39.4	10.2	–	–	–	–	–	11,759	–	6.7	–		86
			B	2.1	44.4	42.5	11.0	–	–	–	–	–	12,680	–	–	–		
			C	–	45.3	43.4	11.3	–	–	–	–	–	12,945	–	–	–		
149	Rains no. 2 mine Sub 1 bed	SW.NW.NE.7–13S–9E 4395880mN 503850mE	A	2.5	45.0	45.2	7.2	.6	–	–	–	–	13,130	–	–	–	D	6
			C	–	46.2	46.4	7.4	–	–	–	–	–	13,470	–	–	–		
150	Rains no. 2 mine Sub 1 bed		A	3.4	43.8	44.6	8.2	.6	–	–	–	–	12,840	–	–	–	D	6
			C	–	45.3	46.2	8.5	–	–	–	–	–	13,290	–	–	–		
151	Rains no. 2 mine Sub 1 bed		A	2.9	44.6	44.6	8.0	.6	–	–	–	–	12,960	–	–	–	D	6
			C	–	45.9	45.9	8.2	–	–	–	–	–	13,350	–	–	–		
152	Rains no. 2 mine Sub 1 bed		A	3.3	44.1	45.4	7.3	.6	–	–	–	–	12,970	–	–	–	D	6
			C	–	45.6	46.9	7.5	–	–	–	–	–	13,410	–	–	–		
153	Rains no. 2 mine Sub 1 bed		A	4.8	42.7	44.3	8.2	.6	–	–	–	–	12,590	–	–	–	D	6
			C	–	44.9	46.5	8.6	–	–	–	–	–	13,230	–	–	–		
154	Rains no. 2 mine Sub 1 bed		A	2.9	43.6	45.9	7.6	.5	–	–	–	–	12,990	–	–	–		73
			C	–	44.9	47.3	7.8	–	–	–	–	–	13,380	–	–	–		
155	Rains no. 2 mine Sub no. 1 bed		A	3.4	44.9	44.6	7.1	.8	–	–	–	–	13,070	–	–	–	D	8
			C	–	46.5	46.2	7.3	–	–	–	–	–	13,520	–	–	–		
156	Rains no. 2 mine Sub no. 1 bed		A	3.9	44.1	42.8	9.2	.7	–	–	–	–	12,610	–	–	–	T	8
			C	–	45.9	44.5	9.6	–	–	–	–	–	13,130	–	–	–		
157	Rains no. 2 mine Castlegate B bed		A	3.4	44.3	45.4	6.9	.6	–	–	–	–	13,070	–	–	–	T	7
			C	–	45.9	47.0	7.1	–	–	–	–	–	13,530	–	–	–		
158	Rains no. 2 mine Castlegate B bed		A	3.4	44.1	44.9	7.6	.6	–	–	–	–	12,890	–	–	–	T	7
			C	–	45.6	46.5	7.9	–	–	–	–	–	13,350	–	–	–		
159	Rains no. 2 mine Castlegate B bed		A	2.4	44.3	45.8	7.5	.5	–	–	–	–	13,110	–	–	–	D	7
			C	–	45.4	46.9	7.7	–	–	–	–	–	13,430	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
160	Rains no. 2 mine		A	4.3	42.9	43.7	9.1	.6	–	–	–	–	12,560	–	–	–	T	7
	Castlegate B bed		C	–	44.8	45.7	9.5	–	–	–	–	–	13,120	–	–	–		
161	Rains no. 2 mine		A	6.9	42.5	43.0	7.5	.6	–	–	–	–	12,420	–	–	–	T	7
	Castlegate B bed		C	–	45.7	46.2	8.1	–	–	–	–	–	13,330	–	–	–		
162	Rains no. 2 mine		A	3.4	–	–	5.7	.55	–	–	–	–	–	–	–	–		88
	Castlegate A bed																	
163	Rains no. 3 mine	7–13S–9E	A	3.6	43.6	45.8	7.0	.4	–	–	–	–	12,910	–	–	–	T	11
	Castlegate A bed		C	–	45.2	47.5	7.3	–	–	–	–	–	13,390	–	–	–		
164	Rains no. 3 mine		A	3.4	41.4	47.5	7.6	.4	–	–	–	–	12,920	–	–	–	T	11
	Castlegate A bed		C	–	42.9	49.2	7.9	–	–	–	–	–	13,370	–	–	–		
165	Rains no. 3 mine		A	4.1	42.6	45.4	8.0	.4	–	–	–	–	12,600	–	–	–	T	11
	Castlegate A bed		C	–	44.4	47.3	8.3	–	–	–	–	–	13,140	–	–	–		
166	Rains no. 3 mine		A	4.6	42.0	46.0	7.4	.4	–	–	–	–	12,620	–	–	48	T	11
	Castlegate A bed		C	–	44.0	48.2	7.8	–	–	–	–	–	13,240	–	–	–		
167	Rains no. 3 mine		A	6.0	42.2	45.7	6.1	.4	–	–	–	–	12,600	–	–	–	T	11
	Castlegate A bed		C	–	44.9	48.6	6.5	–	–	–	–	–	13,400	–	–	–		
168	Rains no. 3 mine		A	4.3	41.2	44.5	10.0	.5	–	–	–	–	12,350	–	–	–		10
	Castlegate A bed		C	–	43.1	46.5	10.4	–	–	–	–	–	12,910	–	–	–		
169	Rains no. 3 mine		A	5.0	41.4	45.7	8.0	.4	–	–	–	–	12,540	–	–	47		10
	Castlegate A bed		C	–	43.6	48.1	8.2	–	–	–	–	–	13,200	–	–	–		
170	Rains no. 3 mine		A	6.0	42.1	45.7	6.2	.5	5.5	74.2	1.4	11.8	12,600	–	–	–		10
	Castlegate A bed		C	–	44.8	48.6	6.6	–	–	–	–	–	13,400	–	–	–		
171	Royal mine	NE.NE.NW.35–12S–9E	A	3.2	–	–	6.7	.32	–	–	–	–	–	–	–	–		88
	Kenilworth bed	4399040mN 510460mE																
172	Royal mine		A	5.0	–	–	6.4	.36	–	–	–	–	–	–	–	–		88
	Kenilworth bed																	
173	Royal mine		A	5.7	37.9	44.4	12.1	–	–	–	–	–	11,629	–	–	–		86
	Kenilworth bed		B	3.98	38.6	45.1	12.4	–	–	–	–	–	11,838	–	–	–		
			C	–	40.2	47.1	12.8	–	–	–	–	–	12,329	–	–	–		
174	Royal mine		A	5.0	42.3	–	7.3	.32	–	–	–	–	12,311	–	–	–		86
			B	1.9	43.7	–	8.1	.33	–	–	–	–	12,712	–	–	–		
			C	–	44.5	–	8.2	.33	–	–	–	–	12,997	–	–	–		
175	Royal mine		A	3.7	41.4	47.1	7.8	.4	–	–	–	–	12,750	–	–	–		15
	Kenilworth bed		C	–	43.0	48.9	8.1	–	–	–	–	–	13,240	–	–	–		
176	Royal no. 1 mine		A	3.3	42.5	48.0	6.2	.4	5.6	73.2	1.4	13.2	13,060	2,230	1.0	–		38
			B	2.3	43.0	48.5	6.25	.4	5.54	73.99	1.36	12.46	13,200	–	–	–		
			C	–	44.0	49.6	6.4	.4	5.4	75.7	1.4	10.7	13,510	–	–	–		
			D	–	47.0	53.0	–	.4	5.8	80.9	1.5	11.4	14,430	–	–	–		
177	Royal no. 1 mine		A	2.3	43.0	49.6	5.1	.4	–	–	–	–	13,320	2,200	.6	–		39
	Castlegate C bed		C	–	44.0	50.8	5.2	.4	–	–	–	–	13,540	–	–	–		
178	Royal no. 2 mine		A	3.05	43.45	46.93	6.57	.47	5.67	73.25	1.41	12.63	13,122	–	.9	–		38
	Royal no. 2 bed		C	–	44.82	48.40	6.78	.48	5.50	75.56	1.45	10.23	13,536	–	–	–		
			D	–	48.08	51.92	–	.51	5.90	81.05	1.56	10.98	14,521	–	–	–		
179	Royal no. 2 mine		A	3.1	43.5	46.8	6.6	.5	5.7	73.3	1.4	12.5	13,120	2,170	.9	–		38
	Royal no. 2 bed		B	2.1	43.9	47.4	6.63	.47	5.62	73.93	1.42	11.93	13,240	–	–	–		
			C	–	44.8	48.4	6.8	.5	5.5	75.6	1.5	10.1	13,540	–	–	–		
			D	–	48.1	51.9	–	.5	5.9	81.1	1.6	10.9	14,520	–	–	–		
180	Royal no. 2 mine		A	2.9	42.5	48.6	6.0	.5	5.7	72.3	1.4	14.1	13,150	–	1.0	–		39
			C	–	43.7	50.1	6.2	.5	5.5	74.5	1.4	11.9	13,540	–	–	–		
			D	–	46.6	53.4	–	.6	5.8	79.4	1.5	12.7	14,440	–	–	–		
181	Royal no. 2 mine		A	2.6	43.1	48.2	6.1	.5	–	–	–	–	13,240	2,200	.8	–		39
182	Royal no. 2 mine		A	3.4	41.8	48.6	6.2	.5	–	–	–	–	13,040	2,200	1.2	–		39
183	Royal no. 2 mine		A	2.8	43.9	43.8	9.4	.7	–	–	–	–	12,780	–	–	–		73
	Sub 2 bed		C	–	45.2	45.1	9.7	–	–	–	–	–	13,150	–	–	–		
184	Royal no. 2 mine		A	2.4	42.6	47.2	7.8	.6	–	–	–	–	13,000	–	–	–		73
	Sub 2 bed		C	–	43.6	48.4	8.0	–	–	–	–	–	13,320	–	–	–		
185	Royal no. 2 mine		A	3.5	43.6	47.2	5.7	.4	–	–	–	–	13,030	–	–	–	D	6
	Sub 1 bed		C	–	45.2	48.9	5.9	–	–	–	–	–	13,500	–	–	–		
186	Royal no. 2 mine		A	2.6	41.2	48.2	8.0	.3	–	–	–	–	12,920	–	–	–	D	8
	Sub 1 bed		C	–	42.3	49.5	8.2	–	–	–	–	–	13,270	–	–	–		
187	Royal no. 2 mine		A	3.2	41.8	47.9	7.1	.4	–	–	–	–	13,000	–	–	–	D	8
	Sub 1 bed		C	–	43.2	49.5	7.3	–	–	–	–	–	13,430	–	–	–		
188	Royal no. 2 mine		A	3.7	42.4	46.7	7.2	.5	–	–	–	–	13,010	–	–	48		10
	Kenilworth bed		C	–	44.0	48.5	7.5	–	–	–	–	–	13,510	–	–	–		
189	Royal no. 2 mine		A	2.7	40.9	47.3	9.1	.3	–	–	–	–	12,610	–	–	–		10
	Kenilworth bed		C	–	42.0	48.6	9.4	–	–	–	–	–	12,960	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
190	Royal no. 2 mine		A	2.9	40.8	48.5	7.9	.3	–	–	–	–	12,830	–	–	–		10
	Kenilworth bed		C	–	42.0	49.9	8.1	–	–	–	–	–	13,210	–	–	–		
191	Royal no. 2 mine		A	3.9	41.9	46.7	7.5	.3	–	–	–	–	12,760	–	–	–		10
	Kenilworth bed		C	–	43.6	48.6	7.8	–	–	–	–	–	13,270	–	–	–		
192	Royal no. 2 mine		A	2.4	41.8	48.1	7.7	.3	–	–	–	–	12,980	–	–	–		10
	Kenilworth bed		C	–	42.8	49.3	7.9	–	–	–	–	–	13,300	–	–	–		
193	Royal no. 2 mine		A	7.0	42.1	44.3	6.6	.5	5.6	75.4	1.4	10.0	12,600	–	–	–		10
	Kenilworth bed		C	–	45.3	47.6	7.1	–	–	–	–	–	13,550	–	–	–		
194	Royal no. 2 mine		A	2.7	41.1	48.4	7.9	.3	–	–	–	–	12,910	–	–	–	D	11
	Kenilworth bed		C	–	42.2	49.7	8.1	–	–	–	–	–	13,270	–	–	–		
195	Royal no. 2 mine		A	2.2	42.8	47.2	7.7	.4	–	–	–	–	12,990	–	–	–	D	11
	Kenilworth bed		C	–	43.8	48.3	7.9	–	–	–	–	–	13,280	–	–	–		
196	Royal no. 2 mine		A	3.8	41.8	47.6	6.7	.3	–	–	–	–	13,000	–	–	–	D	11
	Kenilworth bed		C	–	43.5	49.5	7.0	–	–	–	–	–	13,510	–	–	–		
197	Royal no. 2 mine		A	6.1	41.1	46.1	6.7	.4	–	–	–	–	12,700	–	–	–	D	11
	Kenilworth bed		C	–	43.8	49.1	7.1	–	–	–	–	–	13,530	–	–	–		
198	Royal no. 2 mine		A	8.1	40.1	45.7	6.2	.4	–	–	–	–	12,590	–	–	–	D	11
	Kenilworth bed		C	–	43.6	49.7	6.7	–	–	–	–	–	13,700	–	–	–		
199	Royal no. 2 mine		A	3.9	41.8	47.1	7.2	.3	–	–	–	–	12,940	–	–	–		13
	Kenilworth bed		C	–	43.5	49.0	7.5	–	–	–	–	–	13,470	–	–	–		
200	Spring Canyon mine no. 4	SE.NW.9–13S–9E	A	4.1	43.8	45.4	6.7	.4	–	–	–	–	12,920	–	–	–	T	14
	Castlegate B bed	4395720mN 506700mE	C	–	45.7	47.3	7.0	–	–	–	–	–	13,480	–	–	–		
201	Spring Canyon mine no. 4		A	3.3	44.0	46.8	5.9	.4	–	–	–	–	13,230	–	–	–	D	14
	Castlegate B bed		C	–	45.5	48.4	6.1	–	–	–	–	–	13,680	–	–	–		
202	Spring Canyon mine no. 4		A	3.4	42.4	47.5	6.7	.4	–	–	–	–	12,890	–	–	–	D	6
	Castlegate B bed		C	–	43.9	49.2	6.9	–	–	–	–	–	13,340	–	–	–		
203	Spring Canyon mine no. 4		A	3.0	42.4	47.4	7.2	.4	–	–	–	–	12,960	–	–	–	D	6
	Castlegate B bed		C	–	43.7	48.9	7.4	–	–	–	–	–	13,360	–	–	–		
204	Spring Canyon mine no. 4		A	2.7	43.3	47.8	6.2	.3	–	–	–	–	13,060	–	–	–	D	6
	Castlegate B bed		C	–	44.5	49.1	6.4	–	–	–	–	–	13,420	–	–	–		
205	Spring Canyon mine no. 4		A	2.8	43.3	47.6	6.3	.3	–	–	–	–	13,060	–	–	–	D	12
	Castlegate B bed		C	–	44.5	49.0	6.5	–	–	–	–	–	13,440	–	–	–		
206	Spring Canyon mine no. 4		A	4.1	43.1	47.2	5.7	.3	–	–	–	–	13,000	–	–	–	D	12
	Castlegate B bed		C	–	44.9	49.2	5.9	–	–	–	–	–	13,560	–	–	–		
207	Spring Canyon mine no. 4		A	3.6	43.5	47.3	5.6	.3	–	–	–	–	13,140	–	–	–	T	13
	Castlegate B bed		C	–	45.1	49.1	5.8	–	–	–	–	–	13,630	–	–	–		
208	Spring Canyon mine no. 4		A	4.2	42.9	47.8	5.1	.4	–	–	–	–	13,310	–	–	–	T	13
	Castlegate B bed		C	–	44.8	49.9	5.3	–	–	–	–	–	13,710	–	–	–		
209	Spring Canyon mine no. 4		A	3.2	43.1	48.0	5.7	.4	–	–	–	–	13,160	–	–	–	D	13
	Castlegate B bed		C	–	44.5	49.6	5.9	–	–	–	–	–	13,590	–	–	–		
210	Spring Canyon mine no. 4		A	5.8	42.6	46.3	5.4	.4	–	–	–	–	12,820	–	–	–	T	13
	Castlegate B bed		C	–	45.2	49.1	5.7	–	–	–	–	–	13,610	–	–	–		
211	Spring Canyon mine no. 4		A	4.4	43.1	46.5	6.0	.3	–	–	–	–	12,913	–	–	–		73
	Castlegate B bed		C	–	45.1	48.6	6.3	–	–	–	–	–	13,900	–	–	–		
212	Spring Canyon mine no. 4		A	2.9	43.7	46.9	6.5	.4	–	–	–	–	13,030	–	–	–		73
	Castlegate B bed		C	–	45.0	48.3	6.7	–	–	–	–	–	13,420	–	–	–		
213	Spring Canyon mine no. 4		A	3.7	43.2	46.8	6.3	.4	–	–	–	–	12,960	–	–	–		73
	Castlegate B bed		C	–	44.9	48.6	6..5	–	–	–	–	–	13,460	–	–	–		
214	Spring Canyon mine no. 4		A	3.7	43.2	46.2	6.8	.5	–	–	–	–	12,810	–	–	–		73
	Castlegate B bed		C	–	44.9	48.0	7.1	–	–	–	–	–	13,300	–	–	–		
215	Spring Canyon mine no. 4		A	4.3	43.2	45.1	7.5	.7	–	–	–	–	12,760	–	–	–		73
	Castlegate B bed		C	–	45.1	47.1	7.8	–	–	–	–	–	13,330	–	–	–		
216	Spring Canyon mine no. 4		A	3.1	43.7	47.1	6.1	.4	–	–	–	–	13,060	–	–	–		73
	Castlegate B bed		C	–	45.1	48.6	6.3	–	–	–	–	–	13,480	–	–	–		
217	Spring Canyon mine no. 4		A	3.0	43.5	47.2	6.3	.4	–	–	–	–	13,050	–	–	–		73
	Castlegate B bed		C	–	44.8	48.7	6.5	–	–	–	–	–	13,450	–	–	–		
218	Spring Canyon mine no. 4		A	5.5	43.1	43.9	7.5	.7	–	–	–	–	12,610	–	–	–		73
	Castlegate B bed		C	–	45.6	46.5	7.9	–	–	–	–	–	13,340	–	–	–		
219	Spring Canyon mine no. 4		A	3.0	43.4	47.0	6.6	.3	–	–	–	–	12,950	–	–	–		8
	Castlegate B bed		C	–	44.7	48.5	6.8	–	–	–	–	–	13,350	–	–	–		
220	Spring Canyon mine no. 4		A	3.2	43.0	48.4	5.4	.3	–	–	–	–	13,110	–	–	–		8
	Castlegate B bed		C	–	44.4	50.0	5.6	–	–	–	–	–	13,550	–	–	–		
221	Spring Canyon mine no. 4		A	2.8	43.3	47.4	6.5	.4	–	–	–	–	12,980	–	–	–		8
	Castlegate B bed		C	–	44.5	48.8	6.7	–	–	–	–	–	13,350	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES				ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
222	Spring Canyon mine no. 4 Castlegate B bed		A	3.6	42.6	46.6	7.2	.4	–	–	–	–	12,820	–	–	–		8
			C	–	44.2	48.3	7.5	–	–	–	–	–	13,300	–	–	–		
223	Spring Canyon mine no. 4 Castlegate B bed		A	3.9	42.5	47.0	6.6	.4	–	–	–	–	12,860	–	–	–		8
			C	–	44.2	48.9	6.9	–	–	–	–	–	13,380	–	–	–		
224	Spring Canyon mine no. 4 Castlegate B bed		A	3.8	42.5	47.9	5.8	.4	–	–	–	–	13,050	–	–	–		8
			C	–	44.2	49.8	6.0	–	–	–	–	–	13,570	–	–	–		
225	Spring Canyon mine no. 4 Castlegate B bed		A	3.3	41.9	48.9	5.9	.4	–	–	–	–	13,150	–	–	–	T	9
			C	–	43.3	50.6	6.1	–	–	–	–	–	13,590	–	–	–		
226	Spring Canyon mine no. 4 Castlegate B bed		A	3.1	43.5	47.6	5.8	.3	–	–	–	–	13,060	–	–	–	T	9
			C	–	44.9	49.1	6.0	–	–	–	–	–	13,470	–	–	–		
227	Spring Canyon mine no. 4 Castlegate B bed		A	2.9	43.0	47.5	6.6	.3	–	–	–	–	13,010	–	–	–	T	9
			C	–	44.3	48.9	6.8	–	–	–	–	–	13,400	–	–	–		
228	Spring Canyon mine no. 4 Castlegate B bed		A	3.1	43.3	47.8	5.8	.3	–	–	–	–	13,080	–	–	–	D	9
			C	–	44.7	49.3	6.0	–	–	–	–	–	13,490	–	–	–		
229	Spring Canyon mine no. 4 Castlegate B bed		A	3.0	43.8	46.4	6.8	.3	–	–	–	–	13,080	–	–	–	D	9
			C	–	45.2	47.8	7.0	–	–	–	–	–	13,480	–	–	–		
230	Spring Canyon mine no. 4 Castlegate B bed		A	3.4	42.4	48.2	6.0	.5	–	–	–	–	13,170	–	–	–	T	9
			C	–	43.9	49.9	6.2	–	–	–	–	–	13,630	–	–	–		
231	Spring Canyon mine no. 4 Castlegate B bed		A	2.9	43.2	48.0	5.9	.4	–	–	–	–	13,130	–	–	–	T	9
			C	–	44.5	49.4	6.1	–	–	–	–	–	13,520	–	–	–		
232	Spring Canyon mine no. 4 Castlegate B bed		A	3.1	43.6	47.3	6.0	.4	–	–	–	–	13,070	–	–	–	D	9
			C	–	45.0	48.8	6.2	–	–	–	–	–	13,490	–	–	–		
233	Spring Canyon mine no. 4 Castlegate B bed		A	3.9	42.8	47.3	6.1	.4	–	–	–	–	13,030	–	–	–	D	9
			C	–	44.5	49.2	6.3	–	–	–	–	–	13,560	–	–	–		
234	Spring Canyon mine no. 4 Castlegate B bed		A	4.1	43.1	46.9	6.6	.3	–	–	–	–	12,980	–	–	–	D	9
			C	–	44.9	48.9	6.2	–	–	–	–	–	13,540	–	–	–		
235	Spring Canyon mine no. 4 Castlegate B bed		A	3.8	43.8	47.0	5.4	.4	–	–	–	–	13,190	–	–	–	T	9
			C	–	45.5	48.9	5.6	–	–	–	–	–	13,720	–	–	–		
236	Spring Canyon mine no. 4 Castlegate B bed		A	5.6	42.5	46.4	5.6	.4	–	–	–	–	12,820	–	–	–	D	9
			C	–	45.0	49.1	5.9	–	–	–	–	–	13,580	–	–	–		
237	Spring Canyon mine no. 4 Castlegate B bed		A	5.9	43.3	46.0	4.8	.4	5.6	76.1	1.4	11.4	12,960	–	–	–	T	9
			C	–	46.0	48.9	5.1	–	–	–	–	–	13,770	–	–	–		
238	Spring Canyon mine no. 4 Castlegate B bed		A	3.3	43.0	47.3	6.5	.3	–	–	–	–	12,980	–	–	–	D	11
			C	–	44.4	48.9	6.7	–	–	–	–	–	13,420	–	–	–		
239	Spring Canyon mine no. 4 Castlegate B bed		A	3.5	42.3	47.6	6.7	.3	–	–	–	–	12,890	–	–	–	D	11
			C	–	43.8	49.3	6.9	–	–	–	–	–	13,360	–	–	–		
240	Spring Canyon mine no. 4 Castlegate B bed		A	3.0	42.8	47.6	6.6	.3	–	–	–	–	12,990	–	–	–	D	11
			C	–	44.1	49.1	6.8	–	–	–	–	–	13,390	–	–	–		
241	Spring Canyon mine no. 4 Castlegate B bed		A	2.9	42.8	47.6	6.7	.3	–	–	–	–	12,900	–	–	–	D	11
			C	–	44.1	49.0	6.9	–	–	–	–	–	13,290	–	–	–		
242	Spring Canyon mine no. 4 Castlegate B bed		A	3.0	43.5	47.8	5.7	.3	–	–	–	–	13,150	–	–	–	D	11
			C	–	44.8	49.3	5.9	–	–	–	–	–	13,660	–	–	–		
243	Spring Canyon mine no. 4 Castlegate B bed		A	4.3	42.5	47.2	6.0	.3	–	–	–	–	12,930	–	–	–	D	11
			C	–	44.4	49.3	6.3	–	–	–	–	–	13,510	–	–	–		
244	Spring Canyon mine no. 4 Castlegate B bed		A	6.8	40.8	47.0	5.4	.3	–	–	–	–	12,700	–	–	–	D	11
			C	–	43.8	50.4	5.8	–	–	–	–	–	13,630	–	–	–		
245	Spring Canyon mine no. 4 Castlegate B bed		A	6.4	41.6	46.0	6.1	.4	–	–	–	–	12,630	–	–	–	D	11
			C	–	44.4	49.1	6.5	–	–	–	–	–	13,490	–	–	–		
246	Spring Canyon mine no. 4 Castlegate B bed		A	3.6	42.9	46.9	6.7	.4	–	–	–	–	13,020	–	–	–	T	7
			C	–	44.5	48.6	6.9	–	–	–	–	–	13,510	–	–	–		
247	Spring Canyon mine no. 4 Castlegate B bed		A	3.9	42.6	48.0	5.6	.3	–	–	–	–	13,110	–	–	–	T	7
			C	–	44.3	49.9	5.8	–	–	–	–	–	13,640	–	–	–		
248	Spring Canyon mine no. 4 Castlegate B bed		A	3.0	43.3	48.1	5.6	.3	–	–	–	–	13,160	–	–	–	D	7
			C	–	44.6	49.6	5.8	–	–	–	–	–	13,570	–	–	–		
249	Spring Canyon mine no. 4 Castlegate B bed		A	4.1	42.6	47.7	5.7	.3	–	–	–	–	13,040	–	–	–	T	7
			C	–	44.4	49.7	5.9	–	–	–	–	–	13,600	–	–	–		
250	Spring Canyon mine no. 4 Castlegate B bed		A	2.3	43.1	48.6	6.1	.4	–	–	–	–	13,260	–	–	–	D	7
			C	–	44.1	49.7	6.2	–	–	–	–	–	13,570	–	–	–		
251	Spring Canyon mine no. 4 Castlegate B bed		A	4.2	42.2	46.9	6.6	.3	–	–	–	–	12,840	–	–	–	T	7
			C	–	44.1	49.0	6.9	–	–	–	–	–	13,400	–	–	–		
252	Spring Canyon mine no. 4 Castlegate B bed		A	5.5	41.0	45.9	7.6	.4	–	–	–	–	12,590	–	–	–	T	7
			C	–	43.4	48.6	8.0	–	–	–	–	–	13,330	–	–	–		
253	Spring Canyon mine no. 4 Castlegate B bed		A	6.3	40.3	47.3	6.1	.4	–	–	–	–	12,660	–	–	–	D	7
			C	–	43.0	50.5	6.5	–	–	–	–	–	13,510	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES AN	M	VM	FC	Ash	ULTIMATE ANALYSES S	H	C	N	O	Btu/lb	OTHER TESTS AST	ADL	HGI	Kind of Sample	Ref. Source
254	Spring Canyon mine no. 4 Castlegate B bed		A	7.9	40.9	45.1	6.1	.3	–	–	–	–	12,410	–	–	–	T	7
			C	–	44.4	49.0	6.6	–	–	–	–	–	13,470	–	–	–		
255	Spring Canyon mines 1-5	13S–9E	A	4.6	43.9	45.9	5.6	.9	6.1	72.1	1.4	13.9	13,050	–	1.6	–		39
			C	–	46.0	48.1	5.9	.9	5.8	75.5	1.5	10.4	13,670	–	–	–		
			D	–	48.9	51.1	–	1.0	6.2	80.3	1.6	10.9	14,530	–	–	–		
256	Spring Canyon mines 1-5		A	4.6	43.7	46.3	5.4	.8	–	–	–	–	13,110	2,180	1.7	–		39
257	Spring Canyon mines 1-5		A	4.5	44.4	44.6	6.5	.9	–	–	–	–	12,860	2,130	1.6	–		39
258	Spring Canyon mine no. 1 Sub seam no. 3	NE.SW.9–13S–9E 4395180mN 506930mE	A	4.3	44.1	45.7	5.9	1.0	–	–	–	–	13,040	2,150	1.4	–		39
259	Spring Canyon mines 1-5	13S–9E	A	3.3	–	–	6.0	1.29	–	–	–	–	–	–	–	–		88
260	Spring Canyon mines 1-5		A	4.58	43.3	45.2	6.95	–	–	–	–	–	12,950	–	–	–		86
			B	2.42	44.69	45.7	7.2	–	–	–	–	–	13,198	–	–	–		
			C	–	45.5	47.3	7.3	–	–	–	–	–	13,400	–	–	–		
261	Spring Canyon mines 1-5		A	3.0	43.0	45.9	8.1	–	–	–	–	–	12,730	–	–	–		86
			B	2.3	44.2	45.3	8.3	–	–	–	–	–	13,020	–	–	–		
			C	–	44.4	47.3	8.3	–	–	–	–	–	13,130	–	–	–		
262	Spring Canyon mines 1-5		A	4.4	41.4	47.1	7.0	–	–	–	–	–	12,779	–	–	–		86
			B	2.3	42.4	48.2	7.2	–	–	–	–	–	13,073	–	–	–		
			C	–	43.3	49.3	7.4	–	–	–	–	–	13,373	–	–	–		
263	Spring Canyon mines 1-5		A	3.7	43.5	44.9	8.0	–	–	–	–	–	12,670	–	–	–		86
			B	2.3	44.3	45.2	8.2	–	–	–	–	–	12,916	–	–	–		
			C	–	45.1	46.61	8.3	–	–	–	–	–	13,160	–	–	–		
264	Spring Canyon mines 1-5		A	3.8	41.3	46.6	8.3	–	–	–	–	–	12,530	–	–	–		86
			B	1.5	42.3	47.8	8.4	–	–	–	–	–	12,830	–	–	–		
			C	–	42.95	48.5	8.6	–	–	–	–	–	13,024	–	–	–		
265	Spring Canyon mines 1-5		A	3.2	36.6	52.9	7.3	–	–	–	–	–	12,969	–	–	–		86
			B	1.5	37.5	53.6	7.4	–	–	–	–	–	13,189	–	–	–		
			C	–	38.1	54.5	7.5	–	–	–	–	–	13,394	–	–	–		
266	Spring Canyon mines 1-5		A	2.2	41.4	49.1	7.2	–	–	–	–	–	13,139	–	–	–		86
			B	1.2	41.9	49.6	7.3	–	–	–	–	–	13,276	–	–	–		
			C	–	42.4	50.3	7.4	–	–	–	–	–	13,440	–	–	–		
267	Spring Canyon mines 1-5		A	3.7	40.3	48.8	7.3	–	–	–	–	–	12,853	–	–	–		86
			B	1.6	41.1	49.9	7.5	–	–	–	–	–	13,132	–	–	–		
			C	–	41.8	50.7	7.6	–	–	–	–	–	13,340	–	–	–		
268	Spring Canyon mines 1-5		A	4.3	43.3	46.5	5.9	–	–	–	–	–	12,981	–	1.0	–		86
			B	2.0	44.3	47.6	6.1	–	–	–	–	–	13,293	–	–	–		
			C	–	45.2	48.6	6.2	–	–	–	–	–	13,564	–	–	–		
269	Spring Canyon mines 1-5		A	4.4	43.4	43.9	8.3	.89	–	–	–	–	12,750	–	2.9	–		86
			B	1.3	44.8	45.3	8.6	.92	–	–	–	–	13,169	–	–	–		
			C	–	45.4	45.9	8.7	.93	–	–	–	–	13,338	–	–	–		
270	Spring Canyon mines 1-5		A	0.9	–	–	–	–	–	–	–	–	13,319	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,440	–	–	–		
271	Spring Canyon mines 1-5		A	1.8	–	–	–	–	–	–	–	–	13,271	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,511	–	–	–		
272	Spring Canyon mines 1-5		A	2.5	–	–	–	–	–	–	–	–	13,130	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,469	–	–	–		
273	Spring Canyon mines 1-5		A	2.3	–	–	–	–	–	–	–	–	12,875	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,178	–	–	–		
274	Spring Canyon mines 1-5		A	3.3	–	–	–	–	–	–	–	–	12,755	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,190	–	–	–		
275	Spring Canyon mines 1-5		A	4.3	–	–	–	–	–	–	–	–	12,566	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,125	–	–	–		
276	Spring Canyon mines 1-5		A	–	–	–	–	–	–	–	–	–	12,910	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,190	–	–	–		
277	Spring Canyon mines 1-5		A	–	–	–	–	–	–	–	–	–	12,861	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,400	–	–	–		
278	Spring Canyon mines 1-5		A	2.98	–	–	–	–	–	–	–	–	12,833	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,227	–	–	–		
279	Spring Canyon mines 1-5		A	2.5	–	–	–	–	–	–	–	–	13,352	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,692	–	–	–		
280	Spring Canyon mines 1-5		A	–	–	–	–	–	–	–	–	–	12,820	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,315	–	–	–		
281	Spring Canyon mines 1-5		A	–	–	–	–	–	–	–	–	–	12,804	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,555	–	–	–		
282	Spring Canyon mines 1-5		A	–	–	–	–	–	–	–	–	–	13,090	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,164	–	–	–		
283	Spring Canyon mine no. 4 Castlegate B bed	SE.NW.9–13S–9E 4395720mN 506700mE	A	4.3	42.6	47.4	5.7	.3	–	–	–	–	12,900	–	–	–		10
			C	–	44.5	49.5	6.0	–	–	–	–	–	13,480	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
284	Spring Canyon mine no. 4 Castlegate B bed		A	4.0	41.9	47.8	6.3	.4	–	–	–	–	12,930	–	–	–		10
			C	–	43.6	49.8	6.6	–	–	–	–	–	13,470	–	–	–		
285	Spring Canyon mine no. 4 Castlegate B bed		A	3.2	43.1	48.5	5.2	.3	–	–	–	–	13,200	–	–	–		10
			C	–	44.5	50.1	5.4	–	–	–	–	–	13,640	–	–	–		
286	Spring Canyon mine no. 4 Castlegate B bed		A	4.6	42.6	47.2	5.5	.4	–	–	–	–	12,990	–	–	–		10
			C	–	44.7	49.5	5.8	–	–	–	–	–	13,620	–	–	–		
287	Spring Canyon mine no. 4 Castlegate B bed		A	3.4	42.5	48.2	5.9	.4	–	–	–	–	13,260	–	–	–		10
			C	–	44.0	49.9	6.1	–	–	–	–	–	13,730	–	–	–		
288	Spring Canyon mines 1-5	13S–9E	A	3.4	43.1	47.8	5.7	.4	–	–	–	–	13,110	–	–	–		10
			C	–	44.6	49.5	5.9	–	–	–	–	–	13,570	–	–	–		
289	Spring Canyon mines 1-5		A	1.6	–	–	–	–	–	–	–	–	12,680	–	–	–		86
			C	–	–	–	–	–	–	–	–	–	12,889	–	–	–		
290	Spring Canyon mines 1-5		A	8.3	42.4	44.6	4.8	.7	–	–	–	–	12,290	–	–	–		13
			C	–	46.2	48.6	5.2	–	–	–	–	–	13,410	–	–	–		
291	Spring Canyon no. 1 mine Sub 3 seam	NE.SW.9–13S–9E 4395180mN 506930mE	A	4.44	42.87	44.26	8.43	.55	5.78	70.43	1.42	13.39	12,690	–	2.4	–		38
			C	–	44.86	46.32	8.82	.58	5.54	73.70	1.49	9.87	13,280	–	–	–		
			D	–	49.20	50.80	–	.64	6.08	80.83	1.63	10.82	14,564	–	–	–		
292	Spring Canyon no. 1 mine Sub 3 seam		A	4.4	42.9	44.3	8.4	.6	5.8	70.4	1.4	13.4	12,790	2,150	2.4	–		38
			B	2.1	43.9	45.4	8.63	.56	5.65	72.13	1.45	11.58	13,000	–	–	–		
			C	–	44.9	46.3	8.8	.6	5.8	73.7	1.5	9.9	13,280	–	–	–		
			D	–	49.2	50.8	–	.6	6.1	80.8	1.6	10.9	14,560	–	–	–		
293	Spring Canyon no. 1 mine Sub 3 seam		A	5.2	41.2	45.5	8.1	.6	5.9	69.3	1.4	14.7	12,530	–	3.6	–		39
			C	–	43.5	48.0	8.5	.6	5.6	73.1	1.5	10.7	13,210	–	–	–		
			D	–	47.5	52.5	–	.6	6.1	79.9	1.6	11.8	14,440	–	–	–		
294	Spring Canyon no. 1 mine Sub 3 seam		A	6.3	44.1	44.7	4.9	.5	–	–	–	–	12,200	2,240	4.8	–		39
295	Spring Canyon no. 1 mine Sub 3 seam		A	4.3	42.5	45.7	7.5	.6	–	–	–	–	12,740	2,310	2.6	–		39
296	Spring Canyon no. 1 mine Sub 3 seam		A	6.7	40.4	45.7	7.2	.6	–	–	–	–	12,440	2,280	5.4	–		39
297	Spring Canyon no. 1 mine Sub 3 seam		A	3.3	42.0	46.2	8.5	.6	–	–	–	–	12,670	2,180	1.8	–		39
298	Spring Canyon no. 2 mine Sub 2 seam	SE.NW.9–13S–9E 4395400mN 506680mE	A	6.0	42.9	46.2	4.9	.9	6.0	71.8	1.5	14.9	12,940	2,110	3.9	–		38
			B	2.2	44.7	48.0	5.13	.88	5.82	74.72	1.58	11.87	13,470	–	–	–		
			C	–	45.7	49.0	5.3	.9	5.7	76.4	1.6	10.1	13,770	–	–	–		
			D	–	48.2	51.8	–	1.0	6.0	80.6	1.7	10.7	14,540	–	–	–		
299	Spring Canyon no. 3 mine Castlegate A	NW.NW.9–13S–9E 4395480mN 506530mE	A	4.9	42.2	44.7	8.2	.4	5.7	70.2	1.4	14.1	12,530	2,190	2.8	–		38
			B	2.2	43.4	46.0	8.38	.4	5.55	72.17	1.40	12.10	12,890	–	–	–		
			C	–	44.4	47.0	8.6	.4	5.4	73.8	1.4	10.4	13,180	–	–	–		
			D	–	48.5	51.5	–	.5	6.0	80.7	1.6	11.2	14,410	–	–	–		
300	Spring Canyon no. 3 mine		A	5.1	41.5	47.6	5.8	.5	5.9	71.5	.9	15.4	12,740	–	3.2	–		39
			C	–	43.7	50.2	6.1	.5	5.6	75.3	1.0	11.5	13,420	–	–	–		
			D	–	46.5	53.5	–	.5	5.9	80.2	1.0	12.4	14,300	–	–	–		
301	Spring Canyon no. 3 mine		A	5.8	40.7	46.5	7.0	.5	–	–	–	–	12,620	2,200	4.2	–		39
302	Spring Canyon no. 3 mine		A	4.7	41.5	48.7	5.1	.4	–	–	–	–	12,910	2,150	3.1	–		39
303	Spring Canyon no. 3 mine		A	5.2	41.2	48.1	5.5	.5	–	–	–	–	12,850	2,180	3.4	–		39
304	Spring Canyon no. 3 mine		A	3.9	42.8	47.5	5.8	.5	–	–	–	–	13,010	2,200	2.2	–		39
305	Spring Canyon no. 5 mine Kenilworth bed	SE.SW.4–13S–9E 4396340mN 506680mE	A	3.7	45.7	41.3	9.2	.5	5.6	72.5	1.5	10.3	12,620	–	–	–		15
			C	–	47.5	42.9	9.6	–	–	–	–	–	13,100	–	–	–		
306	Spring Canyon no. 7 mine Kenilworth bed	SW.SW.4–13S–9E 4396200mN 506210mE	A	3.1	46.0	43.2	7.7	.4	–	–	–	–	12,990	–	–	–	T	20
			C	–	47.5	44.6	7.9	–	–	–	–	–	13,410	–	–	–		
307	Spring Canyon no. 7 mine Kenilworth bed		A	3.4	45.6	43.5	7.5	.4	–	–	–	–	12,950	–	–	–	T	20
			C	–	47.2	45.0	7.8	–	–	–	–	–	13,410	–	–	–		
308	Spring Canyon no. 7 mine Kenilworth bed		A	3.3	45.6	43.7	7.4	.4	–	–	–	–	12,890	–	–	–	T	20
			C	–	47.2	45.2	7.7	–	–	–	–	–	13,320	–	–	–		
309	Spring Canyon no. 7 mine Kenilworth bed		A	3.7	45.6	43.2	7.5	.4	–	–	–	–	12,820	–	–	–	T	20
			C	–	47.3	44.9	7.8	–	–	–	–	–	13,310	–	–	–		
310	Spring Canyon no. 7 mine Kenilworth bed		A	4.6	44.0	43.7	7.7	.4	–	–	–	–	12,680	–	–	–	T	20
			C	–	46.1	45.8	8.1	–	–	–	–	–	13,290	–	–	–		
311	Spring Canyon no. 7 mine Kenilworth bed		A	5.5	44.7	42.9	6.9	.4	5.7	74.0	1.4	11.2	12,640	–	–	–	T	20
			C	–	47.3	45.4	7.3	–	–	–	–	–	13,380	–	–	–		
312	Spring Canyon no. 7 mine Kenilworth bed		A	3.4	45.3	44.4	6.9	.5	–	–	–	–	13,070	–	–	–	T	17
			C	–	46.9	46.0	7.1	–	–	–	–	–	13,520	–	–	–		
313	Spring Canyon no. 7 mine Kenilworth bed		A	3.5	45.4	43.2	7.9	.4	–	–	–	–	12,840	–	–	–	D	17
			C	–	47.0	44.8	8.2	–	–	–	–	–	13,320	–	–	–		
314	Spring Canyon no. 7 mine Kenilworth bed		A	3.7	45.7	43.8	6.7	.5	–	–	–	–	13,120	–	–	–	T	17
			C	–	47.5	45.5	7.0	–	–	–	–	–	13,630	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
315	Spring Canyon no. 7 mine Kenilworth bed		A	3.1	45.5	44.4	7.0	.5	–	–	–	–	13,050	–	–	–	T	17
			C	–	47.0	45.8	7.2	–	–	–	–	–	13,470	–	–	–		
316	Spring Canyon no. 7 mine Kenilworth bed		A	3.8	45.4	44.3	6.5	.5	–	–	–	–	13,020	–	–	–	T	17
			C	–	47.2	46.0	6.8	–	–	–	–	–	13,530	–	–	–		
317	Spring Canyon no. 7 mine Kenilworth bed		A	6.4	44.9	42.5	6.2	.5	5.7	74.9	1.4	10.9	12,680	–		–	T	17
			C	–	48.0	45.4	6.6	–	–	–	–	–	13,560	–	–	–		
318	Spring Canyon Tipple	16–13S–9E	A	5.7	39.0	46.1	9.1	.7	–	–	–	–	12,390	–	–	–	D	87
			C	–	41.4	48.9	9.7	–	–	–	–	–	13,140	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,550	–	–	–		
319	Spring Canyon Tipple		A	3.5	41.9	46.7	7.9	.6	–	–	–	–	12,910	–	–	–	D	87
			C	–	43.4	48.4	8.2	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,580	–	–	–		
320	Spring Canyon Tipple		A	4.3	40.6	46.7	8.4	.6	–	–	–	–	12,750	–	–	–	D	87
			C	–	42.4	48.8	8.8	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,610	–	–	–		
321	Spring Canyon Tipple		A	3.7	41.5	46.5	8.3	.5	–	–	–	–	12,850	–	–	–	D	87
			C	–	43.1	48.3	8.6	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,600	–	–	–		
322	Spring Canyon Tipple		A	4.0	40.7	45.8	9.5	.5	–	–	–	–	12,590	–	–	–	D	87
			C	–	42.4	47.7	9.9	–	–	–	–	–	13,110	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,550	–	–	–		
323	Spring Canyon Tipple		A	2.9	42.1	47.7	7.3	.6	–	–	–	–	13,160	–	–	–	D	87
			C	–	43.4	49.1	7.5	–	–	–	–	–	13,550	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,650	–	–	–		
324	Spring Canyon Tipple		A	3.0	41.3	47.2	8.4	.6	–	–	–	–	12,920	–	–	–	D	87
			C	–	42.6	48.7	8.7	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,590	–	–	–		
325	Spring Canyon Tipple		A	2.2	43.6	47.9	6.3	.4	–	–	–	–	13,350	–	–	–	D	87
			C	–	44.6	49.0	6.4	–	–	–	–	–	13,650	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,580	–	–	–		
326	Spring Canyon Tipple		A	3.0	42.7	46.7	7.7	.5	–	–	–	–	13,020	–	–	–	D	87
			C	–	44.0	48.1	7.9	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,570	–	–	–		
327	Spring Canyon Tipple		A	3.5	41.7	46.3	8.5	.6	–	–	–	–	12,820	–	–	–	D	87
			C	–	43.2	48.0	8.8	–	–	–	–	–	13,280	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,560	–	–	–		
328	Spring Canyon Tipple		A	3.5	40.7	46.5	7.3	.7	–	–	–	–	13,000	–	–	–	D	87
			C	–	42.2	48.2	7.6	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,580	–	–	–		
329	Spring Canyon Tipple		A	2.9	42.5	46.6	8.0	.5	–	–	–	–	13,030	–	–	–	D	87
			C	–	43.8	48.0	8.2	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,620	–	–	–		
330	Spring Canyon Tipple		A	3.0	41.5	46.9	8.5	.6	–	–	–	–	12,890	–	–	–	D	87
			C	–	42.8	48.4	8.8	–	–	–	–	–	13,290	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,570	–	–	–		
331	Spring Canyon Tipple		A	2.4	41.1	47.2	9.3	.6	–	–	–	–	12,810	–	–	–	D	87
			C	–	42.1	48.4	9.5	–	–	–	–	–	13,130	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		
332	Spring Canyon Tipple		A	3.4	41.9	46.6	8.1	.6	–	–	–	–	12,910	–	–	–	D	87
			C	–	43.4	48.2	8.4	–	–	–	–	–	13,360	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,590	–	–	–		
333	Spring Canyon Tipple		A	2.7	43.0	47.1	7.2	.6	–	–	–	–	13,190	–	–	–	D	87
			C	–	44.2	48.4	7.4	–	–	–	–	–	13,560	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,640	–	–	–		
334	Spring Canyon Tipple		A	2.2	41.3	47.8	8.7	.5	–	–	–	–	12,960	–	–	–	D	87
			C	–	42.2	48.9	8.9	–	–	–	–	–	13,250	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,540	–	–	–		
335	Spring Canyon Tipple		A	3.1	43.1	46.7	7.1	.5	–	–	–	–	13,230	–	–	–	D	87
			C	–	44.5	48.2	7.3	–	–	–	–	–	13,650	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,720	–	–	–		
336	Spring Canyon Tipple		A	2.8	43.7	47.1	6.3	.6	–	–	–	–	13,300	–	–	–	D	87
			C	–	45.0	48.5	6.5	–	–	–	–	–	13,680	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,630	–	–	–		
337	Spring Canyon Tipple		A	3.0	42.8	47.8	6.4	.7	–	–	–	–	13,350	–	–	–	D	87
			C	–	44.1	49.3	6.6	–	–	–	–	–	13,760	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,730	–	–	–		
338	Spring Canyon Tipple		A	2.7	43.3	47.4	6.6	.6	–	–	–	–	13,290	–	–	–	D	87
			C	–	44.5	48.7	6.8	–	–	–	–	–	13,660	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,660	–	–	–		
339	Spring Canyon Tipple		A	2.9	41.9	47.7	7.6	.6	–	–	–	–	13,050	–	–	–	D	87
			C	–	43.1	49.1	7.8	–	–	–	–	–	13,440	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,580	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
340	Spring Canyon Tipple		A	2.9	41.0	49.3	6.8	.6	–	–	–	–	13,260	–	–	–	D	87
			C	–	42.2	50.8	7.0	–	–	–	–	–	13,660	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,690	–	–	–		
341	Spring Canyon Tipple		A	3.1	42.2	48.0	6.7	.6	–	–	–	–	13,250	–	–	–	D	87
			C	–	43.6	49.5	6.9	–	–	–	–	–	13,670	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,680	–	–	–		
342	Spring Canyon Tipple		A	3.1	42.5	47.6	6.8	.6	–	–	–	–	13,210	–	–	–	D	87
			C	–	43.9	49.1	7.0	–	–	–	–	–	13,630	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,660	–	–	–		
343	Spring Canyon Tipple		A	3.3	43.1	46.7	6.9	.6	–	–	–	–	13,130	–	–	–	D	87
			C	–	44.6	48.3	7.1	–	–	–	–	–	13,580	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,620	–	–	–		
344	Spring Canyon Tipple		A	3.2	42.2	48.0	6.6	.7	–	–	–	–	13,180	–	–	–	D	87
			C	–	43.6	49.6	6.8	–	–	–	–	–	13,620	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,610	–	–	–		
345	Spring Canyon Tipple		A	2.6	41.2	47.9	8.3	.5	–	–	–	–	12,990	–	–	–	D	87
			C	–	42.3	49.2	8.5	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,580	–	–	–		
346	Spring Canyon Tipple		A	3.2	42.7	48.4	5.7	.6	–	–	–	–	13,320	–	–	–	D	87
			C	–	44.1	50.0	5.9	–	–	–	–	–	13,760	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,620	–	–	–		
347	Spring Canyon Tipple		A	3.3	42.9	48.3	5.5	.7	–	–	–	–	13,360	–	–	–	D	87
			C	–	44.4	49.9	5.7	–	–	–	–	–	13,820	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,660	–	–	–		
348	Spring Canyon Tipple		A	3.5	43.7	47.3	5.5	.7	–	–	–	–	13,250	–	–	–	D	87
			C	–	45.3	49.0	5.7	–	–	–	–	–	13,730	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,560	–	–	–		
349	Spring Canyon Tipple		A	3.7	42.1	47.5	6.7	.7	–	–	–	–	13,030	–	–	–	D	87
			C	–	43.7	49.3	7.0	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,550	–	–	–		
350	Spring Canyon Tipple		A	4.4	40.1	49.4	6.1	.7	–	–	–	–	13,150	–	–	–	D	87
			C	–	41.9	51.7	6.4	–	–	–	–	–	13,750	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,690	–	–	–		
351	Spring Canyon Tipple		A	4.2	44.1	46.4	5.4	.6	–	–	–	–	13,050	2,250	–	–	T	87
			C	–	46.0	48.4	5.6	–	–	–	–	–	13,620	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
352	Spring Canyon Tipple		A	4.1	42.6	46.6	6.7	.7	–	–	–	–	12,980	–	–	–	D	87
			C	–	44.4	48.6	7.0	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,550	–	–	–		
353	Spring Canyon Tipple		A	4.2	43.5	45.2	7.1	.7	–	–	–	–	12,860	2,310	–	–	T	87
			C	–	45.4	47.2	7.4	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–			
354	Spring Canyon Tipple		A	3.8	42.6	45.8	7.8	.7	–	–	–	–	12,760	2,340	–	–	T	87
			C	–	44.3	47.6	8.1	–	–	–	–	–	13,260	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
355	Spring Canyon Tipple		A	4.0	42.5	46.4	7.1	.7	–	–	–	–	12,870	2,330	–	–	T	87
			C	–	44.3	48.3	7.4	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
356	Spring Canyon Tipple		A	4.9	42.0	45.8	7.2	.7	–	–	–	–	12,690	2,310	–	–	T	87
			C	–	44.2	48.2	7.6	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		
357	Spring Canyon Tipple		A	3.7	43.3	46.9	6.1	.8	–	–	–	–	13,190	–	–	–	D	87
			C	–	45.0	48.7	6.3	–	–	–	–	–	13,700	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,620	–	–	–		
358	Spring Canyon Tipple		A	3.2	43.7	46.5	6.7	.7	–	–	–	–	13,120	–	–	–	D	87
			C	–	45.1	48.0	6.9	–	–	–	–	–	13,550	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,550	–	–	–		
359	Spring Canyon Tipple		A	5.6	41.1	46.3	7.1	.9	–	–	–	–	12,530	–	–	–	D	87
			C	–	43.5	49.0	7.5	–	–	–	–	–	13,270	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
360	Spring Canyon Tipple		A	3.4	43.4	46.5	6.8	.7	–	–	–	–	13,060	–	–	–	D	87
			C	–	44.9	48.1	7.0	–	–	–	–	–	13,520	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,540	–	–	–		
361	Spring Canyon Tipple		A	3.4	43.9	45.8	7.0	.9	–	–	–	–	13,030	–	–	–	D	87
			C	–	45.4	47.4	7.2	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,540	–	–	–		
362	Spring Canyon Tipple		A	3.7	42.4	45.7	8.2	.8	–	–	–	–	12,730	–	–	–	D	87
			C	–	44.0	47.5	8.5	–	–	–	–	–	13,220	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
363	Spring Canyon Tipple		A	3.6	44.8	45.6	6.0	.7	–	–	–	–	13,020	–	–	–	D	87
			C	–	46.5	47.3	6.2	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
364	Spring Canyon Tipple		A	4.0	42.0	44.9	9.0	.9	–	–	–	–	12,510	–	–	–	D	87
			C	–	43.8	46.8	9.4	–	–	–	–	–	13,030	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–			
365	Spring Canyon Tipple		A	5.2	42.0	44.1	8.7	.8	–	–	–	–	12,440	2,340	–	–	D	87
			C	–	44.3	46.5	9.2	–	–	–	–	–	13,120	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–			
366	Spring Canyon Tipple		A	3.2	42.7	44.0	10.1	.9	–	–	–	–	12,580	–	–		D	87
			C	–	44.1	45.5	10.4	–	–	–	–	–	13,000	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		
367	Spring Canyon Tipple		A	2.9	43.0	44.9	9.2	.9	–	–	–	–	12,690	2,330	–	–	D	87
			C	–	44.3	46.2	9.5	–	–	–	–	–	13,070	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		
368	Spring Canyon Tipple		A	4.4	41.4	44.1	10.1	.9	–	–	–	–	12,320	2,410	–	–	D	87
			C	–	43.3	46.1	10.6	–	–	–	–	–	12,890	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
369	Spring Canyon Tipple		A	4.9	41.7	43.7	9.7	.9	–	–	–	–	12,320	2,390	–	–	D	87
			C	–	43.9	45.9	10.2	–	–	–	–	–	12,950	–	–			
			D	–	–	–	–	–	–	–	–	–	14,420	–	–			
370	Spring Canyon Tipple		A	3.3	45.9	44.8	6.0	1.3	–	–	–	–	13,270	2,090	–	–	T	87
			C	–	47.5	46.3	6.2	–	–	–	–	–	13,720	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,630	–	–			
371	Spring Canyon Tipple		A	3.3	43.4	45.3	6.1	1.1	–	–	–	–	13,230	2,080	–	–	T	87
			C	–	46.9	46.8	6.3	–	–	–	–	–	13,680	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,600	–	–			
372	Spring Canyon Tipple		A	3.2	44.1	44.0	8.6	1.1	–	–	–	–	12,900	2,190	–	–	T	87
			C	–	45.6	45.5	8.9	–	–	–	–	–	13,330	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,630	–	–			
373	Spring Canyon Tipple		A	3.7	43.1	44.6	8.6	.8	–	–	–	–	12,710	–	–	–	D	87
			C	–	44.8	46.3	8.9	–	–	–	–	–	13,200	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–			
374	Spring Canyon Tipple		A	3.3	44.7	43.8	8.2	1.0	–	–	–	–	12,950	2,200	–	–	T	87
			C	–	46.2	45.3	8.5	–	–	–	–	–	13,390	–	–			
			D	–	–	–	–	–	–	–	–	–	14,630	–	–			
375	Spring Canyon Tipple		A	4.5	43.6	43.9	7.9	.9	–	–	–	–	12,760	2,170	–	–	T	87
			C	–	45.7	46.0	8.3	–	–	–	–	–	13,360	–	–			
			D	–	–	–	–	–	–	–	–	–	14,570	–	–			
376	Spring Canyon Tipple Castlegate B bed		A	4.2	42.2	47.0	6.6	.4	–	–	–	–	12,830	2,240	–	–	T	87
			C	–	44.0	49.1	6.9	–	–	–	–	–	13,390	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–			
377	Spring Canyon Tipple Castlegate B bed		A	4.1	43.1	47.2	5.7	.3	–	–	–	–	13,040	2,230	–	–	T	87
			C	–	44.9	49.2	5.9	–	–	–	–	–	13,600	–	–			
			D	–	–	–	–	–	–	–	–	–	14,450	–	–			
378	Spring Canyon Tipple Castlegate B bed		A	2.7	43.8	45.7	7.8	.8	–	–	–	–	12,940	–	–	–	D	87
			C	–	45.0	47.0	8.0	–	–	–	–	–	13,300	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
379	Spring Canyon Tipple Castlegate B bed		A	3.8	42.9	47.3	6.0	.3	–	–	–	–	12,970	2,220	–	–	T	87
			C	–	44.6	49.2	6.2	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
380	Spring Canyon Tipple Castlegate B bed		A	3.7	44.2	46.5	5.6	.3	–	–	–	–	13,090	2,220	–	–	T	87
			C	–	45.9	48.3	5.8	–	–	–	–	–	13,590	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
381	Spring Canyon Tipple Castlegate B bed		A	3.9	44.8	46.1	5.2	.4	–	–	–	–	13,180	2,220	–	–	T	87
			C	–	46.6	48.0	5.4	–	–	–	–	–	13,710	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–	–		
382	Spring Canyon Tipple Castlegate B bed		A	4.3	44.5	45.7	5.5	.4	–	–	–	–	13,090	2,200	–	–	T	87
			C	–	46.5	47.8	5.7	–	–	–	–	–	13,680	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		
383	Spring Canyon Tipple Castlegate B bed		A	2.7	42.7	43.8	10.8	.9	–	–	–	–	12,610	–	–	–	D	87
			C	–	43.9	45.0	11.1	–	–	–	–	–	12,960	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,580	–	–	–		
384	Spring Canyon Tipple Castlegate B bed		A	3.7	42.8	44.7	8.9	.8	–	–	–	–	12,750	2,240	–	–	D	87
			C	–	44.4	46.4	9.2	–	–	–	–	–	13,240	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,580	–	–	–		
385	Spring Canyon Tipple Castlegate B bed		A	3.7	43.3	43.7	9.2	.9	–	–	–	–	12,620	–	–	–	D	87
			C	–	45.0	45.4	9.6	–	–	–	–	–	13,110	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,500	–	–	–		
386	Spring Canyon Tipple Castlegate B bed		A	2.9	44.3	45.9	6.9	1.0	–	–	–	–	13,140	–	–	–	D	87
			C	–	45.6	47.3	7.1	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,560	–	–	–		
387	Spring Canyon Tipple Castlegate B bed		A	4.3	43.2	45.1	7.5	.7	–	–	–	–	12,760	2,220	–	–	D	87
			C	–	45.1	47.1	7.8	–	–	–	–	–	13,330	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
388	Spring Canyon Tipple Castlegate B bed		A	5.5	43.1	43.9	7.5	.7	–	–	–	–	12,610	2,200	–	–	D	87
			C	–	45.6	46.5	7.9	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
389	Spring Canyon Tripple Castlegate B bed		A	4.4	43.1	46.5	6.0	.5	–	–	–	–	12,910	–	–	–	D	87
			C	–	45.1	48.6	6.3	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,410	–	–	–		
390	Spring Canyon Tipple Castlegate B bed		A	2.9	43.7	46.9	6.5	.4	–	–	–	–	13,030	2,220	–	–	D	87
			C	–	45.0	48.3	6.7	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
391	Spring Canyon Tipple Castlegate B bed		A	3.1	43.7	47.1	6.1	.4	–	–	–	–	13,060	2,180	–	–	D	87
			C	–	45.1	48.6	6.3	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
392	Spring Canyon Tipple Castlegate B bed		A	3.7	43.2	46.8	6.3	.4	–	–	–	–	12,960	–	–	–	D	87
			C	–	44.9	48.6	6.5	–	–	–	–	–	13,460	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
393	Spring Canyon Tipple Castlegate B bed		A	3.7	43.2	46.2	6.8	.5	–	–	–	–	12,810	–	–	–	D	87
			C	–	44.9	48.0	7.1	–	–	–	–	–	13,300	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,320	–	–	–		
394	Spring Canyon Tipple Castlegate B bed		A	5.1	41.8	46.6	6.5	.2	–	–	–	–	12,790	2,290	–	–	T	87
			C	–	44.0	49.1	6.9	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
395	Spring Canyon Tipple Castlegate B bed		A	3.6	42.9	46.9	6.7	.4	–	–	–	–	13,020	2,210	–	–	T	87
			C	–	44.5	48.6	6.9	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		
396	Spring Canyon Tipple Castlegate B bed		A	3.9	42.6	48.0	5.6	.3	–	–	–	–	13,110	2,230	–	–	T	87
			C	–	44.3	49.9	5.8	–	–	–	–	–	13,640	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
397	Spring Canyon Tipple Castlegate B bed		A	4.1	42.6	47.7	5.7	.3	–	–	–	–	13,040	2,290	–	–	T	87
			C	–	44.4	49.7	5.9	–	–	–	–	–	13,600	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
398	Spring Canyon Tipple Castlegate B bed		A	4.2	42.2	46.9	6.6	.3	–	–	–	–	12,840	2,210	–	–	T	87
			C	–	44.1	49.0	6.9	–	–	–	–	–	13,400	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
399	Spring Canyon Tipple Castlegate B bed		A	5.5	41.0	45.9	7.6	.4	–	–	–	–	12,600	2,360	–	–	T	87
			C	–	43.4	48.6	8.0	–	–	–	–	–	13,330	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–	–		
400	Spring Canyon Tipple Castlegate B bed		A	6.3	40.3	47.3	6.1	.4	–	–	–	–	12,660	2,290	–	–	D	87
			C	–	43.0	50.5	6.5	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
401	Spring Canyon Tipple Castlegate B bed		A	7.9	40.9	45.1	6.1	.3	–	–	–	–	12,410	2,260	–	–	T	87
			C	–	44.4	49.0	6.6	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
402	Spring Canyon Tipple Castlegate B bed		A	3.4	42.4	47.5	6.7	.4	–	–	–	–	12,890	2,250	–	–	D	87
			C	–	43.9	49.2	6.9	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,330	–	–	–		
403	Spring Canyon Tipple Castlegate B bed		A	3.0	42.4	47.4	7.2	.4	–	–	–	–	12,960	–	–	–	D	87
			C	–	43.7	48.9	7.4	–	–	–	–	–	13,360	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
404	Spring Canyon Tipple Castlegate B bed		A	2.7	41.1	45.3	5.9	.3	–	–	–	–	13,060	2,240	–	–	D	87
			C	–	44.5	49.1	6.4	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,340	–	–	–		
405	Spring Canyon Tipple Castlegate B bed		A	3.0	43.4	47.0	6.6	.3	–	–	–	–	12,950	–	–	–	D	87
			C	–	44.7	48.5	6.8	–	–	–	–	–	13,350	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,320	–	–	–		
406	**Spring Canyon Tipple Castlegate B bed**		A	2.8	43.3	47.4	6.5	.4	–	–	–	–	12,980	2,230	–	–	D	87
			C	–	44.5	48.8	6.7	–	–	–	–	–	13,350	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,310	–	–	–		
407	**Spring Canyon Tipple Castlegate B bed**		A	3.6	42.6	46.6	7.2	.4	–	–	–	–	12,820	–	–	–	D	87
			C	–	44.2	48.3	7.5	–	–	–	–	–	13,300	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
408	**Spring Canyon Tipple Castlegate B bed**		A	3.9	42.5	47.0	6.6	.4	–	–	–	–	12,860	2,220	–	–	D	87
			C	–	44.2	48.9	6.9	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
409	**Spring Canyon Tipple Castlegate B bed**		A	3.8	42.5	47.9	5.8	.4	–	–	–	–	13,050	–	–	–	D	87
			C	–	44.2	49.8	6.0	–	–	–	–	–	13,570	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		
410	**Spring Canyon Tipple Castlegate B bed**		A	3.3	41.9	48.9	6.0	.4	–	–	–	–	13,140	2,240	–	–	T	87
			C	–	43.3	50.6	6.1	–	–	–	–	–	13,590	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
411	**Spring Canyon Tipple Castlegate B bed**		A	3.1	43.5	47.6	5.8	.3	–	–	–	–	13,050	2,230	–	–	T	87
			C	–	44.9	49.1	6.0	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,330	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
412	Spring Canyon Tipple Castlegate B bed		A	2.9	43.0	47.5	6.6	.3	–	–	–	–	13,010	2,300	–	–	T	87
			C	–	44.3	48.9	6.8	–	–	–	–	–	13,400	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
413	Spring Canyon Tipple Castlegate B bed		A	3.1	43.3	47.8	5.8	.3	–	–	–	–	13,070	–	–	–	D	87
			C	–	44.7	49.3	6.0	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
414	Spring Canyon Tipple Castlegate B bed		A	3.4	42.4	48.2	6.0	.5	–	–	–	–	13,170	2,260	–	–	T	87
			C	–	43.9	49.9	6.2	–	–	–	–	–	13,630	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,530	–	–	–		
415	Spring Canyon Tipple Castlegate B bed		A	2.9	43.2	48.0	5.9	.4	–	–	–	–	13,130	2,300	–	–	T	87
			C	–	44.5	49.4	6.1	–	–	–	–	–	13,520	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
416	Spring Canyon Tipple Castlegate B bed		A	3.1	43.6	47.3	6.0	.4	–	–	–	–	13,070	2,230	–	–	D	87
			C	–	45.0	48.8	6.2	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
417	Spring Canyon Tipple Castlegate B bed		A	4.9	42.8	46.5	5.8	.4	–	–	–	–	12,900	2,220	–	–	D	87
			C	–	45.0	48.9	6.1	–	–	–	–	–	13,560	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		
418	Spring Canyon Tipple Castlegate B bed		A	3.8	43.8	47.0	5.4	.4	–	–	–	–	13,200	2,240	–	–	T	87
			C	–	45.5	48.9	5.6	–	–	–	–	–	13,720	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,530	–	–	–		
419	Spring Canyon Tipple Castlegate B bed		A	5.9	43.3	46.0	4.8	.4	–	–	–	–	12,960	2,250	–	–	T	87
			C	–	46.0	48.9	5.1	–	–	–	–	–	13,770	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,510	–	–	–		
420	Spring Canyon Tipple Castlegate B bed		A	4.3	42.6	47.4	5.7	.3	–	–	–	–	12,900	–	–	–	D	87
			C	–	44.5	49.5	6.0	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,340	–	–	–		
421	Spring Canyon Tipple Castlegate B bed		A	4.0	41.9	47.8	6.3	.4	–	–	–	–	12,930	–	–	–	D	87
			C	–	43.6	49.8	6.6	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
422	Spring Canyon Tipple Castlegate B bed		A	3.2	43.1	48.5	5.2	.3	–	–	–	–	13,200	2,220	–	–	D	87
			C	–	44.5	50.1	5.4	–	–	–	–	–	13,640	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
423	Spring Canyon Tipple Castlegate B bed		A	4.6	42.6	47.2	5.5	.4	–	–	–	–	12,990	2,190	–	–	D	87
			C	–	44.7	49.5	5.8	–	–	–	–	–	13,620	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
424	Spring Canyon Tipple Castlegate B bed		A	3.4	43.1	47.8	5.7	.4	–	–	–	–	13,110	2,200	–	–	D	87
			C	–	44.6	49.5	5.9	–	–	–	–	–	13,570	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
425	Spring Canyon Tipple Castlegate B bed		A	3.3	42.9	47.3	6.5	.3	–	–	–	–	12,980	–	–	–	D	87
			C	–	44.4	48.9	6.7	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
426	Spring Canyon Tipple Castlegate B bed		A	3.5	42.3	47.6	6.7	.3	–	–	–	–	12,890	–	–	–	D	87
			C	–	43.8	49.3	6.9	–	–	–	–	–	13,360	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
427	Spring Canyon Tipple Castlegate B bed		A	3.0	42.8	47.6	6.6	.3	–	–	–	–	12,990	–	–	–	D	87
			C	–	44.1	49.1	6.8	–	–	–	–	–	13,390	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
428	Spring Canyon Tipple Castlegate B bed		A	2.9	42.8	47.6	6.7	.3	–	–	–	–	12,900	–	–	–	D	87
			C	–	44.1	49.0	6.9	–	–	–	–	–	13,290	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,270	–	–	–		
429	Spring Canyon Tipple Castlegate B bed		A	4.3	42.5	47.2	6.0	.3	–	–	–	–	12,930	2,240	–	–	D	87
			C	–	44.4	49.3	6.3	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
430	Spring Canyon Tipple Castlegate B bed		A	6.8	40.8	47.0	5.4	.3	–	–	–	–	12,700	2,230	–	–	D	87
			C	–	43.8	50.4	5.8	–	–	–	–	–	13,630	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
431	Spring Canyon Tipple Castlegate B bed		A	4.1	43.1	47.2	5.7	.3	–	–	–	–	13,000	2,240	–	–	D	87
			C	–	44.9	49.2	5.9	–	–	–	–	–	13,560	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,410	–	–	–		
432	Spring Canyon Tipple Castlegate B bed		A	3.6	43.5	47.3	5.6	.3	–	–	–	–	13,140	2,270	–	–	T	87
			C	–	45.1	49.1	5.8	–	–	–	–	–	13,630	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
433	Spring Canyon Tipple Castlegate B bed		A	4.2	42.9	47.8	5.1	.4	–	–	–	–	13,130	2,260	–	–	T	87
			C	–	44.8	49.9	5.3	–	–	–	–	–	13,710	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
434	Spring Canyon Tipple Castlegate B bed		A	5.8	42.6	46.3	5.4	.4	–	–	–	–	12,820	2,210	–	50	T	87
			C	–	45.2	49.1	5.7	–	–	–	–	–	13,610	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
435	Spring Canyon Tipple Castlegate B bed		A	4.1	43.8	45.4	6.7	.4	–	–	–	–	12,930	2,260	–	48	T	87
			C	–	45.7	47.3	7.0	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
				AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
436	Spring Canyon Tipple Castlegate A & D beds		A C D	4.5 – –	45.1 47.2 –	42.9 44.9 –	7.5 7.9 –	.6 – –	–	–	–	–	12,720 13,320 14,460	2,220 – –	–	–	T	87
437	Spring Canyon Tipple Castlegate A & D beds		A C D	3.7 – –	45.9 47.7 –	43.3 45.0 –	7.0 7.3 –	.5 – –	–	–	–	–	13,040 13,540 14,610	2,190 – –	–	–	T	87
438	Spring Canyon Tipple Castlegate A & D beds		A C D	3.6 – –	46.2 47.9 –	42.6 44.2 –	7.6 7.9 –	.5 – –	–	–	–	–	12,870 13,350 14,500	2,190 – –	–	–	T	87
439	Spring Canyon Tipple Castlegate A & D beds		A C D	3.8 – –	43.6 45.3 –	44.8 46.6 –	8.9 8.1 –	.4 – –	–	–	–	–	12,790 13,300 14,470	2,440 – –	–	–	D	87
440	Spring Canyon Tipple Castlegate A & D beds		A C D	3.6 – –	45.5 47.2 –	43.6 45.2 –	7.3 7.6 –	.5 – –	–	–	–	–	12,830 13,310 14,400	2,190 – –	–	–	T	87
441	Spring Canyon Tipple Castlegate A & D beds		A C D	4.0 – –	45.4 47.3 –	43.0 44.8 –	7.6 7.9 –	.6 – –	–	–	–	–	12,800 13,330 14,470	2,190 – –	–	–	T	87
442	Spring Canyon Tipple Castlegate A & D beds		A C D	5.7 – –	44.1 46.8 –	42.4 45.0 –	7.7 8.2 –	.6 – –	–	–	–	–	12,490 13,240 14,420	2,260 – –	–	–	T	87
443	Spring Canyon Tipple Castlegate A & D beds		A C D	5.0 – –	43.8 46.1 –	42.8 45.1 –	8.4 8.8 –	.4 – –	–	–	–	–	12,520 13,180 14,450	2,230 – –	–	–	D	87
444	Spring Canyon Tipple Castlegate D bed		A C D	3.7 – –	45.7 47.5 –	41.3 42.9 –	9.2 9.6 –	.5 – –	5.6	72.5	1.5	10.3	12,620 13,100 14,490	2,260 – –	–	–	T	87
445	Spring Canyon Tipple Castlegate D bed		A C D	3.4 – –	45.3 46.9 –	44.4 46.0 –	6.9 7.1 –	.5 – –	–	–	–	–	13,060 13,520 14,550	2,130 – –	–	–	T	87
446	Spring Canyon Tipple Castlegate D bed		A C D	3.5 – –	45.4 47.0 –	43.2 44.8 –	7.9 8.2 –	.4 – –	–	–	–	–	12,850 13,320 14,510	2,200 – –	–	–	D	87
447	Spring Canyon Tipple Castlegate D bed		A C D	3.7 – –	45.7 47.5 –	43.8 45.5 –	6.7 7.0 –	.5 – –	–	–	–	–	13,130 13,630 14,660	2,180 – –	–	–	T	87
448	Spring Canyon Tipple Castlegate D bed		A C D	3.1 – –	45.5 47.0 –	44.4 45.8 –	7.0 7.2 –	.5 – –	–	–	–	–	13,050 13,470 14,520	2,130 – –	–	–	T	87
449	Spring Canyon Tipple Castlegate D bed		A C D	3.8 – –	45.4 47.2 –	44.3 46.0 –	6.5 6.8 –	.5 – –	–	–	–	–	13,020 13,530 14,520	2,130 – –	–	–	T	87
450	Spring Canyon Tipple Castlegate D bed		A C D	6.4 – –	44.9 48.0 –	42.5 45.4 –	6.2 6.6 –	.5 – –	5.7	74.9	1.4	10.9	12,690 13,560 14,520	2,110 – –	–	–	T	87
451	Spring Canyon Tipple Castlegate D bed		A C D	4.2 – –	45.4 47.4 –	43.0 44.9 –	7.4 7.7 –	.3 – –	–	–	–	–	12,780 13,340 14,450	2,120 – –	–	–	T	87
452	Spring Canyon Tipple Castlegate D bed		A C D	3.1 – –	46.0 47.5 –	43.2 44.6 –	7.7 7.9 –	.4 – –	–	–	–	–	12,990 13,410 14,560	2,130 – –	–	–	T	87
453	Spring Canyon Tipple Castlegate D bed		A C D	3.4 – –	45.6 47.2 –	43.5 45.0 –	7.5 7.8 –	.4 – –	–	–	–	–	12,950 13,410 14,540	2,090 – –	–	40 – –	T	87
454	Spring Canyon Tipple Castlegate D bed		A C D	3.3 – –	45.6 47.2 –	43.6 45.1 –	7.4 7.7 –	.4 – –	–	–	–	–	12,880 13,320 14,430	2,130 – –	–	–	T	87
455	Spring Canyon Tipple Castlegate D bed		A C D	3.7 – –	45.6 47.3 –	43.2 44.9 –	7.5 7.8 –	.4 – –	–	–	–	–	12,820 13,310 14,440	2,130 – –	–	–	T	87
456	Spring Canyon Tipple Castlegate D bed		A C D	4.6 – –	44.0 46.1 –	43.7 45.8 –	7.7 8.1 –	.4 – –	–	–	–	–	12,680 13,290 14,460	2,130 – –	–	–	T	87
457	Spring Canyon Tipple Castlegate D bed		A C D	5.5 – –	44.7 47.3 –	42.9 45.4 –	7.5 7.3 –	.4 – –	5.7	74.0	1.4	11.2	12,640 13,380 14,430	2,090 – –	–	–	T	87
458	Standard mine Castlegate B bed	8–13S–9E	A C	3.5 –	42.6 44.1	47.7 49.4	6.3 6.5	.4 –	–	–	–	–	12,940 13,410	– –	–	–	D	6
459	Standard mine Castlegate B bed		A C	3.1 –	44.0 45.4	45.3 46.8	7.6 7.8	.9 –	–	–	–	–	12,970 13,380	– –	–	–	D	6
460	Standard mine Castlegate bed		A C D	3.19 – –	44.25 45.71 –	45.86 47.38 –	6.69 6.91 –	.49 – –	–	–	–	–	12,991 13,419 14,415	– – –	–	–		72

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
461	Standard mine Castlegate B bed		A C	3.2 –	45.3 46.8	45.2 46.7	6.3 6.5	.8 –	– –	– –	– –	– –	13,240 13,680	– –	– –	– –	D	8
462	Standard mine Castlegate B bed		A C	2.8 –	45.8 47.1	44.8 46.1	6.6 6.8	.8 –	– –	– –	– –	– –	13,200 13,580	– –	– –	– –	D	8
463	Standard mine Castlegate B bed		A C	2.9 –	42.6 43.9	46.8 48.2	7.7 7.9	.3 –	– –	– –	– –	– –	12,860 13,240	– –	– –	– –	D	8
464	Standard mine Castlegate B bed		A C	3.2 –	44.2 45.7	46.5 48.0	6.1 6.3	.7 –	– –	– –	– –	– –	13,160 13,590	– –	– –	– –	D	8
465	Standard mine Castlegate B bed		A C	3.1 –	44.4 45.8	46.4 47.9	7.1 6.3	.6 –	– –	– –	– –	– –	13,160 13,580	– –	– –	– –	D	8
466	Standard mine Castlegate B bed		A C	3.9 –	43.4 45.2	45.6 47.4	7.1 7.4	.6 –	– –	– –	– –	– –	12,910 13,430	– –	– –	– –	D	8
467	Standard mine Castlegate A, Sub 1, 2, 3		A C	2.7 –	46.2 47.5	44.7 45.9	6.4 6.6	.7 –	– –	– –	– –	– –	13,300 13,670	– –	– –	– –	D	9
468	Standard mine Castlegate A, Sub 1, 2, 3		A C	3.0 –	45.2 46.6	43.9 45.3	7.9 8.1	.9 –	– –	– –	– –	– –	13,030 13,430	– –	– –	– –	D	9
469	Standard mine Castlegate A, Sub 1, 2, 3		A C	3.2 –	45.6 45.0	46.4 47.9	6.9 7.1	.5 –	– –	– –	– –	– –	12,970 13,400	– –	– –	– –		7
470	Standard mine Castlegate bed		A C D	3.77 – –	45.76 47.55 50.72	44.47 46.21 49.28	6.00 6.24 –	.36 .37 .39	5.88 5.67 6.05	73.42 75.99 81.05	1.35 1.40 1.49	13.29 10.33 11.02	13,070 13,583 14,488	– –	1.6 –	– –		38
471	Standard mine Castlegate bed		A C D	4.90 – –	42.85 45.06 48.13	46.18 48.56 51.87	6.07 6.38 –	.41 .43 .46	5.80 5.53 5.91	71.80 75.50 80.64	1.37 1.44 1.54	14.55 10.72 11.45	12,848 13,511 14,431	– –	2.8 –	– –		38
472	Standard mine Castlegate A, Sub 1, 2, 3		A C	2.4 –	46.4 47.5	45.9 47.0	5.4 5.5	.9 –	– –	– –	– –	– –	13,530 13,860	– –	– –	– –		73
473	Standard mine Castlegate A, Sub 1, 2, 3		A C	2.6 –	43.9 45.1	46.8 48.1	6.6 6.8	.6 –	– –	– –	– –	– –	13,050 13,390	– –	– –	– –		73
474	Standard mine Castlegate A, Sub 1, 2, 3		A C	2.4 –	45.3 46.4	44.0 45.1	8.3 8.5	.9 –	– –	– –	– –	– –	12,950 13,270	– –	– –	– –		73
475	Standard mine Castlegate A, Sub 1, 2, 3		A C	2.7 –	44.9 45.9	46.0 47.0	6.9 7.1	.9 –	– –	– –	– –	– –	13,160 13,530	– –	– –	– –		73
476	Standard mine Castlegate A, Sub 1, 2, 3		A C	3.0 –	44.2 45.6	44.6 46.0	8.1 8.4	.9 –	– –	– –	– –	– –	12,980 13,380	– –	– –	– –		73
477	Standard mine Castlegate A, Sub 1, 2, 3		A C	5.2 –	42.3 44.6	43.3 45.7	9.2 9.7	.9 –	– –	– –	– –	– –	12,430 13,120	– –	– –	– –		73
478	Standard mine Castlegate A, Sub 1, 2, 3		A C	4.4 –	42.5 44.5	44.4 46.4	8.7 9.1	.8 –	– –	– –	– –	– –	12,530 13,110	– –	– –	– –		73
479	Standard mine Castlegate A, Sub 1, 2, 3		A C	2.7 –	44.5 45.7	45.0 46.2	7.9 8.1	.8 –	– –	– –	– –	– –	12,970 13,330	– –	– –	– –		73
480	Standard mine Castlegate A, Sub 1, 2, 3		A C	4.7 –	43.6 45.7	42.9 45.0	8.9 9.3	.8 –	– –	– –	– –	– –	12,520 13,140	– –	– –	– –		73
481	Standard mine Castlegate A, Sub 1, 2, 3		A B C D	4.9 2.1 – –	42.9 44.1 45.1 48.1	46.1 47.5 48.5 51.9	6.1 6.25 6.4 –	.4 .42 .4 .5	5.8 5.65 5.5 5.9	71.8 73.89 75.5 80.6	1.4 1.41 1.4 1.5	14.5 12.38 10.3 11.5	12,850 13,220 13,510 14,430	2,150 – – –	2.8 – – –	– – – –		38
482	Standard mine Castlegate A, Sub 1, 2, 3		A B C D	3.8 2.2 – –	45.8 46.5 47.6 50.7	44.4 45.2 46.2 49.3	6.0 6.10 6.2 –	.4 .37 .4 .4	5.9 5.79 5.7 6.1	73.1 74.33 76.0 81.1	1.4 1.37 1.4 1.5	13.2 12.04 10.3 10.9	13,070 13,290 13,580 14,490	2,150 – – –	1.6 – – –	– – – –		38
483	Standard mine Castlegate A, Sub 1, 2, 3		A C D	3.8 – –	43.4 45.2 47.9	47.3 49.1 52.1	5.5 5.7 –	.5 .5 .5	6.0 5.8 6.1	72.9 75.8 80.3	1.3 1.4 1.4	13.8 10.8 11.7	13,060 13,580 14,400	– – –	2.2 – –	– – –		39
484	Standard mine Castlegate A, Sub 1, 2, 3		A	3.4	42.2	49.4	5.0	.6	–	–	–	–	13,100	2,150	1.9	–		39
485	Standard mine Castlegate A, Sub 1, 2, 3		A	4.1	44.0	47.5	4.4	.4	–	–	–	–	13,230	2,150	2.6	–		39
486	Standard mine Castlegate A, Sub 1, 2, 3		A	3.5	44.2	46.7	5.6	.4	–	–	–	–	13,100	2,180	2.0	–		39
487	Standard mine Castlegate A, Sub 1, 2, 3		A	3.8	43.7	46.4	6.1	.5	–	–	–	–	12,910	2,040	2.2	–		39
488	Standard mine Castlegate A, Sub 1, 2, 3		A	3.4	–	–	5.9	.79	–	–	–	–	–	–	–	–		88
489	Standard mine Castlegate A, Sub 1, 2, 3		A B C	5.1 2.6 –	43.8 45.4 46.2	42.8 43.3 45.0	8.3 8.6 8.8	– – –	– – –	– – –	– – –	– – –	12,700 13,147 13,390	– – –	– – –	– – –		86

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
490	Standard mine		A	4.4	43.8	43.9	7.8	–	–	–	–	–	12,700	–	–	–		86
	Castlegate A, Sub 1, 2, 3		B	2.5	45.1	44.4	8.0	–	–	–	–	–	13,121	–	–	–		
			C	–	45.9	45.9	8.2	–	–	–	–	–	13,360	–	–	–		
491	Standard mine		A	3.3	42.8	40.8	13.2	–	–	–	–	–	11,770	–	–	–		86
	Castlegate A, Sub 1, 2, 3		B	2.2	43.0	41.4	13.4	–	–	–	–	–	11,930	–	–	–		
			C	–	43.8	42.6	13.6	–	–	–	–	–	12,160	–	–	–		
492	Standard mine		A	4.02	44.6	41.9	9.4	–	–	–	–	–	12,520	–	–	–		86
	Castlegate A, Sub 1, 2, 3		B	2.08	45.8	42.38	9.71	–	–	–	–	–	12,827	–	–	–		
			C	–	46.6	43.5	9.95	–	–	–	–	–	13,080	–	–	–		
493	Standard mine		A	3.96	44.6	43.6	7.8	–	–	–	–	–	12,850	–	–	–		86
	Castlegate A, Sub 1, 2, 3		B	2.32	45.67	44.0	7.99	–	–	–	–	–	13,109	–	–	–		
			C	–	46.5	45.4	8.1	–	–	–	–	–	13,380	–	–	–		
494	Standard mine		A	3.6	43.2	45.3	7.9	–	–	–	–	–	13,020	–	–	–		86
	Castlegate A, Sub 1, 2, 3		B	2.1	43.5	46.5	7.9	–	–	–	–	–	13,161	–	–	–		
			C	–	44.8	47.1	8.7	–	–	–	–	–	13,520	–	–	–		
495	Standard mine		A	2.7	45.4	44.7	7.2	.7	–	–	–	–	13,140	–	–	–		10
	Castlegate A, Sub 1, 2, 3		C	–	46.7	45.9	7.4	–	–	–	–	–	13,500	–	–	–		
496	Standard mine		A	2.5	45.4	45.0	7.0	.8	–	–	–	–	13,230	–	–	–		10
	Castlegate A, Sub 1, 2, 3		C	–	46.6	46.2	7.2	–	–	–	–	–	13,570	–	–	–		
497	Standard mine		A	2.7	43.6	46.6	7.1	.6	–	–	–	–	13,080	–	–	–		10
	Castlegate A, Sub 1, 2, 3		C	–	44.8	47.9	7.3	–	–	–	–	–	13,440	–	–	–		
498	Standard mine		A	2.4	46.3	43.5	7.8	.8	–	–	–	–	13,090	–	–	–		10
	Castlegate A, Sub 1, 2, 3		C	–	47.4	44.6	8.0	–	–	–	–	–	13,410	–	–	–		
499	Standard mine		A	2.6	45.8	44.0	7.6	.8	–	–	–	–	13,150	–	–	–		10
	Castlegate A, Sub 1, 2, 3		C	–	47.0	45.2	7.8	–	–	–	–	–	13,500	–	–	–		
500	Standard mine		A	2.3	44.7	46.3	6.6	.6	–	–	–	–	13,200	–	–	–		10
	Castlegate A, Sub 1, 2, 3		C	–	45.8	47.4	6.8	–	–	–	–	–	13,510	–	–	–		
501	Standard mine		A	2.8	44.5	44.5	8.2	.8	–	–	–	–	13,010	–	–	–		10
	Castlegate A, Sub 1, 2, 3		C	–	45.8	45.8	8.4	–	–	–	–	–	13,380	–	–	–		
502	Vulcan mine	NW.NW.SE.12–13S–8E	A	3.8	–	–	6.1	1.23	–	–	–	–	–	–	–	–		88
	Castlegate A	4395310mN 502450mE																
503	Vulcan mine		A	3.2	–	–	6.0	1.45	–	–	–	–	–	–	–	–		88
	Castlegate A																	
504	Vulcan mine		A	3.2	48.5	41.2	7.1	–	–	–	–	–	13,094	–	–	–		86
	Sub 1 bed		C	–	–	–	–	–	–	–	–	–	13,526	–	–	–		
505	Vulcan mine		A	2.1	–	–	–	–	–	–	–	–	12,618	–	–	–		86
	Sub 1 bed		B	–	–	–	–	–	–	–	–	–	12,889	–	–	–		
506	Vulcan mine		A	.62	–	–	–	–	–	–	–	–	13,080	–	–	–		86
	Sub 1 bed		B	–	–	–	–	–	–	–	–	–	13,162	–	–	–		
507	Vulcan mine		A	4.2	45.0	44.4	6.4	1.7	5.9	74.2	1.6	9.9	13,040	–	–	–		10
	Castlegate Sub no. 1		C	–	47.0	46.3	6.7	–	–	–	–	–	13,620	–	–	–		
508	Vulcan mine		A	5.1	43.9	43.9	7.0	1.6	–	–	–	–	12,690	–	–	47		10
	Castlegate Sub no. 1		C	–	46.3	46.3	7.4	–	–	–	–	–	13,370	–	–	–		
509	Western mine	SW.NE.SW.7–13S–8E	A	3.5	45.3	45.3	6.0	.8	–	–	–	–	13,240	–	–	–	D	21
	Castlegate B bed	4395000mN 503480mE	C	–	46.9	46.9	6.2	–	–	–	–	–	13,720	–	–	–		
510	Western mine		A	4.0	44.2	45.3	6.5	.7	–	–	–	–	13,000	–	–	–	D	21
	Castlegate B bed		C	–	46.0	47.2	6.8	–	–	–	–	–	13,550	–	–	–		
511	Western mine		A	4.2	42.7	44.9	8.1	.7	–	–	–	–	12,720	–	–	–	D	21
	Castlegate B bed		C	–	44.6	46.9	8.5	–	–	–	–	–	13,280	–	–	–		
512	Western mine		A	4.9	42.8	44.5	7.8	.8	–	–	–	–	12,630	–	–	–	D	21
	Castlegate B bed		C	–	45.0	46.8	8.2	–	–	–	–	–	13,280	–	–	–		
513	Western mine		A	3.6	46.2	45.1	5.1	.8	–	–	–	–	13,340	–	–	–	D	19
			C	–	47.9	46.8	5.3	–	–	–	–	–	13,850	–	–	–		
514	Western mine		A	4.3	44.7	44.4	6.6	.8	–	–	–	–	12,910	–	–	–	D	19
			C	–	46.7	46.4	6.9	–	–	–	–	–	13,510	–	–	–		
515	Western mine		A	3.9	45.5	45.4	5.3	.6	–	–	–	–	13,240	–	–	–	D	20
			C	–	47.3	47.2	5.5	–	–	–	–	–	13,780	–	–	–		
516	Western mine		A	4.5	44.9	44.8	5.8	.7	–	–	–	–	13,040	–	–	–	D	20
			C	–	47.0	46.9	6.1	–	–	–	–	–	13,670	–	–	–		
517	Western mine		A	3.9	44.8	45.4	6.0	1.0	–	–	–	–	13,140	–	–	–		14
			C	–	46.6	47.2	6.2	–	–	–	–	–	13,670	–	–	–		
518	Western mine		A	4.0	44.7	46.9	4.3	.7	–	–	–	–	13,410	–	–	–	D	17
	Castlegate Sub 1 bed		C	–	46.4	48.9	4.5	–	–	–	–	–	13,980	–	–	–		
519	Western mine		A	3.8	45.2	46.0	5.0	.7	–	–	–	–	13,230	–	–	–	D	17
	Castlegate Sub 1 bed		C	–	47.0	47.8	5.2	–	–	–	–	–	13,770	–	–	–		
520	Western mine		A	3.9	45.4	46.1	4.6	.8	–	–	–	–	13,340	–	–	–	T	17
	Castlegate Sub 1 bed		C	–	47.2	48.0	4.8	–	–	–	–	–	13,890	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
521	Western mine Castlegate Sub 1 bed		A C	4.1 –	44.8 46.7	45.6 47.5	5.6 5.8	.8 –	– –	– –	– –	– –	13,210 13,770	– –	– –	– –	T	17
522	Western mine Castlegate Sub 1 bed		A C	3.6 –	45.1 46.8	45.0 46.7	6.3 6.5	.8 –	– –	– –	– –	– –	13,180 13,680	– –	– –	– –	D	17
523	Western mine Castlegate Sub 1 bed		A C	4.1 –	44.9 46.8	45.0 46.9	6.0 6.3	.9 –	– –	– –	– –	– –	13,090 13,660	– –	– –	– –	D	17
524	Western mine Castlegate Sub 1 bed		A C	4.6 –	44.1 46.2	45.2 47.4	6.1 6.4	.9 –	– –	– –	– –	– –	12,960 13,590	– –	– –	– –	T	17
525	Western mine		A C	3.6 –	46.8 48.5	44.6 46.3	5.0 5.2	1.1 –	– –	– –	– –	– –	13,380 13,870	– –	– –	– –	T	15
526	Western mine		A C	2.8 –	46.6 47.9	45.5 46.8	5.2 5.3	1.0 –	– –	– –	– –	– –	13,460 13,840	– –	– –	– –	D	15
527	Western mine		A C	3.6 –	46.4 48.1	44.6 46.3	5.4 5.6	1.1 –	– –	– –	– –	– –	13,350 13,840	– –	– –	– –	T	15
528	Western mine		A C	4.3 –	45.6 47.7	44.7 46.7	5.4 5.6	1.1 –	– –	– –	– –	– –	13,190 13,770	– –	– –	– –	T	15
529	Western mine		A C	3.9 –	45.5 47.3	45.0 46.8	5.7 5.9	.9 –	– –	– –	– –	– –	13,140 13,680	– –	– –	– –	D	15
530	Western mine		A C	4.2 –	44.5 46.5	44.9 46.9	6.3 6.6	.9 –	– –	– –	– –	– –	12,960 13,540	– –	– –	– –	D	15
531	Western mine		A C	4.9 –	45.6 47.9	43.6 45.8	6.0 6.3	1.1 –	– –	– –	– –	– –	12,910 13,570	– –	– –	– –	T	15
532	Western mine		A C	3.0 –	47.2 48.7	43.9 45.3	5.8 6.0	1.1 –	– –	– –	– –	– –	13,400 13,820	– –	– –	– –	D	16
533	Western mine		A C	3.2 –	45.1 46.6	47.4 49.0	4.3 4.4	.6 –	– –	– –	– –	– –	13,460 13,900	– –	– –	– –	D	16
534	Western mine		A C	2.9 –	44.8 46.1	45.5 46.9	6.8 7.0	1.0 –	– –	– –	– –	– –	13,100 13,500	– –	– –	– –	D	16
535	Western mine Castlegate Sub 1 bed		A C	3.5 –	45.6 47.3	43.5 45.1	7.3 7.6	1.5 –	– –	– –	– –	– –	13,060 13,540	– –	– –	– –	T	13
536	Western mine Castlegate Sub 1 bed		A C	3.6 –	46.5 48.2	44.3 46.0	5.6 5.8	1.5 –	– –	– –	– –	– –	13,270 13,770	– –	– –	– –	T	13
537	Western mine Castlegate Sub 1 bed		A C	4.1 –	45.7 47.7	44.2 46.1	5.9 6.2	1.3 –	– –	– –	– –	– –	13,150 13,720	– –	– –	– –	T	13
538	Western mine Castlegate Sub 1 bed		A C	4.4 –	45.4 47.5	44.6 46.7	5.5 5.8	1.0 –	– –	– –	– –	– –	13,150 13,760	– –	– –	– –	D	13
539	Western mine		A C	3.4 –	44.1 45.6	43.7 45.2	8.9 9.2	1.3 –	– –	– –	– –	– –	12,790 13,240	– –	– –	– –		11
540	Western mine		A C	3.8 –	45.5 47.3	44.6 46.4	6.1 6.3	2.1 –	– –	– –	– –	– –	13,170 13,680	– –	– –	– –		7
541	Western mine		A C	4.3 –	45.0 47.0	44.3 46.3	6.4 6.7	1.8 –	– –	– –	– –	– –	12,950 13,530	– –	– –	– –		7
542	Western mine		A C	4.4 –	44.7 46.8	44.5 46.5	6.4 6.7	1.8 –	– –	– –	– –	– –	12,940 13,530	– –	– –	– –		7
543	Western mine Sub seam no. 1		A C D	4.0 – –	44.2 46.0 –	45.3 47.2 –	6.5 6.8 –	.7 – –	– – –	– – –	– – –	– – –	13,010 13,550 14,540	2,190 – –	– – –	– – –	D	87
544	Western mine Sub seam no. 1		A C D	3.5 – –	45.3 46.9 –	45.3 46.9 –	6.0 6.2 –	.9 – –	– – –	– – –	– – –	– – –	13,240 13,720 14,630	– – –	– – –	– – –	D	87
545	Western mine Sub seam no. 1		A C D	4.2 – –	42.7 44.6 –	44.9 46.9 –	8.1 8.5 –	.7 – –	– – –	– – –	– – –	– – –	12,720 13,280 14,510	2,200 – –	– – –	– – –	D	87
546	Western mine Sub seam no. 1		A C D	4.9 – –	42.8 45.0 –	44.5 46.8 –	7.8 8.2 –	.8 – –	– – –	– – –	– – –	– – –	12,630 13,280 14,470	2,180 – –	– – –	– – –	D	87
547	Western mine Sub seam no. 1		A C D	3.8 – –	44.8 46.6 –	42.2 43.9 –	9.1 9.5 –	.4 – –	– – –	– – –	– – –	– – –	12,560 13,060 14,430	– – –	– – –	– – –	D	87
548	Western mine		A	4.1	–	–	5.9	.64	–	–	–	–	–	–	–	–		88
549	Western mine		A	–	–	–	–	–	–	–	–	–	12,080	–	–	–		86
550	Western mine		A	–	–	–	–	–	–	–	–	–	12,920	–	–	–		86
551	Western mine		A B C	24.5 22.0 –	31.4 32.4 41.6	33.9 35.0 44.9	10.2 10.6 13.5	– – –	– – –	– – –	– – –	– – –	7,045 7,279 9,332	– – –	– – –	– – –		86

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
552	Western mine		A	16.4	33.7	40.9	8.9	–	–	–	–	–	8,900	–	–	–		86
			B	12.6	35.2	42.8	9.3	–	–	–	–	–	9,304	–	–	–		
			C	–	40.3	49.0	10.7	–	–	–	–	–	10,650	–	–	–		
553	Western mine		A	4.1	47.3	38.1	10.5	–	–	–	–	–	12,100	–	–	–		86
554	Western mine		A	4.6	42.7	42.0	10.7	–	–	–	–	–	12,080	–	–	–		86
555	Western mine		A	3.25	46.6	44.1	6.03	–	–	–	–	–	12,920	–	–	–		86
			B	–	47.1	–	6.09	–	–	–	–	–	13,045	–	–	–		
			C	–	48.2	–	6.23	–	–	–	–	–	13,355	–	–	–		
556	Western mine		A	3.8	–	–	6.1	2.01	–	–	–	–	–	–	–	–		88
557	Western mine		A	4.6	44.0	43.9	7.5	.80	–	–	–	–	12,514	–	–	–		86
			B	2.1	45.2	45.1	7.7	.82	–	–	–	–	12,842	–	–	–		
			C	–	46.1	46.0	7.8	.84	–	–	–	–	13,119	–	–	–		
558	Western mine		A	0.3	–	–	–	–	–	–	–	–	12,938	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	12,978	–	–	–		
559	Western mine		A	0.96	–	–	–	–	–	–	–	–	12,982	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	13,108	–	–	–		
560	Western mine		A	5.1	42.98	44.9	7.0	–	–	–	–	–	12,787	–	–	–		86
			B	1.6	44.6	46.5	7.3	–	–	–	–	–	13,262	–	–	–		
			C	–	45.3	47.3	7.4	–	–	–	–	–	13,478	–	–	–		
561	Western mine		A	3.3	–	–	–	–	–	–	–	–	12,493	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	12,914	–	–	–		
562	Western mine		A	2.8	–	–	–	–	–	–	–	–	12,136	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	12,486	–	–	–		
563	Western mine		A	2.48	–	–	–	–	–	–	–	–	12,587	–	–	–		86
			B	–	–	–	–	–	–	–	–	–	12,907	–	–	–		
564	Western mine		A	3.4	45.9	43.8	7.0	1.4	–	–	–	–	13,200	–	–	–		10
	Castlegate Sub no. 1		C	–	47.5	45.3	7.2	–	–	–	–	–	13,660	–	–	–		
565	Western mine		A	3.5	45.3	43.9	7.3	1.3	–	–	–	–	13,050	–	–	–		10
	Castlegate Sub no. 1		C	–	46.9	45.5	7.6	–	–	–	–	–	13,520	–	–	–		
566	Western mine		A	4.2	43.5	42.4	9.9	1.3	–	–	–	–	12,570	–	–	47		10
	Castlegate Sub no. 1		C	–	45.4	44.3	10.3	–	–	–	–	–	13,120	–	–	–		
567	Western mine		A	6.2	41.6	42.7	9.6	1.0	–	–	–	–	12,140	–	–	–		10
	Castlegate Sub no. 1		C	–	44.3	45.5	10.2	–	–	–	–	–	12,940	–	–	–		
568	Western mine		A	3.8	45.1	46.0	5.1	.8	–	–	–	–	13,290	–	–	–		18
	Castlegate Sub no. 1		C	–	46.9	47.8	5.3	–	–	–	–	–	13,830	–	–	–		
569	Western mine		A	3.3	45.4	45.7	5.5	.8	–	–	–	–	13,340	–	–	–		18
	Castlegate Sub no. 1		C	–	47.0	47.3	5.7	–	–	–	–	–	13,800	–	–	–		
570	Western mine		A	4.2	44.9	45.3	5.6	.7	–	–	–	–	13,140	–	–	–		18
	Castlegate Sub no. 1		C	–	46.9	47.3	5.8	–	–	–	–	–	13,720	–	–	–		
		CASTLEGATE–MATTS SUMMIT QUADRANGLE																
1	Aberdeen mine	SW.10–13S–10E	A	4.51	41.06	48.43	6.02	.54	–	–	–	–	12,791	–	–	–		72
	Castlegate "A"	4394810mN 518190mE	C	–	42.99	50.71	6.30	–	–	–	–	–	13,395	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,296	–	–	–		
2	Aberdeen mine		A	4.66	41.35	47.62	6.37	.41	–	–	–	–	12,627	–	.7	–		38
			C	–	43.37	49.95	6.68	.43	–	–	–	–	13,244	–	–	–		
			D	–	46.48	53.52	–	.46	–	–	–	–	14,193	–	–	–		
3	Aberdeen mine		A	4.47	40.79	49.98	4.76	.32	5.57	72.72	1.25	15.38	12,982	–	–	–		63
			C	–	42.70	52.32	4.98	.33	5.31	76.12	1.31	11.95	13,590	–	–	–		
			D	–	44.94	55.06	–	.35	5.59	80.11	1.38	12.57	14,303	–	–	–		
4	Aberdeen mine		A	3.20	64.31	28.34	4.15	.35	–	–	–	–	–	–	1.4	–		63
			C	–	66.44	29.27	4.29	.36	–	–	–	–	–	–	–	–		
			D	–	69.42	30.58	–	.38	–	–	–	–	–	–	–	–		
5	Aberdeen mine		A	4.5	40.8	49.9	4.8	.3	5.6	72.7	1.3	15.3	12,980	2,150	–	–		62
			C	–	42.7	52.3	5.0	.3	5.3	76.1	1.3	12.0	13,590	–	–	–		
			D	–	44.9	55.1	–	.4	5.6	80.1	1.4	12.5	14,300	–	–	–		
6	Aberdeen mine		A	4.7	41.4	47.5	6.4	.4	–	–	–	–	12,630	2,130	.7	–		38
			C	–	43.4	49.9	6.7	.4	–	–	–	–	13,240	–	–	–		
7	Aberdeen mine		A	4.7	41.3	47.6	6.4	.41	–	–	–	–	12,640	–	.7	–		31
			B	4.0	41.6	48.0	6.4	.41	–	–	–	–	12,710	–	–	–		
			C	–	43.4	49.9	6.7	.43	–	–	–	–	13,240	–	–	–		
			D	–	46.5	53.5	–	.46	–	–	–	–	14,190	–	–	–		
8	Aberdeen no. 1 mine	4–13S–10E	A	3.33	41.96	49.45	5.26	.28	5.83	73.51	1.34	13.78	13,185	–	–	–		85
	Castlegate A bed		B	2.65	42.26	49.79	5.30	.28	5.79	74.03	1.36	13.24	13,279	–	–	–		
			C	–	43.41	51.15	5.44	.29	5.65	76.05	1.39	11.18	13,640	–	–	–		
			D	–	45.60	54.40	–	–	–	–	–	–	13,987	–	–	–		
9	Arronco mine	NE.SW.SW.11–13S–10E	A	4.3	–	–	4.9	.50	–	–	–	–	–	–	–	–		88
	Kenilworth bed	4394910mN 519440mE																

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
10	Arronco mine		A	4.3	–	–	4.8	.46	–	–	–	–	–	–	–	–		88
11	Castlegate mines	2–13S–9E	A	6.1	40.1	45.5	8.3	.56	–	–	–	–	12,220	–	3.5	–		80
	Castlegate group beds		C	–	42.7	48.4	8.9	.60	–	–	–	–	13,010	–	–	–		
			D	–	46.9	53.1	–	.66	–	–	–	–	14,290	–	–	–		
12	Castlegate mines		A	3.83	43.50	50.68	5.82	.52	–	–	–	–	13,048	–	–	–		69
	Castlegate group beds		C	–	–	–	–	–	–	–	–	–	13,568	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,406	–	–	–		
13	Castlegate mines		A	4.72	39.13	48.45	7.70	.49	–	–	–	–	12,681	–	3.5	–		63
	Castlegate group beds		C	–	41.07	50.85	8.08	.51	–	–	–	–	13,309	–	–	–		
			D	–	44.68	55.32	–	.55	–	–	–	–	14,479	–	–	–		
14	Castlegate mine		A	7.6	–	–	4.5	.37	–	–	–	–	–	–	–	–		88
	Castlegate C & D bed																	
15	Castlegate mines		A	3.5	39.4	49.2	7.9	.26	–	–	–	–	13,095	–	–	–		86
	Castlegate group beds		B	1.7	40.1	50.2	8.0	.27	–	–	–	–	13,338	–	–	–		
			C	–	40.8	51.0	8.2	.27	–	–	–	–	13,566	–	–	–		
16	Castlegate mines		A	4.1	40.9	48.9	6.2	.30	–	–	–	–	12,769	–	–	–		86
	Castlegate group beds		B	2.1	41.7	49.9	6.3	.31	–	–	–	–	13,030	–	–	–		
			C	–	42.6	50.9	6.5	.32	–	–	–	–	13,309	–	–	–		
17	Castlegate mines		A	4.6	37.8	52.1	5.6	–	–	–	–	–	12,999	–	–	–		86
	Castlegate group beds		B	2.1	38.8	53.4	5.7	–	–	–	–	–	13,352	–	–	–		
			C	–	39.6	54.6	5.8	–	–	–	–	–	13,631	–	–	–		
18	Castlegate no. 1 mine	NW.1–13S–9E	A	3.81	44.68	44.42	7.09	.61	5.88	71.86	1.39	13.17	12,953	–	1.3	–		38
	Kenilworth bed	4397050mN 511980mE	C	–	46.45	46.18	7.37	.63	5.68	74.71	1.45	10.16	12,465	–	–	–		
			D	–	50.15	49.85	–	.68	6.13	80.65	1.57	10.97	14,537	–	–	–		
19	Castlegate no. 1 mine		A	4.98	41.81	48.44	4.77	.47	5.76	73.10	1.38	14.52	13,063	–	2.2	–		38
	Castlegate C bed		C	–	44.00	50.98	5.02	.49	5.48	76.93	1.45	10.63	13,747	–	–	–		
			D	–	46.33	53.67	–	.52	5.77	81.00	1.53	11.18	14,474	–	–	–		
20	Castlegate no. 1 mine		A	4.57	42.32	46.95	6.16	.49	5.72	71.80	1.37	14.46	12,872	–	1.9	–		38
	Castlegate A bed		C	–	44.35	49.19	6.46	.51	5.46	75.24	1.44	10.89	13,489	–	–	–		
			D	–	47.42	52.59	–	.55	5.84	80.44	1.54	11.63	14,422	–	–	–		
21	Castlegate no. 1 mine		A	4.2	41.1	49.0	5.7	.5	–	–	–	–	12,810	2,220	1.1	–		39
	Castlegate A bed																	
22	Castlegate no. 1 mine		A	4.3	40.3	50.3	4.5	.5	–	–	–	–	12,970	2,060	1.3	–		39
	Castlegate C bed																	
23	Castlegate no. 1 mine		A	2.9	35.7	46.5	4.9	.6	–	–	–	–	13,220	2,220	.6	–		39
	Kenilworth bed																	
24	Castlegate no. 1 mine		A	3.4	44.1	46.0	6.5	.6	–	–	–	–	12,880	2,200	1.1	–		39
	Castlegate group beds																	
25	Castlegate no. 1 mine		A	3.4	44.9	43.7	8.0	.5	–	–	–	–	12,800	2,200	1.0	–		39
	Castlegate group beds																	
26	Castlegate no. 1 mine		A	3.9	43.0	47.6	5.5	.6	5.6	72.2	1.4	14.7	12,910	–	1.0	–		39
	Castlegate group beds		B	2.85	43.43	48.17	5.55	.45	–	–	–	–	13,046	–	–	–		
			C	–	44.7	49.6	5.7	.6	5.4	75.1	1.5	11.8	13,430	–	–	–		
			D	–	47.4	52.6	–	.5	5.7	79.6	1.6	12.6	14,240	–	–	–		
27	Castlegate no. 1 mine		A	4.6	42.3	46.9	6.2	.5	5.7	71.8	1.4	14.4	12,870	2,100	1.9	–		39
	Castlegate A bed		B	2.8	43.1	47.8	6.28	.50	5.62	73.17	1.40	13.03	13,120	–	–	–		
			C	–	44.4	49.1	6.5	.5	5.5	75.2	1.4	10.9	13,490	–	–	–		
			D	–	47.4	52.6	–	.6	5.8	80.4	1.5	11.7	14,420	–	–	–		
28	Castlegate no. 1 mine		A	5.0	41.8	48.4	4.8	.5	5.8	73.1	1.4	14.4	13,060	2,080	2.2	–		38
	Castlegate C bed		B	2.8	42.8	49.5	4.88	.48	5.63	74.75	1.41	12.85	13,360	–	–	–		
			C	–	44.0	51.0	5.0	.5	5.5	76.9	1.5	10.6	13,750	–	–	–		
			D	–	46.3	53.7	–	.5	5.8	81.0	1.5	11.2	14,470	–	–	–		
29	Castlegate no. 1 mine		A	3.8	44.7	44.4	7.1	.6	5.9	71.9	1.4	13.1	12,950	2,130	1.3	–		38
	Kenilworth bed		B	2.6	45.2	45.0	7.18	.62	5.81	72.78	1.41	12.20	13,120	–	–	–		
			C	–	46.5	46.1	7.4	.6	5.7	74.7	1.5	10.1	13,470	–	–	–		
			D	–	50.2	49.8	–	.7	6.1	80.7	1.6	10.9	14,540	–	–	–		
30	Castlegate no. 2 mine	SW.SW.31–12S–10E	A	3.2	41.3	48.7	6.8	.3	–	–	–	–	12,860	–	–	–		6
	Kenilworth bed	4397810mN 512550mE	C	–	42.7	50.3	7.0	–	–	–	–	–	13,280	–	–	–		
31	Castlegate no. 2 mine		A	3.5	41.9	48.5	6.1	.3	–	–	–	–	12,980	–	–	–		6
	Kenilworth bed		C	–	43.4	50.3	6.3	–	–	–	–	–	13,450	–	–	–		
32	Castlegate no. 2 mine		A	4.5	41.4	47.9	6.2	.3	–	–	–	–	12,840	–	–	–		6
	Kenilworth bed		C	–	43.3	50.2	6.5	–	–	–	–	–	13,450	–	–	–		
33	Castlegate no. 2 mine		A	4.6	41.5	47.9	6.0	.3	–	–	–	–	12,870	–	–	–		6
	Kenilworth bed		C	–	43.5	50.2	6.3	–	–	–	–	–	13,500	–	–	–		
34	Castlegate no. 2 mine		A	5.5	41.0	47.8	5.7	.3	–	–	–	–	12,800	–	–	–		6
	Kenilworth bed		C	–	43.4	50.6	6.0	–	–	–	–	–	13,550	–	–	–		
35	Castlegate no. 2 mine		A	3.70	42.80	48.19	5.31	.33	5.78	73.94	1.26	13.38	13,185	–	1.3	–		38
	Kenilworth bed		C	–	44.44	50.05	5.51	.34	5.58	76.78	1.31	10.48	13,691	–	–	–		
			D	–	47.03	52.97	–	.36	5.91	81.26	1.39	11.08	14,488	–	–	–		
36	Castlegate no. 2 mine		A	4.77	40.28	45.96	8.99	.65	5.61	69.62	1.35	13.78	12,499	–	2.6	–		38
	Castlegate B bed		C	–	42.30	48.26	9.44	.68	5.33	73.11	1.42	10.02	13,126	–	–	–		
			D	–	46.70	53.30	–	.75	5.89	80.73	1.57	11.06	14,494	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
37	Castlegate no. 2 mine Kenilworth bed		A C	2.9 –	42.3 43.6	48.0 49.4	6.8 7.0	.2 –	– –	– –	– –	– –	12,980 13,370	– –	– –	– –	T	8
38	Castlegate no. 2 mine Kenilworth bed		A C	2.9 –	42.6 43.9	47.1 48.5	7.4 7.6	.2 –	– –	– –	– –	– –	12,850 13,230	– –	– –	– –	T	8
39	Castlegate no. 2 mine Kenilworth bed		A C	3.3 –	42.2 43.6	47.7 49.3	6.9 7.1	.2 –	– –	– –	– –	– –	12,850 13,300	– –	– –	– –	T	8
40	Castlegate no. 2 mine Kenilworth bed		A C	5.1 –	41.3 43.5	47.6 50.2	6.0 6.3	.2 –	– –	– –	– –	– –	12,850 13,540	– –	– –	45 –	T	8
41	Castlegate no. 2 mine Kenilworth bed		A	3.4	42.1	48.3	6.2	.3	–	–	–	–	12,800	2,200	1.2	–		39
42	Castlegate no. 2 mine Castlegate "C"		A	2.5	43.6	47.7	6.2	.5	–	–	–	–	12,270	2,180	.8	–		39
43	Castlegate no. 2 mine Kenilworth bed		A B C D	3.7 2.4 – –	42.8 43.4 44.4 47.0	48.2 48.8 50.1 53.0	5.3 5.38 5.5 –	.3 .33 .3 .4	5.8 5.71 5.6 5.9	73.9 74.94 76.8 81.3	1.3 1.28 1.3 1.4	13.4 12.36 10.5 11.0	13,190 13,360 13,690 14,490	2,150 – – –	1.3 – – –	– – – –		38
44	Castlegate no. 2 mine Castlegate "C"		A C	3.0 –	43.1 44.4	47.7 49.2	6.2 6.4	.3 .3	– –	– –	– –	– –	13,010 13,410	2,190 –	.8 –	– –		39
45	Castlegate no. 2 mine Castlegate B bed		A B C D	4.8 2.2 – –	40.3 41.4 42.3 46.7	45.9 47.2 48.3 53.3	9.0 9.23 9.4 –	.7 .67 .7 .8	5.6 5.46 5.3 5.9	69.6 71.48 73.1 80.7	1.4 1.39 1.4 1.6	13.7 11.77 10.1 11.0	12,500 12,830 13,125 14,490	2,210 – – –	2.6 – – –	– – – –		38
46	Castlegate no. 2 mine		A C D	2.9 – –	43.3 44.6 47.4	48.2 49.7 52.6	5.6 5.7 –	.4 .4 .4	5.6 5.4 5.8	73.3 75.5 80.1	1.4 1.4 1.5	13.7 11.6 12.2	13,170 13,570 14,390	– – –	.9 – –	– – –		39
47	Castlegate no. 2 mine Castlegate B bed		A	3.2	43.0	49.5	4.3	.6	–	–	–	–	13,340	2,130	.8	–		39
48	Castlegate no. 2 mine Castlegate C bed		A	3.2	43.0	49.3	4.5	.6	–	–	–	–	13,290	2,180	1.0	–		39
49	Castlegate no. 2 mine Castlegate group beds		A	2.9	43.4	47.3	6.4	.3	–	–	–	–	13,010	2,180	.9	–		39
50	Castlegate no. 2 mine Castlegate group beds		A	2.7	43.0	49.2	5.1	.4	–	–	–	–	13,370	2,180	.7	–		39
51	Castlegate prep. plant	NW.5–13S–9E	A C	3.1 –	41.0 42.3	48.8 50.4	7.1 7.3	.5 –	– –	– –	– –	– –	12,920 13,330	– –	– –	– –	T	19
52	Castlegate prep. plant		A C	5.6 –	40.4 42.8	46.5 49.3	7.5 7.9	.5 –	– –	– –	– –	– –	12,500 13,240	– –	– –	– –	T	19
53	Castlegate prep. plant		A C	5.2 –	41.1 43.4	47.8 50.4	5.9 6.2	.4 –	– –	– –	– –	– –	12,780 13,490	– –	– –	– –	T	19
54	Castlegate prep. plant		A C	6.6 –	40.2 43.0	47.6 51.0	5.6 6.0	.4 –	– –	– –	– –	– –	12,580 13,470	– –	– –	– –	T	19
55	Castlegate prep. plant Castlegate B, C, D bed		A C	4.3 –	41.8 43.7	46.1 48.2	7.8 8.1	.5 –	– –	– –	– –	– –	12,740 13,310	– –	– –	– –	T	16
56	Castlegate prep. plant Castlegate B, C, D bed		A C	5.2 –	42.0 44.3	46.8 49.4	6.0 6.3	.5 –	– –	– –	– –	– –	12,780 13,490	– –	– –	– –	T	16
57	Four Points mine Castlegate "A"	SE.NE.SW.NW.16–13S–10E 4394110mN 516190mE	A C D	5.90 – –	40.11 42.63 45.68	47.70 50.69 54.32	6.29 6.68 –	.36 .38 .41	– – –	– – –	– – –	– – –	– – –	– – –	2.0 – –	– – –		62
58	Four Points mine Castlegate "A"		A C D	5.16 – –	40.71 42.92 45.49	48.78 51.44 54.51	5.35 4.64 –	.33 .36 .38	– – –	– – –	– – –	– – –	12,870 13,570 14,382	– – –	1.4 – –	– – –		62
59	Four Points mine Castlegate "A"		A C D	5.58 – –	38.92 41.22 45.56	46.51 40.26 54.44	8.99 9.52 –	.51 .54 .60	5.27 4.92 5.44	67.84 71.85 79.41	1.07 1.14 1.25	16.32 12.03 13.30	12,170 12,889 14,245	– – –	1.1 – –	– – –		62
60	Heiner Panther mine Castlegate "B"	NE.SE.SE.1–13S–9E 4396650mN 512400mE	A C D	3.9 – –	41.6 43.3 45.9	49.1 51.0 54.1	5.4 5.7 –	.5 .5 .5	5.7 5.5 5.8	71.9 74.8 79.3	1.4 1.4 1.5	15.1 12.1 12.9	13,020 13,540 14,350	– – –	1.4 – –	– – –		39
61	Heiner Panther mine Castlegate "B"		A	3.7	41.8	48.3	6.2	.5	–	–	–	–	12,840	2,190	1.4	–		39
62	Heiner Panther mine Castlegate "B"		A	3.6	41.6	49.5	5.3	.5	–	–	–	–	13,280	2,130	1.2	–		39
63	Heiner Panther mine Castlegate "B"		A	4.1	41.3	49.5	5.1	.5	–	–	–	–	13,010	2,130	1.6	–		39
64	Heiner Panther mine Castlegate B bed		A	3.7	41.7	49.4	5.2	.4	–	–	–	–	13,060	2,150	1.3	–		39
65	Heiner Panther mine Castlegate "B"		A B C D	3.6 2.3 – –	45.6 46.2 47.3 50.1	45.4 46.0 47.1 49.9	5.4 5.45 5.6 –	.6 .59 .6 .6	6.1 6.0 5.9 6.2	74.3 75.28 77.1 81.6	1.4 1.44 1.5 1.6	12.2 11.24 9.3 10.0	13,340 13,510 13,830 14,650	2,110 – – –	1.3 – – –	– – – –		38

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
66	Heiner Panther mine		A	3.56	45.62	45.44	5.38	.58	6.06	74.33	1.42	12.23	13,342	–	1.3	–		38
	Castlegate "B"		C	–	47.30	47.11	5.59	.60	5.87	77.07	1.47	9.40	13,833	–	–	–		
67	Kenilworth mine	SE.NE.SW.NW.16–13S–10E	A	4.6	41.9	46.6	7.0	.4	–	–	–	–	12,720	–	–	–	D	9
	Kenilworth bed	4394110mN 516190mE	C	–	43.9	48.8	7.3	–	–	–	–	–	13,330	–	–	–		
68	Kenilworth mine		A	3.7	42.2	47.9	6.3	.4	–	–	–	–	12,940	–	–	–	D	9
	Kenilworth bed		C	–	43.8	49.7	6.5	–	–	–	–	–	13,440	–	–	–		
69	Kenilworth mine		A	5.2	41.3	47.0	6.4	.4	–	–	–	–	12,710	–	–	–		11
	Kenilworth bed		C	–	43.6	49.6	6.8	–	–	–	–	–	13,410	–	–	–		
70	Kenilworth mine		A	4.4	41.9	45.9	7.8	.4	–	–	–	–	12,720	–	–	–		21
	Kenilworth bed		C	–	43.8	48.0	8.2	–	–	–	–	–	13,300	–	–	–		
71	Kenilworth mine		A	4.3	41.8	46.5	7.4	.4	–	–	–	–	12,730	–	–	–		19
	Kenilworth bed		C	–	43.7	48.6	7.7	–	–	–	–	–	13,320	–	–	–		
72	Kenilworth mine		A	4.0	43.5	45.0	7.5	.3	–	–	–	–	12,820	–	–	–		20
	Kenilworth bed		C	–	45.3	46.9	7.8	–	–	–	–	–	13,370	–	–	–		
73	Kenilworth mine		A	4.4	41.3	46.6	7.7	.4	–	–	–	–	12,860	–	–	–		17
	Kenilworth bed		C	–	43.2	48.7	8.1	–	–	–	–	–	13,280	–	–	–		
74	Kenilworth mine		A	4.6	41.3	47.4	6.7	.4	–	–	–	–	12,740	–	–	–		15
	Kenilworth bed		C	–	43.3	49.7	7.0	–	–	–	–	–	13,360	–	–	–		
75	Kenilworth mine		A	4.4	41.5	46.6	7.6	.4	–	–	–	–	12,690	–	–	–		16
	Kenilworth bed		C	–	43.4	48.7	7.9	–	–	–	–	–	13,290	–	–	–		
76	Kenilworth mine		A	3.7	41.5	48.8	6.0	.3	–	–	–	–	12,970	–	–	–	T	8
	Kenilworth bed		C	–	43.1	50.7	6.2	–	–	–	–	–	13,470	–	–	–		
77	Kenilworth mine		A	3.6	41.8	48.1	6.5	.3	–	–	–	–	12,910	–	–	–	T	8
	Kenilworth bed		C	–	43.4	49.9	6.7	–	–	–	–	–	13,390	–	–	–		
78	Kenilworth mine		A	3.9	41.5	47.1	7.5	.4	–	–	–	–	12,690	–	–	–	T	8
	Kenilworth bed		C	–	43.2	49.0	7.8	–	–	–	–	–	13,210	–	–	–		
79	Kenilworth mine		A	6.5	40.7	45.7	7.1	.4	–	–	–	–	12,430	–	–	–	T	8
	Kenilworth bed		C	–	43.5	48.9	7.6	–	–	–	–	–	13,290	–	–	–		
80	Kenilworth mine		A	3.4	42.3	48.7	5.6	.2	–	–	–	–	13,020	–	–	–	T	8
	Kenilworth bed		C	–	43.8	50.4	5.8	–	–	–	–	–	13,480	–	–	–		
81	Kenilworth mine		A	3.4	41.9	48.8	5.9	.4	–	–	–	–	13,020	–	–	–	T	8
	Kenilworth bed		C	–	43.4	50.5	6.1	–	–	–	–	–	13,480	–	–	–		
82	Kenilworth mine		A	3.5	41.9	47.4	7.2	.4	–	–	–	–	12,840	–	–	–	D	8
	Kenilworth bed		C	–	43.4	49.1	7.5	–	–	–	–	–	13,310	–	–	–		
83	Kenilworth mine		A	4.0	43.0	46.8	6.2	.3	–	–	–	–	12,850	–	–	–	T	8
	Kenilworth bed		C	–	44.8	48.7	6.5	–	–	–	–	–	13,390	–	–	–		
84	Kenilworth mine		A	5.6	41.9	46.9	5.6	.3	–	–	–	–	12,720	–	–	43	T	8
	Kenilworth bed		C	–	44.4	49.7	5.9	–	–	–	–	–	13,480	–	–	–		
85	Kenilworth mine		A	3.2	42.3	47.6	6.9	.3	–	–	–	–	12,920	–	–	–	D	8
	Kenilworth bed		C	–	43.7	49.2	7.1	–	–	–	–	–	13,350	–	–	–		
86	Kenilworth mine		A	4.5	41.6	47.6	6.3	.4	–	–	–	–	12,840	–	–	–	D	8
	Kenilworth bed		C	–	43.6	49.8	6.6	–	–	–	–	–	13,450	–	–	–		
87	Kenilworth mine		A	6.16	40.81	48.48	4.55	.37	5.57	71.47	1.37	16.67	12,674	–	3.2	–		38
	Aberdeen bed		C	–	43.49	51.66	4.85	.39	5.21	76.16	1.46	11.93	13,505	–	–	–		
			D	–	45.71	54.29	–	.41	5.48	80.04	1.53	12.54	14,195	–	–	–		
88	Kenilworth mine		A	5.01	43.68	46.51	4.80	.41	5.83	71.93	1.31	15.72	12,821	–	2.0	–		38
	Kenilworth bed		C	–	45.98	48.97	5.05	.43	5.55	75.72	1.38	11.87	13,496	–	–	–		
			D	–	48.42	51.58	–	.45	5.85	79.75	1.45	12.50	14,215	–	–	–		
89	Kenilworth mine		A	4.42	44.10	46.54	4.94	.68	5.64	72.34	1.29	15.11	12,825	–	1.5	–		38
	Royal Blue bed		C	–	46.14	48.69	5.17	.71	5.39	75.68	1.35	11.70	13,417	–	–	–		
			D	–	48.65	51.35	–	.75	5.68	79.80	1.42	12.35	14,148	–	–	–		
90	Kenilworth mine		A	4.03	41.06	50.48	4.43	.65	–	–	–	–	13,054	–	1.8	–		38
	Royal Blue bed		C	–	42.78	52.60	4.62	.68	–	–	–	–	13,603	–	–	–		
			D	–	44.85	55.15	–	.71	–	–	–	–	14,261	–	–	–		
91	Kenilworth mine		A	5.99	38.84	49.11	6.06	.49	–	–	–	–	12,434	–	2.2	–		38
	Aberdeen bed		C	–	41.31	52.24	6.45	.52	–	–	–	–	13,226	–	–	–		
			D	–	44.16	55.84	–	.56	–	–	–	–	14,137	–	–	–		
92	Kenilworth mine		A	5.05	41.85	47.41	5.69	.55	–	–	–	–	12,740	–	.9	–		38
	Kenilworth bed		C	–	44.08	49.93	5.99	.58	–	–	–	–	13,419	–	–	–		
			D	–	46.89	53.11	–	.62	–	–	–	–	14,274	–	–	–		
93	Kenilworth mine		A	3.0	42.9	46.8	7.4	.5	–	–	–	–	12,850	–	–	–		73
	Kenilworth bed		C	–	44.2	48.2	7.6	–	–	–	–	–	13,250	–	–	–		
94	Kenilworth mine		A	3.0	42.9	47.6	6.5	.5	–	–	–	–	12,800	–	–	–		73
	Kenilworth bed		C	–	44.2	49.1	6.7	–	–	–	–	–	13,200	–	–	–		
95	Kenilworth mine		A	3.1	42.9	47.7	6.3	.5	–	–	–	–	12,950	–	–	–		73
	Kenilworth bed		C	–	44.3	49.2	6.5	–	–	–	–	–	13,360	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
96	Kenilworth mine Aberdeen bed		A	4.94	40.31	48.81	5.98	.58	–	–	–	–	12,686	–	–	–		69
			C	–	42.39	51.32	6.29	–	–	–	–	–	13,345	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,241	–	–	–		
97	Kenilworth mine		A	3.4	41.5	48.8	6.3	.3	–	–	–	–	12,860	–	–	–	T	6
			C	–	43.0	50.5	6.5	–	–	–	–	–	13,320	–	–	–		
98	Kenilworth mine		A	5.2	41.2	47.4	6.2	.5	–	–	–	–	12,720	–	–	–	T	6
			C	–	43.5	50.0	6.5	–	–	–	–	–	13,410	–	–	–		
99	Kenilworth mine		A	3.5	42.0	47.0	7.5	.4	–	–	–	–	12,710	–	–	–	D	6
			C	–	43.5	48.7	7.8	–	–	–	–	–	13,170	–	–	–		
100	Kenilworth mine		A	5.3	41.7	47.0	6.1	.5	–	–	–	–	12,740	–	–	–	T	6
			C	–	44.0	49.6	6.4	–	–	–	–	–	13,450	–	–	–		
101	Kenilworth mine		A	6.4	41.3	46.7	5.6	.4	–	–	–	–	12,660	–	–	44	T	6
			C	–	44.1	49.9	6.0	–	–	–	–	–	13,520	–	–	–		
102	Kenilworth mine		A	6.0	41.0	46.4	6.7	.5	–	–	–	–	12,570	–	–	–	T	6
			C	–	43.5	49.4	7.1	–	–	–	–	–	13,370	–	–	–		
103	Kenilworth mine		A	4.1	41.4	45.8	8.6	.5	–	–	–	–	12,440	–	–	–	D	6
			C	–	43.2	47.8	9.0	–	–	–	–	–	12,970	–	–	–		
104	Kenilworth mine		A	4.9	41.8	47.6	5.6	.4	–	–	–	–	12,840	–	–	–	T	6
			C	–	44.0	50.1	5.9	–	–	–	–	–	13,500	–	–	–		
105	Kenilworth mine		A	5.2	40.7	48.7	5.4	.3	–	–	–	–	12,870	–	1.4	–		62
			C	–	42.9	51.5	5.6	.4	–	–	–	–	13,570	–	–	–		
106	Kenilworth mine		A	5.9	40.1	47.7	6.3	.4	–	–	–	–	–	–	2.0	–		62
			C	–	42.6	50.7	6.7	.4	–	–	–	–	–	–	–	–		
107	Kenilworth mine Castlegate A bed		A	6.2	40.8	48.4	4.6	.4	5.6	71.5	1.4	16.5	12,670	2,120	3.2	–		38
			B	3.1	42.1	50.1	4.70	.38	5.39	73.79	1.41	14.33	13,090	–	–	–		
			C	–	43.5	51.6	4.9	.4	5.2	76.2	1.5	11.8	13,510	–	–	–		
			D	–	45.7	54.3	–	.4	5.5	80.0	1.5	12.6	14,200	–	–	–		
108	Kenilworth mine		A	3.2	43.4	48.3	5.1	.4	–	–	–	–	12,820	2,180	1.4	–		39
109	Kenilworth mine		A	3.4	43.5	47.3	5.8	.3	–	–	–	–	12,710	2,180	1.7	–		39
110	Kenilworth mine		A	3.9	43.0	47.9	5.2	.3	–	–	–	–	12,680	2,180	1.7	–		39
111	Kenilworth mine		A	3.7	43.1	47.8	5.4	.4	5.7	72.0	1.3	15.2	12,700	–	1.6	–		39
			C	–	44.8	49.6	5.6	.4	5.5	74.8	1.4	12.3	13,190	–	–	–		
			D	–	47.4	52.6	–	.4	5.8	79.2	1.4	13.2	13,960	–	–	–		
112	Kenilworth mine Castlegate A & Kenilworth beds		A	3.3	44.4	47.4	4.9	.6	–	–	–	–	12,910	2,180	1.3	–		39
113	Kenilworth mine Kenilworth bed		A	3.1	44.3	45.9	6.7	.4	–	–	–	–	12,680	2,200	1.2	–		39
114	Kenilworth mine Kenilworth bed		A	4.5	43.1	47.0	5.4	.3	–	–	–	–	12,720	2,090	1.6	–		39
115	Kenilworth mine Kenilworth bed		A	3.8	43.7	46.9	5.6	.4	5.0	72.5	1.4	14.4	12,750	–	1.4	–		39
			C	–	45.4	48.8	5.8	.4	5.5	75.3	1.4	11.6	13,250	–	–	–		
			D	–	48.2	51.8	–	.5	5.9	79.9	1.5	12.2	14,070	–	–	–		
116	Kenilworth mine Castlegate A bed		A	6.0	38.3	49.1	6.1	.5	–	–	–	–	12,430	2,150	2.2	–		38
			B	3.9	39.7	50.2	6.2	.50	–	–	–	–	12,710	–	–	–		
			C	–	41.3	52.2	6.5	.5	–	–	–	–	13,230	–	–	–		
			D	–	44.2	55.8	–	.6	–	–	–	–	14,140	–	–	–		
117	Kenilworth mine Kenilworth bed		A	5.0	43.7	46.5	4.8	.4	5.8	71.9	1.3	15.8	12,820	2,130	2.0	–		38
			B	3.1	44.6	47.4	4.90	.42	5.72	73.39	1.34	13.23	13,080	–	–	–		
			C	–	46.0	48.9	5.1	.4	5.6	75.7	1.4	11.8	13,500	–	–	–		
			D	–	48.4	51.6	–	.5	5.9	79.8	1.5	12.3	14,220	–	–	–		
118	Kenilworth mine Royal Blue bed		A	4.4	44.1	46.5	5.0	.7	5.6	72.3	1.3	15.1	12,830	–	1.5	–		38
			B	3.0	44.8	47.2	5.01	.69	5.56	73.42	1.31	14.01	13,020	–	–	–		
			C	–	46.1	48.7	5.2	.7	5.4	75.7	1.4	11.6	13,420	–	–	–		
			D	–	48.7	51.3	–	.8	5.7	79.8	1.4	12.3	14,150	–	–	–		
119	Kenilworth mine		A	5.1	41.9	47.3	5.7	.6	–	–	–	–	12,740	2,150	.9	–		38
			B	4.2	42.2	47.9	5.7	.56	–	–	–	–	12,860	–	–	–		
			C	–	44.1	49.9	6.0	.6	–	–	–	–	13,420	–	–	–		
			D	–	46.9	53.1	–	.62	–	–	–	–	14,270	–	–	–		
120	Kenilworth mine Royal Blue bed		A	4.0	41.1	50.5	4.4	.7	–	–	–	–	13,050	2,150	1.8	–		38
			B	2.3	41.8	51.4	4.5	.65	–	–	–	–	13,290	–	–	–		
			C	–	42.8	52.6	4.6	.7	–	–	–	–	13,600	–	–	–		
			D	–	44.9	55.1	–	.71	–	–	–	–	14,260	–	–	–		
121	Kenilworth mine		A	5.58	38.92	46.51	8.99	.51	5.27	67.84	1.07	16.32	12,170	–	1.1	–		62
			C	–	41.22	49.26	9.52	.54	4.92	71.85	1.14	12.03	12,889	–	–	–		
			D	–	45.56	54.44	–	.60	5.44	79.41	1.25	13.30	14,245	–	–	–		
122	Kenilworth mine Aberdeen bed		A	4.4	–	–	5.2	.46	–	–	–	–	–	–	–	–	T	88
123	Kenilworth mine Kenilworth bed		A	6.5	–	–	5.3	.39	–	–	–	–	–	–	–	–	T	88

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
124	Kenilworth mine		A	3.4	41.5	47.1	8.1	–	–	–	–	–	12,510	–	–	–		86
			B	2.2	42.1	47.5	8.2	–	–	–	–	–	12,721	–	–	–		
			C	–	42.9	48.8	8.3	–	–	–	–	–	12,950	–	–	–		
125	Kenilworth mine		A	4.9	40.8	46.4	7.98	–	–	–	–	–	12,320	–	–	–		86
			B	2.5	42.1	47.1	8.2	–	–	–	–	–	12,710	–	–	–		
			C	–	42.9	48.7	8.4	–	–	–	–	–	12,970	–	–	–		
126	Kenilworth mine		A	4.9	40.7	42.0	12.4	–	–	–	–	–	11,960	–	–	–		86
			B	2.18	41.8	44.2	12.7	–	–	–	–	–	12,299	–	–	–		
			C	–	42.8	44.2	13.0	–	–	–	–	–	12,560	–	–	–		
127	Kenilworth mine		A	5.6	43.0	40.97	10.5	–	–	–	–	–	12,360	–	–	–		86
			B	–	44.1	–	10.7	–	–	–	–	–	12,694	–	–	–		
			C	–	45.7	–	11.1	–	–	–	–	–	13,100	–	–	–		
128	Kenilworth mine		A	7.2	37.5	44.99	10.3	–	–	–	–	–	11,986	–	–	–		86
			B	3.4	39.0	46.8	10.7	–	–	–	–	–	12,474	–	–	–		
			C	–	40.4	48.5	11.1	–	–	–	–	–	12,917	–	–	–		
129	Kenilworth mine		A	6.4	39.0	47.5	7.1	–	–	–	–	–	12,300	–	–	–		86
			B	2.5	40.6	49.5	7.4	–	–	–	–	–	12,810	–	–	–		
			C	–	41.7	50.8	7.6	–	–	–	–	–	13,140	–	–	–		
130	Kenilworth mine		A	4.7	43.6	41.5	10.2	–	–	–	–	–	12,550	–	–	–		86
			B	2.0	44.9	42.6	10.5	–	–	–	–	–	12,906	–	–	–		
			C	–	45.8	43.5	10.7	–	–	–	–	–	13,172	–	–	–		
131	Kenilworth mine		A	4.0	39.8	43.4	12.7	–	–	–	–	–	12,071	–	–	–		86
			B	1.4	41.9	43.6	13.1	–	–	–	–	–	12,406	–	–	–		
			C	–	42.5	44.2	13.3	–	–	–	–	–	12,582	–	–	–		
132	Kenilworth mine		A	4.8	36.6	51.6	7.1	–	–	–	–	–	12,588	–	–	–		86
			B	2.3	37.5	52.9	7.3	–	–	–	–	–	12,911	–	–	–		
			C	–	38.4	54.2	7.5	–	–	–	–	–	13,216	–	–	–		
133	Kenilworth mine		A	4.2	37.0	51.9	6.9	–	–	–	–	–	12,623	–	–	–		86
			B	2.3	37.7	52.9	7.1	–	–	–	–	–	12,875	–	–	–		
			C	–	38.6	54.1	7.2	–	–	–	–	–	13,181	–	–	–		
134	Kenilworth mine		A	3.7	40.8	48.3	7.2	–	–	–	–	–	12,564	–	–	–		86
			B	2.1	41.47	49.1	7.3	–	–	–	–	–	12,774	–	–	–		
			C	–	42.4	50.2	7.5	–	–	–	–	–	13,047	–	–	–		
135	Kenilworth mine		A	4.96	39.8	47.9	7.3	–	–	–	–	–	12,455	–	–	–		86
			B	2.1	41.0	49.4	7.5	–	–	–	–	–	12,831	–	–	–		
			C	–	41.9	50.4	7.7	–	–	–	–	–	13,105	–	–	–		
136	Kenilworth mine		A	5.6	39.9	47.7	6.9	–	–	–	–	–	12,195	–	–	–		86
			B	3.5	40.8	48.7	7.0	–	–	–	–	–	12,468	–	–	–		
			C	–	42.2	50.5	7.3	–	–	–	–	–	12,918	–	–	–		
137	Kenilworth mine		A	6.5	41.4	46.8	5.2	–	–	–	–	–	12,584	–	–	–		86
			B	2.1	43.4	49.1	5.5	–	–	–	–	–	13,185	–	–	–		
			C	–	44.3	50.1	5.6	–	–	–	–	–	13,465	–	–	–		
138	Kenilworth mine		A	6.7	36.1	51.1	6.1	–	–	–	–	–	12,585	–	–	–		86
			B	2.8	87.6	53.3	6.3	–	–	–	–	–	13,115	–	–	–		
			C	–	38.7	54.8	6.5	–	–	–	–	–	13,486	–	–	–		
139	Kenilworth mine		A	5.5	37.6	49.8	7.1	.26	–	–	–	–	12,594	–	3.5	–		86
			B	4.0	38.2	50.6	7.2	.26	–	–	–	–	12,797	–	–	–		
			C	–	39.8	52.7	7.5	.27	–	–	–	–	13,333	–	–	–		
140	Kenilworth mine		A	4.9	42.4	48.4	5.4	.35	–	–	–	–	12,822	–	2.4	–		86
			B	2.4	42.5	49.6	5.5	.36	–	–	–	–	13,159	–	–	–		
			C	–	43.5	50.3	5.7	.37	–	–	–	–	13,480	–	–	–		
141	Kenilworth mine		A	5.95	40.96	46.1	7.0	.28	–	–	–	–	12,429	–	–	–		86
			B	1.7	42.7	48.3	7.4	.30	–	–	–	–	12,994	–	–	–		
			C	–	43.6	48.97	7.5	.30	–	–	–	–	13,215	–	–	–		
142	Kenilworth mine		A	4.9	41.4	48.4	5.4	.35	–	–	–	–	12,822	–	–	–		86
			B	4.4	42.45	49.6	5.5	.36	–	–	–	–	13,159	–	–	–		
			C	–	43.5	50.84	5.7	.37	–	–	–	–	13,480	–	–	–		
143	Kenilworth mine		A	4.1	42.1	47.0	6.8	.4	–	–	–	–	12,820	–	–	–		18
			C	–	43.9	49.0	7.1	–	–	–	–	–	13,380	–	–	–		
144	Kenilworth mine		A	4.5	41.6	46.4	7.5	.4	–	–	–	–	12,710	–	–	–		18
			C	–	43.6	48.6	7.8	–	–	–	–	–	13,310	–	–	–		
145	Kenilworth mine		A	4.4	42.1	48.1	5.4	–	–	–	–	–	–	–	–	–		59
			D	–	46.7	53.3	–	.5	5.8	80.5	1.5	11.7	14,370	–	–	–		
146	Kenilworth prep. plant Castlegate group and Kenilworth beds	16–13S–10E	A	3.0	42.3	47.3	7.4	.5	–	–	–	–	12,960	–	–	–	D	87
			C	–	43.6	48.8	7.6	–	–	–	–	–	13,360	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
147	Kenilworth prep. plant		A	6.1	40.2	45.5	8.2	.8	–	–	–	–	12,160	–	–	–	D	87
			C	–	42.8	48.5	8.7	–	–	–	–	–	12,950	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,180	–	–	–		
148	Kenilworth prep. plant		A	3.1	41.5	48.7	6.7	.5	–	–	–	–	13,020	–	–	–	D	87
			C	–	42.8	50.3	6.9	–	–	–	–	–	13,440	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
149	Kenilworth prep. plant		A	3.7	42.8	47.3	6.3	.5	–	–	–	–	12,990	–	–	–	D	87
			C	–	44.4	49.1	6.5	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
150	Kenilworth prep. plant		A	2.9	41.0	50.1	6.0	.4	–	–	–	–	13,180	–	–	–	D	87
			C	–	42.2	51.6	6.2	–	–	–	–	–	13,570	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
151	Kenilworth prep. plant		A	3.7	40.7	49.1	6.5	.5	–	–	–	–	13,000	–	–	–	D	87
			C	–	42.3	51.0	6.7	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
152	Kenilworth prep. plant		A	3.9	40.9	48.5	6.6	.3	–	–	–	–	12,800	–	–	–	D	87
			C	–	42.6	50.5	6.9	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,310	–	–	–		
153	Kenilworth prep. plant		A	3.6	41.4	48.4	6.7	.5	–	–	–	–	12,950	–	–	–	D	87
			C	–	42.9	50.2	6.9	–	–	–	–	–	13,430	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
154	Kenilworth prep. plant		A	2.9	40.6	49.8	6.7	.4	–	–	–	–	13,100	–	–	–	D	87
			C	–	41.8	51.3	6.9	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–	–		
155	Kenilworth prep. plant		A	3.0	41.2	49.1	6.7	.4	–	–	–	–	13,010	–	–	–	D	87
			C	–	42.5	50.6	6.9	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
156	Kenilworth prep. plant		A	4.4	40.2	49.2	6.2	.4	–	–	–	–	12,830	–	–	–	D	87
			C	–	42.0	51.5	6.5	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
157	Kenilworth prep. plant		A	2.8	40.2	49.9	7.1	.4	–	–	–	–	12,900	–	–	–	D	87
			C	–	41.4	51.3	7.3	–	–	–	–	–	13,270	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,310	–	–	–		
158	Kenilworth prep. plant		A	3.3	40.5	50.5	5.7	.4	–	–	–	–	13,180	–	–	–	D	87
			C	–	41.9	52.2	5.9	–	–	–	–	–	13,630	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
159	Kenilworth prep. plant		A	3.0	41.5	49.1	6.4	.4	–	–	–	–	13,030	–	–	–	D	87
			C	–	42.8	50.6	6.6	–	–	–	–	–	13,430	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
160	Kenilworth prep. plant		A	2.6	40.3	50.9	6.1	.4	–	–	–	–	13,260	–	–	–	D	87
			C	–	41.4	52.3	6.3	–	–	–	–	–	13,610	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,530	–	–	–		
161	Kenilworth prep. plant		A	2.9	41.5	49.4	6.2	.4	–	–	–	–	13,100	–	–	–	D	87
			C	–	42.7	50.9	6.4	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,410	–	–	–		
162	Kenilworth prep. plant		A	2.6	40.9	49.9	6.6	.4	–	–	–	–	13,050	–	–	–	D	87
			C	–	42.0	51.2	6.8	–	–	–	–	–	13,400	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
163	Kenilworth prep. plant		A	3.4	41.5	49.0	6.1	.4	–	–	–	–	12,990	–	–	–	D	87
			C	–	43.0	50.7	6.3	–	–	–	–	–	13,450	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
164	Kenilworth prep. plant		A	2.8	42.8	48.6	5.8	.4	–	–	–	–	13,200	–	–	–	D	87
			C	–	44.0	50.0	6.0	–	–	–	–	–	13,580	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
165	Kenilworth prep. plant		A	2.7	43.0	47.2	7.1	.5	–	–	–	–	12,960	–	–	–	D	87
			C	–	44.2	48.5	7.3	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
166	Kenilworth prep. plant		A	3.4	41.5	49.0	6.1	.4	–	–	–	–	13,010	–	–	–	D	87
			C	–	43.0	50.7	6.3	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
167	Kenilworth prep. plant		A	3.1	42.0	48.4	6.6	.5	–	–	–	–	12,970	–	–	–	D	87
			C	–	43.3	49.9	6.8	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,360	–	–	–		
168	Kenilworth prep. plant		A	3.4	42.4	47.8	6.4	.5	–	–	–	–	12,960	–	–	–	D	87
			C	–	43.9	49.5	6.6	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
169	Kenilworth prep. plant		A	3.4	41.6	49.5	5.5	.3	–	–	–	–	13,070	–	–	–	D	87
			C	–	43.1	51.2	5.7	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
170	Kenilworth prep. plant		A	3.8	41.0	50.0	5.2	.4	–	–	–	–	13,170	–	–	–	D	87
			C	–	42.6	52.0	5.4	–	–	–	–	–	13,690	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,470	–	–	–		
171	Kenilworth prep. plant		A	3.2	41.8	49.2	6.0	.3	–	–	–	–	13,070	–	–	–	D	87
			C	–	43.2	50.6	6.2	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
172	Kenilworth prep. plant		A	3.1	42.4	48.4	6.1	.4	–	–	–	–	12,930	–	–	–	D	87
			C	–	43.8	49.9	6.3	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,240	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
173	Kenilworth prep. plant		A	3.4	42.4	48.0	6.2	.5	–	–	–	–	12,950	–	–	–	D	87
			C	–	43.9	49.7	6.4	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,330	–	–	–		
174	Kenilworth prep. plant		A	5.3	41.9	47.2	5.7	.5	–	–	–	–	12,770	–	–	–	D	87
			C	–	44.2	49.8	6.0	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,340	–	–	–		
175	Kenilworth prep. plant		A	3.6	42.6	48.1	5.7	.5	–	–	–	–	12,970	–	–	–	D	87
			C	–	44.2	49.9	5.9	–	–	–	–	–	13,450	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,290	–	–	–		
176	Kenilworth prep. plant		A	4.1	42.6	47.1	6.2	.5	–	–	–	–	12,790	–	–	–	D	87
			C	–	44.4	49.1	6.5	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,270	–	–	–		
177	Kenilworth prep. plant		A	3.7	42.4	47.7	6.3	.5	–	–	–	–	12,840	–	–	–	D	87
			C	–	44.0	49.5	6.5	–	–	–	–	–	13,330	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,260	–	–	–		
178	Kenilworth prep. plant		A	3.6	42.4	48.2	5.8	.4	–	–	–	–	12,980	–	–	–	D	87
			C	–	44.0	50.0	6.0	–	–	–	–	–	13,460	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,320	–	–	–		
179	Kenilworth prep. plant		A	3.8	42.0	47.9	6.3	.4	–	–	–	–	12,950	–	–	–	D	87
			C	–	43.7	49.8	6.5	–	–	–	–	–	13,460	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
180	Kenilworth prep. plant		A	5.4	42.4	46.4	5.9	.4	–	–	–	–	12,690	–	–	–	D	87
			C	–	44.8	49.0	6.2	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,300	–	–	–		
181	Kenilworth prep. plant		A	3.6	42.8	47.3	6.3	.5	–	–	–	–	12,940	2,200	–	–	D	87
			C	–	44.4	49.1	6.5	–	–	–	–	–	13,420	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
182	Kenilworth prep. plant		A	3.0	43.1	46.9	7.0	.4	–	–	–	–	12,900	–	–	–	D	87
			C	–	44.4	48.4	7.2	–	–	–	–	–	13,300	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,330	–	–	–		
183	Kenilworth prep. plant		A	3.0	42.5	48.5	6.0	.4	–	–	–	–	13,100	–	–	–	D	87
			C	–	43.8	50.0	6.2	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
184	Kenilworth prep. plant		A	5.4	42.0	46.7	5.9	.5	–	–	–	–	12,770	–	–	–	D	87
			C	–	44.4	49.4	6.2	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
185	Kenilworth prep. plant		A	4.3	42.4	47.9	5.4	.4	–	–	–	–	12,990	2,240	–	–	D	87
			C	–	44.3	50.1	5.6	–	–	–	–	–	13,570	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
186	Kenilworth prep. plant		A	5.3	42.9	45.6	6.2	.6	–	–	–	–	12,640	–	–	–	D	87
			C	–	45.3	48.2	6.5	–	–	–	–	–	13,350	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,280	–	–	–		
187	Kenilworth prep. plant		A	3.8	42.5	47.2	6.4	.5	–	–	–	–	12,880	2,730	–	–	D	87
			C	–	44.2	49.1	6.7	–	–	–	–	–	13,390	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
188	Kenilworth prep. plant		A	3.6	42.8	47.1	6.5	.5	–	–	–	–	12,910	–	–	–	D	87
			C	–	44.4	48.9	6.7	–	–	–	–	–	13,390	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
189	Kenilworth prep. plant		A	5.6	41.6	46.8	5.9	.5	–	–	–	–	12,690	2,210	–	–	D	87
			C	–	44.1	49.6	6.3	–	–	–	–	–	13,440	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,340	–	–	–		
190	Kenilworth prep. plant		A	4.9	41.8	47.8	5.4	.4	–	–	–	–	12,900	2,220	–	–	D	87
			C	–	44.0	50.3	5.7	–	–	–	–	–	13,560	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
191	Kenilworth prep. plant		A	3.2	42.4	46.9	7.6	.4	–	–	–	–	12,700	–	–	–	D	87
			C	–	43.8	48.4	7.8	–	–	–	–	–	13,120	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,230	–	–	–		
192	Kenilworth prep. plant		A	3.4	43.2	46.9	6.5	.4	–	–	–	–	12,870	–	–	–	D	87
			C	–	44.7	48.6	6.7	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,280	–	–	–		
193	Kenilworth prep. plant		A	3.0	40.8	49.8	6.4	.6	–	–	–	–	12,160	–	–	–	D	87
			C	–	42.1	51.3	6.6	–	–	–	–	–	13,570	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,530	–	–	–		
194	Kenilworth prep. plant		A	4.0	42.4	47.0	6.5	.5	–	–	–	–	12,850	–	–	–	D	87
			C	–	44.2	49.0	6.8	–	–	–	–	–	13,390	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
195	Kenilworth prep. plant		A	5.1	41.9	46.9	6.2	.6	–	–	–	–	12,750	2,220	–	–	D	87
			C	–	44.1	49.4	6.5	–	–	–	–	–	13,440	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
196	Kenilworth prep. plant		A	4.0	42.4	47.9	5.7	.5	–	–	–	–	12,970	2,240	–	–	D	87
			C	–	44.2	49.9	5.9	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,360	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
197	Kenilworth prep. plant		A	3.5	42.9	46.9	6.7	.4	–	–	–	–	12,870	2,150	–	–	D	87
			C	–	44.5	48.6	6.9	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,330	–	–	–		
198	Kenilworth prep. plant		A	3.6	43.1	46.9	6.5	.4	–	–	–	–	12,900	2,220	–	–	D	87
			C	–	44.7	48.6	6.7	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,340	–	–	–		
199	Kenilworth prep. plant		A	4.0	42.7	47.1	6.1	.5	–	–	–	–	12,930	2,210	–	–	D	87
			C	–	44.5	49.1	6.4	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
200	Kenilworth prep. plant		A	3.0	42.9	46.8	7.4	.5	–	–	–	–	12,850	–	–	–	D	87
			C	–	44.2	48.2	7.6	–	–	–	–	–	13,250	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,340	–	–	–		
201	Kenilworth prep. plant		A	3.1	42.9	47.7	6.3	.5	–	–	–	–	12,950	–	–	–	D	87
			C	–	44.3	49.2	6.5	–	–	–	–	–	13,360	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,290	–	–	–		
202	Kenilworth prep. plant		A	3.0	42.9	47.6	6.5	.5	–	–	–	–	12,800	–	–	–	D	87
			C	–	44.2	49.1	6.7	–	–	–	–	–	13,200	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,150	–	–	–		
203	Kenilworth prep. plant		A	3.5	42.0	47.0	7.5	.4	–	–	–	–	12,710	–	–	–	D	87
			C	–	43.5	48.7	7.8	–	–	–	–	–	13,170	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,280	–	–	–		
204	Kenilworth prep. plant		A	4.1	41.4	45.8	8.6	.5	–	–	–	–	12,440	2,240	–	–	D	87
			C	–	43.2	47.8	9.0	–	–	–	–	–	12,970	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,250	–	–	–		
205	Kenilworth prep. plant		A	3.5	41.9	47.4	7.2	.4	–	–	–	–	12,840	–	–	–	D	87
			C	–	43.4	49.1	7.5	–	–	–	–	–	13,310	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
206	Kenilworth prep. plant		A	3.2	42.3	47.6	6.9	.3	–	–	–	–	12,920	2,160	–	–	D	87
			C	–	43.7	49.2	7.1	–	–	–	–	–	13,350	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
207	Kenilworth prep. plant		A	4.5	41.6	47.6	6.3	.4	–	–	–	–	12,840	2,180	–	–	D	87
			C	–	43.6	49.8	6.6	–	–	–	–	–	13,450	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
208	Kenilworth prep. plant		A	4.6	41.9	46.6	7.0	.4	–	–	–	–	12,720	2,200	–	–	D	87
			C	–	43.9	48.8	7.3	–	–	–	–	–	13,330	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
209	Kenilworth prep. plant		A	3.7	42.2	47.9	6.3	.4	–	–	–	–	12,940	2,180	–	–	D	87
			C	–	43.8	49.7	6.5	–	–	–	–	–	13,440	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
210	Kenilworth prep. plant		A	5.5	42.8	45.7	6.0	.5	–	–	–	–	12,650	–	–	–	D	87
			C	–	45.3	48.4	6.3	–	–	–	–	–	13,390	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,290	–	–	–		
211	Kenilworth prep. plant		A	5.2	41.3	47.0	6.4	.4	–	–	–	–	12,710	2,200	–	–	D	87
			C	–	43.6	49.6	6.8	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
212	Kenilworth prep. plant		A	5.2	42.0	46.8	6.0	.5	–	–	–	–	12,790	2,240	–	–	WT	87
			C	–	44.3	49.4	6.3	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
213	Kenilworth prep. plant		A	4.4	41.5	46.6	7.6	.4	–	–	–	–	12,710	2,240	–	–	D	87
			C	–	43.4	48.7	7.9	–	–	–	–	–	13,290	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
214	Kenilworth prep. plant		A	4.4	41.3	46.6	7.7	.4	–	–	–	–	12,700	2,240	–	–	D	87
			C	–	43.2	48.7	8.1	–	–	–	–	–	13,280	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
215	Kenilworth prep. plant		A	4.1	42.1	47.0	6.8	.4	–	–	–	–	12,830	2,180	–	–	D	87
			C	–	43.9	49.0	7.1	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
216	Kenilworth prep. plant		A	4.5	41.6	46.4	7.5	.4	–	–	–	–	12,710	2,160	–	–	D	87
			C	–	43.6	48.6	7.8	–	–	–	–	–	13,310	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		
217	Kenilworth prep. plant		A	4.3	41.8	46.5	7.4	.4	–	–	–	–	12,750	2,180	–	–	D	87
			C	–	43.7	48.6	7.7	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
218	Kenilworth prep. plant		A	4.0	43.5	45.0	7.5	.3	–	–	–	–	12,840	2,180	–	–	D	87
			C	–	45.3	46.9	7.8	–	–	–	–	–	13,370	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,500	–	–	–		
219	Kenilworth prep. plant		A	4.4	41.9	45.9	7.8	.4	–	–	–	–	12,710	–	–	–	D	87
			C	–	43.8	48.0	8.2	–	–	–	–	–	13,300	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,490	–	–	–		
220	Kenilworth prep. plant		A	4.3	42.3	45.6	7.8	.3	–	–	–	–	12,740	2,300	–	–	D	87
			C	–	44.2	47.6	8.2	–	–	–	–	–	13,310	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,500	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of	Ref.
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	Sample	Source
221	Kenilworth prep. plant		A	3.6	40.8	45.2	10.4	.5	–	–	–	–	12,350	–	–	–	D	87
			C	–	42.3	46.9	10.8	–	–	–	–	–	12,810	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,360	–	–	–		
222	Kenilworth prep. plant		A	8.4	42.3	42.9	6.4	.6	–	–	–	–	11,880	2,160	–	54	T	87
			C	–	46.2	46.8	7.0	–	–	–	–	–	12,970	–	–	–		
			D	–	–	–	–	–	–	–	–	–	13,950	–	–	–		
223	Kenilworth prep. plant		A	8.7	40.4	45.6	5.4	.5	–	–	–	–	12,190	2,730	–	48	T	87
			C	–	44.2	49.9	5.9	–	–	–	–	–	13,350	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,190	–	–	–		
224	Kenilworth prep. plant		A	5.1	41.6	47.7	5.6	.5	–	–	–	–	12,840	2,160	–	–	T	87
			C	–	43.8	50.3	5.9	–	–	–	–	–	13,530	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
225	Kenilworth prep. plant Castlegate A bed		A	4.2	41.3	48.9	5.7	.5	–	–	–	–	12,760	2,180	–	–	T	87
			C	–	43.1	51.0	5.9	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,160	–	–	–		
226	Kenilworth prep. plant Castlegate A bed		A	4.4	42.3	48.2	5.2	.4	–	–	–	–	12,920	2,190	–	–	T	87
			C	–	44.2	50.4	5.4	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,280	–	–	–		
227	Kenilworth prep. plant Castlegate A bed		A	4.2	42.2	47.7	5.9	.4	–	–	–	–	12,780	2,180	–	–	T	87
			C	–	44.0	49.8	6.2	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,220	–	–	–		
228	Kenilworth prep. plant Castlegate A bed		A	4.2	42.0	48.1	5.7	.4	–	–	–	–	12,930	2,180	–	–	T	87
			C	–	43.8	50.2	6.0	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,360	–	–	–		
229	Kenilworth prep. plant		A	4.3	41.6	48.6	5.5	.4	–	–	–	–	13,010	2,190	–	–	T	87
			C	–	43.5	50.8	5.7	–	–	–	–	–	13,590	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,410	–	–	–		
230	Kenilworth prep. plant Castlegate A bed		A	5.6	41.2	47.8	5.5	.4	–	–	–	–	12,850	2,140	–	–	T	87
			C	–	43.6	50.6	5.8	–	–	–	–	–	13,610	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		
231	Kenilworth prep. plant Castlegate A bed		A	7.6	41.2	45.6	5.5	.4	–	–	–	–	12,460	2,130	–	–	T	87
			C	–	44.6	49.4	6.0	–	–	–	–	–	13,490	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
232	Kenilworth prep. plant Castlegate A bed		A	6.9	40.8	43.9	8.4	.5	–	–	–	–	12,020	2,640	–	–	T	87
			C	–	43.8	47.2	9.0	–	–	–	–	–	12,910	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,190	–	–	–		
233	Kenilworth prep. plant Castlegate A bed		A	6.4	42.9	46.5	4.2	.5	–	–	–	–	12,730	2,400	–	–	T	87
			C	–	45.8	49.7	4.5	–	–	–	–	–	13,600	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,240	–	–	–		
234	Kenilworth prep. plant Castlegate A bed		A	6.6	41.9	45.0	6.4	.4	–	–	–	–	12,400	2,660	–	–	T	87
			C	–	44.9	48.2	6.9	–	–	–	–	–	13,280	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,260	–	–	–		
235	Kenilworth prep. plant Castlegate A bed		A	6.5	41.0	42.9	9.6	.5	–	–	–	–	11,880	2,840	–	–	T	87
			C	–	43.8	45.9	10.3	–	–	–	–	–	12,710	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,170	–	–	–		
236	Kenilworth prep. plant Castlegate A bed		A	7.1	40.3	43.2	9.4	.6	–	–	–	–	11,840	2,660	–	–	T	87
			C	–	43.4	46.5	10.1	–	–	–	–	–	12,740	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,170	–	–	–		
237	Kenilworth prep. plant Castlegate A bed		A	7.8	39.9	44.2	8.1	.5	–	–	–	–	11,920	2,620	–	–	T	87
			C	–	43.3	47.9	8.8	–	–	–	–	–	12,930	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,180	–	–	–		
238	Kenilworth prep. plant Castlegate A bed		A	7.8	41.4	45.1	5.7	.6	–	–	–	–	12,340	2,710	–	–	WT	87
			C	–	44.9	48.9	6.2	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,260	–	–	–		
239	Kenilworth prep. plant Castlegate A bed		A	8.2	41.0	45.1	5.7	.5	–	–	–	–	12,300	2,760	–	–	WT	87
			C	–	44.7	49.1	6.2	–	–	–	–	–	13,400	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,290	–	–	–		
240	Kenilworth prep. plant Castlegate A bed		A	7.8	41.7	45.1	5.4	.7	5.6	74.6	1.6	11.6	12,350	2,710	–	47	WT	87
			C	–	45.2	48.9	5.9	–	–	–	–	–	13,390	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,230	–	–	–		
241	Kenilworth prep. plant Castlegate A bed		A	7.4	41.4	45.5	5.7	.5	–	–	–	–	12,340	2,650	–	–	WT	87
			C	–	44.7	49.1	6.2	–	–	–	–	–	13,330	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,210	–	–	–		
242	Kenilworth prep. plant Castlegate A bed		A	10.3	40.3	45.7	3.8	.5	–	–	–	–	12,280	2,470	–	–	WT	87
			C	–	44.9	50.9	4.2	–	–	–	–	–	13,690	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,290	–	–	–		
243	Kenilworth prep. plant Castlegate A bed		A	9.1	39.8	46.5	4.5	.4	–	–	–	–	12,220	2,490	–	–	WT	87
			C	–	43.8	51.2	5.0	–	–	–	–	–	13,440	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,150	–	–	–		
244	Kenilworth prep. plant Castlegate A bed		A	9.6	40.0	46.2	4.2	.5	5.4	76.0	1.4	12.0	12,200	2,520	–	–	WT	87
			C	–	44.2	51.1	4.7	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,170	–	–	–		
245	Kenilworth prep. plant Castlegate A bed		A	8.2	40.1	47.1	4.6	.4	–	–	–	–	12,400	2,620	–	–	WT	87
			C	–	43.7	51.3	5.0	–	–	–	–	–	13,510	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,220	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
246	Kenilworth prep. plant Castlegate A bed		A C D	8.2 – –	39.3 42.8 –	47.5 51.7 –	5.0 5.5 –	.4 – –	– – –	– – –	– – –	– – –	12,160 13,250 14,020	2,360 – –	– – –	– – –	WT	87
247	Kenilworth prep. plant Castlegate A bed		A C D	9.3 – –	41.5 45.8 –	44.1 48.6 –	5.1 5.6 –	.5 – –	– – –	– – –	– – –	– – –	12,070 13,310 14,100	2,160 – –	– – –	– – –	T	87
248	Kenilworth prep. plant Castlegate A bed		A C D	8.5 – –	42.4 46.3 –	44.4 48.5 –	4.8 5.2 –	.5 – –	– – –	– – –	– – –	– – –	12,240 13,380 14,110	2,160 – –	– – –	– – –	T	87
249	Kenilworth prep. plant Castlegate B bed		A C D	7.6 – –	40.7 44.0 –	45.1 48.8 –	6.7 7.2 –	.6 – –	– – –	– – –	– – –	– – –	12,140 13,140 14,160	2,500 – –	– – –	– – –	T	87
250	Kenilworth prep. plant Castlegate B bed		A C D	6.7 – –	41.0 43.9 –	47.7 51.1 –	4.7 5.0 –	.6 – –	– – –	– – –	– – –	– – –	12,650 13,560 14,270	2,460 – –	– – –	– – –	T	87
251	Kenilworth prep. plant Castlegate B bed		A C D	6.9 – –	40.6 43.6 –	48.0 51.6 –	4.5 4.8 –	.5 – –	– – –	– – –	– – –	– – –	12,700 13,640 14,330	2,450 – –	– – –	– – –	T	87
252	Kenilworth prep. plant Castlegate B bed		A C D	6.7 – –	41.1 44.1 –	47.1 50.5 –	5.0 5.4 –	.5 – –	– – –	– – –	– – –	– – –	12,600 13,510 14,280	2,420 – –	– – –	– – –	WT	87
253	Kenilworth prep. plant Castlegate B bed		A C D	7.7 – –	40.2 43.6 –	47.4 51.3 –	4.7 5.1 –	.5 – –	– – –	– – –	– – –	– – –	12,500 13,540 14,270	2,460 – –	– – –	– – –	WT	87
254	Kenilworth prep. plant Castlegate B bed		A C D	9.1 – –	41.5 45.6 –	45.0 49.5 –	4.5 4.9 –	.5 – –	– – –	– – –	– – –	– – –	12,220 13,440 14,130	2,470 – –	– – –	– – –	WT	87
255	Kenilworth prep. plant Castlegate B bed		A C D	7.9 – –	40.7 44.2 –	44.2 48.0 –	7.2 7.8 –	.6 – –	– – –	– – –	– – –	– – –	11,980 13,010 14,110	2,510 – –	– – –	– – –	T	87
256	Kenilworth prep. plant Castlegate B bed		A C D	10.4 – –	38.7 43.2 –	45.7 51.0 –	5.2 5.8 –	.6 – –	– – –	– – –	– – –	– – –	12,020 13,420 14,250	2,380 – –	– – –	– – –	WT	87
257	Kenilworth prep. plant Castlegate C bed		A C D	4.3 – –	42.2 44.1 –	45.0 47.0 –	8.5 8.9 –	.4 – –	5.2 – –	74.5 – –	1.3 – –	9.7 – –	12,650 13,220 14,510	2,250 – –	– – –	48 – –	T	87
258	Kenilworth prep. plant Kenilworth bed		A C D	5.2 – –	42.4 44.7 –	46.7 49.3 –	5.7 6.0 –	.4 – –	– – –	– – –	– – –	– – –	12,720 13,420 14,280	2,170 – –	– – –	– – –	T	87
259	Kenilworth prep. plant Kenilworth bed		A C D	3.8 – –	41.9 43.6 –	48.9 50.8 –	5.4 5.6 –	.5 – –	– – –	– – –	– – –	– – –	12,940 13,450 14,250	2,120 – –	– – –	– – –	T	87
260	Kenilworth prep. plant Kenilworth bed		A C D	2.8 – –	41.4 42.6 –	48.7 50.1 –	7.1 7.3 –	.5 – –	– – –	– – –	– – –	– – –	13,060 13,440 14,500	2,220 – –	– – –	– – –	T	87
261	Kenilworth prep. plant Kenilworth bed		A C D	3.7 – –	42.7 44.3 –	48.1 49.9 –	5.6 5.8 –	.4 – –	– – –	– – –	– – –	– – –	12,930 13,430 14,260	2,170 – –	– – –	– – –	T	87
262	Kenilworth prep. plant Kenilworth bed		A C D	3.8 – –	42.6 44.3 –	46.4 48.2 –	7.2 7.5 –	.4 – –	– – –	– – –	– – –	– – –	12,690 13,190 14,260	2,200 – –	– – –	– – –	T	87
263	Kenilworth prep. plant Kenilworth bed		A C D	4.1 – –	43.1 44.9 –	46.8 48.8 –	6.0 6.3 –	.4 – –	– – –	– – –	– – –	– – –	12,830 13,380 14,280	2,170 – –	– – –	– – –	T	87
264	Kenilworth prep. plant Kenilworth bed		A C D	6.5 – –	42.3 45.2 –	46.0 49.2 –	5.2 5.6 –	.4 – –	– – –	– – –	– – –	– – –	12,620 13,500 14,300	2,160 – –	– – –	– – –	T	87
265	Kenilworth prep. plant Kenilworth bed		A C D	5.3 – –	41.0 43.3 –	47.0 49.6 –	6.7 7.1 –	.3 – –	– – –	– – –	– – –	– – –	12,650 13,360 14,380	2,210 – –	– – –	– – –	T	87
266	Kenilworth prep. plant Kenilworth bed		A C D	3.7 – –	41.5 43.1 –	48.8 50.7 –	6.0 6.2 –	.3 – –	– – –	– – –	– – –	– – –	12,970 13,470 14,360	2,160 – –	– – –	– – –	T	87
267	Kenilworth prep. plant Kenilworth bed		A C D	3.6 – –	41.8 43.4 –	48.1 49.9 –	6.5 6.7 –	.3 – –	– – –	– – –	– – –	– – –	12,910 13,390 14,350	2,270 – –	– – –	– – –	T	87
268	Kenilworth prep. plant Kenilworth bed		A C D	3.9 – –	41.5 43.2 –	47.1 49.0 –	7.5 7.8 –	.4 – –	– – –	– – –	– – –	– – –	12,690 13,210 14,330	2,290 – –	– – –	– – –	T	87
269	Kenilworth prep. plant Kenilworth bed		A C D	6.5 – –	40.7 43.5 –	45.7 48.9 –	7.1 7.6 –	.4 – –	– – –	– – –	– – –	– – –	12,430 13,290 14,380	2,220 – –	– – –	44 – –	T	87

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
270	Kenilworth prep. plant		A	4.4	41.3	48.2	6.1	.1	–	–	–	–	12,880	2,200	–	–	WT	87
	Kenilworth bed		C	–	43.2	50.4	6.4	–	–	–	–	–	13,470	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
271	Kenilworth prep. plant		A	5.7	41.1	46.7	6.5	.5	–	–	–	–	12,620	2,150	–	–	U	87
	Kenilworth bed		C	–	43.6	49.5	6.9	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
272	Kenilworth prep. plant		A	3.4	41.5	48.8	6.3	.3	–	–	–	–	12,870	2,130	–	–	U	87
	Kenilworth bed		C	–	43.0	50.5	6.5	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,250	–	–	–		
273	Kenilworth prep. plant		A	5.2	41.2	47.4	6.2	.5	–	–	–	–	12,710	2,130	–	–	U	87
	Kenilworth bed		C	–	43.5	50.0	6.5	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,340	–	–	–		
274	Kenilworth prep. plant		A	3.2	41.3	48.7	6.8	.3	–	–	–	–	12,860	2,240	–	–	T	87
	Kenilworth bed		C	–	42.7	50.3	7.0	–	–	–	–	–	13,280	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,280	–	–	–		
275	Kenilworth prep. plant		A	3.5	41.9	48.5	6.8	.3	–	–	–	–	12,980	2,180	–	–	WT	87
	Kenilworth bed		C	–	43.4	50.3	7.0	–	–	–	–	–	13,450	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
276	Kenilworth prep. plant		A	5.3	41.7	47.0	6.1	.5	–	–	–	–	12,740	2,160	–	–	WU	87
	Kenilworth bed		C	–	44.0	49.6	6.4	–	–	–	–	–	13,450	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
277	Kenilworth prep. plant		A	4.5	41.4	47.9	6.2	.3	–	–	–	–	12,840	2,240	–	–	WT	87
	Kenilworth bed		C	–	43.3	50.2	6.5	–	–	–	–	–	13,450	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
278	Kenilworth prep. plant		A	4.6	41.5	47.9	6.0	.3	–	–	–	–	12,880	2,190	–	43	WT	87
	Kenilworth bed		C	–	43.5	50.2	6.3	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,410	–	–	–		
279	Kenilworth prep. plant		A	6.4	41.3	46.7	5.6	.4	–	–	–	–	12,650	2,190	–	44	WU	87
	Kenilworth bed		C	–	44.1	49.9	6.0	–	–	–	–	–	13,520	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
280	Kenilworth prep. plant		A	6.0	40.9	46.4	6.7	.5	–	–	–	–	12,570	2,160	–	–	U	87
	Kenilworth bed		C	–	43.5	49.4	7.1	–	–	–	–	–	13,370	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
281	Kenilworth prep. plant		A	5.5	41.0	47.8	5.7	.3	–	–	–	–	12,800	2,190	–	–	WT	87
	Kenilworth bed		C	–	43.4	50.6	6.0	–	–	–	–	–	13,550	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,410	–	–	–		
282	Kenilworth prep. plant		A	4.9	41.8	47.6	5.6	.4	–	–	–	–	12,840	2,180	–	–	WT	87
	Kenilworth bed		C	–	44.0	50.1	5.9	–	–	–	–	–	13,500	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
283	Kenilworth prep. plant		A	2.9	42.3	48.0	6.8	.2	–	–	–	–	12,980	2,270	–	–	T	87
	Kenilworth bed		C	–	43.6	49.4	7.0	–	–	–	–	–	13,370	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
284	Kenilworth prep. plant		A	3.4	41.9	48.8	5.9	.4	–	–	–	–	13,020	2,150	–	–	U	87
	Kenilworth bed		C	–	43.4	50.5	6.1	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,360	–	–	–		
285	Kenilworth prep. plant		A	2.9	42.6	47.1	7.4	.2	–	–	–	–	12,850	2,240	–	–	T	87
	Kenilworth bed		C	–	43.9	48.5	7.6	–	–	–	–	–	13,230	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,320	–	–	–		
286	Kenilworth prep. plant		A	3.3	42.2	47.7	6.9	.2	–	–	–	–	12,860	2,220	–	–	WT	87
	Kenilworth bed		C	–	43.6	49.3	7.1	–	–	–	–	–	13,300	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,320	–	–	–		
287	Kenilworth prep. plant		A	5.6	41.9	46.9	5.6	.3	–	–	–	–	12,730	2,170	–	43	U	87
	Kenilworth bed		C	–	44.4	49.7	5.9	–	–	–	–	–	13,480	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,330	–	–	–		
288	Kenilworth prep. plant		A	4.8	42.5	45.5	7.2	.4	–	–	–	–	12,740	2,230	–	–	T	87
	Kenilworth bed		C	–	44.6	47.8	7.6	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
289	Kenilworth prep. plant		A	4.9	42.4	45.5	7.2	.4	–	–	–	–	12,720	2,230	–	–	T	87
	Kenilworth bed		C	–	44.6	47.8	7.6	–	–	–	–	–	13,380	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
290	Kenilworth prep. plant		A	3.3	43.3	46.5	6.9	.4	5.4	75.3	1.4	10.4	12,970	2,180	–	–	T	87
	Kenilworth bed		C	–	44.8	48.1	7.1	–	–	–	–	–	13,410	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
291	Kenilworth prep. plant		A	4.7	41.5	47.5	6.4	.5	–	–	–	–	12,830	2,190	–	–	WT	87
	Castlegate A and		C	–	43.5	49.8	6.7	–	–	–	–	–	13,460	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,430	–	–	–		
292	Kenilworth prep. plant		A	5.3	41.5	47.0	6.3	.5	–	–	–	–	12,730	2,210	–	–	WT	87
	Castlegate A and		C	–	43.8	49.6	6.6	–	–	–	–	–	13,440	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,390	–	–	–		
293	Kenilworth prep. plant		A	5.8	41.3	47.1	5.8	.5	–	–	–	–	12,760	2,190	–	–	WT	87
	Castlegate A and		C	–	43.8	50.0	6.2	–	–	–	–	–	13,550	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,450	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
294	Kenilworth prep. plant		A	4.8	41.0	46.6	7.5	.6	–	–	–	–	12,580	2,180	–	–	T	87
	Castlegate A and		C	–	43.1	49.0	7.9	–	–	–	–	–	13,210	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,340	–	–	–		
295	Kenilworth prep. plant		A	8.3	39.8	45.9	6.0	.5	–	–	–	–	12,400	2,180	–	–	T	87
	Castlegate A and		C	–	43.4	50.1	6.5	–	–	–	–	–	13,520	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,460	–	–	–		
296	Kenilworth prep. plant		A	3.2	42.6	46.8	7.5	.5	–	–	–	–	12,900	2,230	–	–	T	87
	Castlegate A and		C	–	44.0	48.3	7.7	–	–	–	–	–	13,330	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		
297	Kenilworth prep. plant		A	4.9	42.9	45.7	6.5	.5	–	–	–	–	12,730	2,190	–	–	WT	87
	Castlegate A and		C	–	45.1	48.1	6.8	–	–	–	–	–	13,390	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,370	–	–	–		
298	Kenilworth prep. plant		A	8.3	41.1	44.7	6.0	.5	–	–	–	–	12,310	2,190	–	–	T	87
	Castlegate A and		C	–	44.8	48.7	6.5	–	–	–	–	–	13,420	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
299	Kenilworth prep. plant		A	3.8	41.4	49.8	5.0	.5	–	–	–	–	13,010	2,180	–	–	T	87
	Castlegate C and		C	–	43.0	51.8	5.2	–	–	–	–	–	13,520	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,260	–	–	–		
300	Kenilworth prep. plant		A	3.7	41.9	49.1	5.3	.3	–	–	–	–	13,090	2,210	–	–	T	87
	Castlegate C and		C	–	43.5	51.0	5.5	–	–	–	–	–	13,590	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
301	Kenilworth prep. plant		A	3.8	41.8	48.6	5.9	.5	–	–	–	–	12,920	2,200	–	–	WT	87
	Castlegate C and		C	–	43.4	50.5	6.1	–	–	–	–	–	13,430	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,300	–	–	–		
302	Kenilworth prep. plant		A	4.3	40.4	49.5	5.8	.5	–	–	–	–	12,980	2,180	–	–	WT	87
	Castlegate C and		C	–	42.2	51.7	6.1	–	–	–	–	–	13,560	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,440	–	–	–		
303	Kenilworth prep. plant		A	4.8	41.8	48.4	5.0	.5	–	–	–	–	12,940	2,200	–	–	WT	87
	Castlegate C and		C	–	43.9	50.8	5.3	–	–	–	–	–	13,590	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,350	–	–	–		
304	Kenilworth prep. plant		A	4.3	41.9	47.9	5.9	.4	–	–	–	–	12,780	2,200	–	–	T	87
	Castlegate C and		C	–	43.8	50.0	6.2	–	–	–	–	–	13,350	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,230	–	–	–		
305	Kenilworth prep. plant		A	7.6	40.5	47.4	4.5	.4	–	–	–	–	12,580	2,200	–	–	WT	87
	Castlegate C and		C	–	43.8	51.3	4.9	–	–	–	–	–	13,620	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,320	–	–	–		
306	Kenilworth prep. plant		A	4.3	42.0	46.1	7.8	.5	–	–	–	–	12,740	2,180	–	47	T	87
	Castlegate C and		C	–	43.7	48.2	8.1	–	–	–	–	–	13,310	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,480	–	–	–		
307	Kenilworth prep. plant		A	5.2	41.1	47.8	5.9	.4	–	–	–	–	12,790	2,130	–	–	WT	87
	Castlegate C and		C	–	43.4	50.4	6.2	–	–	–	–	–	13,490	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
308	Kenilworth prep. plant		A	3.1	41.0	48.8	7.1	.5	–	–	–	–	12,920	–	–	43	T	87
	Castlegate C and		C	–	42.3	50.4	7.3	–	–	–	–	–	13,330	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
309	Kenilworth prep. plant		A	5.6	40.4	46.5	7.5	.5	–	–	–	–	12,500	2,130	–	–	T	87
	Castlegate C and		C	–	42.8	49.3	7.9	–	–	–	–	–	13,240	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,380	–	–	–		
310	Kenilworth prep. plant		A	6.6	40.2	47.6	5.6	.4	–	–	–	–	12,580	2,160	–	–	WT	87
	Castlegate C and		C	–	43.0	51.0	6.0	–	–	–	–	–	13,470	–	–	–		
	Kenilworth beds		D	–	–	–	–	–	–	–	–	–	14,330	–	–	–		
311	Milburn mine	NE.SW.SW.11–13S–10E	A	4.0	45.7	44.7	5.6	.54	–	–	–	–	12,920	–	.7	–		31
	Kenilworth bed	4394910mN 519440mE	B	3.3	46.0	45.0	5.7	.54	–	–	–	–	13,000	–	–	–		
			C	–	47.6	46.5	5.9	.56	–	–	–	–	13,460	–	–	–		
			D	–	50.6	49.4	–	.59	–	–	–	–	14,290	–	–	–		
								SUNNYSIDE NW QUADRANGLE										
1	Rock Canyon mine	SE.NE.32–13S–13E	A	6.67	38.58	49.54	5.21	1.04	–	–	–	–	12,110	–	2.9	–		37
	Rock Canyon bed	4388960mN 544950mE	C	–	41.34	53.08	5.58	1.11	–	–	–	–	12,976	–	–	–		
			D	–	43.78	56.22	–	1.18	–	–	–	–	13,743	–	–	–		
2	Rock Canyon mine		A	7.9	37.2	48.5	6.4	1.4	4.9	73.0	1.5	12.3	11,880	–	–	46	T	8
	Rock Canyon bed		C	–	40.4	52.7	6.9	–	–	–	–	–	12,910	–	–	–		
3	Rock Canyon mine		A	4.3	39.4	48.9	7.4	1.9	–	–	–	–	12,710	–	–	45		9
	Rock Canyon bed		C	–	41.2	51.1	7.7	–	–	–	–	–	13,270	–	–	–		
4	Rock Canyon mine		A	3.1	39.4	49.7	7.8	2.0	–	–	–	–	12,940	–	–	–	T	13
	Rock Canyon bed		C	–	40.7	51.3	8.0	–	–	–	–	–	13,340	–	–	–		
5	Rock Canyon mine		A	3.8	40.0	48.7	7.9	2.4	–	–	–	–	12,820	–	–	–	T	13
	Rock Canyon bed		C	–	41.4	50.4	8.2	–	–	–	–	–	13,330	–	–	–		
6	Rock Canyon mine		A	5.7	38.4	48.4	7.5	2.2	–	–	–	–	12,610	–	–	–		14
	Rock Canyon bed		C	–	40.7	51.3	8.0	–	–	–	–	–	13,370	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
								SUNNYSIDE SE QUADRANGLE										
1	Columbia no. 1 mine Lower Sunnyside bed	NW.NW.NW.21–15S–14E 4373250mN 556090mE	A	4.58	36.73	54.18	4.51	.95	5.86	74.47	1.55	12.66	13,132	–	–	–		85
			B	2.61	37.48	55.30	4.61	.98	5.74	76.00	1.58	11.09	13,403	–	–	–		
			C	–	38.49	56.78	4.73	1.00	5.60	78.04	1.62	9.01	13,762	–	–	–		
			D	–	39.90	60.10	–	–	–	–	–	–	13,829	–	–	–		
2	Columbia mine Lower Sunnyside bed		A	5.7	–	–	5.8	.94	–	–	–	–	–	–	–	–		88
3	Columbia mine Lower Sunnyside bed		A	7.1	–	–	7.1	1.37	–	–	–	–	–	–	–	–		88
4	Columbia mine Lower Sunnyside bed		A	5.4	38.1	50.4	6.1	1.0	5.6	72.2	1.5	13.6	12,920	–	2.3	–		70
			C	–	40.3	53.3	6.4	1.0	5.3	76.4	1.6	9.3	13,660	–	–	–		
			D	–	43.1	56.9	–	1.1	5.6	81.6	1.7	10.0	14,600	–	–	–		
5	Columbia mine Lower Sunnyside bed		A	4.6	38.8	50.6	6.0	1.0	5.7	72.9	1.5	12.9	13,030	–	1.5	–		70
			C	–	40.6	53.1	6.3	1.1	5.4	76.4	1.6	9.2	13,660	–	–	–		
			D	–	43.4	56.6	–	1.1	5.8	81.5	1.7	9.9	14,580	–	–	–		
6	Columbia mine Lower Sunnyside bed		A	5.1	38.4	51.4	5.1	.8	5.8	74.1	1.5	12.7	13,210	–	2.7	–		70
			C	–	40.4	54.3	5.3	.8	5.5	78.1	1.6	8.7	13,910	–	–	–		
			D	–	42.7	57.3	–	.8	5.8	82.5	1.7	9.2	14,690	–	–	–		
7	Columbia mine Lower Sunnyside bed		A	6.4	37.2	51.6	4.8	.7	5.8	72.8	1.5	14.4	13,010	–	3.6	–		70
			C	–	39.8	55.1	5.1	.8	5.4	77.8	1.6	9.3	13,900	–	–	–		
			D	–	41.9	58.1	–	.8	5.7	82.0	1.7	9.8	14,650	–	–	–		
8	Columbia mine Lower Sunnyside bed		A	4.7	38.6	51.8	4.9	.8	5.7	74.2	1.5	12.9	13,240	–	1.5	–		70
			C	–	40.5	54.4	5.1	.9	5.4	77.9	1.6	9.1	13,900	–	–	–		
			D	–	42.7	57.3	–	.9	5.7	82.1	1.7	9.6	14,650	–	–	–		
9	Columbia mine Lower Sunnyside bed		A	5.1	36.7	53.3	4.9	.8	5.6	73.6	1.6	13.5	13,090	–	2.1	–		70
			C	–	38.7	56.1	5.2	.8	5.3	77.5	1.7	9.5	13,790	–	–	–		
			D	–	40.8	59.2	–	.9	5.6	81.8	1.8	9.9	14,550	–	–	–		
10	Columbia mine Lower Sunnyside bed		A	5.0	37.9	51.8	5.3	.9	–	–	–	–	13,190	–	.8	–		70
			C	–	39.9	54.6	5.5	.9	–	–	–	–	13,890	–	–	–		
			D	–	42.2	57.8	–	1.0	–	–	–	–	14,710	–	–	–		
11	Columbia mine Lower Sunnyside bed		A	4.4	38.3	51.7	5.6	.8	–	–	–	–	13,190	–	1.3	–		70
			C	–	40.0	54.2	5.8	.8	–	–	–	–	13,800	–	–	–		
			D	–	42.5	57.5	–	.8	–	–	–	–	14,650	–	–	–		
12	Columbia mine Lower Sunnyside bed		A	4.9	38.1	50.4	6.6	1.0	–	–	–	–	12,930	–	2.6	–		70
			C	–	40.1	52.9	7.0	1.1	–	–	–	–	13,600	–	–	–		
			D	–	43.1	56.9	–	1.2	–	–	–	–	14,610	–	–	–		
13	Columbia mine Lower Sunnyside bed		A	5.4	38.1	50.4	6.1	1.0	5.6	72.2	1.5	13.6	13,015	–	–	–		89
14	Columbia mine Lower Sunnyside bed		A	4.6	38.8	50.6	6.0	1.0	5.7	72.9	1.5	12.9	13,132	–	–	–		89
15	Columbia mine Lower Sunnyside bed		A	5.1	38.4	51.4	5.1	.8	5.8	74.1	1.5	12.7	13,295	–	–	–		89
16	Sunnyside mine Lower Sunnyside bed	SE.NE.SE.SW.32–14S–14E 4378540mN 555140mE	A	3.43	37.72	51.68	7.17	.78	–	–	–	–		–	1.5	–		80
			C	–	39.06	53.52	7.42	.81	–	–	–	–		–	–	–		
			D	–	42.19	57.81	–	.87	–	–	–	–	–	–	–	–		
17	Sunnyside mine A Seam		A	15.2	33.9	46.2	4.7	.60	–	–	–	–	9,530	–	2.5	–		76
			B	13.0	34.7	47.4	4.9	.62	–	–	–	–	9,770	–	–	–		
			C	–	39.9	54.5	5.6	.71	–	–	–	–	11,230	–	–	–		
			D	–	42.3	57.7	–	.75	–	–	–	–	11,900	–	–	–		
18	Sunnyside mine Lower Sunnyside bed		A	6.7	38.6	49.5	5.2	1.04	–	–	–	–	12,110	–	2.9	–		76
			B	3.9	39.7	51.0	5.4	1.07	–	–	–	–	12,470	–	–	–		
			C	–	41.3	53.1	5.6	1.11	–	–	–	–	12,980	–	–	–		
			D	–	43.8	56.2	–	1.18	–	–	–	–	13,740	–	–	–		
19	Sunnyside mine Lower Sunnyside bed		A	3.37	38.04	52.75	5.84	.60	–	–	–	–	–	–	1.3	–		62
			C	–	39.37	54.59	6.04	.62	–	–	–	–	–	–	–	–		
			D	–	41.90	58.10	–	.66	–	–	–	–	–	–	–	–		
20	Sunnyside mine Lower Sunnyside bed		A	7.0	39.87	46.92	6.21	.69	–	–	–	–	12,247	–	–	–		72
			C	–	42.87	50.45	6.68	–	–	–	–	–	13,169	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,112	–	–	–		
21	Sunnyside mine Lower Sunnyside bed		A	4.1	37.9	51.7	6.3	.7	–	–	–	–	13,220	–	–	–		40
22	Sunnyside mine Lower Sunnyside bed		A	4.5	38.5	51.2	5.8	1.3	5.6	73.6	1.6	12.1	13,110	–	2.2	–		70
			C	–	40.3	53.6	6.1	1.3	5.3	77.1	1.7	8.5	13,730	–	–	–		
			D	–	42.9	57.1	–	1.4	5.7	82.1	1.8	9.0	14,620	–	–	–		
23	Sunnyside mine Lower Sunnyside bed		A	5.8	38.4	50.2	5.6	1.0	5.8	72.7	1.5	13.4	13,080	–	4.6	–		70
			C	–	40.8	53.3	5.9	1.1	5.4	77.2	1.6	8.8	13,890	–	–	–		
			D	–	43.3	56.7	–	1.1	5.8	82.0	1.7	9.4	14,760	–	–	–		
24	Sunnyside mine Lower Sunnyside bed		A	3.4	38.5	50.8	7.3	1.2	5.6	73.2	1.6	11.1	–	–	1.4	–		70
			C	–	39.8	52.6	7.6	1.3	5.4	75.8	1.6	8.3	–	–	–	–		
			D	–	43.1	56.9	–	1.4	5.8	82.0	1.7	9.1	–	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
25	Sunnyside mine Lower Sunnyside bed		A	5.9	38.6	49.8	5.7	1.0	5.7	72.1	1.5	14.0	13,000	–	4.2	–		70
			C	–	40.9	53.0	6.1	1.0	5.4	76.6	1.6	9.3	13,800	–	–	–		
			D	–	43.6	56.4	–	1.1	5.8	81.6	1.7	9.8	14,700	–	–	–		
26	Sunnyside mine Lower Sunnyside bed		A	4.3	37.2	53.2	5.3	1.3	–	–	–	–	13,280	–	2.0	–		70
			C	–	38.9	55.5	5.6	1.4	–	–	–	–	13,880	–	–	–		
			D	–	41.2	58.8	–	1.5	–	–	–	–	14,700	–	–	–		
27	Sunnyside mine Lower Sunnyside bed		A	3.8	37.9	50.0	8.3	2.0	–	–	–	–	12,950	–	1.7	–		70
			C	–	39.4	51.9	8.7	2.1	–	–	–	–	13,470	–	–	–		
			D	–	43.1	56.9	–	2.2	–	–	–	–	14,740	–	–	–		
28	Sunnyside mine Lower Sunnyside bed		A	4.9	36.6	50.5	8.0	1.4	–	–	–	–	12,820	–	2.6	–		70
			C	–	38.5	53.1	8.4	1.5	–	–	–	–	13,480	–	–	–		
			D	–	42.0	58.0	–	1.6	–	–	–	–	14,720	–	–	–		
29	Sunnyside mine Upper bed		A	3.4	37.9	53.4	5.3	.6	–	–	–	–	13,360	–	1.1	–		70
			C	–	39.2	55.3	5.5	.6	–	–	–	–	13,830	–	–	–		
			D	–	41.5	58.5	–	.7	–	–	–	–	14,630	–	–	–		
30	Sunnyside mine Upper bed		A	4.5	37.1	51.9	6.5	.6	–	–	–	–	12,990	–	2.0	–		70
			C	–	38.8	54.4	6.8	.7	–	–	–	–	13,590	–	–	–		
			D	–	41.6	58.4	–	.7	–	–	–	–	14,580	–	–	–		
31	Sunnyside mine Upper Sunnyside bed		A	3.4	37.9	53.4	5.3	.6	–	–	–	–	13,447	–	–	–		89
32	Sunnyside mine Sunnyside bed		A	3.4	38.5	50.8	7.3	1.2	5.6	73.2	1.6	11.1	–	–	–	–		89
33	Sunnyside mine Sunnyside bed		A	5.9	38.6	49.8	5.7	1.0	5.7	72.1	1.5	14.0	13,088	–	–	–		89
34	Sunnyside mine Sunnyside bed		A	4.5	38.5	51.2	5.8	1.3	5.6	73.6	1.6	12.1	13,207	–	–	–		89
35	Sunnyside mine Sunnyside bed		A	5.8	38.4	50.2	5.6	1.0	5.8	72.7	1.5	13.4	13,169	–	–	–		89
36	Sunnyside mine Sunnyside bed		A	3.5	38.9	52.3	5.3	1.1	5.6	74.5	1.6	11.9	13,599	–	–	–		89
37	Sunnyside mine Lower Sunnyside bed		A	4.7	36.5	51.4	7.4	–	–	–	–	–	–	–	–	–		59
			D	–	41.7	58.3	–	.9	5.7	82.3	1.8	9.3	14,820	–	–	–		
38	Sunnyside mine Lower Sunnyside bed		A	14.6	–	–	5.1	.94	–	–	–	–	–	–	–	–		88
39	Sunnyside no. 1 mine Lower Sunnyside bed	SE.SW.32–14S–14E 4378650mN 555140mE	A	4.7	–	–	5.9	1.19	–	–	–	–	–	–	–	–		88
40	Sunnyside no. 1 mine Lower Sunnyside bed		A	4.6	–	–	4.8	1.22	–	–	–	–	–	–	–	–		88
41	Sunnyside no. 1 mine Lower Sunnyside bed		A	6.0	38.7	48.7	6.6	1.7	5.4	71.3	1.5	13.5	12,840	2,390	3.4	–		37
			B	2.7	40.0	50.5	6.8	1.79	5.23	73.79	1.57	10.80	13,290	–	–	–		
			C	–	41.1	51.9	7.0	1.8	5.1	75.8	1.6	8.7	13,660	–	–	–		
			D	–	44.2	55.8	–	2.0	5.5	81.5	1.7	9.3	14,680	–	–	–		
42	Sunnyside no. 1 mine Lower Sunnyside bed		A	3.8	37.8	51.2	7.2	1.8	–	–	–	–	12,990	2,510	1.8	–		39
43	Sunnyside no. 1 mine Lower Sunnyside bed		A	4.9	37.8	50.8	7.0	1.0	–	–	–	–	12,970	2,180	2.7	–		39
44	Sunnyside no. 1 mine Lower Sunnyside bed		A	3.1	36.8	48.2	11.9	3.0	–	–	–	–	12,420	2,200	1.4	–		39
45	Sunnyside no. 1 mine Upper Sunnyside bed		A	4.2	39.0	51.5	5.3	.9	–	–	–	–	13,180	2,340	2.0	–		39
46	Sunnyside no. 1 mine Lower Sunnyside bed		A	3.6	37.3	53.2	5.9	.6	–	–	–	–	13,270	2,570	1.5	–		39
47	Sunnyside no. 1 mine Lower Sunnyside bed		A	3.3	38.5	54.0	4.2	.5	–	–	–	–	13,660	2,540	1.3	–		39
48	Sunnyside no. 1 mine Lower Sunnyside bed		A	4.8	38.2	51.1	5.9	.8	–	–	–	–	13,070	2,180	2.8	–		39
49	Sunnyside no. 1 mine Lower Sunnyside bed		A	4.0	38.0	51.3	6.7	1.2	5.6	72.8	1.6	12.1	13,120	–	1.9	–		39
			C	–	39.6	53.4	7.0	1.2	5.3	75.8	1.6	8.1	13,670	–	–	–		
			D	–	42.6	57.4	–	1.3	5.7	81.6	1.8	9.6	14,700	–	–	–		
50	Sunnyside no. 3 mine Lower Seam	NW.NE.5–15S–14E 4378210mN 555360mE	A	5.1	39.9	47.7	7.3	1.37	–	–	–	–	12,770	–	2.1	–		76
			B	3.0	40.8	48.7	7.5	1.40	–	–	–	–	13,040	–	–	–		
			C	–	42.1	50.2	7.7	1.44	–	–	–	–	13,450	–	–	–		
			D	–	45.6	54.4	–	1.56	–	–	–	–	14,570	–	–	–		
51	Sunnyside no. 3 mine Upper Seam		A	5.1	38.4	48.7	7.81	.51	5.54	70.72	1.58	13.84	12,620	–	1.5	–		76
			B	3.6	39.1	49.4	7.93	.52	5.54	71.80	1.60	12.70	12,810	–	–	–		
			C	–	40.5	51.3	8.23	.54	5.25	74.49	1.66	9.83	13,290	–	–	–		
			D	–	44.1	55.9	–	.59	5.72	81.17	1.81	10.71	14,490	–	–	–		
52	Sunnyside no. 3 mine Lower Sunnyside bed		A	6.0	38.1	48.8	7.1	.56	–	–	–	–	11,990	–	1.0	–		76
			B	5.0	38.5	49.3	7.2	.57	–	–	–	–	12,110	–	–	–		
			C	–	40.5	51.9	7.6	.60	–	–	–	–	12,750	–	–	–		
			D	–	43.8	56.2	–	.65	–	–	–	–	13,800	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
53	Sunnyside no. 3 mine Upper Sunnyside bed		A	5.1	38.5	48.6	7.8	.5	5.5	70.7	1.6	13.8	12,620	3,010	1.5	–		37
			B	3.6	39.1	49.4	7.9	.52	5.45	71.80	1.60	12.70	12,810	–	–	–		
			C	–	40.5	51.3	8.2	.5	5.3	74.5	1.7	9.8	13,290	–	–	–		
			D	–	44.1	55.9	–	.6	5.7	81.2	1.8	10.7	14,490	–	–	–		
54	Sunnyside no. 3 mine Lower Sunnyside bed		A	5.1	39.9	47.7	7.3	1.4	–	–	–	–	12,770	2,550	2.1	–		37
			B	5.0	40.8	48.7	7.5	1.40	–	–	–	–	13,040	–	–	–		
			C	–	42.1	50.2	7.7	1.4	–	–	–	–	13,450	–	–	–		
			D	–	45.6	54.4	–	1.56	–	–	–	–	14,570	–	–	–		
55	Sunnyside no. 3 mine Lower Sunnyside bed		A	4.1	38.0	49.8	8.1	1.2	5.7	71.9	1.5	11.6	12,840	2,980	1.1	–		38
			B	3.0	38.4	50.5	8.1	1.16	5.59	72.74	1.49	10.82	12,980	–	–	–		
			C	–	39.6	52.0	8.4	1.2	5.4	75.0	1.5	8.5	13,380	–	–	–		
			D	–	43.2	56.8	–	1.3	5.9	81.8	1.7	9.3	14,610	–	–	–		
56	Sunnyside no. 3 mine Lower Sunnyside bed		A	4.3	37.2	51.8	6.7	1.1	5.6	72.2	1.6	12.8	12,990	–	1.9	–		39
			C	–	38.9	54.1	7.0	1.2	5.4	75.5	1.6	9.3	13,570	–	–	–		
			D	–	41.9	58.1	–	1.3	5.8	81.2	1.7	10.0	14,600	–	–	–		
57	Sunnyside no. 3 mine Lower Sunnyside bed		A	3.9	37.2	50.7	8.2	1.0	–	–	–	–	12,800	2,960	1.8	–		39
58	Sunnyside no. 3 mine Lower Sunnyside bed		A	4.8	38.3	51.6	6.3	1.2	–	–	–	–	13,200	2,280	2.0	–		39
59	Sunnyside no. 3 mine Lower Sunnyside bed		A	5.9	38.7	44.8	6.6	.56	5.43	71.28	1.52	13.45	11,990	–	3.4	–		31
			B	2.7	40.0	50.5	6.8	1.79	5.24	73.79	1.57	10.80	13,290	–	–	–		
			C	–	41.1	51.9	6.8	.60	5.07	75.80	1.62	8.66	12,750	–	–	–		
			D	–	44.2	56.2	–	.65	5.45	81.52	1.74	9.31	13,800	–	–	–		
60	Sunnyside no. 3 mine Lower Sunnyside bed		A	4.4	38.2	50.5	6.9	.8	–	–	–	–	12,760	2,620	1.2	–		31
			B	3.3	38.6	51.1	7.0	.83	–	–	–	–	–	–	–	–		
			C	–	39.9	52.8	7.3	.9	–	–	–	–	13,350	–	–	–		
			D	–	43.0	57.0	–	.93	–	–	–	–	–	–	–	–		
61	Outcrop Lower Sunnyside bed		A	5.08	39.94	47.69	7.29	1.37	–	–	–	–	12,769	–	2.1	–		37
			C	–	42.08	50.24	7.68	1.44	–	–	–	–	13,453	–	–	–		
			D	–	45.48	54.42	–	1.56	–	–	–	–	14,573	–	–	–		
SUNNYSIDE SW QUADRANGLE																		
1	Drill hole Lower Sunnyside bed	SE.18–14S–14E 4283600mN 554350mE	C	–	39.5	53.3	7.2	.70	–	–	–	–	13,790	2,400	–	–		87
			D	–	–	–	–	–	–	–	–	8.9	14,860	–	–	–		
WELLINGTON–MINNIE MAUD W QUADRANGLE																		
1	Knight-Ideal mine Gilson bed	E ½.NW.10–13S–11E 4396090mN 527790mE	A	4.09	38.06	52.59	5.26	.48	–	–	–	–	–	–	1.1	–		62
			C	–	39.68	54.84	5.48	.50	–	–	–	–	–	–	–	–		
			D	–	41.98	58.02	–	.53	–	–	–	–	–	–	–	–		
2	Knight-Ideal mine Gilson bed		A	5.42	36.32	52.16	6.10	.54	–	–	–	–	12,220	–	1.0	–		63
			C	–	38.40	55.15	6.45	.57	–	–	–	–	12,920	–	–	–		
			D	–	41.05	58.95	–	.61	–	–	–	–	13,811	–	–	–		
3	Knight-Ideal mine Gilson bed		A	4.0	39.1	48.9	8.1	.4	–	–	–	–	12,460	–	–	–		73
			C	–	40.7	50.9	8.4	–	–	–	–	–	12,980	–	–	–		
4	Knight-Ideal mine Gilson bed		A	4.6	38.8	49.2	7.3	.5	–	–	–	–	12,510	–	–	–		73
			C	–	40.7	51.6	7.7	–	–	–	–	–	13,110	–	–	–		
5	Knight-Ideal mine Gilson bed		A	3.6	39.1	49.5	7.8	.5	–	–	–	–	12,550	–	–	–		73
			C	–	40.6	51.3	8.1	–	–	–	–	–	13,020	–	–	–		
6	Knight-Ideal mine Gilson bed		A	4.6	39.2	49.1	7.1	.5	–	–	–	–	12,600	–	–	–		73
			C	–	41.1	51.5	7.4	–	–	–	–	–	13,210	–	–	–		
7	Knight-Ideal mine Gilson bed		A	3.3	39.2	49.5	8.0	.5	–	–	–	–	12,560	–	–	–		73
			C	–	40.5	51.2	8.3	–	–	–	–	–	12,990	–	–	–		
8	Knight-Ideal mine Gilson bed		A	4.7	38.8	49.3	7.2	.6	–	–	–	–	12,470	–	–	–		73
			C	–	40.7	51.7	7.6	–	–	–	–	–	13,090	–	–	–		
9	Knight-Ideal mine Gilson bed		A	4.9	39.0	47.9	8.2	.5	–	–	–	–	12,320	–	–	–		73
			C	–	41.0	50.4	8.6	–	–	–	–	–	12,960	–	–	–		
10	Knight-Ideal mine Gilson bed		A	4.2	39.2	48.7	8.0	.5	–	–	–	–	12,430	–	–	–		73
			C	–	40.9	50.8	8.3	–	–	–	–	–	12,980	–	–	–		
11	Knight-Ideal mine Gilson bed		A	4.8	36.6	47.1	11.5	–	–	–	–	–	11,849	–	–	–		86
			B	2.4	37.7	48.1	11.9	–	–	–	–	–	12,223	–	–	–		
			C	–	38.4	49.5	12.1	–	–	–	–	–	12,445	–	–	–		
12	Knight-Ideal mine Gilson bed		A	4.8	35.5	49.2	10.5	–	–	–	–	–	11,942	–	–	–		86
			B	2.0	36.5	50.7	10.8	–	–	–	–	–	12,288	–	–	–		
			C	–	37.2	51.7	11.1	–	–	–	–	–	12,544	–	–	–		
13	Knight-Ideal mine Gilson bed		A	5.1	34.2	50.1	10.6	–	–	–	–	–	11,942	–	–	–		86
			B	2.5	35.2	51.5	10.9	–	–	–	–	–	12,276	–	–	–		
			C	–	36.1	52.8	11.2	–	–	–	–	–	12,584	–	–	–		
14	Knight-Ideal mine Gilson bed		A	5.9	30.9	51.9	11.2	–	–	–	–	–	11,762	–	–	–		86
			B	1.2	32.5	54.6	11.8	–	–	–	–	–	12,353	–	–	–		
			C	–	32.9	55.2	11.9	–	–	–	–	–	12,502	–	–	–		
15	Knight-Ideal mine Gilson bed		A	5.5	40.5	44.0	10.1	–	–	–	–	–	11,743	–	–	–		86
			B	2.5	41.7	45.4	10.3	–	–	–	–	–	12,018	–	–	–		
			C	–	42.8	46.6	10.7	–	–	–	–	–	12,426	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
16	Knight-Ideal mine		A	5.6	35.5	50.6	8.3	–	–	–	–	–	12,268	–	–	–		86
	Gilson bed		B	2.8	36.6	52.1	8.5	–	–	–	–	–	12,637	–	–	–		
			C	–	37.6	53.6	8.7	–	–	–	–	–	12,997	–	–	–		
17	Knight-Ideal mine		A	5.8	39.5	47.2	7.5	.55	–	–	–	–	12,316	–	–	–		86
	Gilson bed		B	2.2	40.98	49.0	7.8	.57	–	–	–	–	12,973	–	–	–		
			C	–	41.9	50.1	8.0	.58	–	–	–	–	13,078	–	–	–		
18	Knight-Ideal mine		A	4.3	39.3	50.5	5.8	.4	5.2	75.4	1.4	11.5	12,830	–	–	–	T	7
	Gilson bed		C	–	41.1	52.8	6.1	–	–	–	–	–	13,400	–	–	–		
19	Knight-Ideal mine		A	3.4	39.7	50.1	6.8	.4	–	–	–	–	12,730	–	–	–	D	7
	Gilson bed		C	–	41.1	51.9	7.0	–	–	–	–	–	13,180	–	–	–		
20	Knight-Ideal mine		A	4.4	39.4	49.5	6.7	.3	–	–	–	–	12,750	–	–	–	T	7
	Gilson bed		C	–	41.2	51.8	7.0	–	–	–	–	–	13,330	–	–	–		
21	Knight-Ideal mine		A	3.6	39.5	50.1	6.7	.4	–	–	–	–	12,730	–	–	–	D	7
	Gilson bed		C	–	41.0	52.0	7.0	–	–	–	–	–	13,210	–	–	–		
22	Knight-Ideal mine		A	4.4	40.1	47.2	8.3	.3	–	–	–	–	12,490	–	–	–	T	7
	Gilson bed		C	–	41.9	49.4	8.7	–	–	–	–	–	13,070	–	–	–		
23	Knight-Ideal mine		A	4.1	39.1	48.8	8.0	.4	–	–	–	–	12,480	–	–	–	D	7
	Gilson bed		C	–	40.8	50.9	8.3	–	–	–	–	–	13,010	–	–	–		
24	Knight-Ideal mine		A	6.3	39.0	48.4	6.3	.3	–	–	–	–	12,460	–	–	–	T	7
	Gilson bed		C	–	41.6	51.7	6.7	–	–	–	–	–	13,300	–	–	–		
25	Knight-Ideal mine		A	4.9	38.3	46.5	9.4	.5	–	–	–	–	12,010	–	–	–	T	7
	Gilson bed		C	–	40.3	49.8	9.9	–	–	–	–	–	12,630	–	–	–		
26	Knight-Ideal mine		A	4.5	38.3	50.3	6.9	.5	–	–	–	–	12,640	–	–	–	T	7
	Gilson bed		C	–	40.1	52.7	7.2	–	–	–	–	–	13,230	–	–	–		
27	Knight-Ideal mine		A	4.7	38.0	48.2	9.1	.5	–	–	–	–	12,260	–	–	–	T	7
	Gilson bed		C	–	39.9	50.6	9.5	–	–	–	–	–	12,870	–	–	–		
28	Knight-Ideal mine		A	5.0	38.5	49.4	7.1	.5	–	–	–	–	12,500	–	–	–	T	7
	Gilson bed		C	–	40.5	52.0	7.5	–	–	–	–	–	13,160	–	–	–		
29	Knight-Ideal mine		A	4.7	36.2	46.5	12.6	.4	–	–	–	–	11,700	–	–	–	T	7
	Gilson bed		C	–	38.0	48.8	13.2	–	–	–	–	–	12,280	–	–	–		
30	Knight-Ideal mine		A	4.4	36.7	46.6	12.3	.5	–	–	–	–	11,800	–	–	–	T	7
	Gilson bed		C	–	38.4	48.7	12.9	–	–	–	–	–	12,340	–	–	–		
31	Knight-Ideal mine		A	3.7	39.3	49.2	7.8	.4	–	–	–	–	12,530	–	–	–	D	7
	Gilson bed		C	–	40.8	51.1	8.1	–	–	–	–	–	13,010	–	–	–		
32	Knight-Ideal mine		A	5.0	36.7	47.6	10.7	.5	–	–	–	–	11,950	–	–	–	T	7
	Gilson bed		C	–	38.6	50.1	11.3	–	–	–	–	–	12,570	–	–	–		
33	Knight-Ideal mine		A	3.5	38.9	48.1	9.6	.4	–	–	–	–	12,250	–	–	–	D	7
	Gilson bed		C	–	40.3	49.8	9.9	–	–	–	–	–	12,690	–	–	–		
34	Knight-Ideal mine		A	5.1	37.9	48.9	8.1	.4	–	–	–	–	12,260	–	–	–	D	7
	Gilson bed		C	–	39.9	51.5	8.5	–	–	–	–	–	12,920	–	–	–		
35	Knight-Ideal mine		A	6.0	37.0	48.1	8.8	.5	–	–	–	–	12,040	–	–	–	T	7
	Gilson bed		C	–	39.4	51.2	9.4	–	–	–	–	–	12,810	–	–	–		
36	Knight-Ideal mine		A	6.4	37.1	48.0	8.5	.5	–	–	–	–	12,130	–	–	–	T	7
	Gilson bed		C	–	39.6	51.3	9.1	–	–	–	–	–	12,960	–	–	–		
37	Knight-Ideal mine		A	5.7	37.1	48.3	9.0	.5	–	–	–	–	12,100	–	–	–	T	7
	Gilson bed		C	–	39.3	51.2	9.5	–	–	–	–	–	12,830	–	–	–		
38	Knight-Ideal mine		A	5.1	38.2	48.9	7.9	.4	–	–	–	–	12,340	–	–	–	D	7
	Gilson bed		C	–	40.2	51.5	8.3	–	–	–	–	–	13,000	–	–	–		
39	Knight-Ideal mine		A	5.7	39.4	47.6	7.3	1.0	–	–	–	–	12,230	–	–	–	D	7
	Gilson bed		C	–	41.8	50.5	7.7	–	–	–	–	–	12,970	–	–	–		
40	Knight-Ideal mine		A	4.9	34.5	52.3	8.3	–	–	–	–	–	11,950	–	–	–		86
	Gilson bed		B	2.7	36.3	52.4	8.6	–	–	–	–	–	12,223	–	–	–		
			C	–	37.4	53.7	8.9	–	–	–	–	–	12,563	–	–	–		
41	Knight-Ideal mine		A	4.3	–	–	5.9	.36	–	–	–	–	–	–	–	–		88
	Gilson bed																	
42	Knight-Ideal mine		A	4.0	39.0	49.0	8.1	.4	–	–	–	–	12,540	–	–	–		6
	Gilson bed		C	–	40.6	51.0	8.4	–	–	–	–	–	13,060	–	–	–		
43	Knight-Ideal mine		A	4.0	38.9	48.6	8.5	.4	–	–	–	–	12,480	–	–	–	D	6
	Gilson bed		C	–	40.5	50.6	8.9	–	–	–	–	–	13,000	–	–	–		
44	Knight-Ideal mine		A	3.5	40.0	50.0	6.5	.4	–	–	–	–	12,810	–	–	–	D	6
	Gilson bed		C	–	41.5	51.8	6.7	–	–	–	–	–	13,270	–	–	–		
45	Knight-Ideal mine		A	3.9	38.2	48.1	9.8	.4	–	–	–	–	12,210	–	–	–	D	6
	Gilson bed		C	–	39.8	50.0	10.2	–	–	–	–	–	12,710	–	–	–		
46	Knight-Ideal mine		A	4.6	38.6	47.7	9.1	.4	–	–	–	–	12,340	–	–	–	D	6
	Gilson bed		C	–	40.5	50.0	9.5	–	–	–	–	–	12,930	–	–	–		
47	Knight-Ideal mine		A	6.0	38.0	47.2	8.8	.3	–	–	–	–	12,140	–	–	–	D	6
	Gilson bed		C	–	40.4	50.2	9.4	–	–	–	–	–	12,920	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
48	Knight-Ideal mine		A	5.1	38.2	46.2	10.6	.41	–	–	–	–	11,851	–	–	–		86
	Gilson bed		B	2.2	39.3	47.6	10.9	.42	–	–	–	–	12,207	–	–	–		
			C	–	40.2	48.6	11.2	.43	–	–	–	–	12,485	–	–	–		
49	Knight-Ideal mine		A	4.6	38.9	48.8	7.6	.5	–	–	–	–	12,420	–	–	–	D	8
	Gilson bed		C	–	40.8	51.2	8.0	–	–	–	–	–	13,020	–	–	–		
50	Knight-Ideal mine		A	4.0	38.2	47.8	10.0	.4	–	–	–	–	12,150	–	–	–	D	8
	Gilson bed		C	–	39.8	49.8	10.4	–	–	–	–	–	12,660	–	–	–		
51	Knight-Ideal mine		A	4.7	39.2	48.9	7.3	.5	–	–	–	–	12,470	–	–	–	D	8
	Gilson bed		C	–	41.1	51.3	7.7	–	–	–	–	–	13,080	–	–	–		
52	Knight-Ideal mine		A	4.4	39.9	50.2	5.5	.4	–	–	–	–	12,930	–	–	–	T	8
	Gilson bed		C	–	41.7	52.5	5.8	–	–	–	–	–	13,510	–	–	–		
53	Knight-Ideal mine		A	4.3	39.4	50.8	5.5	.4	–	–	–	–	12,890	–	–	–	T	8
	Gilson bed		C	–	41.2	53.1	5.7	–	–	–	–	–	13,460	–	–	–		
54	Knight-Ideal mine		A	4.3	39.1	50.2	6.3	.4	–	–	–	–	12,760	–	–	–	D	8
	Gilson bed		C	–	40.9	52.5	6.6	–	–	–	–	–	13,330	–	–	–		
55	Knight-Ideal mine		A	3.2	39.8	49.6	7.5	.4	–	–	–	–	12,700	–	–	–	D	8
	Gilson bed		C	–	41.1	51.2	7.7	–	–	–	–	–	13,120	–	–	–		
56	Knight-Ideal mine		A	5.4	38.2	46.4	9.9	.4	–	–	–	–	12,080	–	–	47	T	8
	Gilson bed		C	–	40.4	49.1	10.5	–	–	–	–	–	12,770	–	–	–		
57	Knight-Ideal mine		A	4.5	38.4	48.1	9.0	.4	–	–	–	–	12,290	–	–	–	D	8
	Gilson bed		C	–	40.2	50.4	9.4	–	–	–	–	–	12,870	–	–	–		
58	Knight-Ideal mine		A	3.9	38.8	48.7	8.6	.4	–	–	–	–	12,460	–	–	–	D	8
	Gilson bed		C	–	40.4	50.7	8.9	–	–	–	–	–	12,970	–	–	–		
59	Knight-Ideal mine		A	7.0	37.7	47.2	8.2	.4	–	–	–	–	12,040	–	–	–	T	8
	Gilson bed		C	–	40.5	50.7	8.8	–	–	–	–	–	12,950	–	–	–		
60	Knight-Ideal mine		A	4.3	38.5	48.9	8.3	.5	–	–	–	–	12,350	–	–	–	D	8
	Gilson bed		C	–	40.2	51.1	8.7	–	–	–	–	–	12,910	–	–	–		
61	Knight-Ideal mine		A	5.7	37.8	48.3	8.2	.5	–	–	–	–	12,240	–	–	–	D	8
	Gilson bed		C	–	40.1	51.2	8.7	–	–	–	–	–	12,980	–	–	–		
62	Knight-Ideal mine		A	4.3	37.7	47.0	11.1	–	–	–	–	–	12,043	–	1.76	–		86
	Gilson bed		B	1.7	38.7	48.3	11.4	–	–	–	–	–	12,363	–	–	–		
			C	–	39.3	49.1	11.6	–	–	–	–	–	12,582	–	–	–		
63	Knight-Ideal mine		A	2.4	–	–	–	–	–	–	–	–	12,662	–	–	–		86
	Gilson bed		B	–	–	–	–	–	–	–	–	–	12,979	–	–	–		
64	Knight-Ideal mine		A	2.6	–	–	–	–	–	–	–	–	12,562	–	–	–		86
	Gilson bed		B	–	–	–	–	–	–	–	–	–	12,900	–	–	–		
65	Knight-Ideal mine		A	4.23	37.6	49.0	9.1	–	–	–	–	–	12,211	–	–	–		86
	Gilson bed		B	1.7	38.6	50.3	9.4	–	–	–	–	–	12,529	–	–	–		
			C	–	39.3	51.2	9.5	–	–	–	–	–	12,750	–	–	–		
66	Knight-Ideal mine		A	2.4	–	–	–	–	–	–	–	–	12,569	–	–	–		86
	Gilson bed		B	–	–	–	–	–	–	–	–	–	12,875	–	–	–		
67	Knight-Ideal mine		A	4.0	37.1	49.98	8.9	–	–	–	–	–	12,292	–	–	–		86
	Gilson bed		B	1.8	37.97	51.2	9.1	–	–	–	–	–	12,582	–	–	–		
68	Knight-Ideal mine		A	4.4	–	–	–	–	–	–	–	–	12,761	–	–	–		86
	Gilson bed		B	–	–	–	–	–	–	–	–	–	13,348	–	–	–		
69	Knight-Ideal mine		A	2.98	–	–	–	–	–	–	–	–	12,633	–	–	–		86
	Gilson bed		B	–	–	–	–	–	–	–	–	–	13,021	–	–	–		
70	Knight-Ideal mine		A	3.2	–	–	–	–	–	–	–	–	12,589	–	–	–		86
	Gilson bed		B	–	–	–	–	–	–	–	–	–	13,004	–	–	–		
71	Knight-Ideal mine		A	7.5	36.6	48.8	7.1	–	–	–	–	–	12,093	–	6.0	–		86
	Gilson bed		B	0.8	39.3	52.3	7.6	–	–	–	–	–	12,981	–	–	–		
			C	–	39.6	52.7	7.7	–	–	–	–	–	13,079	–	–	–		
72	Knight-Ideal mine		A	4.71	36.1	48.2	11.0	–	–	–	–	–	11,969	–	–	–		86
	Gilson bed		B	1.99	37.2	49.6	11.3	–	–	–	–	–	12,311	–	–	–		
			C	–	37.9	50.6	11.5	–	–	–	–	–	12,561	–	–	–		
73	Knight-Ideal mine		A	5.7	38.4	48.3	7.6	.7	–	–	–	–	12,480	–	–	–	D	9
	Gilson bed		C	–	40.7	51.2	8.1	–	–	–	–	–	13,230	–	–	–		
74	Knight-Ideal mine		A	4.1	40.1	49.4	6.4	.5	–	–	–	–	12,930	–	–	–	T	9
	Gilson bed		C	–	41.8	51.5	6.7	–	–	–	–	–	13,480	–	–	–		
75	Knight-Ideal mine		A	4.3	39.2	49.5	7.0	.6	–	–	–	–	12,760	–	–	–	T	9
	Gilson bed		C	–	41.0	51.7	7.3	–	–	–	–	–	13,330	–	–	–		
76	Knight-Ideal mine		A	3.6	40.1	50.2	6.1	.5	–	–	–	–	12,860	–	–	–	D	9
	Gilson bed		C	–	41.6	52.1	6.3	–	–	–	–	–	13,340	–	–	–		
77	Knight-Ideal mine		A	4.5	38.9	48.7	7.9	.6	–	–	–	–	12,620	–	–	–	T	9
	Gilson bed		C	–	40.7	51.0	8.3	–	–	–	–	–	13,210	–	–	–		
78	Knight-Ideal mine		A	3.8	38.7	49.3	8.3	.5	–	–	–	–	12,580	–	–	–	D	9
	Gilson bed		C	–	40.2	51.2	8.6	–	–	–	–	–	13,080	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
				AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
79	Knight-Ideal mine		A	3.4	39.6	49.3	7.7	.5	–	–	–	–	12,580	–	–	–	D	9
	Gilson bed		C	–	41.0	51.0	8.0	–	–	–	–	–	13,020	–	–	–		
80	Knight-Ideal mine		A	4.3	38.3	49.0	8.4	.6	–	–	–	–	12,520	–	–	42	T	9
	Gilson bed		C	–	40.0	51.2	8.8	–	–	–	–	–	13,080	–	–	–		
81	Knight-Ideal mine		A	4.9	38.1	48.6	8.4	.5	–	–	–	–	12,430	–	–	–	D	9
	Gilson bed		C	–	40.1	51.1	8.8	–	–	–	–	–	13,070	–	–	–		
82	Knight-Ideal mine		A	6.7	37.8	48.8	6.7	.5	–	–	–	–	12,440	–	–	–	D	9
	Gilson bed		C	–	40.5	52.3	7.2	–	–	–	–	–	13,330	–	–	–		
83	Knight-Ideal mine		A	6.6	38.0	47.4	8.0	.6	–	–	–	–	12,250	–	–	–	T	9
	Gilson bed		C	–	40.7	50.7	8.6	–	–	–	–	–	13,120	–	–	–		
84	Knight-Ideal mine		A	4.8	37.8	48.7	8.7	–	–	–	–	–	12,372	–	2.8	–		86
	Gilson bed		B	1.3	39.2	50.5	9.1	–	–	–	–	–	12,821	–	–	–		
			C	–	39.7	51.1	9.2	–	–	–	–	–	–	–	–	–		
85	Knight-Ideal mine		A	7.97	37.6	48.4	6.1	–	–	–	–	–	12,255	–	–	–		86
	Gilson bed		B	1.4	40.3	51.8	6.5	–	–	–	–	–	13,131	–	–	–		
			C	–	40.8	52.6	6.6	–	–	–	–	–	13,316	–	–	–		
86	Knight-Ideal mine		A	2.2	–	–	–	–	–	–	–	–	12,725	–	–	–		86
	Gilson bed		B	–	–	–	–	–	–	–	–	–	13,009	–	–	–		
87	Knight-Ideal mine		A	–	–	–	–	–	–	–	–	–	12,493	–	–	–		86
	Gilson bed		B	–	–	–	–	–	–	–	–	–	12,758	–	–	–		
88	Knight-Ideal mine		A	8.4	36.0	52.0	3.6	–	–	–	–	–	12,115	–	4.6	–		86
	Gilson bed		B	3.0	38.1	55.1	3.8	–	–	–	–	–	12,822	–	–	–		
			C	–	39.3	56.8	3.9	–	–	–	–	–	–	–	–	–		
89	Knight-Ideal mine		A	7.4	33.6	49.7	9.3	–	–	–	–	–	11,831	–	4.9	–		86
	Gilson bed		B	2.1	35.5	52.5	9.8	–	–	–	–	–	12,499	–	–	–		
			C	–	36.3	53.7	10.0	–	–	–	–	–	12,774	–	–	–		
90	Knight-Ideal mine		A	4.9	31.4	52.3	11.2	–	–	–	–	–	11,727	–	2.5	–		86
	Gilson bed		B	1.5	32.5	54.5	11.6	–	–	–	–	–	12,151	–	–	–		
			C	–	32.98	55.3	11.7	–	–	–	–	–	12,331	–	–	–		
91	Knight-Ideal mine		A	3.1	40.0	51.1	5.8	.5	–	–	–	–	13,000	–	–	–		10
	Gilson bed		C	–	41.3	52.7	6.0	–	–	–	–	–	13,410	–	–	–		
92	Knight-Ideal mine		A	4.2	39.1	50.1	6.6	.4	–	–	–	–	12,720	–	–	–		10
	Gilson bed		C	–	40.8	52.3	6.9	–	–	–	–	–	13,280	–	–	–		
93	Knight-Ideal mine		A	4.2	38.2	50.9	6.7	.4	–	–	–	–	12,760	–	–	–		10
	Gilson bed		C	–	39.9	53.1	7.0	–	–	–	–	–	13,320	–	–	–		
94	Knight-Ideal mine		A	4.0	38.4	49.7	7.9	.4	–	–	–	–	12,590	–	–	–		10
	Gilson bed		C	–	40.0	51.8	8.2	–	–	–	–	–	13,110	–	–	–		
95	Knight-Ideal mine		A	3.7	38.4	48.2	9.6	.5	–	–	–	–	12,400	–	–	–		10
	Gilson bed		C	–	39.9	50.1	10.0	–	–	–	–	–	12,880	–	–	–		
96	Knight-Ideal mine		A	3.7	39.1	47.2	10.0	.4	–	–	–	–	12,350	–	–	–		10
	Gilson bed		C	–	40.6	49.0	10.4	–	–	–	–	–	12,800	–	–	–		
97	Knight-Ideal mine		A	5.4	37.3	48.9	8.4	.5	–	–	–	–	12,330	–	–	–		10
	Gilson bed		C	–	39.4	51.7	8.9	–	–	–	–	–	13,030	–	–	–		
98	Knight-Ideal mine		A	3.7	39.7	51.2	5.4	.6	–	–	–	–	13,000	–	–	–	T	11
	Gilson bed		C	–	41.2	53.2	5.6	–	–	–	–	–	13,510	–	–	–		
99	Knight-Ideal mine		A	4.3	38.7	50.1	7.0	.5	–	–	–	–	12,640	–	–	–	D	11
	Gilson bed		C	–	40.4	52.3	7.3	–	–	–	–	–	13,210	–	–	–		
100	Knight-Ideal mine		A	4.0	38.6	49.3	8.1	.5	–	–	–	–	12,520	–	–	–	D	11
	Gilson bed		C	–	40.2	51.4	8.4	–	–	–	–	–	13,040	–	–	–		
101	Knight-Ideal mine		A	4.3	39.0	50.7	6.0	.7	–	–	–	–	12,830	–	–	–	T	11
	Gilson bed		C	–	40.7	53.0	6.3	–	–	–	–	–	13,400	–	–	–		
102	Knight-Ideal mine		A	3.7	39.1	50.8	6.5	.5	–	–	–	–	12,810	–	–	–	D	11
	Gilson bed		C	–	40.6	52.7	6.7	–	–	–	–	–	13,300	–	–	–		
103	Knight-Ideal mine		A	3.3	39.6	48.1	9.1	.6	–	–	–	–	12,550	–	–	–	D	11
	Gilson bed		C	–	40.9	49.7	9.4	–	–	–	–	–	12,970	–	–	–		
104	Knight-Ideal mine		A	4.6	38.4	48.1	8.9	.6	–	–	–	–	12,300	–	–	44	T	11
	Gilson bed		C	–	40.3	50.4	9.3	–	–	–	–	–	12,890	–	–	–		
105	Knight-Ideal mine		A	4.1	38.7	48.6	8.5	.5	–	–	–	–	12,510	–	–	–	D	11
	Gilson bed		C	–	40.4	50.7	8.9	–	–	–	–	–	13,040	–	–	–		
106	Knight-Ideal mine		A	4.9	37.9	46.0	11.2	.6	–	–	–	–	12,030	–	–	–	D	11
	Gilson bed		C	–	39.8	48.4	11.8	–	–	–	–	–	12,650	–	–	–		
107	Knight-Ideal mine		A	6.1	38.6	48.1	7.2	.6	–	–	–	–	12,340	–	–	–	T	11
	Gilson bed		C	–	41.1	51.2	7.7	–	–	–	–	–	13,130	–	–	–		
108	Knight-Ideal mine		A	3.7	38.8	47.8	9.7	.5	–	–	–	–	12,400	–	–	–	D	12
	Gilson bed		C	–	40.3	49.6	10.1	–	–	–	–	–	12,880	–	–	–		
109	Knight-Ideal mine		A	4.6	38.1	47.4	9.9	.5	–	–	–	–	12,190	–	–	–	D	12
	Gilson bed		C	–	39.9	49.7	10.4	–	–	–	–	–	12,780	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
110	Knight-Ideal mine Gilson bed		A C	5.2 –	37.9 40.0	50.1 52.9	6.7 7.1	.4 –	5.1 –	76.3 –	1.5 –	9.6 –	12,770 13,460	– –	– –	– –	T	12
111	Outcrop Kenilworth bed	1–13S–10E	A C	4.0 –	45.7 47.6	44.7 46.5	5.6 5.9	.5 .6	– –	– –	– –	– –	12,920 13,460	2,130 –	.7 –	– –		38
112	Rio Grande mine Gilson seam	W.NW.SW.SE.7–13S–11E 4394950mN 523400mE	A C D	5.68 – –	41.87 44.39 46.76	47.68 50.55 53.24	4.77 5.06 –	.58 .61 .64	– – –	– – –	– – –	– – –	12,638 13,399 14,114	– – –	.3 – –	– – –		37
113	Rio Grande mine Gilson seam		A B C D	5.7 5.4 – –	41.8 42.0 44.4 46.8	47.7 47.8 50.5 53.2	4.8 4.8 5.1 –	.58 .58 .61 .64	– – – –	– – – –	– – – –	– – – –	12,640 12,680 13,400 14,110	– – – –	– – – –	– – – –		36
114	Rio Grande mine Gilson seam		A B C	5.7 5.4 –	41.9 42.0 44.4	47.6 47.8 50.5	4.8 4.8 5.1	.6 .58 .6	– – –	– – –	– – –	– – –	12,640 12,680 13,400	2,220 – –	.3 – –	– – –		37
115	Rio Grande mine Gilson seam		A C D	3.4 – –	40.4 41.8 43.7	52.0 53.9 56.3	4.2 4.3 –	.4 .4 .4	– – –	– – –	– – –	– – –	12,980 13,440 14,050	– – –	.6 – –	– – –		70
116	Rio Grande mine Gilson seam		A C	6.0 –	37.8 40.2	46.6 49.6	9.6 10.2	.6 –	4.9 –	71.1 –	1.4 –	11.8 –	11,900 12,660	– –	– –	45 –		9
117	Rio Grande mine Gilson seam		A B	5.2 –	– –	– –	– –	– –	– –	– –	– –	– –	12,052 12,716	– –	– –	– –		86
118	Blue Flame mine Castlegate A bed	NE.SE.NE.18–13S–11E 4394370mN 523940mE	A	5.7	–	–	7.0	.56	–	–	–	–	–	–	–	–		88
119	Blue Flame mine Castlegate A bed Upper split		A B C	5.6 3.0 –	39.3 40.4 41.6	50.1 51.4 53.0	5.1 5.2 5.4	– – –	– – –	– – –	– – –	– – –	12,822 13,168 13,575	– – –	– – –	– – –		86
120	Blue Flame mine Castlegate A bed		A	5.2	–	–	4.1	.38	–	–	–	–	–	–	–	–			88
121	Blue Flame mine Castlegate A bed		A C	5.3 –	40.1 42.3	50.0 52.8	4.6 4.9	.3 –	– –	– –	– –	– –	12,750 13,470	– –	– –	– –	T	7
122	Blue Flame mine Castlegate A bed		A C	5.2 –	40.6 42.8	50.1 52.9	4.1 4.3	.4 –	5.3 –	76.6 –	1.5 –	11.9 –	12,910 13,620	– –	– –	– –	T	7
123	Blue Flame mine Castlegate A bed		A C	5.6 –	41.7 44.2	48.1 51.0	4.5 4.8	.3 –	– –	– –	– –	– –	12,880 13,640	– –	– –	– –	T	8
124	Blue Flame mine Castlegate A bed		A C	5.3 –	41.6 43.9	47.8 50.5	5.3 5.6	.4 –	– –	– –	– –	– –	12,740 13,460	– –	– –	– –	T	8
125	Blue Flame mine Castlegate A bed		A C	5.7 –	42.0 44.5	47.9 50.8	4.4 4.7	.4 –	– –	– –	– –	– –	12,880 13,650	– –	– –	43 –	T	8
126	Blue Flame mine Castlegate A bed		A C	5.6 –	41.5 44.0	48.8 51.7	4.1 4.3	.4 –	– –	– –	– –	– –	12,820 13,580	– –	– –	– –	T	8
127	Blue Flame mine Castlegate A bed Upper split		A C	6.1 –	39.7 42.3	49.7 52.9	4.5 4.8	.4 –	– –	– –	– –	– –	12,690 13,510	– –	– –	– –	T	9
128	Blue Flame mine Castlegate A bed Upper split		A C	5.4 –	39.9 42.2	50.0 52.9	4.6 4.9	.6 –	– –	– –	– –	– –	12,860 13,590	– –	– –	– –	T	9
129	Blue Flame mine Castlegate A bed Upper split		A C	6.0 –	39.9 42.4	50.1 53.3	4.0 4.3	.5 –	– –	– –	– –	– –	12,800 13,620	– –	– –	– –	T	9
130	Blue Flame mine Castlegate A bed		A C	6.1 –	39.8 42.4	50.6 53.9	3.5 3.7	.6 –	– –	– –	– –	– –	12,880 13,720	– –	– –	– –	T	9
131	Blue Flame mine Castlegate A bed Upper split		A C	5.6 –	40.3 42.7	49.0 51.9	5.1 5.4	.6 –	– –	– –	– –	– –	12,770 13,530	– –	– –	45 –	T	11
132	Blue Flame mine Castlegate A bed Upper split		A C	6.3 –	41.2 44.0	47.5 50.7	5.0 5.3	.8 –	– –	– –	– –	– –	12,690 13,540	– –	– –	– –	T	11
133	Blue Flame mine Castlegate A bed Upper split		A C	4.5 –	40.7 42.6	48.2 50.5	6.6 6.9	.8 –	– –	– –	– –	– –	12,750 13,350	– –	– –	– –	T	11
134	Blue Flame mine Castlegate A bed Upper split		A C	7.6 –	39.1 42.3	49.9 54.0	3.4 3.7	.7 –	– –	– –	– –	– –	12,670 13,710	– –	– –	– –	T	11
135	Blue Flame mine Castlegate A bed		A C	6.4 –	39.6 42.3	49.5 52.9	4.5 4.8	.6 –	– –	– –	– –	– –	12,680 13,540	– –	– –	– –	T	13
136	Blue Flame mine Castlegate A bed		A C	7.4 –	38.9 42.0	49.5 53.5	4.2 4.5	.7 –	– –	– –	– –	– –	12,500 13,500	– –	– –	– –	T	13
137	Zion Security mine Gilson bed	SE.SW.7–13S–11E 4395000mN 523100mE	A	6.0	–	–	5.0	.46	–	–	–	–	–	–	–	–		88

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES				ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
				AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI	
WELLINGTON NE QUADRANGLE																		
1	Dugout Canyon mine Gilson bed	SE.SE.NW.23–13S–12E 4392320mN 539080mE	A B C D	8.5 3.4 – –	39.8 42.0 43.5 45.4	47.9 50.5 52.3 54.6	3.8 4.1 4.2 –	.48 .51 .52 .54	– – – –	– – – –	– – – –	– – – –	12,810 13,520 14,000 14,620	– – – –	– – – –	– – – –		36
2	Dugout Canyon mine Gilson bed		A C D	4.98 – –	38.20 40.20 41.91	52.94 55.72 58.09	3.88 4.08 –	.54 .57 .59	– – –	– – –	– – –	– – –	– – –	– – –	2.4 – –	– – –		62
3	Dugout Canyon mine Sunnyside bed		A	4.8	–	–	4.6	.45	–	–	–	–	–	–	–	–		88
4	Dugout Canyon mine Sunnyside bed		A	4.5	–	–	4.4	.41	–	–	–	–	–	–	–	–		88
5	Dugout Canyon mine Gilson bed		A C	4.5 –	38.6 40.4	49.5 51.8	7.4 7.8	.8 –	5.2 –	74.4 –	1.4 –	10.4 –	12,760 13,360	– –	– –	41 –	T	9
6	Dugout Canyon mine Gilson bed		A C	5.7 –	38.4 40.7	48.3 51.2	7.6 8.1	.7 –	– –	– –	– –	– –	12,480 13,230	– –	– –	– –	D	9
7	Dugout Canyon mine Gilson bed		A B C	4.1 1.3 –	38.5 39.6 40.1	49.6 51.0 51.7	7.9 8.1 8.2	.74 .77 .78	– – –	– – –	– – –	– – –	12,623 12,990 13,161	– – –	– – –	– – –		86
8	Dugout Canyon mine Gilson bed		A B C	3.8 1.7 –	38.2 39.1 39.7	49.7 50.8 51.7	8.2 8.4 8.6	.82 .84 .86	– – –	– – –	– – –	– – –	12,580 12,856 13,078	– – –	– – –	– – –		86
9	Dugout Canyon mine Gilson bed		A B C	4.2 1.5 –	38.5 39.5 40.1	49.98 51.4 52.2	7.4 7.6 7.7	.69 .71 .72	– – –	– – –	– – –	– – –	12,660 13,014 13,218	– – –	– – –	– – –		86
10	Knight-Ideal mine Gilson bed	SE.SE.NW.23–13S–12E 4392320mN 539080mE	A C	3.9 –	38.6 40.2	51.0 53.1	6.4 6.7	.5 –	– –	– –	– –	– –	12,990 13,520	– –	– –	– –		13
11	Knight-Ideal mine Gilson bed		A C	5.8 –	38.2 40.5	50.1 53.2	5.9 6.3	.5 –	– –	– –	– –	– –	12,700 13,480	– –	– –	– –		13
12	Knight-Ideal mine Gilson bed		A C	5.3 –	38.3 40.4	50.0 52.8	6.4 6.8	.5 –	– –	– –	– –	– –	12 680 13,390	– –	– –	– –		13
13	Knight-Ideal mine Gilson bed		A C	4.1 –	39.6 41.3	51.8 54.0	4.5 4.7	.4 –	– –	– –	– –	– –	13,230 13,790	– –	– –	– –	T	15
14	Knight-Ideal mine Gilson bed		A C	3.9 –	39.5 41.1	52.0 54.1	4.6 4.8	.4 –	– –	– –	– –	– –	13,230 13,770	– –	– –	– –	D	15
15	Knight-Ideal mine Gilson bed		A C	5.1 –	39.3 41.4	51.8 54.6	3.8 4.0	.5 –	– –	– –	– –	– –	13,220 13,930	– –	– –	– –	T	15
16	Knight-Ideal mine Gilson bed		A C	4.8 –	38.6 40.5	50.6 53.2	6.0 6.3	.4 –	– –	– –	– –	– –	12,940 13,590	– –	– –	– –	T	15
17	Knight-Ideal mine Gilson bed		A C	4.2 –	38.8 40.5	51.8 54.1	5.2 5.4	.4 –	– –	– –	– –	– –	13,170 13,760	– –	– –	– –	D	15
18	Knight-Ideal mine Gilson bed		A C	3.8 –	39.3 40.9	50.1 52.1	6.7 7.0	.4 –	– –	– –	– –	– –	13,000 13,530	– –	– –	– –	D	15
19	Knight-Ideal mine Gilson bed		A C	5.0 –	38.3 40.3	49.5 52.1	7.2 7.6	.4 –	– –	– –	– –	– –	12,700 13,370	– –	– –	– –	T	15
20	Knight-Ideal mine Gilson bed		A C	4.9 –	38.7 40.7	50.3 52.9	6.1 6.4	.4 –	– –	– –	– –	– –	12,900 13,580	– –	– –	– –	D	15
21	Knight-Ideal mine Gilson bed		A C	6.4 –	38.5 41.1	47.9 51.2	7.2 7.7	.5 –	– –	– –	– –	– –	12,490 13,350	– –	– –	– –	T	15
22	Knight-Ideal mine Gilson bed		A C	5.3 –	38.5 40.7	50.7 53.5	5.5 5.8	.5 –	– –	– –	– –	– –	12,860 13,580	– –	– –	– –		18
23	Knight-Ideal prep. plant Gilson bed		A C	4.7 –	38.9 40.8	52.7 55.3	3.7 3.9	.5 –	– –	– –	– –	– –	13,320 13,980	– –	– –	– –	T	14
24	Knight-Ideal prep. plant Gilson bed		A C	3.1 –	39.6 40.9	51.9 53.6	5.3 5.5	.6 –	– –	– –	– –	– –	13,200 13,610	– –	– –	– –	D	14
25	Knight-Ideal prep. plant Gilson bed		A C	3.8 –	39.1 40.6	50.8 52.8	6.3 6.6	.4 –	– –	– –	– –	– –	12,960 13,470	– –	– –	– –	D	14
26	Knight-Ideal prep. plant Gilson bed		A C	3.2 –	38.8 40.1	52.4 54.1	5.6 5.8	.5 –	– –	– –	– –	– –	13,110 13,540	– –	– –	– –	D	14
27	Knight-Ideal prep. plant Gilson bed		A C	5.2 –	39.0 41.1	51.3 54.1	4.6 4.8	.5 –	– –	– –	– –	– –	13,120 13,830	– –	– –	– –	T	14
28	Knight-Ideal prep. plant Gilson bed		A C	4.5 –	39.3 41.1	50.9 53.3	5.3 5.6	.6 –	– –	– –	– –	– –	13,030 13,640	– –	– –	– –	T	14
29	Knight-Ideal prep. plant Gilson bed		A C	3.4 –	39.6 41.0	50.8 52.6	6.2 6.4	.6 –	– –	– –	– –	– –	12,980 13,440	– –	– –	– –	D	14
30	Knight-Ideal prep. plant Gilson bed		A C	4.9 –	38.4 40.4	51.8 54.5	4.9 5.2	.5 –	– –	– –	– –	– –	13,080 13,760	– –	– –	– –	T	14

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
31	Knight-Ideal prep. plant Gilson bed		A C	4.2 –	38.7 40.4	50.8 53.0	6.3 6.6	.5 –	– –	– –	– –	– –	12,860 13,420	– –	– –	– –	D	14
32	Knight-Ideal prep. plant Gilson bed		A C	6.8 –	38.1 40.9	49.6 53.2	5.5 5.9	.6 –	– –	– –	– –	– –	12,660 13,580	– –	– –	– –	T	14
33	Knight-Ideal no. 2 mine Gilson bed		A C	4.5 –	39.4 41.3	52.0 54.4	4.1 4.3	.4 –	– –	– –	– –	– –	13,290 13,910	– –	– –	– –	T	16
34	Knight-Ideal no. 2 mine Gilson bed		A C	5.1 –	38.4 40.5	51.5 54.3	4.9 5.2	.4 –	– –	– –	– –	– –	13,010 13,710	– –	– –	– –	T	16
35	Knight-Ideal no. 2 mine Gilson bed		A C	4.9 –	38.9 40.9	51.1 53.7	5.1 5.4	.4 –	– –	– –	– –	– –	13,070 13,740	– –	– –	– –	T	16
36	Knight-Ideal no. 2 mine Gilson bed		A C	5.0 –	38.8 40.8	51.1 53.8	5.1 5.4	.4 –	– –	– –	– –	– –	13,040 13,720	– –	– –	– –	T	16
37	Knight-Ideal no. 2 mine Gilson bed		A C	5.5 –	38.8 41.1	50.0 52.9	5.7 6.0	.4 –	– –	– –	– –	– –	12,880 13,640	– –	– –	– –	D	16
38	Knight-Ideal no. 2 mine Gilson bed		A C	6.7 –	38.4 41.2	49.9 53.5	4.9 5.3	.4 –	– –	– –	– –	– –	12,810 13,730	– –	– –	– –	T	16
39	Knight-Ideal no. 2 mine Gilson bed		A C	5.5 –	37.5 39.7	51.4 54.4	5.6 5.9	.8 –	– –	– –	– –	– –	12,860 13,610	– –	– –	– –	D	17
40	Knight-Ideal no. 2 mine Gilson bed		A C	5.9 –	37.8 40.2	49.9 53.0	6.4 6.8	.7 –	– –	– –	– –	– –	12,660 13,470	– –	– –	– –	D	17
41	Knight-Ideal no. 2 mine Gilson bed		A C	3.8 –	39.2 40.7	51.3 53.3	5.8 6.0	.6 –	– –	– –	– –	– –	13,130 13,670	– –	– –	– –	D	19
42	Knight-Ideal no. 2 mine Gilson bed		A C	5.9 –	38.2 40.6	50.2 53.4	5.6 6.0	.5 –	– –	– –	– –	– –	12,800 13,610	– –	– –	– –	D	19
43	Knight-Ideal no. 2 mine Gilson bed		A C	3.5 –	40.0 41.4	52.3 54.2	4.2 4.4	.4 –	– –	– –	– –	– –	13,390 13,880	– –	– –	– –	D	20
44	Knight-Ideal no. 2 mine Gilson bed		A C	4.4 –	39.0 40.8	51.9 54.3	4.7 4.9	.4 –	– –	– –	– –	– –	13,250 13,860	– –	– –	– –	D	20
45	Knight-Ideal no. 2 mine Gilson bed		A C	5.5 –	38.5 40.7	50.9 53.9	5.1 5.4	.5 –	– –	– –	– –	– –	12,980 13,740	– –	– –	– –	D	20
46	Knight-Ideal no. 2 mine Gilson bed		A C	3.7 –	39.8 41.3	51.2 53.2	5.3 5.5	.6 –	– –	– –	– –	– –	13,270 13,790	– –	– –	– –	D	20
47	Knight-Ideal no. 2 mine Gilson bed		A C	5.4 –	38.9 41.1	50.7 53.6	5.0 5.3	.5 –	– –	– –	– –	– –	13,070 13,830	– –	– –	– –	D	20
48	Knight-Ideal no. 2 mine Gilson bed		A C	4.9 –	39.3 41.3	50.6 53.2	5.2 5.5	.5 –	– –	– –	– –	– –	13,020 13,710	– –	– –	– –	D	20
49	Knight-Ideal no. 2 mine Gilson bed		A C	6.2 –	38.2 40.7	50.4 53.7	5.3 5.6	.5 –	– –	– –	– –	– –	12,830 13,680	– –	– –	– –	D	20
50	Knight-Ideal no. 2 mine Gilson bed		A C	3.4 –	39.3 40.7	52.3 54.1	5.0 5.2	.5 –	– –	– –	– –	– –	13,390 13,860	– –	– –	– –	D	21
51	Knight-Ideal no. 2 mine Gilson bed		A C	3.5 –	**39.5** **40.9**	**52.1** **54.0**	**4.9** **5.1**	.4 –	– –	– –	– –	– –	13,350 13,840	– –	– –	– –	D	21
52	Knight-Ideal no. 2 mine Gilson bed		A C	5.1 –	38.6 40.7	51.3 54.1	4.9 5.2	.4 –	– –	– –	– –	– –	13,100 13,800	– –	– –	– –	D	21
53	Knight-Ideal no. 2 mine Gilson bed		A C	4.0 –	39.2 40.8	52.2 54.4	4.6 4.8	.4 –	– –	– –	– –	– –	13,280 13,830	– –	– –	– –	D	21
54	Knight-Ideal no. 2 mine Gilson bed		A C	5.7 –	38.2 40.5	51.0 54.1	5.1 5.4	.4 –	– –	– –	– –	– –	12,900 13,690	– –	– –	– –	D	21
55	Knight-Ideal no. 2 mine Gilson bed		A C D	5.1 – –	38.6 40.7 –	51.3 54.1 –	4.9 5.2 –	.4 – –	– – –	– – –	– – –	– – –	13,100 13,800 14,560	2,200 – –	– – –	– – –	WD	87
56	Knight-Ideal no. 2 mine Gilson bed		A C D	3.4 – –	39.3 40.7 –	52.3 54.1 –	5.0 5.2 –	.5 – –	– – –	– – –	– – –	– – –	13,390 13,860 14,620	– – –	– – –	– – –	WD	87
57	Knight-Ideal no. 2 mine Gilson bed		A C D	3.5 – –	39.5 40.9 –	52.1 54.0 –	4.9 5.1 –	.4 – –	– – –	– – –	– – –	– – –	13,360 13,840 14,580	2,220 – –	– – –	– – –	WD	87
58	Knight-Ideal no. 2 mine Gilson bed		A C D	5.7 – –	**38.2** **40.5** –	**51.0** **54.1** –	**5.1** **5.4** –	.4 – –	– – –	– – –	– – –	– – –	12,910 13,690 14,470	– – –	– – –	– – –	D	87
59	Soldier Canyon mine Rock Canyon bed	NW.NE.18–13S–12E 4394480mN 533220mE	A C D	3.3 – –	**39.3** **40.6** –	**51.6** **53.4** –	**5.8** **6.0** –	.5 – –	– – –	– – –	– – –	– – –	13,350 13,810 14,690	– – –	– – –	– – –	D	87
60	Soldier Canyon mine Rock Canyon bed		A C D	3.6 – –	**38.9** **40.4** –	**49.2** **51.0** –	**8.3** **8.6** –	.6 – –	– – –	– – –	– – –	– – –	12,640 13,110 14,340	– – –	– – –	– – –	D	87

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
61	Soldier Canyon mine Rock Canyon bed		A C D	4.2 – –	38.5 40.2 –	49.6 51.8 –	7.7 8.0 –	.5 – –	– – –	– – –	– – –	– – –	12,620 13,170 14,320	– – –	– – –	– – –	D	87
62	Soldier Canyon mine Rock Canyon bed		A C D	5.3 – –	38.0 40.1 –	49.9 52.7 –	6.8 7.2 –	.5 – –	– – –	– – –	– – –	– – –	12,590 13,290 14,320	2,340 – –	– – –	– – –	T	87
63	Soldier Canyon mine Rock Canyon bed		A C D	5.2 – –	38.2 40.3 –	51.3 54.1 –	5.3 5.6 –	.5 – –	– – –	– – –	– – –	– – –	12,830 13,530 14,330	2,180 – –	– – –	– – –	T	87
64	Soldier Canyon mine Rock Canyon bed		A C D	5.0 – –	38.2 40.2 –	48.6 51.2 –	8.2 8.6 –	.4 – –	– – –	– – –	– – –	– – –	12,390 13,040 14,270	2,520 – –	– – –	– – –	T	87
65	Soldier Canyon mine Rock Canyon bed		A C D	5.2 – –	37.5 39.6 –	48.5 51.2 –	8.7 9.2 –	.4 – –	– – –	– – –	– – –	– – –	12,290 12,960 14,270	2,540 – –	– – –	– – –	T	87
66	Soldier Canyon mine Rock Canyon bed		A	5.0	–	–	7.8	.58	–	–	–	–	–	–	–	–		88
67	Soldier Canyon mine Rock Canyon bed		A C D	5.0 – –	39.0 41.1 –	48.2 50.7 –	7.8 8.2 –	.6 – –	– – –	– – –	– – –	– – –	12,320 12,970 14,130	2,430 – –	– – –	– – –	T	87
68	Soldier Canyon mine Rock Canyon bed		A C D	4.3 – –	38.0 39.7 –	47.2 49.3 –	10.5 11.0 –	.7 – –	– – –	– – –	– – –	– – –	11,960 12,500 14,040	2,590 – –	– – –	– – –	T	87
69	Soldier Canyon mine Rock Canyon bed		A C D	4.4 – –	38.0 39.8 –	46.1 48.2 –	11.5 12.0 –	.7 – –	– – –	– – –	– – –	– – –	11,840 12,390 14,080	2,520 – –	– – –	– – –	T	87
70	Soldier Canyon mine Rock Canyon bed		A C	6.3 –	38.1 –	45.2 –	10.4 –	– –	– –	– –	– –	– –	11,390 12,150	– –	– –	– –		86
71	Soldier Canyon mine Rock Canyon bed		A C D	3.1 – –	39.3 40.6 –	50.9 52.5 –	6.7 6.9 –	.3 – –	– – –	– – –	– – –	– – –	12,770 13,180 14,160	– – –	– – –	– – –	D	87
72	Soldier Canyon mine Rock Canyon bed		A C D	5.4 – –	37.7 39.9 –	48.2 50.9 –	8.7 9.2 –	.4 – –	– – –	– – –	– – –	– – –	12,270 12,970 14,280	2,570 – –	– – –	– – –	T	87
73	Soldier Canyon mine Rock Canyon bed		A C D	6.5 – –	37.8 40.4 –	48.0 51.3 –	7.8 8.3 –	.5 – –	– – –	– – –	– – –	– – –	12,220 13,070 14,250	2,570 – –	– – –	44 – –	T	87
74	Soldier Canyon mine Rock Canyon bed		A C D	4.9 – –	37.6 39.5 –	47.9 50.4 –	9.6 10.1 –	.5 – –	– – –	– – –	– – –	– – –	12,160 12,790 14,230	2,520 – –	– – –	– – –	D	87
75	Soldier Canyon mine Rock Canyon bed		A C D	4.7 – –	38.7 40.6 –	48.3 50.7 –	8.3 8.7 –	.6 – –	– – –	– – –	– – –	– – –	12,390 13,000 14,240	– – –	– – –	– – –	D	87
76	Soldier Canyon mine Rock Canyon bed		A C D	5.6 – –	38.5 40.8 –	48.2 51.1 –	7.6 8.1 –	.4 – –	– – –	– – –	– – –	– – –	12,350 13,080 14,230	2,440 – –	– – –	– – –	T	87
77	Soldier Canyon mine Rock Canyon bed		A C D	5.4 – –	39.8 42.1 –	49.8 52.6 –	5.0 5.3 –	.4 – –	– – –	– – –	– – –	– – –	12,890 13,630 14,390	2,360 – –	– – –	– – –	T	87
78	Soldier Canyon mine Rock Canyon bed		A C D	4.9 – –	38.4 40.4 –	48.4 50.9 –	8.3 8.7 –	.6 – –	– – –	– – –	– – –	– – –	12,440 13,080 14,330	2,520 – –	– – –	– – –	T	87
79	Soldier Canyon mine Rock Canyon bed		A C D	6.2 – –	37.7 40.2 –	47.9 51.1 –	8.2 8.7 –	.6 – –	– – –	– – –	– – –	– – –	12,260 13,070 14,320	2,530 – –	– – –	– – –	T	87
80	Soldier Canyon mine Rock Canyon bed		A C D	5.2 – –	38.2 40.3 –	48.9 51.6 –	7.7 8.1 –	.6 – –	– – –	– – –	– – –	– – –	12,510 13,200 14,360	2,500 – –	– – –	– – –	T	87
81	Soldier Canyon mine Rock Canyon bed		A C D	5.3 – –	39.1 41.3 –	51.0 53.9 –	4.5 4.8 –	.5 – –	– – –	– – –	– – –	– – –	12,980 13,710 14,400	2,370 – –	– – –	– – –	T	87
82	Soldier Canyon mine Rock Canyon bed		A C D	4.7 – –	37.8 39.7 –	48.1 50.5 –	9.3 9.8 –	.5 – –	– – –	– – –	– – –	– – –	12,360 12,970 14,380	2,570 – –	– – –	– – –	T	87
83	Soldier Canyon mine Rock Canyon bed		A C D	5.1 – –	37.4 39.4 –	47.9 50.5 –	9.6 10.1 –	.5 – –	– – –	– – –	– – –	– – –	12,220 12,880 14,330	2,630 – –	– – –	– – –	T	87
84	Soldier Canyon mine Rock Canyon bed		A C D	4.7 – –	38.1 40.0 –	49.4 51.8 –	7.8 8.2 –	.5 – –	– – –	– – –	– – –	– – –	12,580 13,200 14,380	2,540 – –	– – –	– – –	D	87
85	Soldier Canyon mine Rock Canyon bed		A C D	4.2 – –	39.1 40.8 –	49.1 51.2 –	7.7 8.0 –	.5 – –	– – –	– – –	– – –	– – –	12,620 13,170 14,320	2,410 – –	– – –	– – –	D	87

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
86	Soldier Canyon mine Rock Canyon bed		A C D	5.4 – –	38.1 40.3 –	48.6 51.4 –	7.9 8.3 –	.6 – –	– – –	– – –	– – –	– – –	12,440 13,150 14,340	2,500 – –	– – –	– – –	T	87
87	Soldier Canyon mine Rock Canyon bed		A C D	3.9 – –	38.1 39.6 –	49.2 51.2 –	8.8 9.2 –	.4 – –	– – –	– – –	– – –	– – –	12,480 12,990 14,310	2,540 – –	– – –	– – –	D	87
88	Soldier Canyon mine Rock Canyon bed		A C D	4.8 – –	38.7 40.6 –	49.0 51.5 –	7.5 7.9 –	.3 – –	– – –	– – –	– – –	– – –	12,410 13,040 14,160	2,420 – –	– – –	– – –	D	87
89	Soldier Canyon mine Rock Canyon bed		A C D	5.9 – –	37.9 40.3 –	48.9 52.0 –	7.2 7.7 –	.4 – –	– – –	– – –	– – –	– – –	12,450 13,230 14,330	2,420 – –	– – –	– – –	T	87
90	Soldier Canyon mine Rock Canyon bed		A C D	5.6 – –	38.9 41.2 –	50.1 53.1 –	5.4 5.7 –	.4 – –	– – –	– – –	– – –	– – –	12,760 13,520 14,340	2,300 – –	– – –	– – –	T	87
91	Soldier Canyon mine Rock Canyon bed		A C D	5.6 – –	37.9 40.2 –	48.8 51.7 –	7.6 8.1 –	.4 – –	– – –	– – –	– – –	– – –	12,470 13,210 14,370	2,510 – –	– – –	– – –	T	87
92	Soldier Canyon mine Rock Canyon bed		A C D	6.0 – –	37.8 40.2 –	48.5 51.6 –	7.7 8.2 –	.5 – –	– – –	– – –	– – –	– – –	12,360 13,150 14,320	2,440 – –	– – –	45 – –	T	87
93	Soldier Canyon mine Rock Canyon bed		A C D	5.6 – –	38.4 40.7 –	49.1 52.0 –	6.9 7.3 –	.4 – –	– – –	– – –	– – –	– – –	12,610 13,360 14,410	2,460 – –	– – –	– – –	T	87
94	Soldier Canyon mine Rock Canyon bed		A C D	4.3 – –	39.0 40.7 –	50.2 52.5 –	6.5 6.8 –	.4 – –	– – –	– – –	– – –	– – –	12,740 13,310 14,280	2,330 – –	– – –	– – –	D	87
95	Soldier Canyon mine Rock Canyon bed		A C D	5.2 – –	38.2 40.3 –	48.8 51.5 –	7.8 8.2 –	.5 – –	– – –	– – –	– – –	– – –	12,390 13,070 14,240	2,440 – –	– – –	– – –	T	87
96	Soldier Canyon mine Rock Canyon bed		A C D	4.6 – –	40.1 42.0 –	47.1 49.4 –	8.2 8.6 –	.5 – –	– – –	– – –	– – –	– – –	12,450 13,050 14,280	2,430 – –	– – –	– – –	T	87
97	Soldier Canyon mine Rock Canyon bed		A C D	5.6 – –	38.1 40.4 –	48.7 51.6 –	7.6 8.0 –	.4 – –	5.1 – –	74.6 – –	1.5 – –	10.4 – –	12,360 13,090 14,230	2,440 – –	– – –	43 – –	T	87
	WOODSIDE NE QUADRANGLE																	
1	Book Cliffs mine Lower Sunnyside bed	SW.SW.SW.NW.10–16S–14E 4366540mN 555390mE	A C D	9.79 – –	33.39 37.01 39.83	59.44 55.92 60.17	6.38 7.07 –	.60 .67 .72	– – –	– – –	– – –	– – –	– – –	– – –	3.5 – –	– – –		62
2	Book Cliffs mine Lower Sunnyside bed		A B C D	9.0 5.1 – –	31.8 33.2 34.9 38.4	51.9 53.2 56.1 61.6	8.2 8.5 9.0 –	.5 .47 .5 .6	5.0 4.71 4.4 4.7	62.2 64.88 68.4 75.1	1.3 1.30 1.4 1.5	22.8 20.11 16.3 18.1	10,860 11,330 11,940 13,120	– – – –	4.1 – – –	– – – –		62
3	Book Cliffs mine Lower Sunnyside mine		A	5.3	–	–	9.4	.69	–	–	–	–	–	–	–	–		88
4	Book Cliffs mine Lower Sunnyside bed		A B C	5.6 3.3 –	35.1 36.0 37.3	48.5 49.7 51.4	10.7 11.0 11.3	– – –	– – –	– – –	– – –	– – –	11,448 11,727 12,131	– – –	– – –	– – –		86
5	Book Cliffs mine Lower Sunnyside bed		A B C	6.37 3.3 –	34.8 35.9 37.1	51.6 53.3 55.2	7.3 7.5 7.7	.92 .95 .99	– – –	– – –	– – –	– – –	12,159 12,560 12,986	– – –	– – –	– – –		86
6	Book Cliffs mine Lower Sunnyside bed		A B C	6.7 2.8 –	33.5 34.9 35.9	52.5 54.7 56.3	7.3 7.6 7.8	– – –	– – –	– – –	– – –	– – –	12,509 13,037 13,413	– – –	– – –	– – –		86
7	Book Cliffs mine Lower Sunnyside bed		A C	5.9 –	37.5 39.8	48.6 51.6	8.1 8.6	.9 –	5.1 –	73.9 –	1.5 –	10.0 –	12,400 13,170	– –	– –	– –	T	7
8	Book Cliffs mine Lower Sunnyside bed		A C	4.0 –	38.2 39.8	50.0 52.1	7.8 8.1	.6 –	– –	– –	– –	– –	12,590 13,120	– –	– –	– –	D	7
9	Book Cliffs mine Lower Sunnyside bed		A C	4.6 –	38.1 39.9	49.7 52.1	7.6 8.0	.7 –	– –	– –	– –	– –	12,660 13,270	– –	– –	– –	D	7
10	Book Cliffs mine Lower Sunnyside bed		A C	5.9 –	37.5 39.9	47.8 50.8	8.8 9.3	.9 –	– –	– –	– –	– –	12,300 13,070	– –	– –	– –	T	7
11	Book Cliffs mine Lower Sunnyside bed		A C	6.7 –	37.1 39.8	47.7 51.1	8.5 9.1	.8 –	– –	– –	– –	– –	12,210 13,090	– –	– –	– –	T	7
12	Book Cliffs mine Lower Sunnyside bed		A C	4.2 –	37.8 39.5	50.1 52.3	7.9 8.2	.9 –	– –	– –	– –	– –	12,500 13,050	– –	– –	– –	D	7
13	Book Cliffs mine Lower Sunnyside bed		A	5.9	–	–	8.1	.86	–	–	–	–	–	–	–	–		88

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
14	Book Cliffs mine		A	3.9	38.5	49.3	8.3	.8	–	–	–	–	12,660	–	–	–	D	6
	Lower Sunnyside bed		C	–	40.1	51.3	8.6	–	–	–	–	–	13,170	–	–	–		
15	Book Cliffs mine		A	6.4	38.4	48.2	7.0	.8	–	–	–	–	12,390	–	–	49	T	8
	Lower Sunnyside bed		C	–	41.0	51.5	7.5	–	–	–	–	–	13,240	–	–	–		
16	Book Cliffs mine		A	5.7	39.5	49.8	5.0	.7	–	–	–	–	12,720	–	–	–	D	8
	Lower Sunnyside bed		C	–	41.9	52.8	5.3	–	–	–	–	–	13,490	–	–	–		
17	Book Cliffs mine		A	5.9	38.5	49.5	6.1	.6	–	–	–	–	12,750	–	–	–	T	8
	Lower Sunnyside bed		C	–	40.9	52.6	6.5	–	–	–	–	–	13,540	–	–	–		
18	Book Cliffs mine		A	4.3	38.1	48.7	8.9	–	–	–	–	–	12,565	–	1.8	–		86
	Lower Sunnyside bed		B	2.1	39.0	49.9	9.1	–	–	–	–	–	12,857	–	–	–		
			C	–	39.8	50.9	9.3	–	–	–	–	–	13,130	–	–	–		
19	Book Cliffs mine		A	3.5	44.7	41.6	10.2	–	–	–	–	–	12,684	–	1.8	–		86
	Lower Sunnyside bed		B	1.6	45.6	42.4	10.4	–	–	–	–	–	12,932	–	–	–		
			C	–	46.3	43.1	10.6	–	–	–	–	–	13,145	–	–	–		
20	Book Cliffs mine		A	4.8	37.4	49.8	7.9	–	–	–	–	–	12,193	–	2.2	–		86
	Lower Sunnyside bed		B	1.8	38.6	51.4	8.2	–	–	–	–	–	12,577	–	–	–		
			C	–	39.3	52.3	8.3	–	–	–	–	–	12,810	–	–	–		
21	Book Cliffs mine		A	5.2	37.99	47.6	9.2	–	–	–	–	–	12,508	–	3.4	–		86
	Lower Sunnyside bed		B	2.2	39.2	49.1	9.5	–	–	–	–	–	12,909	–	–	–		
			C	–	40.1	50.2	9.7	–	–	–	–	–	13,194	–	–	–		
22	Book Cliffs mine		A	3.5	–	–	–	–	–	–	–	–	12,582	–	–	–		86
	Lower Sunnyside bed		B	–	–	–	–	–	–	–	–	–	13,041	–	–	–		
23	Book Cliffs mine		A	5.5	38.4	50.5	5.7	.7	–	–	–	–	12,760	–	–	–		9
	Lower Sunnyside bed		C	–	40.6	53.4	6.0	–	–	–	–	–	13,510	–	–	–		
24	Book Cliffs mine		A	2.1	–	–	–	–	–	–	–	–	13,036	–	–	–		86
	Lower Sunnyside bed		C	–	–	–	–	–	–	–	–	–	13,318	–	–	–		
25	Book Cliffs mine		A	3.98	–	–	–	–	–	–	–	–	13,004	–	–	–		86
	Lower Sunnyside bed		B	–	–	–	–	–	–	–	–	–	13,543	–	–	–		
26	Book Cliffs mine		A	4.85	37.8	51.99	5.4	–	–	–	–	–	12,908	–	–	–		86
	Lower Sunnyside bed		B	1.56	39.1	53.8	5.6	–	–	–	–	–	13,354	–	–	–		
			C	–	39.7	54.6	5.7	–	–	–	–	–	13,566	–	–	–		
27	Book Cliffs mine		A	3.3	–	–	–	–	–	–	–	–	12,778	–	–	–		86
	Lower Sunnyside bed		B	–	–	–	–	–	–	–	–	–	13,209	–	–	–		
28	Book Cliffs mine		A	1.9	–	–	–	–	–	–	–	–	13,195	–	–	–		86
	Lower Sunnyside bed		B	–	–	–	–	–	–	–	–	–	13,451	–	–	–		
29	Book Cliffs mine		A	4.98	–	–	–	–	–	–	–	–	12,463	–	–	–		86
	Lower Sunnyside bed		B	–	–	–	–	–	–	–	–	–	13,116	–	–	–		
30	Book Cliffs mine		A	2.7	–	–	–	–	–	–	–	–	13,355	–	–	–		86
	Lower Sunnyside bed		B	–	–	–	–	–	–	–	–	–	13,728	–	–	–		
31	Book Cliffs mine		A	2.3	–	–	–	–	–	–	–	–	13,293	–	–	–		86
	Lower Sunnyside bed		B	–	–	–	–	–	–	–	–	–	13,601	–	–	–		
32	Book Cliffs mine		A	3.4	–	–	–	–	–	–	–	–	12,909	–	–	–		86
	Lower Sunnyside bed		C	–	–	–	–	–	–	–	–	–	13,369	–	–	–		
33	Book Cliffs mine		A	4.7	–	–	–	–	–	–	–	–	12,155	–	–	–		86
	Lower Sunnyside bed		B	–	–	–	–	–	–	–	–	–	12,757	–	–	–		
34	Book Cliffs mine		A	3.4	–	–	–	–	–	–	–	–	12,560	–	–	–		86
	Lower Sunnyside bed		B	–	–	–	–	–	–	–	–	–	13,005	–	–	–		
35	Book Cliffs mine		A	5.0	38.6	51.0	5.4	.6	–	–	–	–	12,950	–	–	–		10
	Lower Sunnyside bed		C	–	40.6	53.7	5.7	–	–	–	–	–	13,630	–	–	–		
36	Book Cliffs mine		A	5.7	38.4	49.8	6.1	.7	–	–	–	–	12,740	–	–	–		10
	Lower Sunnyside bed		C	–	40.7	52.8	6.5	–	–	–	–	–	13,510	–	–	–		
37	Book Cliffs mine		A	4.6	38.4	50.5	6.6	.6	–	–	–	–	12,860	–	–	–	D	11
	Lower Sunnyside bed		C	–	40.2	52.9	6.9	–	–	–	–	–	13,480	–	–	–		
38	Book Cliffs mine		A	5.6	37.1	49.3	8.0	.5	–	–	–	–	12,390	–	–	–	T	11
	Lower Sunnyside bed		C	–	39.3	52.2	8.5	–	–	–	–	–	13,130	–	–	–		
39	Book Cliffs mine		A	5.3	37.6	50.1	7.0	.7	–	–	–	–	12,640	–	–	–	D	11
	Lower Sunnyside bed		C	–	39.7	52.9	7.4	–	–	–	–	–	13,350	–	–	–		
40	Book Cliffs mine		A	4.0	38.5	49.7	7.8	.6	–	–	–	–	12,670	–	–	–	D	11
	Lower Sunnyside bed		C	–	40.1	51.8	8.1	–	–	–	–	–	13,190	–	–	–		
41	Book Cliffs mine		A	6.2	37.9	49.8	6.1	.7	–	–	–	–	12,670	–	–	–	D	11
	Lower Sunnyside bed		C	–	40.4	53.1	6.5	–	–	–	–	–	13,510	–	–	–		
42	Book Cliffs mine		A	5.9	37.0	50.7	6.4	.8	–	–	–	–	12,720	–	–	51	T	11
	Lower Sunnyside Bed		C	–	39.3	53.9	6.8	–	–	–	–	–	13,510	–	–	–		
43	Book Cliffs mine		A	5.7	37.8	48.8	7.7	.8	–	–	–	–	12,470	–	–	–	D	11
	Lower Sunnyside bed		C	–	40.1	51.7	8.2	–	–	–	–	–	13,220	–	–	–		
44	Book Cliffs mine		A	5.4	38.0	49.7	6.9	.7	–	–	–	–	12,630	–	–	–	D	11
	Lower Sunnyside bed		C	–	40.2	52.5	7.3	–	–	–	–	–	13,350	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
45	Book Cliffs mine		A	6.7	37.9	49.5	5.9	.8	–	–	–	–	12,590	–	–	–	D	11
	Lower Sunnyside bed		C	–	40.6	53.1	6.3	–	–	–	–	–	13,490	–	–	–		
46	Book Cliffs mine		A	8.1	36.3	48.4	7.2	.9	–	–	–	–	12,140	–	–	–	T	11
	Lower Sunnyside bed		C	–	39.5	52.7	7.8	–	–	–	–	–	13,210	–	–	–		
47	Book Cliffs mine		A	5.8	38.1	50.2	5.9	.6	–	–	–	–	12,710	–	–	–	D	12
	Lower Sunnyside bed		C	–	40.4	53.3	6.3	–	–	–	–	–	13,490	–	–	–		
48	Book Cliffs mine		A	5.6	39.9	48.4	6.0	.6	–	–	–	–	12,770	–	–	–	D	12
	Lower Sunnyside bed		C	–	42.3	51.3	6.4	–	–	–	–	–	13,530	–	–	–		
49	Book Cliffs mine		A	6.7	37.8	49.0	6.5	.7	–	–	–	–	12,530	–	–	–	D	12
	Lower Sunnyside bed		C	–	40.5	52.5	7.0	–	–	–	–	–	13,430	–	–	–		
50	Book Cliffs mine		A	5.9	37.5	48.8	7.7	.7	–	–	–	–	12,430	–	–	–	D	12
	Lower Sunnyside bed		C	–	39.9	51.9	8.2	–	–	–	–	–	13,210	–	–	–		
51	Book Cliffs mine		A	4.6	38.3	50.4	6.8	.6	–	–	–	–	12,770	–	–	–	D	12
	Lower Sunnyside bed		C	–	40.1	52.8	7.1	–	–	–	–	–	13,390	–	–	–		
52	Book Cliffs mine		A	5.6	38.2	49.6	6.6	.7	–	–	–	–	12,660	–	–	–	D	12
	Lower Sunnyside bed		C	–	40.5	52.5	7.0	–	–	–	–	–	13,410	–	–	–		
53	Book Cliffs mine		A	5.5	38.2	50.2	6.1	.7	–	–	–	–	12,730	–	–	–	D	13
	Lower Sunnyside bed		C	–	40.4	53.1	6.5	–	–	–	–	–	13,470	–	–	–		
54	Book Cliffs mine		A	6.5	38.0	48.7	6.8	.8	–	–	–	–	12,540	–	–	–	T	13
	Lower Sunnyside bed		C	–	40.6	52.1	7.3	–	–	–	–	–	13,420	–	–	–		
55	Book Cliffs mine		A	6.2	37.7	49.9	6.2	.7	–	–	–	–	12,630	–	–	–	D	13
	Lower Sunnyside bed		C	–	40.2	53.2	6.6	–	–	–	–	–	13,460	–	–	–		
56	Book Cliffs mine		A	5.6	37.5	50.1	6.8	.7	–	–	–	–	12,680	–	–	–	D	13
	Lower Sunnyside bed		C	–	39.7	53.1	7.2	–	–	–	–	–	13,430	–	–	–		
57	Book Cliffs mine		A	6.9	37.8	49.3	6.0	.6	–	–	–	–	12,570	–	–	–	D	13
	Lower Sunnyside bed		C	–	40.6	53.0	6.4	–	–	–	–	–	13,500	–	–	–		
58	Book Cliffs mine		A	6.8	38.3	48.6	6.3	.7	–	–	–	–	12,560	–	–	–	T	13
	Lower Sunnyside bed		C	–	41.1	52.1	6.8	–	–	–	–	–	13,460	–	–	–		
59	Book Cliffs mine		A	6.4	38.1	49.5	6.0	.6	–	–	–	–	12,640	–	–	–	D	13
	Lower Sunnyside bed		C	–	40.7	52.9	6.4	–	–	–	–	–	13,500	–	–	–		
60	Book Cliffs mine		A	8.1	37.3	48.2	6.4	.7	–	–	–	–	12,340	–	–	–	T	13
	Lower Sunnyside bed		C	–	40.6	52.4	7.0	–	–	–	–	–	13,420	–	–	–		
61	Book Cliffs mine		A	6.0	39.2	49.4	5.5	.7	–	–	–	–	12,880	–	–	–	T	14
	Lower Sunnyside bed		C	–	41.7	52.5	5.8	–	–	–	–	–	13,700	–	–	–		
62	Book Cliffs mine		A	7.1	38.2	48.3	6.4	.7	–	–	–	–	12,490	–	–	–	D	14
	Lower Sunnyside bed		C	–	41.1	52.0	6.9	–	–	–	–	–	13,440	–	–	–		
63	Book Cliffs mine		A	5.1	38.3	50.7	5.9	.7		–	–	–	12,870	–	–	–	D	14
	Lower Sunnyside bed		C	–	40.4	53.4	6.2	–	–	–	–	–	13,560	–	–	–		
64	Book Cliffs mine		A	6.2	38.2	49.5	6.1	.6	–	–	–	–	12,650	–	–	–	D	14
	Lower Sunnyside bed		C	–	40.7	52.8	6.5	–	–	–	–	–	13,490	–	–	–		
65	Book Cliffs mine		A	5.7	38.7	49.7	5.9	.6	–	–	–	–	12,760	–	–	–	D	14
	Lower Sunnyside bed		C	–	41.0	52.7	6.3	–	–	–	–	–	13,530	–	–	–		
66	Book Cliffs mine		A	4.1	38.5	51.3	6.1	.6	–	–	–	–	12,950	–	–	–	D	14
	Lower Sunnyside bed		C	–	40.1	53.5	6.4	–	–	–	–	–	13,500	–	–	–		
67	Book Cliffs mine		A	7.6	37.7	48.7	6.0	.9	–	–	–	–	12,490	–	–	–	T	14
	Lower Sunnyside bed		C	–	40.8	52.7	6.5	–	–	–	–	–	13,510	–	–	–		
68	Book Cliffs mine		A	6.1	38.2	49.9	5.8	.6	–	–	–	–	12,670	–	–	–	D	15
	Lower Sunnyside bed		C	–	40.7	53.1	6.2	–	–	–	–	–	13,500	–	–	–		
69	Book Cliffs mine		A	6.8	37.5	49.4	6.3	.6	–	–	–	–	12,490	–	–	–	D	15
	Lower Sunnyside bed		C	–	40.2	53.0	6.8	–	–	–	–	–	13,410	–	–	–		
70	Book Cliffs mine		A	5.9	38.2	50.0	5.9	.6	–	–	–	–	12,640	–	–	–	D	15
	Lower Sunnyside bed		C	–	40.6	53.1	6.3	–	–	–	–	–	13,440	–	–	–		
71	Book Cliffs mine		A	6.7	37.3	49.3	6.7	.7	–	–	–	–	12,500	–	–	–	D	16
	Lower Sunnyside bed		C	–	40.0	52.8	7.2	–	–	–	–	–	13,410	–	–	–		
72	Book Cliffs mine		A	6.3	37.9	49.1	6.7	.7	–	–	–	–	12,580	–	–	–	D	16
	Lower Sunnyside bed		C	–	40.4	52.4	7.2	–	–	–	–	–	13,440	–	–	–		
73	Book Cliffs mine		A	3.8	38.6	51.0	6.6	.7	–	–	–	–	12,950	–	–	–	D	16
	Lower Sunnyside bed		C	–	40.1	53.0	6.9	–	–	–	–	–	13,470	–	–	–		
74	Book Cliffs mine		A	5.9	37.8	49.9	6.4	.7	–	–	–	–	12,680	–	–	–	D	16
	Lower Sunnyside bed		C	–	40.2	53.0	6.8	–	–	–	–	–	13,480	–	–	–		
75	Book Cliffs mine		A	5.8	38.1	49.7	6.4	.6	–	–	–	–	12,690	–	–	–	D	16
	Lower Sunnyside bed		C	–	40.4	52.8	6.8	–	–	–	–	–	13,490	–	–	–		
76	Book Cliffs mine		A	5.6	37.4	50.8	6.2	.7	–	–	–	–	12,760	–	–	–	D	17
	Lower Sunnyside bed		C	–	39.6	53.8	6.6	–	–	–	–	–	13,530	–	–	–		
77	Book Cliffs mine		A	6.0	38.3	48.5	7.2	.7	–	–	–	–	12,510	–	–	–	T	17
	Lower Sunnyside bed		C	–	40.7	51.6	7.7	–	–	–	–	–	13,300	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Sample	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
78	Book Cliffs mine		A	6.2	38.0	48.2	7.6	.7	–	–	–	–	12,470	–	–	–	T	17
	Lower Sunnyside bed		C	–	40.5	51.4	8.1	–	–	–	–	–	13,280	–	–	–		
79	Book Cliffs mine		A	5.7	38.5	49.2	6.6	.7	–	–	–	–	12,700	–	–	–	D	17
	Lower Sunnyside bed		C	–	40.8	52.2	7.0	–	–	–	–	–	13,480	–	–	–		
80	Book Cliffs mine		A	6.9	38.2	48.5	6.4	.7	–	–	–	–	12,590	–	–	–	T	17
	Lower Sunnyside bed		C	–	41.0	52.1	6.9	–	–	–	–	–	13,520	–	–	–		
81	Book Cliffs mine		A	5.6	38.2	49.7	6.5	.7	–	–	–	–	12,700	–	–	–	D	17
	Lower Sunnyside bed		C	–	40.5	52.6	6.9	–	–	–	–	–	13,460	–	–	–		
82	Book Cliffs mine		A	5.4	38.7	49.7	6.2	.6	–	–	–	–	12,830	–	–	–	D	17
	Lower Sunnyside bed		C	–	40.9	52.5	6.6	–	–	–	–	–	13,570	–	–	–		
83	Book Cliffs mine		A	5.0	38.5	50.2	6.4	.7	–	–	–	–	12,830	–	–	–		18
	Lower Sunnyside bed		C	–	40.5	52.8	6.7	–	–	–	–	–	13,520	–	–	–		
84	Book Cliffs mine		A	6.0	38.4	49.4	6.2	.7	–	–	–	–	12,710	–	–	–		18
	Lower Sunnyside bed		C	–	40.9	52.5	6.6	–	–	–	–	–	13,530	–	–	–		
85	Book Cliffs mine		A	6.0	38.4	49.8	5.7	.6	–	–	–	–	12,740	–	–	–		18
	Lower Sunnyside bed		C	–	40.9	53.0	6.1	–	–	–	–	–	13,560	–	–	–		
86	Book Cliffs mine		A	5.3	38.7	49.6	6.3	.6	–	–	–	–	12,780	–	–	–		18
	Lower Sunnyside bed		C	–	40.9	52.4	6.7	–	–	–	–	–	13,510	–	–	–		
87	Book Cliffs mine		A	6.0	38.7	49.1	6.2	.6	–	–	–	–	12,660	–	–	–		18
	Lower Sunnyside bed		C	–	41.2	52.2	6.6	–	–	–	–	–	13,490	–	–	–		
88	Book Cliffs mine		A	4.9	38.6	50.5	6.0	.7	–	–	–	–	12,780	–	–	–	D	19
	Lower Sunnyside bed		C	–	40.6	53.1	6.3	–	–	–	–	–	13,440	–	–	–		
89	Book Cliffs mine		A	6.0	38.4	49.4	6.3	.6	–	–	–	–	12,530	–	–	–	D	19
	Lower Sunnyside bed		C	–	40.8	52.5	6.7	–	–	–	–	–	13,330	–	–	–		
90	Book Cliffs mine		A	6.4	38.5	49.2	5.9	.6	–	–	–	–	12,610	–	–	–	D	19
	Lower Sunnyside bed		C	–	41.1	52.6	6.3	–	–	–	–	–	13,480	–	–	–		
91	Book Cliffs mine		A	5.9	38.3	49.2	6.6	.7	–	–	–	–	12,590	–	–	–	D	19
	Lower Sunnyside bed		C	–	40.7	52.3	7.0	–	–	–	–	–	13,380	–	–	–		
92	Book Cliffs mine		A	5.8	38.7	49.3	6.2	.6	–	–	–	–	12,670	–	–	–	D	19
	Lower Sunnyside bed		C	–	41.1	52.3	6.6	–	–	–	–	–	13,470	–	–	–		
93	Book Cliffs mine		A	6.6	38.3	49.0	6.1	.6	–	–	–	–	12,550	–	–	–	D	19
	Lower Sunnyside bed		C	–	41.0	52.5	6.5	–	–	–	–	–	13,440	–	–	–		
94	Book Cliffs mine		A	5.7	38.9	48.8	6.6	.6	–	–	–	–	12,630	–	–	–	D	20
	Lower Sunnyside bed		C	–	41.2	51.8	7.0	–	–	–	–	–	13,400	–	–	–		
95	Book Cliffs mine		A	5.7	38.7	48.8	6.8	.6	–	–	–	–	12,650	–	–	–	D	20
	Lower Sunnyside bed		C	–	41.0	51.8	7.2	–	–	–	–	–	13,420	–	–	–		
96	Book Cliffs mine		A	6.2	39.1	49.6	5.1	.6	–	–	–	–	12,750	–	–	–	D	20
	Lower Sunnyside bed		C	–	41.7	52.9	5.4	–	–	–	–	–	13,600	–	–	–		
97	Book Cliffs mine		A	6.4	37.8	48.2	7.6	1.0	–	–	–	–	12,380	2,350	–	48	T	87
	Lower Sunnyside bed		C	–	40.4	51.5	8.1	–	–	–	–	–	13,230	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
98	Book Cliffs mine		A	5.5	38.4	49.0	7.1	.7	–	–	–	–	12,590	2,430	–	–	D	87
	Lower Sunnyside bed		C	–	40.6	51.9	7.5	–	–	–	–	–	13,320	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,400	–	–	–		
99	Book Cliffs mine		A	6.3	38.2	47.8	7.7	.8	–	–	–	–	12,400	2,450	–	–	T	87
	Lower Sunnyside bed		C	–	40.8	51.0	8.2	–	–	–	–	–	13,230	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,410	–	–	–		
100	Book Cliffs mine		A	5.9	38.1	48.9	7.1	.7	–	–	–	–	12,550	2,450	–	–	D	87
	Lower Sunnyside bed		C	–	40.5	52.0	7.5	–	–	–	–	–	13,340	–	–	–		
			D	–	–	–	–	–	–	–	–	–	14,420	–	–	–		
101	Book Cliffs mine		A	8.3	37.4	48.5	5.8	–	–	–	–	–	–	–	–	–		59
	Lower Sunnyside bed		D	–	43.5	56.5	–	.7	5.5	80.7	1.7	11.4	14,300	–	–	–		
102	Drill Hole	3–16S–14E	A	3.1	39.0	52.8	5.1	.8	5.6	75.4	1.4	11.7	13,470	–	.7	–		70
	Lower Sunnyside bed		C	–	40.2	54.6	5.2	.9	5.5	77.8	1.5	9.1	13,900	–	–	–		
			D	–	42.4	57.6	–	.9	5.8	82.1	1.6	9.6	14,670	–	–	–		
103	Geneva mine	NW.SW.3–16S–14E	A	4.9	–	–	4.8	.71	–	–	–	–	–	–	–	–		88
	Lower Sunnyside bed	4368100mN 555550mE																
104	Geneva mine		A	2.9	16.4	74.3	6.4	.6	4.5	81.6	1.2	5.7	14,220	2,380	2.5	–		59
	Lower Sunnyside bed																	
105	Geneva mine		A	3.6	16.4	69.7	10.3	1.1	4.3	76.7	1.5	6.1	13,340	2,260	3.0	–		59
	Lower Sunnyside bed																	
106	Geneva mine		A	5.0	38.5	49.9	6.6	.8	5.6	72.4	1.5	13.1	12,900	2,420	1.8	–		59
	Lower Sunnyside bed																	
107	Geneva mine		A	5.2	36.0	52.7	6.1	.8	5.3	71.2	1.3	15.3	13,030	–	2.9	–		62
	Lower Sunnyside bed		B	2.37	37.11	54.27	6.25	.85	5.09	73.35	1.34	13.12	13,419	–	–	–		
			C	–	38.0	55.6	6.4	.8	4.9	75.1	1.4	11.3	13,750	–	–	–		
			D	–	40.6	59.4	–	.9	5.3	80.3	1.5	12.0	14,690	–	–	–		

Table 4. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES AN	M	VM	FC	Ash	ULTIMATE ANALYSES S	H	C	N	O	Btu/lb	OTHER TESTS AST	ADL	HGI	Kind of Sample	Ref. Source
108	Geneva mine		A	3.9	38.0	54.3	3.8	.8	–	–	–	–	13,260	–	.5	–		41
	Lower Sunnyside bed		B	3.4	38.2	54.6	3.8	.8	–	–	–	–	13,330	–	–	–		
			C	–	39.5	56.6	3.9	.8	–	–	–	–	13,800	–	–	–		
			D	–	41.1	58.9	–	.9	–	–	–	–	14,370	–	–	–		
109	Geneva mine		A	4.8	38.2	52.0	5.0	.7	–	–	–	–	13,190	–	1.0	–		41
	Lower Sunnyside bed		B	3.8	38.3	52.2	5.0	.7	–	–	–	–	13,190	–	–	–		
			C	–	40.1	54.7	5.2	.8	–	–	–	–	13,840	–	–	–		
			D	–	42.3	57.7	–	.8	–	–	–	–	14,690	–	–	–		
110	Geneva mine		A	4.7	39.1	50.1	6.1	.8	5.6	72.6	1.6	13.3	12,880	–	2.2	–		70
	Lower Sunnyside bed		C	–	41.0	52.6	6.4	.8	5.3	76.2	1.7	9.6	13,520	–	–	–		
			D	–	43.8	56.2	–	.9	5.6	81.4	1.8	10.3	14,430	–	–	–		
	WOODSIDE SE QUADRANGLE																	
1	Peterson prospect	NW.19–18S–15E	A	4.75	33.58	50.24	11.43	1.15	–	–	–	–	–	–	2.3	–		62
	Beckwith zone	4345500mN 562000mE	C	–	35.26	52.74	12.00	1.21	–	–	–	–	–	–	–	–		
			D	–	40.07	59.93	–	1.38	–	–	–	–	–	–	–	–		

Moisture

The moisture content of 1,287 coal samples averages 4.6 percent, ranging from 0.6 to 24.5 percent (table 5). The number of analyses from the Castlegate area influences the field average only slightly, but a better assumption for the eight quadrangles is 4.8 percent.

Table 5. Moisture content of coal, Book Cliffs coal field.

Quadrangle	No. of Samples	Percent Average	Range
Castlegate-Kyune	563	4.1	0.6-24.5
Castlegate-Matts Summit	312	4.7	2.5-10.4
Wellington-Minnie Maud W	136	4.8	2.2- 8.4
Wellington NE	97	4.9	3.1- 8.5
Sunnyside NW	6	5.2	3.1- 7.9
Sunnyside SW	1	4.3	4.3
Sunnyside SE	61	5.1	3.1-15.2
Woodside NE	110	5.5	1.9- 9.8
Woodside SE	1	4.8	4.8
No analyses for remaining quadrangles.			
Book Cliffs coal field	1,287	4.6-(4.8)	0.6-24.5

Volatile Matter

The average percentage for volatile matter is 41.2 percent (table 6), but is influenced by the large number of samples from the Castlegate area. A more accurate figure is 39.4 percent. Volatile matter is highest in the Castlegate-Kyune quadrangle, gradually lessening to the Sunnyside area.

Table 6. Volatile matter content of coal, Book Cliffs coal field.

Quadrangle	No. of Samples	Percent Average	Range
Castlegate-Kyune	514	43.2	31.4-48.5
Castlegate-Matts Summit	306	41.7	35.7-64.3
Wellington-Minnie Maud W	124	38.6	30.9-45.7
Wellington NE	94	38.6	37.4-40.1
Sunnyside NW	6	38.8	37.2-40.0
Sunnyside SW	1	37.8	37.8
Sunnyside SE	56	38.1	33.9-42.9
Woodside NE	96	37.5	16.4-44.7
Woodside SE	1	33.6	33.6
No analyses for remaining quadrangles.			
Book Cliffs coal field	1,198	41.2 (39.4)	16.4-64.3

Fixed Carbon

The fixed carbon average for the field of 47.4 percent (table 7) is also strongly biased by the numerous analyses from the Castlegate area. A 49.1-percent average is more indicative of the entire field. This category is lowest in the Castlegate area and increases across the Soldier Canyon and Sunnyside areas.

Table 7. Fixed carbon content of coal, Book Cliffs coal field.

Quadrangle	No. of Samples	Percent Average	Range
Castlegate-Kyune	513	45.9	33.9-52.9
Castlegate-Matts Summit	306	47.2	28.3-52.1
Wellington-Minnie Maud W	124	48.7	44.0-52.6
Wellington NE	94	50.1	45.2-52.9
Sunnyside NW	6	49.0	48.4-49.7
Sunnyside SW	1	51.0	51.0
Sunnyside SE	56	50.6	44.8-54.2
Woodside NE	96	50.1	41.6-74.3
Woodside SE	1	50.2	50.2
No analyses for remaining quadrangles.			
Book Cliffs coal field	1,197	47.4 (49.1)	28.3-74.3

Ash

The average ash content of the quadrangles (table 8) fluctuates between 6 and 8 percent and is influenced by the presence of splits common in the Spring Canyon area, Coal Canyon area north of Wellington and in the Rock Canyon area.

Table 8. Ash content of coal, Book Cliffs coal field.

Quadrangle	No. of Samples	Percent Average	Range
Castlegate-Kyune	534	6.8	4.3-13.2
Castlegate-Matts Summit	311	6.3	3.8-12.7
Wellington-Minnie Maud W	128	7.5	3.4-12.6
Wellington NE	97	6.4	3.7-11.5
Sunnyside NW	6	7.0	5.2- 7.9
Sunnyside SW	1	6.9	6.9
Sunnyside SE	61	6.3	4.2-11.9
Woodside NE	99	6.7	3.8-10.7
Woodside SE	1	11.4	11.4
No analyses for remaining quadrangles.			
Book Cliffs coal field	1,238	6.7	3.4-13.2

A few analyses discern the major ash constituents of the coal and several spectrochemical analyses of samples of coal ash from the field delineate trace elements. These data are supplied in the quadrangle reports where applicable. The sources for both are Abernethy, Peterson and Gibson (1969a and b).

Sulfur

The sulfur average of 0.58 percent is biased by the large number of analyses in the west part of the field. A more accurate

figure is 0.85 (table 9). Both Castlegate and Wellington quadrangles have low sulfur, but the content fluctuates greatly in the Sunnyside and Woodside quadrangles. The coals in these areas are washed to reduce the sulfur to metallurgical grade.

Table 9. Sulfur content of coal, Book Cliffs coal field.

Quadrangle	No. of Samples	Percent	
		Average	Range
Castlegate-Kyune	489	0.59	0.2 -2.1
Castlegate-Matts Summit	295	0.44	0.1 -0.8
Wellington-Minnie Maud W	110	0.49	0.3 -1.0
Wellington NE	96	0.49	0.3 -0.8
Sunnyside NW	6	1.82	1.0 -2.4
Sunnyside SW	1	0.67	0.67
Sunnyside SE	60	1.02	0.5 -3.0
Woodside NE	91	0.70	0.5 -1.1
Woodside SE	1	1.15	1.15
No analyses for remaining quadrangles.			
Book Cliffs coal field	1,149	0.58 (0.85)	0.1 -3.0

The U. S. Bureau of Mines (Walker and Hartner, 1966) subdivided 36 samples from the Book Cliffs coal field into sulfur groups. These are individually presented in the quadrangle reports.

	Percent	
	Average	Range
Sulfate	0.014	0.00-0.08
Pyritic	0.230	0.00-1.34
Organic	0.518	0.20-0.94
Total sulfur	0.762	0.32-2.01

Calorific Value

The Btu/lb is normally between 12,500 and 13,000 on an as-received basis (table 10) with no apparent difference in the coal on a regional basis.

Table 10. Btu/lb content of coal, Book Cliffs coal field.

Quadrangle	No. of Samples	Percent	
		Average	Range
Castlegate-Kyune	551	12,863	7,045-13,530
Castlegate-Matts Summit	303	12,755	11,840-13,370
Wellington-Minnie Maud W	132	12,451	11,700-13,000
Wellington NE	93	12,645	11,390-13,390
Sunnyside NW	6	12,512	11,880-12,940
Sunnyside SW	1	13,197	13,197
Sunnyside SE	51	12,906	9,530-13,660
Woodside NE	105	12,664	10,860-14,220
No analyses for remaining quadrangles.			
Book Cliffs coal field	1,242	12,762	7,045-14,220

Using figures presumed more diagnostic for the field as a whole, rather than the averages calculated, the Book Cliffs coal has the following characteristics: moisture 4.8 percent, volatile matter 39.4 percent, fixed carbon 49.1 percent, ash 6.7 percent, sulfur 0.85 percent and Btu/lb 12,760.

The ASTM system classifies the coal of the Book Cliffs coal field as bituminous high-volatile B rank. The coal in the Sunnyside area is a coking coal, but must be blended with 15 to 20 percent of low- or medium-volatile coals from other sources to achieve metallurgical grade. The Castlegate area produced coke in the early days but its coke-making industry succumbed to the higher quality product produced at Sunnyside before 1910.

Reserves

All the important coal resources of the Book Cliffs coal field occur in a single formation, the Blackhawk of Upper Cretaceous age. Several coal beds are involved which achieve importance in particular parts of the field. Generally, in the Castlegate and Soldier Canyon areas the imporant beds are in the lower third of the formation; in the Sunnyside area they are in the middle or higher third and in the Woodside area, in the upper half. Most important are the Spring Canyon and Castlegate zones to the west, the Gilson and Rock Canyon beds in the Soldier Canyon area and the Lower Sunnyside bed in the Sunnyside area.

The reserves shown (table 11) were prepared by Clark (1928, p. 101-102, 161) and by Fisher (1936, p. 45). Their calculations are modified to fit quadrangles and eliminate beds averaging less than 4 feet thick. No division separates the reserve into measured reserves (Class I), estimated reserves (Class II) or inferred reserves (Class III). No reserves are included where the cover is greater than 3,000 feet.

Table 11. Coal reserves in the Book Cliffs coal field (in millions of short tons).

Quadrangle	Original Tonnage	Recoverable (Rounded)	Production to date	Recoverable Remaining
Castlegate-Kyune	935	258	53.0	205.0
Castlegate-Matts Summit	717	236	65.0	171.0
Wellington-Minnie Maud W	336	134	2.5	131.5
Wellington NE	530	185	2.6	182.4
Sunnyside NW	197 (272)?	136	(–)[1]	136.0
Sunnyside SW	123	55	13.0	42.0
Sunnyside SE	359	143	39.0	104.0
Woodside NE	399	160	33.5	126.5
Woodside SE	72	36	–	36.0
Other quadrangles lack appreciable reserves.				
Totals	3,668 (3,743)	1,343	208.6	1,134.4

[1]Small production, under 100,000 tons.

The discrepancy in the Sunnyside NW figures is the result of Clark's average thicknesses not corresponding well to experience in the mines. The number in parentheses is favored and was used to determine recoverable coal.

Reserves in adjacent quadrangles are for the most part Class IV; little is known about the coal because drilling data and surface exposures are unavailable. The distance from the coal beds is close enough, however, to assure the presence of such a reserve. The Blackhawk plunges into the Uinta Basin and emerges again on the south flank of the Uinta Mountains in Tabby Mountain and Vernal coal fields. At Tabby Mountain thick seams of coal outcrop in the Mesaverde, but none are known at Vernal. The Vernal field has its coal in the Frontier and Price River beds.

Class IV (potential) reserves are small in the Book Cliffs coal field because of the rapid accumulation of cover behind the outcrops where the coal is best developed. Only to the southeast are large areas of unknown ground with less than 3,000 feet of overburden, but poor outcrop indications predict discouraging reserve figures. A total of 265 million tons is assigned to the Class IV category in areas located along Range Creek east of Columbia and in the vicinity of Kyune. The reserves calculated for this report are classed and summarized as follows:

Class I (measured)	Based on adequate exploration and development data, properly correlated.	
Class II (indicated)	Based on geologic measurement supplemented by limited drill-hole information or limited to 1½ miles from a control point.	$3,668 \times 10^6$ short tons
Class III (inferred)	Based on geologic inference and projection of the habit of the coal beyond 1½ miles from control points.	
Class IV (potential)	Based on geographic and geologic position with little supporting data and includes coal up to 3,000 feet of cover.	265×10^6 short tons
	Total	$3,933 \times 10^6$ short tons

Coal Seams

The Book Cliffs coal field conveniently subdivides into four areas (figure 13). The Castlegate area in the west part of the field extends easterly from the Wasatch Plateau boundary (North Gordon fault zone) to the line dividing R. 10 and 11 E. The Soldier Canyon area extends from the east Castlegate boundary to the line dividing R. 12 and 13 E. or just east of Dugout Canyon. The Sunnyside area involves mostly the sector where the Lower Sunnyside bed is well developed from Rock Canyon southward to Williams Draw. The Woodside area entails the land from Williams Draw to the mouth of Gray Canyon or the boundary with the Sego coal field.

The Lower Sunnyside bed is the most important of the field. It has the greatest aerial extent, has had the greatest production and can produce a metallurgical coke. Other beds include the following (listed from top to bottom with respect to stratigraphic position):

Coal bed or zone	Area of Importance
Beckwith zone	Woodside
Upper Sunnyside bed	Sunnyside
Lower Sunnyside bed	Sunnyside
Rock Canyon bed	Soldier Canyon and Sunnyside
Fish Creek bed	Soldier Canyon
Gilson bed	Soldier Canyon
Kenilworth	Castlegate
Castlegate zone	Castlegate
Spring Canyon zone	Castlegate

These beds are presented in figures 16 and 17 which illustrate coal bed development; details of each bed are more fully discussed in the quadrangle reports. In summary, the Spring Canyon beds are minable west of Price River Canyon, the Castlegate has minable seams throughout the Castlegate area (except locally) and the Kenilworth is best developed between Price River and Deadman Canyon (figure 16). The Gilson seam is the only one of importance between Deadman and Coal canyons. Farther east it thins out at Soldier Canyon and redevelops in the Dugout to Rock Canyon sector of the Book Cliffs. The Rock Canyon bed is well developed from Soldier Canyon to a point a little southeast of Rock Canyon. The Fish Creek bed probably achieves minable thickness between Dugout and Soldier canyons in the Soldier Canyon area. In outcrop the Lower Sunnyside is developed from northwest of Rock Canyon southward into the north Woodside area. The Upper Sunnyside is considered an upper split of the Lower Sunnyside and is locally developed in the Sunnyside area, most notably between Whitmore and Horse canyons. The Beckwith zone, present only in the Woodside area, contains coal beds that are highly lenticular and often split (figure 17). Only locally do beds exceed 4 feet thick.

As alluded to in previous discussions, the Mancos sea retreated gradually during Upper Cretaceous time toward the east. The marine environment was replaced by nearshore marine, beach, lagoonal and finally continental surroundings as time progressed. Older coal beds are in the west part of the field and younger ones to the east. The ancient coasts are thought to have been aligned approximately north-south, as indeed they were except locally. The coasts reflect the structural tendencies of the time. Gross (1961), in an isopach map of the Blackhawk Formation, shows a major irregularity which undoubtedly helped shape the present configuration of the Book Cliffs. His isopachous lines are north-south in the area south of Sunnyside, but swing east-west to the northwest. The thickest section of Blackhawk is known from oil-well data 14 miles north of Sunnyside. This may indicate an embayment which would affect any northward projection of coal pinch-out lines and may extend the thicker coal seams as known in the Sunnyside area toward the northwest as verified by a drill hole near the head of Soldier Canyon.

WATER RESOURCES

Water resources are subdivided into subsurface and surface. The source of both is primarily precipitation which falls on the land (figure 3). Precipitation is closely related to elevation and so the highest figures (up to 25 inches) are located along the west margin of the field and in the Mt. Bartles-Bear Point ridge area north of Sunnyside (20 inches annually). The average precipitation along the upland areas is 12 to 16 inches; immediately along the cliffs it is 10 inches and below the cliffs, 8 inches.

Subsurface Water

Precipitation that falls as rain or snow above the cliffs makes its way into the soil unless the rainfall is torrential. Winter storms are the best sources of subsurface moisture; the moisture infiltrates the more permeable and porous rocks which include sandstones and limestones. Summer storms are largely torrential. The moisture collects in dry creek beds which lead into larger and larger washes until a permanent stream is reached. Nontorrential summer rain is quickly transpired or evaporated and little feeds the subsurface reservoir.

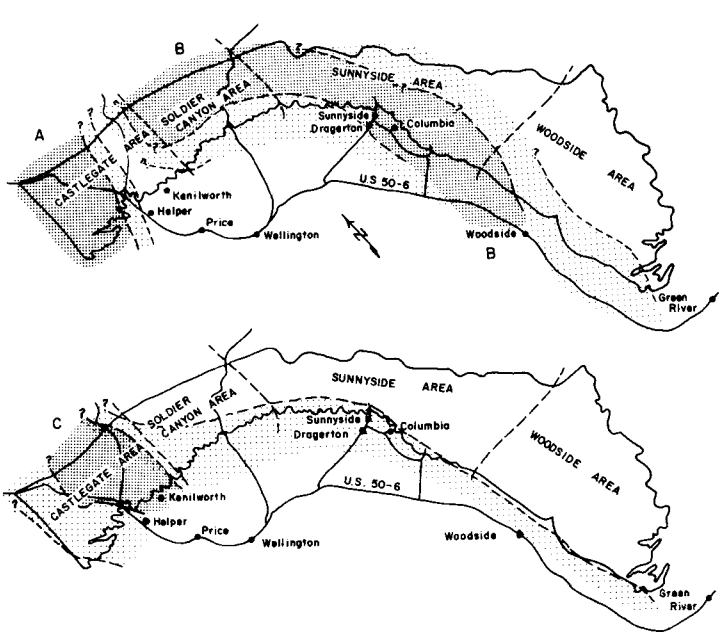


Figure 16. Approximate areas of Spring Canyon (A), Sunnyside (B) and Kenilworth (C) coal development, Book Cliffs coal field. Dark pattern indicates beds 4 feet or more thick, light pattern area of thin coal beds.

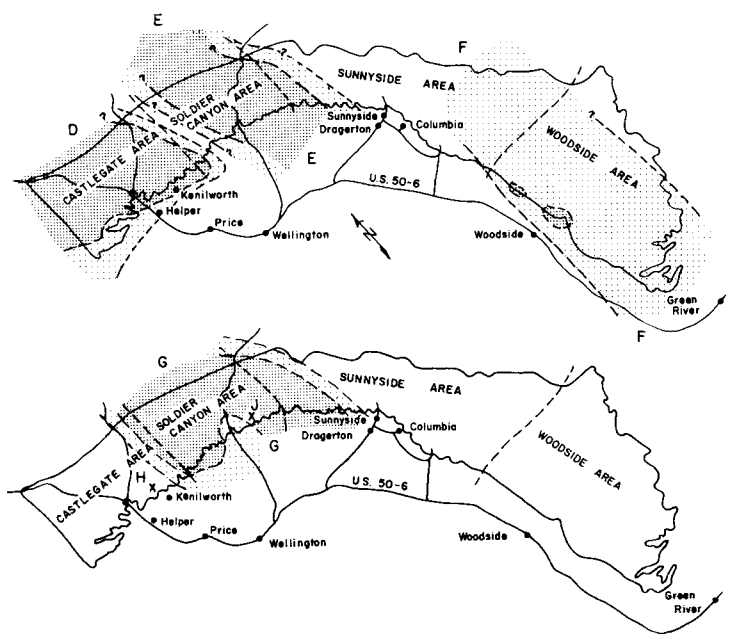


Figure 17. Approximate areas of Castlegate (D), Rock Canyon (E), Beckwith (F), Gilson (G), Royal Blue (H) and Fish Creek (J) coal development, Book Cliffs coal field. Dark pattern indicates beds 4 feet or more thick, light pattern area of thin coal beds.

During migration through rocks the moisture picks up chemical matter; the more impermeable the rock, the more chemical is picked up. Where the subterranean flow is impeded, time for chemical matter to go into solution is increased. Shales usually impart the greatest chemical content to the water. Eventually the water is released to the surface as springs that feed the surface waters. It may be tapped by digging wells at favorable localities. Such sources, however, probably have small yield considering the low precipitation and small recharge area.

Surface Water

Two important streams in the Book Cliffs field area, the Price River and the Green River, flow through the cliffs at opposite ends of the field. The Price River continues to parallel the cliffs to the south and at Woodside cuts through them again, finally flowing into the Green River.

The Price River near Helper, Utah, drains about 530 square miles. During the water years 1914 to 1934, it flowed at an annual average rate ranging from 36 to 274 cfs with an average annual flow of 138 cfs. From 1935 to 1957 the flow was measured at Heiner, a few miles upstream from Helper, where the Price River drains 455 square miles. During these years the annual flow average ranged from 67 to 311 cfs and averaged 112 cfs.

The Price River drains 1,500 square miles by the time it reaches Woodside. Between 1947 and 1957 the annual flow average ranged from 34 to nearly 342 cfs with the average 101 cfs annually showing a loss between Woodside and Heiner.

The Green River was checked at Green River town 57 times between the years 1895 and 1957. The least flow came in 1934 when an average of 1,805 cfs was recorded; the highest flow was recorded in 1907 with 12,275 cfs. Extremes are no longer expected. The resultant flow of water is undoubtedly modified because major reservoirs and dams have been constructed upstream (Flaming Gorge, etc). The 57-year average flow is 6,575 cfs.

Coal Creek, Soldier Creek, Dugout Creek and Whitmore Creek usually have a small but sustained flow, but no measurements have been made. Minnie Maud Creek flows from west to east north of the cliffs, heading north of Kenilworth. It does not cut through the Book Cliffs but empties into the Green River. It drains 231 square miles at Nutters Ranch north of Sunnyside and in the years 1948 to 1955 carried between 6 and 56 cfs for an average of 20 cfs.

Chemically, surface waters above the cliffs are low in dissolved material, usually between 300 and 500 ppm, the concentration found in the Green River in this area. Below the cliffs the water passes over the Mancos Shale and is used for irrigation, both of which help increase the dissolved material to more than 1,200 ppm. Figure 18 shows the approximate weighted-average concentration of dissolved solids in streams flowing in the Book Cliffs area. No reservoirs of consequence occur in this area.

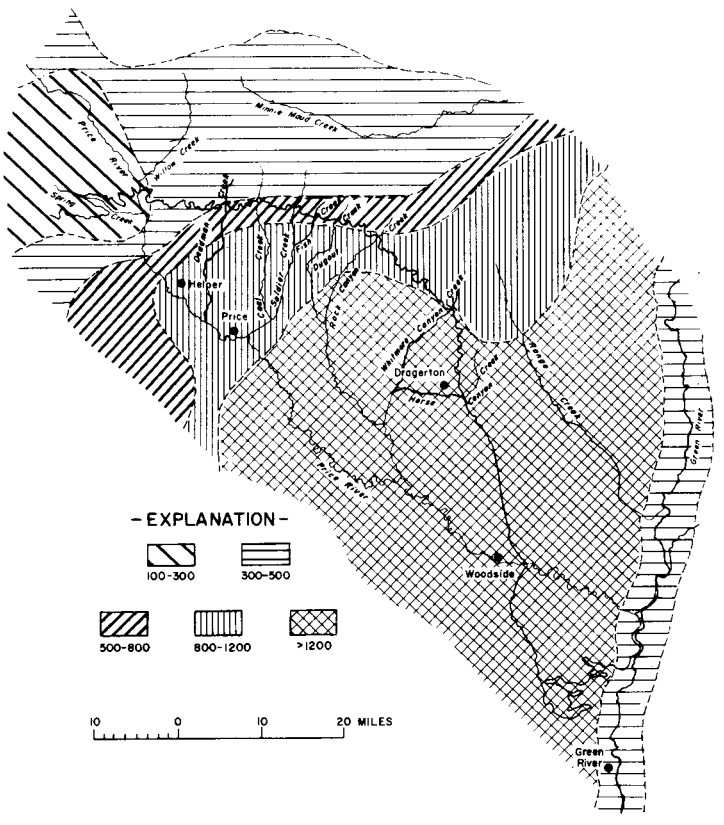


Figure 18. Dissolved solids, weighted average concentration of surface waters, Book Cliffs coal field (after Iorns and others, 1964).

ECONOMIC CONSIDERATIONS AND FORECAST

Good coal is present in the Book Cliffs from Spring Canyon to 3 or 4 miles south of Williams Draw. Only thin coal or local lenses are expected farther south and easterly to the Green River. The productive length thus includes 50 of the 70 miles. Historically activity has been centralized at two nodes. The first is centered around the Price River Canyon north of Helper (Castlegate area) and includes the mines of Spring Canyon, Hardscrabble Canyon, Price River Canyon and Kenilworth. The Castlegate production has amounted to 56.6 percent of the total for the coal field. The coal first produced an inefficient coke but later was used as a first-class domestic fuel. Today the coal is exported to western markets, supplies domestic and industrial users in the less populated areas of Utah and supplies a power plant located at Castlegate which is rated at 188,600 kw. Most of the western users are industrial and governmental, such as government installations, mines and smelters, cement plants, sugar factories and gypsum plants.

The second major area is centered at Sunnyside but extends to Horse Canyon. Forty-one percent of the field's production have originated here. A metallurgical grade coke can be made from this coal if blended with 15 to 20 percent of medium- or low-volatile coal from other sources. The coal is shipped to steel plants at Geneva, Utah (near Provo), and to Fontana, California. Some of the coal has been exported as far away as Japan.

Estimates on the cost of producing a ton of coal in the Book Cliffs have varied from less than $4.00 per ton to more than $9.00 per ton. All Book Cliffs coal must be underground-mined. The most efficient set-ups for extracting coal would be required for the low per-ton figure. More stringent controls on mine safety, price rise on equipment, labor, pollution and land reclamation favor the higher figures. The coal reserves of the Book Cliffs field with little overburden are rapidly being depleted. Mining at greater depth presents other problems which will also affect the costs in an adverse way. In essence the thicker seams will be mined under deep cover in the future; thinner seams, those with splits and other deficiences, will be mined in the shallow depth areas.

Geologic factors which influence costs and mining and the effective use of reserves include the following:

1. Heavy overburden mining
   a. Coal mine bumps (earthquakes)
   b. Methane gas accumulation
   c. Proper ventilation and dust control
2. General mining
   a. Roof control because of bad rock, splits
   b. Coal preparation, washing, etc.
   c. Burned (oxidized) coal
   d. Variable seam thickness
   e. Faults
   f. Multiple coal seams
   g. Steepening of dip
   h. Nature of the floor

In deep mines, gas, dust and methane accumulation become greater problems. The overburden places pressure on the coal seam which naturally seeks release in the open area of a mine. If pillars remain they must be thicker to support the roof. Rock bursts occur and bits and pieces break off the walls and roofs, sometimes with explosive force. Costs of controlling the hazards coupled with a lower recoverability are expected to affect the overall cost of producing the coal.

Western U. S. coal beds are lenticular as well as the rock that contains them. The floor and roof undulate and the thickness changes. Splits of foreign matter such as shale or high-ash coal appear and disappear. In some places the coal is completely gone having been removed by a prehistoric erosional event. All these make the efficient use of mechanical equipment difficult. Coal-seam quality is often impaired by oxidation from the surface which progresses deep in places; coal often has been found burned out as much as several feet behind the outcrop.

Faulting is not much of a problem in the Book Cliffs. The dip of beds locally steepen and level out and present difficulties where encountered. These require changes in mining plans to accommodate mining machinery. In-mine haulage problems are increased by such phenomena.

These characteristics illustrate mining problems and also emphasize that costs will increase over the next few years. Stoker coal generally has sold for $5 to $7 per ton at mine mouth at the larger mines and the market price of coal at Sunnyside has been $5 to $7 per ton (Hileman, Collins and Wilson, 1970, p. 5; their work culminated in 1968).

Most of the coal is moved by rail, small quantities by truck. Rail costs in 1968 (Hileman, Collins and Wilson, 1970, p. 7) were as follows:

Single railroad car freight rates

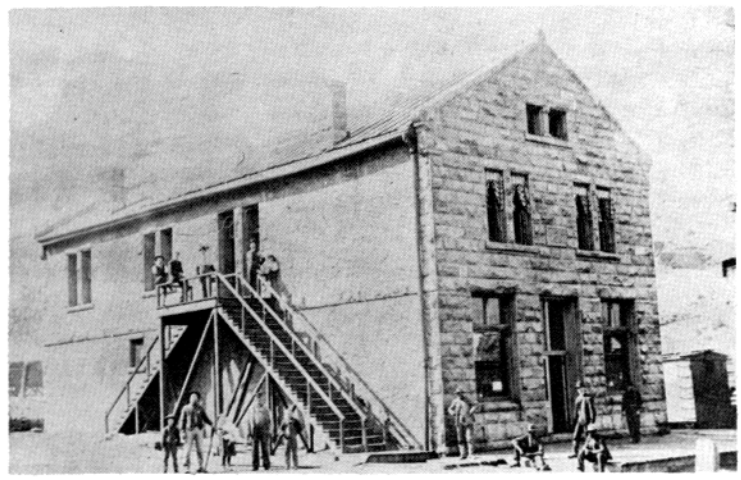
	Per ton
Carbon-Emery County mines to Salt Lake	$3.32
Columbia to Geneva, Utah Steel Plant	2.14
Sunnyside to Fontana, California Steel Plant	5.83

Recently unit trains have been put into operation; the rate from Columbia to Geneva (Utah County) is $1.97 per ton and from Sunnyside to Fontana is $4.80 per ton.

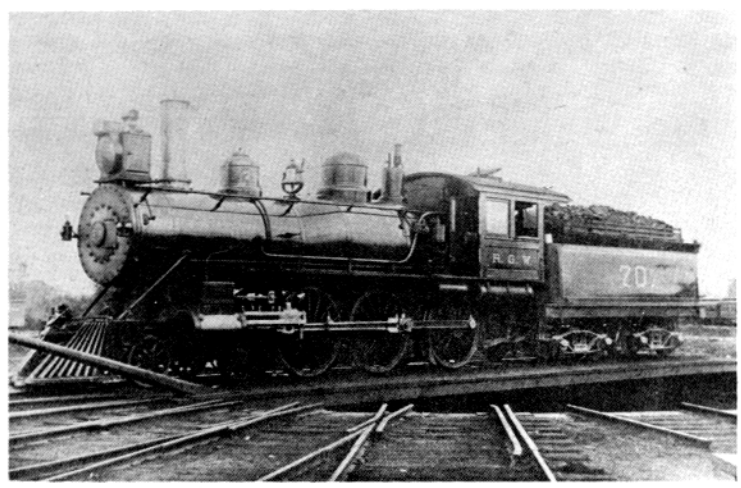
In the recent past, inroads were made by competitive fuels into the coal market. In spite of this, the Book Cliffs mines managed to maintain a steady production rate because of their excellent location, the transportation situation and the natural high quality of the product.

The demand will probably remain the same in the near future for the Book Cliffs mines. Even though the need for power is increasing in the nation it is felt that the Book Cliffs area will not immediately show any increase in that direction. The Intermountain area has not felt a power shortage as keenly as other areas. Even though the Pacific states will need to use coal for their power generation, other areas in Utah are considered more favorable to produce it. The Wasatch Plateau, Kaiparowits and Alton areas are expected to be developed first. Insofar as Sunnyside coal can be used to produce coke it will continue to be mined at a rate dictated by the steel companies. A shortage of coking coal is also becoming imminent in the U. S., and since such coals command a higher price, Sunnyside coal will probably be used for nothing else.

Forecasting is dangerous since a single event could double production or cut it in half. But through 1975, production should be maintained at the current rate or with a slight decrease. Thereafter through 1980, slight increases should be indicated. The Book Cliffs has long led Utah in coal production. It is believed, however, that development in other fields will challenge this distinction in the next 10 years.



Building in Castlegate, Utah, from which Butch Cassidy robbed the company payroll in the early 1900's. Photo copied from Helper Mining Museum original.



Locomotive used to pull coal to Soldier Summit from Helper 1910 to 1930. Photo copied from Helper Mining Museum original.

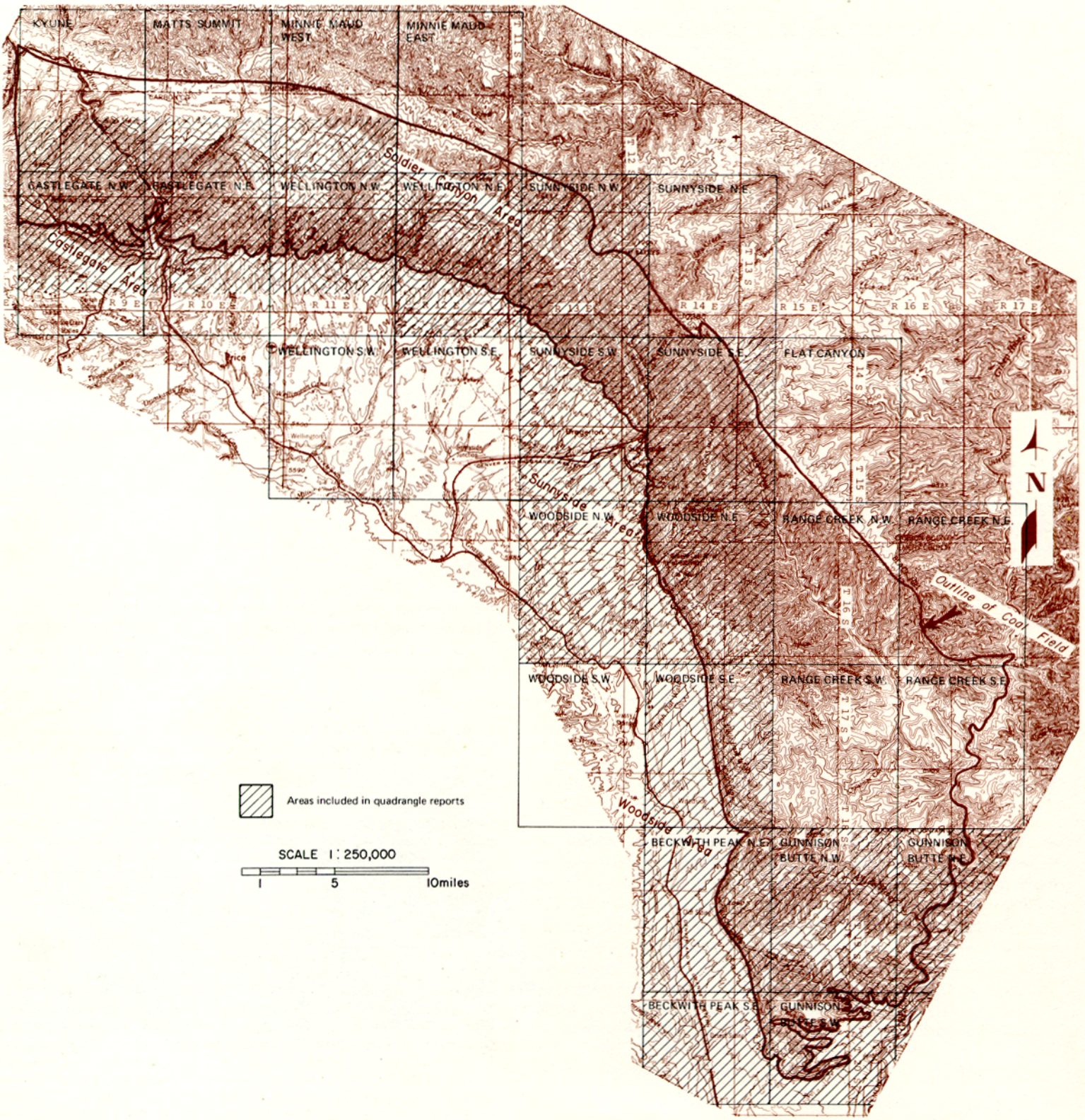


Figure 19. Quadrangle index map, Book Cliffs coal field.

QUADRANGLE REPORTS

BECKWITH PEAK NE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Beckwith Peak NE quadrangle is located near the south end of the Book Cliffs coal field immediately south of the point where the Price River commences to cut through the escarpment (figures 19 and 20). The north edge of the quadrangle lies a few miles south of Woodside village. The valley-like area at the base of the cliffs is the avenue for the principal routes of transportation which here are aligned north-south. These include the Denver and Rio Grande Western Railway and U. S. Highway 50-6 which extend from Denver, Colorado, to Salt Lake City, Utah. No routes provide access from the highway to the base of the cliff and none to the top of the Beckwith Plateau.

The highest elevation on the Beckwith Plateau is a little more than 7,000 feet and most areas on the top are between 6,000 and 7,000 feet. The base of the Book Cliffs is nearly everywhere about 5,200 feet so that the relief ranges between 800 and 1,800 feet. The highway crosses a drainage divide near Cliff Siding; to the north the washes are tributary to the Price River and to the south, to Saleratus Wash. Elevations on the Mancos flat range from 4,600 feet at the north and south map margins to almost 4,900 feet at Cliff Siding, then rise to 5,200 feet at the foot of the cliffs. The coal seams are located high on the cliffs at elevations in excess of 6,000 feet.

STRATIGRAPHY

Geologic mapping is preliminary and incomplete. The cliff was mapped by Fisher (1936) chiefly by triangulation and alidade but most of the upper surface of the Beckwith Plateau has not been mapped geologically or for coal. The quadrangle exhibits the Mancos Shale in the area below the cliffs and up to 500 feet on the lower part of the cliffs. The cliff face is mainly made up of the coal-bearing Blackhawk followed by the Castlegate Sandstone. The immediate upper surface of the Beckwith Plateau is made up of the Price River Formation. The Mancos is at least 4,200 feet thick and the Blackhawk is about 600 feet thick. The initial unit of the Blackhawk is a sandstone cliff about 150 feet thick that correlates with the Kenilworth Sandstone. This is overlain by a medium gray marine shale, much like the Mancos, 100 to 150 feet thick. These are followed by thick sequences of cliff-forming sandstone divided by thin shale and sandy shale beds. This sandstone member is more than 200 feet thick. Near the upper part of the member are coal beds at the horizon of the Sunnyside beds. The sandstone is finally succeeded by 60 to 100 feet of alternating sandstone, shale, carbonaceous shale and coal. Coal occurs in at least two horizons.

STRUCTURE

The structure on the Beckwith Peak NE quadrangle is a simple, mainly easterly dipping monocline. The dip averages 4 to 6 degrees but increases to as much as 10 degrees locally. Occasionally minor faults with displacements up to 25 feet occur.

PROPERTY CONTROL

The lands of the Beckwith Peak NE quadrangle are mostly owned by the Bureau of Land Management (91.1 percent). The state of Utah owns 7.8 percent and 1.1 percent are privately owned. The cliffs are the property of the BLM and state in about the same proportion as that of the remainder of land on the map (figure 14). The privately held land is found entirely along the Price River west of the Book Cliffs. None of this land is leased or permitted for coal at this time (1970).

COAL

Surface Information

The position of the coal in the Blackhawk is exemplified by the following section measured just north of the quadrangle in sec. 19, T. 18 S., R. 15 E.

	Feet
Castlegate Sandstone	
Blackhawk Formation	
Beckwith zone (Upper Shale Member)	
Sandstone with thin carbonaceous shales	6-10
Interbedded sandstone, shale and coal	.8
Sandstone, fine-grained with pyrite nodules	.5
Carbonaceous shale	.1
Coal	6.5
Shaley sandstone, carbonaceous shale and thin coal seams up to 14 inches	.40
Carbonaceous shale	.2
Coal	1.3
Carbonaceous shale	0.5
Shaley sandstone	.10
Sunnyside Sandstone (Middle Sandstone Member)	
Massive sandstone	.40
Thick-bedded to shaley sandstone	.20
Sunnyside coal bed	.4
Massive sandstone	~160
Mancos-like shale (Lower Shale Member)	~100-150
Kenilworth Sandstone (Lower Sandstone Member)	
Massive sandstone (Kenilworth)	~100-150
Mancos Shale	

Fisher's (1936, plate 12) three locations found on this quadrangle are presented here as four sections (figure 21), one for the Beckwith coal and the rest for the Sunnyside coal. None indicates the coal to be 4 feet or more thick in individual seams as found just across the Price River. All sections were measured with the alidade so that some discrepancy may exist in actual measurements. Fisher assumed the Sunnyside coal to average 2 feet in the south half of T. 18 S. He notes that the upper coal beds are lenticular and of local extent. With respect to T. 19 S., Fisher (p. 64-67) reports:

> At location 28 (section 3, Sunnyside coal) it is split by a 3½-foot sandstone parting into an upper bed 14 inches thick and a lower bed 12 inches thick. Between locations 27 and 28 (2 and 3) coal was seen only at the upper horizon. . . It is assumed that the bed has an average workable thickness of 2 feet 6 inches in the northern third of the area but only 14 inches in the southern two-thirds, owing to the presence of a sandstone parting. . .
>
> . . .In the northern part of the area the upper member of the Blackhawk Formation is largely shaley, and any coal that may possibly be present is obscured. In the neighborhood of location 28 (4) the upper part of this member is a cliff-making sandy rock that closely resembles the Castlegate. The separation is based largely on the relative thickness of the units but partly on the presence of the carbonaceous material in the lower beds and the absence of such material in what is here called the Castlegate. Owing to the cliff-making character of the beds near the top of the Blackhawk it was possible to measure five coal beds, three of which are of possible economic value. The upper one of these three is 1 foot 8 inches thick and is thought to be a lens. . .The other two beds are each about 3 feet thick and are separated by 9½ feet of sandstone and shaley sandstone. No coal at this horizon was seen very far to the north.

To the east the coal is expected to thin. No such beds are visible in the Green River Canyon (Gray Canyon) 10 miles to the east.

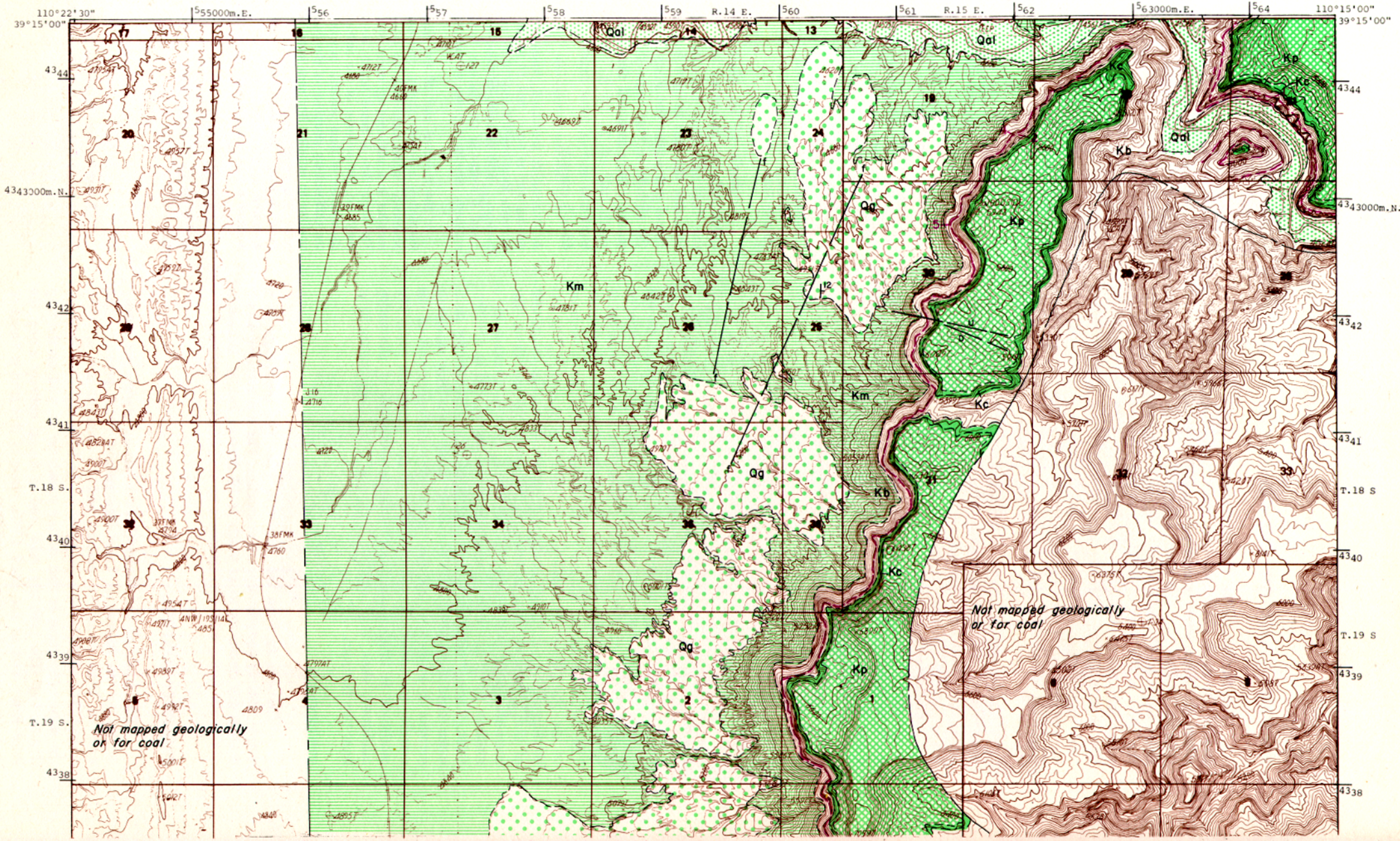
Subsurface Information

None of the coal has more than 1,000 feet of overburden. Coal has not been drilled for on the quadrangle.

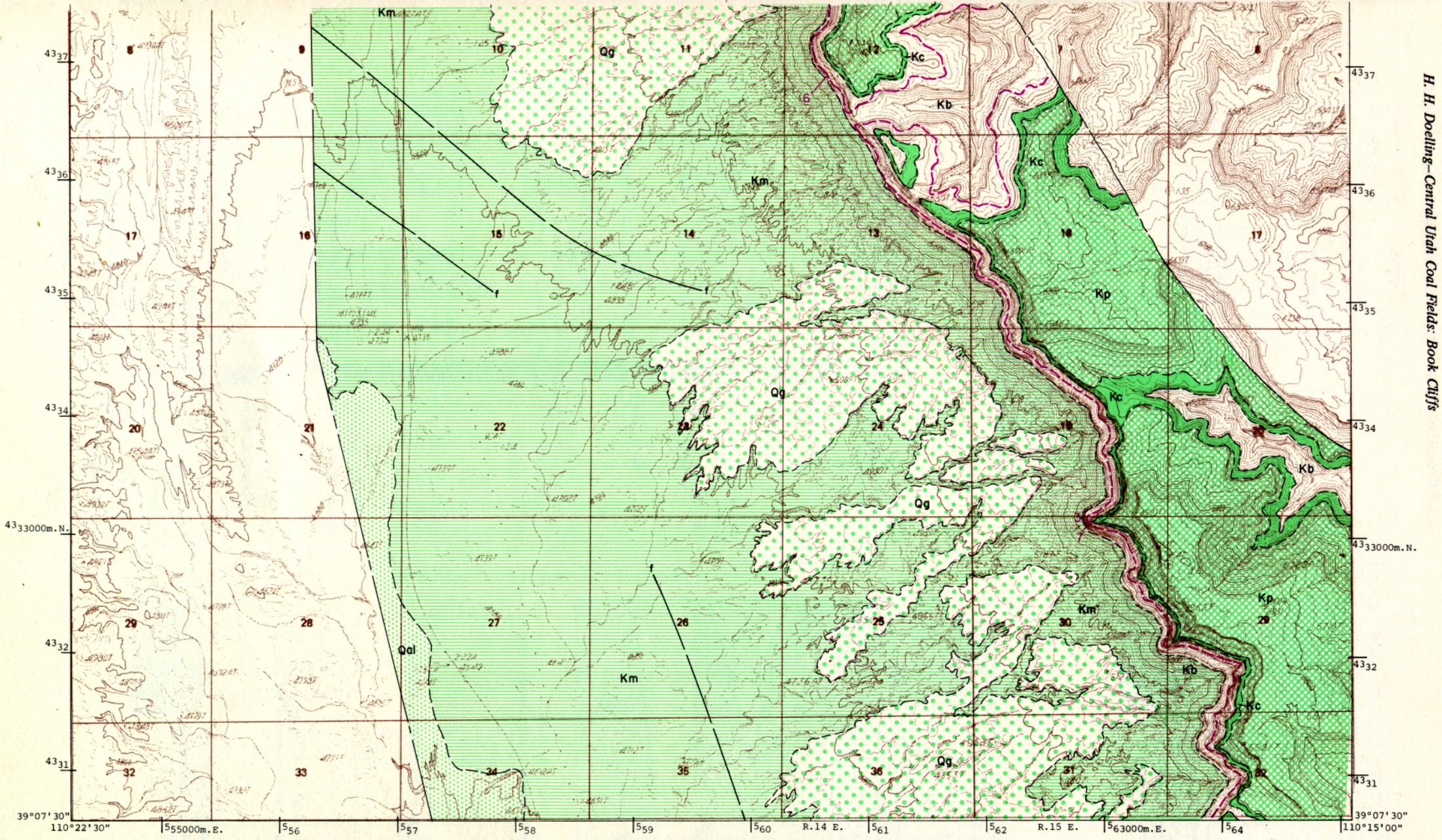
Quality of Coal

No analyses are available for coal on the quadrangle.

BECKWITH PEAK N.E., UTAH



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972



TOPOGRAPHY BY
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SCALE 1:42240

1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER

Geology and coal data by D. J. Fisher, 1936, USGS.

Figure 20. Coal and geology map, Beckwith Peak NE quadrangle (explanation pages 332-333).

EXPLANATION (figures 20, 22, 24, 27, 30, 32, 34, 36, 38, 40, 42 and 44)

32 1.0 Purple — Coal bed
Dashed where inferred or poorly exposed, dotted where burned. Thickness of coal in feet measured at triangles. Larger numbers refer to location of measured section shown on accompanying sheets.

Prospect

Coal mine

Purple — Burned zone
Area covered with natural clinker or red-burned sandstone.

DH — Coal drill hole

3 — Strike and dip of beds

Apparent dip of beds

Syncline
Axis, dashed where approximately located or where ill defined.

Anticline
Axis, dashed where approximately located or where ill defined.

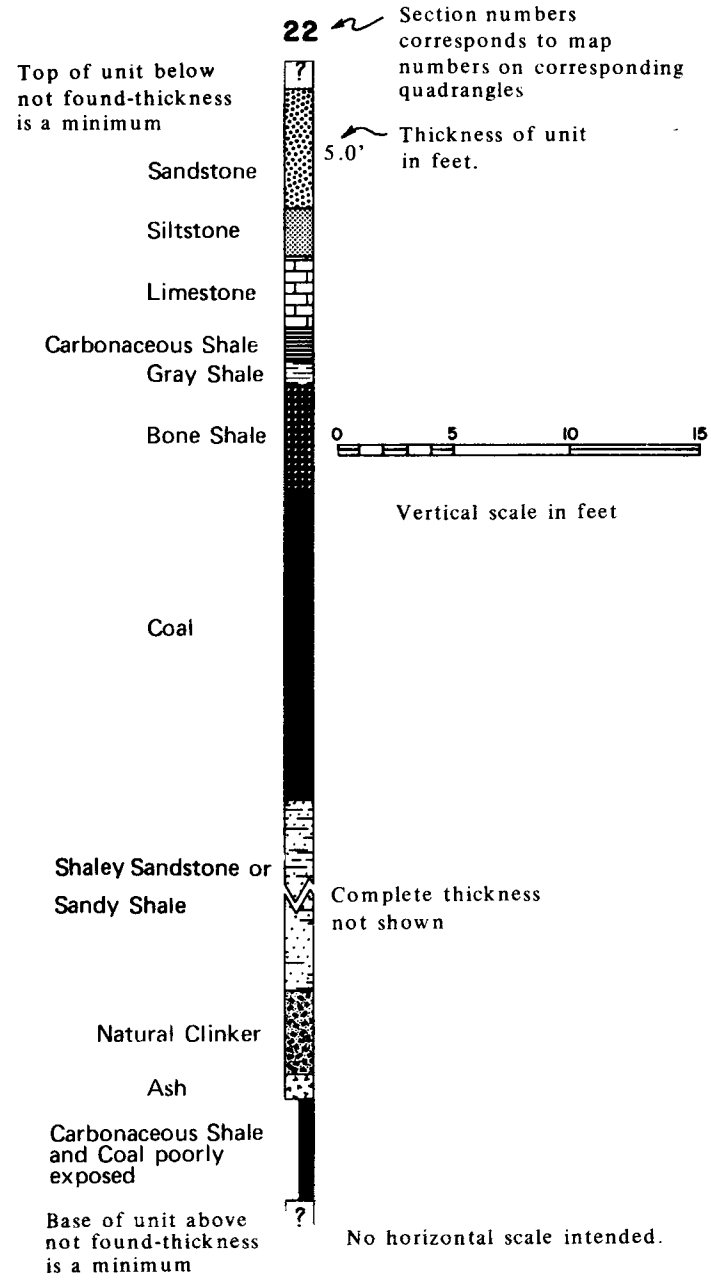
Monocline
Arrow points in direction of dip, dashed where approximately located or where ill defined.

Geologic unit contact
Dashed where location is approximate.

Horizontal strata

D U — Fault
Dashed where inferred or ill defined.

Explanation For Measured Sections



EXPLANATION (continued)

QUATERNARY

Qal — **Alluvium**
Stratified clay, silt, sand, gravel and some unsorted flood deposits.

Ql — **Gravel Deposits**
Partly consolidated, poorly sorted and stratified deposits of rock fragments of local origin, pediments or terrace, up to 50 feet thick.

TERTIARY

Tg — **Green River Formation**
Greenish gray and white claystone and shale, also contains fine-grained and thin-bedded sandstone. Shales often dark brown containing carbonaceous matter. Full thickness not exposed.

Tc — **Colton Formation**
Colton consists of brown to dark red lenticular sandstone, shale and siltstone, thins westwardly and considered a tongue of the Wasatch. 300-2,000 feet thick.

Tw — **Wasatch Formation**
Wasatch predominantly sandstone with interbedded red and green shales with basal conglomerate. Found in east part of field and equivalent to Colton and Flagstaff to west. About 3,000 feet thick.

Tf — **Flagstaff Formation**
Flagstaff mainly light gray and cream colored limestones, variegated shale and fine-grained, reddish brown, calcareous sandstone. 0-500 feet thick.

TERTIARY

CRETACEOUS

KTn / KTt — **North Horn Formation**
Gray to gray green calcareous and silty shale, tan to yellow-gray fine-grained sandstone and minor conglomerate. Unit thickens to west. (KTn) 350-2,500 feet thick.

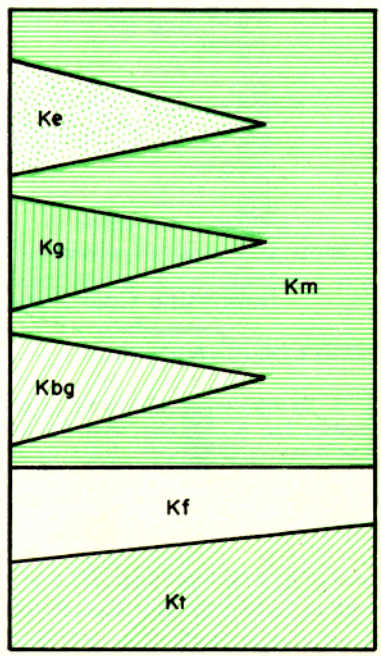
Tuscher Formation
Light gray to cream-white friable massive sandstone and subordinate buff to gray shale that exhibits light greenish cast. Contains minor conglomerate and probably represents lower part of North Horn, only present in east part of field. (KTt) 0-200 feet thick.

Kp — **Price River Formation**
Yellow-gray to white, medium-grained sandstone and shaley sandstone with gray to olive green shale. Contains carbonaceous shale with minor coal and thickens along east edge of field. 500-1,500 feet thick.

Kc — **Castlegate Sandstone**
White to gray, fine- to medium-grained, argillaceous massive resistant sandstone thinning eastwardly with subordinate shale. Carbonaceous east of Horse Canyon, but coal is thin and lignitic. 100-500 feet thick.

Kb — **Blackhawk Formation**
Cyclical littoral and lagoonal deposits with six major cycles. Littoral deposits mainly thick-bedded to massive cliff-forming yellow-gray fine- to medium-grained sandstone, individual beds separated by gray shale. Lagoonal facies consist of thin- to thick-bedded yellow-gray sandstones, shaley sandstones, shale and coal. Coal beds form basis of Book Cliffs coal field. Unit thins eastward grading into the Mancos Shale. 600-1,100 feet thick.

Ks — **Star Point Sandstone**
Yellow-gray massive medium- to fine-grained littoral sandstone tongues projecting easterly, separated by gray marine shale tongues projecting westerly. 0-580 feet thick.



Mancos Shale
Gray marine shale, locally heavily charged with carbonaceous material, slightly calcareous and gypsiferous, nonresistant forming flat desert surfaces and low rounded hills and badlands. Separated mainly to the west into tongues by westward-projecting littoral sandstones which eventually grade into shale. Sandstones are fine- to medium-grained, yellow-gray to tan and medium-bedded to massive and cliff forming. Km, Mancos Shale; Ke, Emery Sandstone; Kg, Garley Canyon Sandstones; Kbg, Blue Gate Shale; Kf, Ferron Sandstone; Kt, Tununk Shale. Total thickness is 4,300-5,050 feet.

Kd — **Dakota Sandstone**
Heterogeneous sandstone, conglomerate and shale, thin resistant cuesta former. 2-126 feet thick.

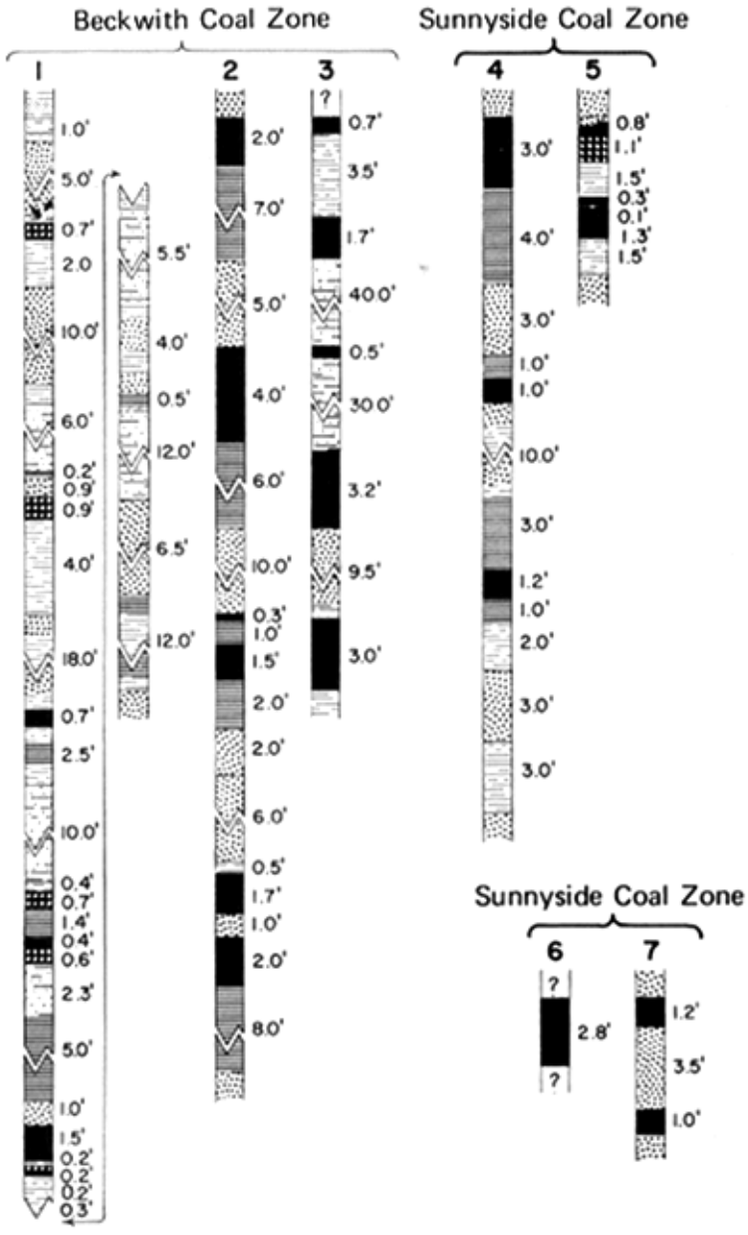


Figure 21. Coal sections of Beckwith Peak NE quadrangle (vertical scale: 1 inch = 8 feet).

Mines and Development

No mines have been opened on the quadrangle and there has been no development for coal.

Reserves

With the available data, reserves cannot be calculated. All sections indicate individual seams are less than 4 feet thick. The area has not been carefully examined and some local areas of thick coal may yet be found. Fisher (1936, p. 56) calculated the following tonnages for the quadrangle extending back 2 miles from the line of outcrop (table 12).

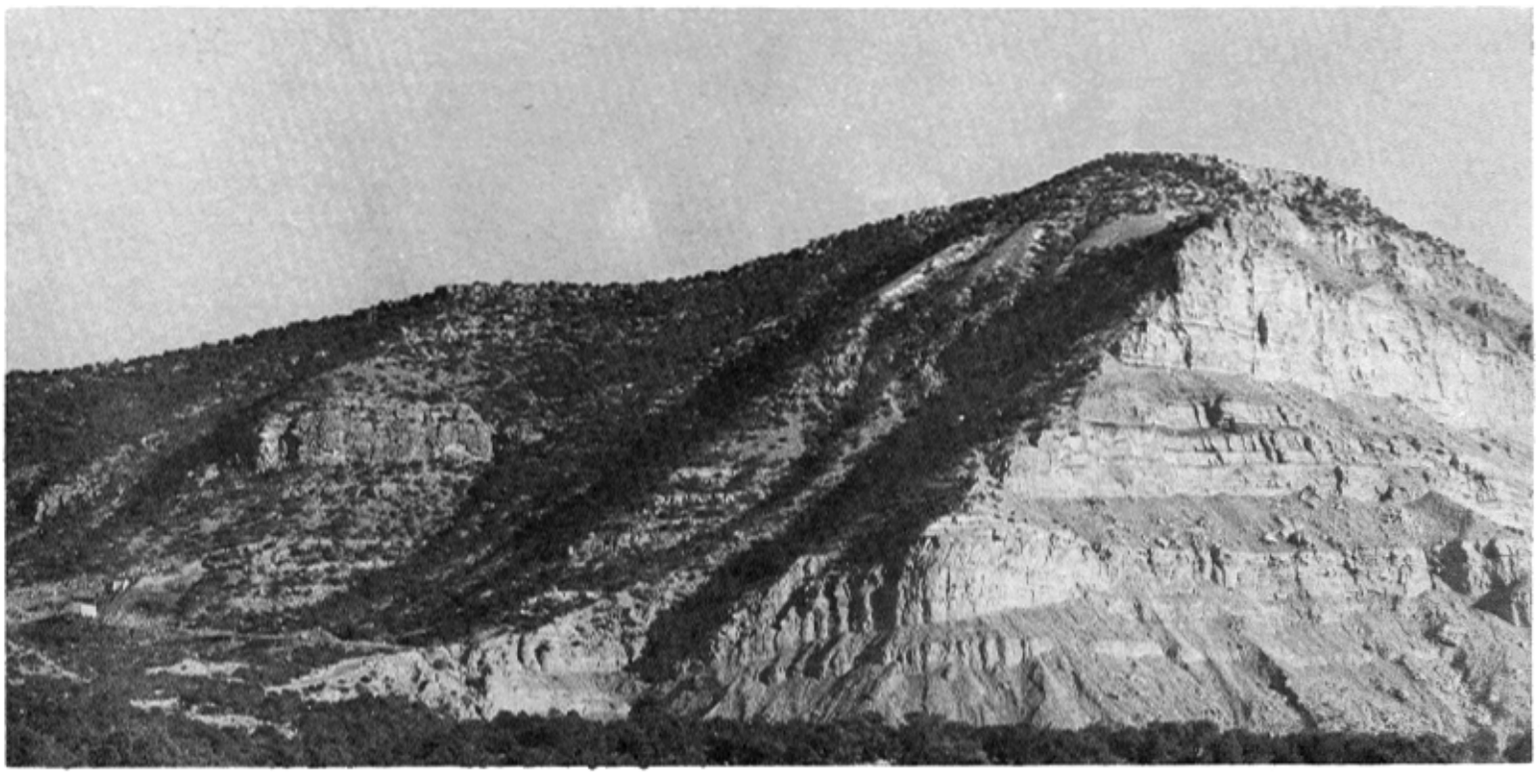
Table 12. Coal reserves of the Beckwith NE quadrangle.

	Average thickness	Sq. miles area	Millions of tons
Upper Blackhawk, higher part	1.5	0.75	1
Upper Blackhawk, lower part	6.0	0.80	6
Sunnyside	2.0	5.69	13
Sunnyside	2.5	3.66	11
Sunnyside	1.17	3.09	4
Total coal			35

PRINCIPAL WORK

Most of the data were derived from Fisher (1936).

Looking easterly at the Book Cliffs about a mile south of Horse Canyon. Mine is the abandoned Book Cliffs mine. Lower sandstone is the Kenilworth; next is the Sunnyside, capped by the Castlegate.



BECKWITH PEAK SE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

Only a small part of the Book Cliffs is exposed on the Beckwith Peak SE quadrangle (figures 19 and 22). With reference to the coal field the map area lies near the southeast end. Most of the area involves the valley of Saleratus Wash. Along the west boundary are the cuestas and hogbacks of the east flank of the San Rafael Swell and in the northeast corner of the map are the coal-bearing cliffs. The relief to the west is about 400 feet maximum, diminishing to practically nothing in the area of Saleratus Wash. Some of the washes, however, have carved vertically walled gullies up to 25 feet deep. The relief increases again westerly, the land becoming hilly and knobby until the base of the Book Cliffs is reached. The maximum relief of the cliffs is 1,700 feet although for the most part the cliff is 1,000 feet high. Elevations in the valley bottom range from 4,200 feet to the south to 4,600 feet to the north. The maximum elevation along the east flank of the San Rafael Swell is 4,936 feet and the maximum elevation above the Book Cliffs is 6,837 feet. The coal occurs at elevations above 5,600 feet on the cliff.

The valley of Saleratus Wash is used as the major transport route through the area. The main line of the Denver and Rio Grande Western Railway, a double wood-pole power transmission line and U. S. Highway 50-6 follow it. These routes are about 3 miles west of the cliffs but presently no access roads lead to the cliffs and the tops are completely inaccessible. The walls are nearly vertical making even on-foot exploration almost impossible. The area is 12 miles northwest of the town of Green River. The top of the cliffs is known as the Beckwith Plateau.

STRATIGRAPHY

The area has been mapped in reconnaissance geologically and for coal. On the map (figure 22) the geology is shown only from Saleratus Wash eastward since the formations of the San Rafael Swell are older and of no bearing on the coal deposits. The Ferron Sandstone Member of the Mancos is exposed on the east flank of the swell but is barren of coal. Important coal deposits are being mined on the west flank 45 miles to the west.

The oldest unit exposed is the Mancos Shale and, if everything above the Dakota to the base of the Mesaverde is included, it is at least 4,200 feet thick. Mostly it is a slightly bluish medium to dark gray fissile to nodular shale. It often carries veinlets of gypsum and calcite. Thin beds of sandstone occasionally occur within it, usually tan and brown. Occasional thin beds of dense limestone also occur within it. A nonresistant formation, it creates areas of low relief. At least 500 feet of the Mancos make up the lower part of the Book Cliffs being supported by the overlying resistant sandstones.

The Mesaverde Group in the quadrangle completes the stratigraphic sequence and consists of the Blackhawk, Castlegate and Price River formations. The Blackhawk Formation is the coal-seam bearer and here consists of a lower massive cliff-forming sandstone, a middle shale unit, a middle sandstone unit and an upper lagoonal sequence of alternating sandstone, shaley sandstone, shale, carbonaceous shale and coal. The lower sand is fine- to medium-grained with numerous thin beds of sandstone below the main massive part. It probably correlates with the Kenilworth Sandstone in the Book Cliffs to the north and west. The middle shale is exactly like the Mancos and probably represents a westward-extending tongue of that unit. The middle sandstone consists of at least two benches of cliff-forming sandstones often separated by shale or coal, which probably corresponds to the Lower Sunnyside horizon. The alternating beds also contain coal seams. The lower sandstone and middle shale are at least 200 feet thick and may be as thick as 300 feet. The middle sandstone is about 220 feet thick and the upper lagoonal beds are about 60 feet thick.

The sandstones of the cliff-forming Castlegate are readily discernible from those of the Blackhawk. They are 100 to 200 feet thick and somewhat coarser in grain than the Blackhawk sands. Above the Castlegate are scabs of the softer Price River Formation, a shale and sandstone sequence.

STRUCTURE

The structure is simple; the strike trends nearly north-south and the dip is 5 to 6 degrees to the east. Some faults have been plotted below the cliffs, but the coal cliffs are relatively free of them.

PROPERTY CONTROL

The lands of the Beckwith Peak SE quadrangle are owned by the Bureau of Land Management (86.4 percent) and by the state of Utah (13.6 percent). The division of land is about the same in the area of the Book Cliffs proper. No current leases or permits for coal exist on the land.

COAL

Surface Information

Seven coal sections are available (figure 23), four from the Sunnyside horizon and three from upper beds. The maximum seam at the Sunnyside horizon is 3 feet 2 inches thick and is split.

According to Fisher (1936, p. 68-69):

> The coal, which is weathered, is dull velvety black to brown-black and carries some resin, fusain and carbonized wood. Cracks in it contain veinlets of gypsum. . .It may be assumed to have an average thickness of 2 feet over 2 square miles in this township (T. 20 S., R. 15 E.), but it seems unlikely to be of any economic value owing to its thinness, its probable high ash content, its inaccessible position and its shale roof and floor.

All but one of Fisher's sections, here repeated, were taken by alidade and so are of doubtful accuracy. He indicates that all coal seems to disappear in an easterly direction, hinting that the area is of little value. Further outcrop investigations are necessary to confirm this.

Subsurface Information

No drill-hole data are available for the quadrangle, but all the coal is believed within 1,000 feet of the surface.

Quality of Coal

No analyses are available of the coal.

Mines and Development

No mines and no development for coal are reported for the quadrangle.

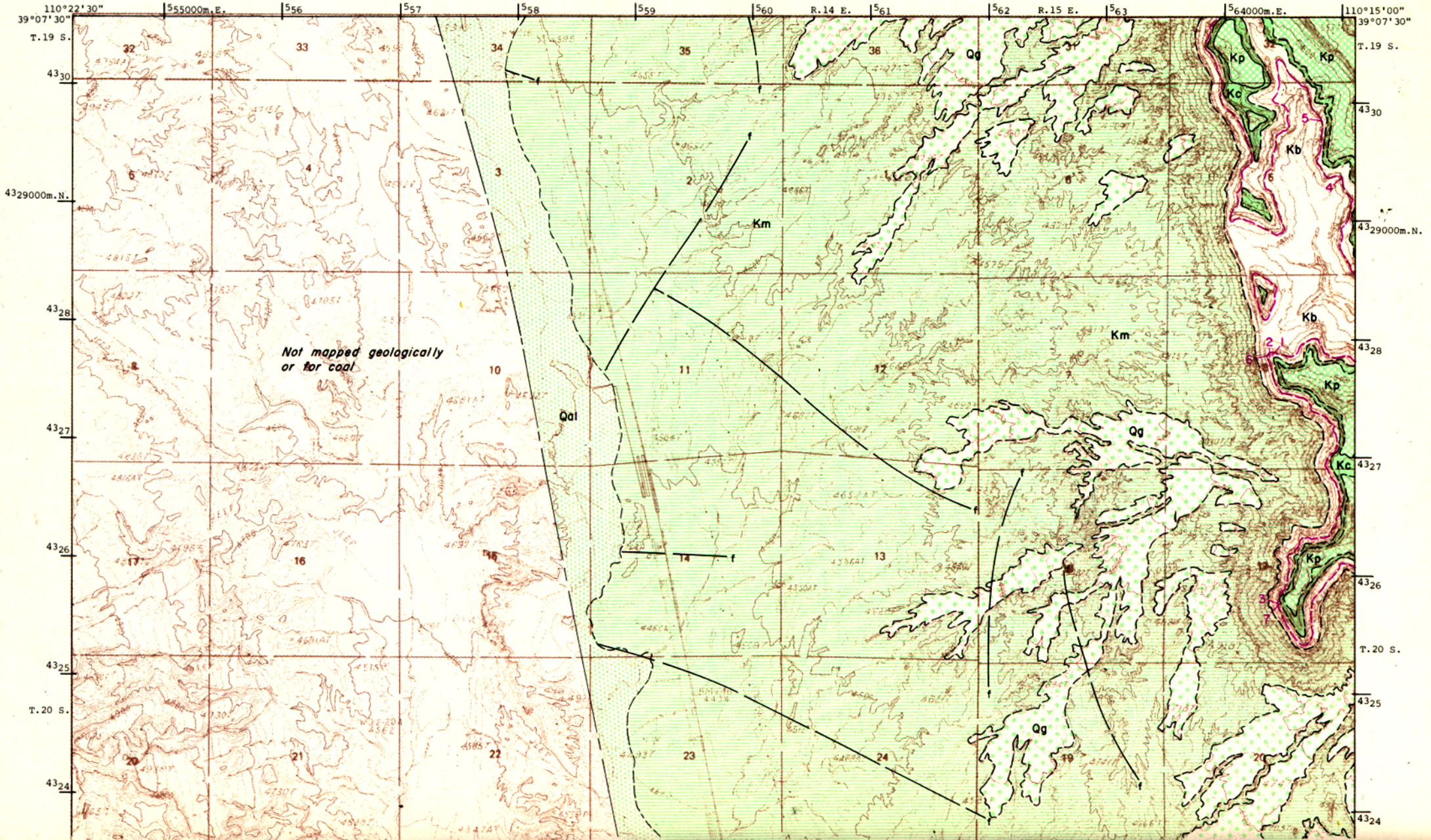
Reserves

No reserves of coal in beds more than 4 feet thick are present on this quadrangle. The area has only been cursorily checked; small tonnages may be located, but this is doubtful.

PRINCIPAL WORK

Practically all the data presented for the Beckwith Peak SE quadrangle are from Fisher (1936).

BECKWITH PEAK S.E., UTAH



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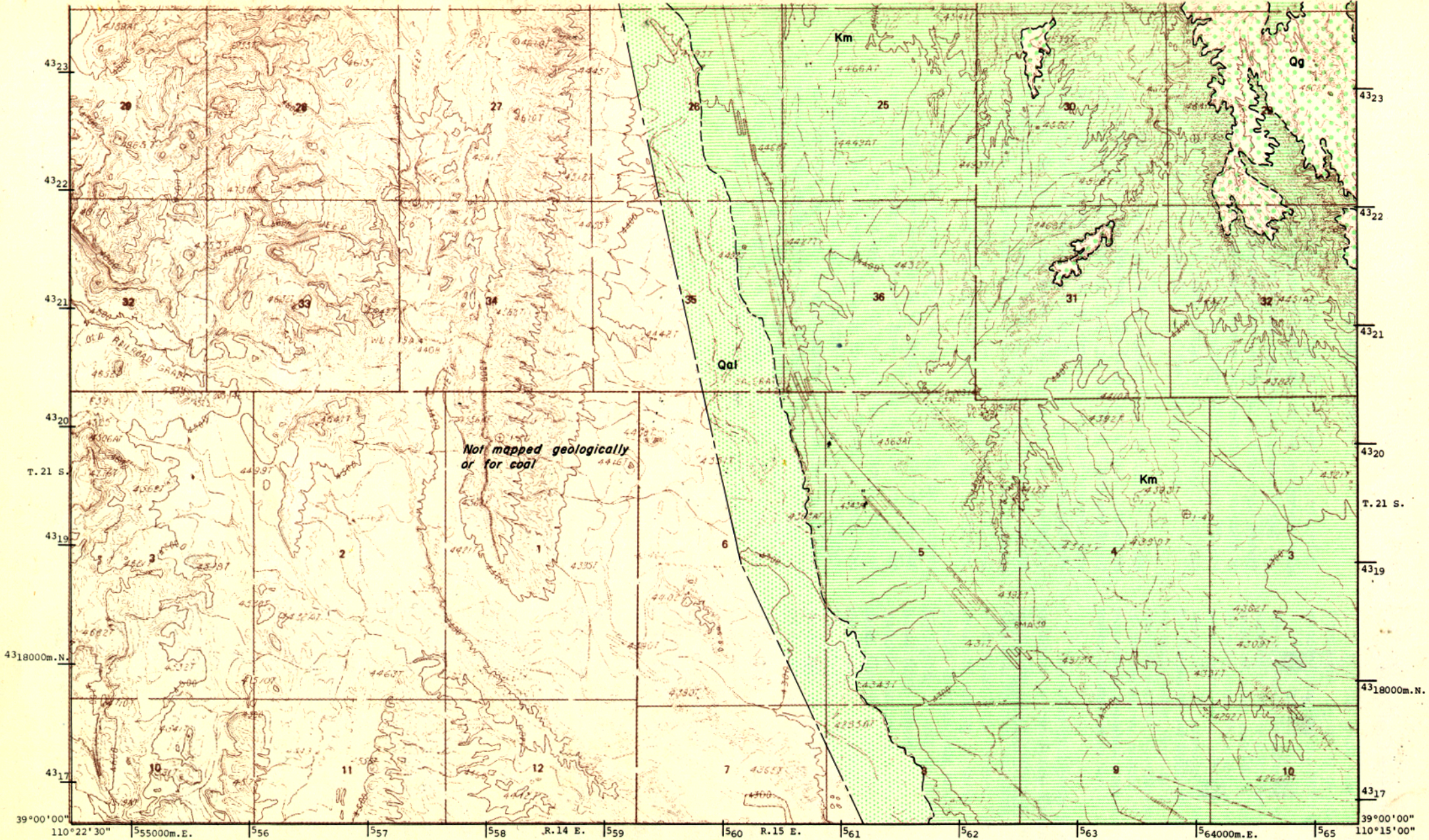


Figure 22. Coal and geology map, Beckwith Peak SE quadrangle (explanation pages 332-333).

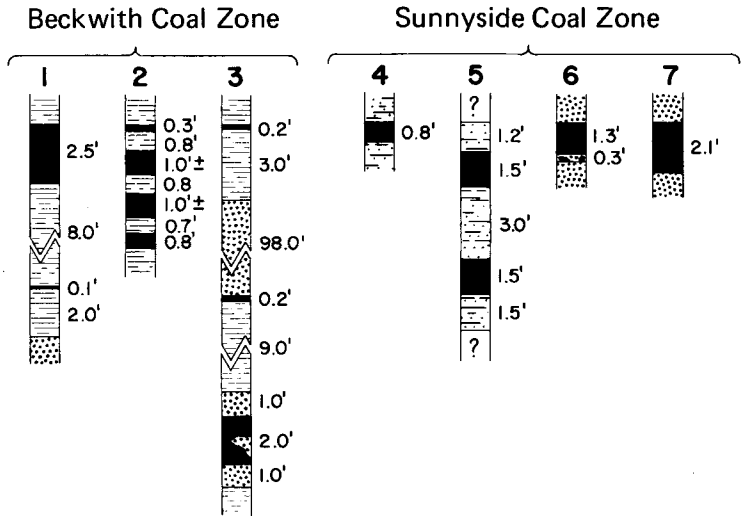


Figure 23. Coal sections of Beckwith Peak SE quadrangle (vertical scale: 1 inch = 8 feet).

CASTLEGATE–KYUNE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Castlegate-Kyune quadrangle is a composite produced by joining the north two-thirds of the Castlegate NW quadrangle with the south one-third of the Kyune quadrangle (figures 19 and 24). The source quadrangles are those of the U. S. Geological Survey topographic series. The quadrangle is the westernmost assigned to the Book Cliffs coal field; the boundary with the Wasatch Plateau coal field is about 1½ miles farther west. Essentially the map covers the Spring Canyon district of the Castlegate area.

Spring Canyon and Ford Ridge (Forge Mountain) are the principal topographic features. The Price River Canyon cuts across the northeast corner of the map and the Book Cliffs are found along the south margin. The principal coal mines of the area have been opened on the walls of Spring Canyon and its principal tributaries. The base of the Book Cliffs is at elevations of 6,000 to 7,500 feet. The tops range from 7,250 feet in the east to almost 8,500 feet to the west. Above the cliff the area is mountainous and the highest point is marked by Forge Mountain, 9,840 feet above sea level. The coal mines lie between 6,500 and 7,500 feet.

The Utah Railway skirts the base of the cliffs and connects with the D&RGW Railway at Castlegate about a mile east of the east map boundary. A branch line of the D&RGW runs in the bottom of Spring Canyon as far up as the abandoned town of Standardville and leaves the main line near Helper. A paved road parallels the canyon and the railroad connecting with U. S. Highway 50-6 to the east. A well maintained secondary road gives access to the Hardscrabble Canyon mines. Only a few jeep-type or recreation roads give access to the remainder of the area. Both the D&RGW Railway and U. S. Highway 50-6 use the Price River Canyon and extend westward to Salt Lake City and eastward to Denver.

STRATIGRAPHY

The Mancos Shale is exposed at the base of the Book Cliffs. Only the upper 800 feet of the 5,000-foot unit are present on the mapped area. The dark bluish gray shale is mainly represented by the upper Masuk Tongue Member which becomes sandy toward the top. The Masuk makes up the upper 800 feet of the Mancos and its outcrops are mainly rounded hills or steep badland cliffs, the soft shales supported by the overlying sandstones of the Mesaverde Group. The surface of the Mancos is usually rubble strewn with sandstone blocks and gravel from overlying beds. In some places benches of gravel mark an old temporary base level. Also small landslides have developed on the incompetent unit.

The first unit of the Mesaverde Group is the Star Point Sandstone. It is barren of coal and consists of three sandstone tongues projecting eastward separated by two westward-projecting tongues of the Mancos Shale. The lowest sandstone is the Panther Tongue which thickens from east to west being about 100 to 125 feet along the west edge of the quadrangle. "The top surface is cross-bedded and well indurated, and the beds of sandstone range in thickness from 1 to 10 feet. The lower half of the bed is generally thin-bedded sandstone grading downward into sandy shale and shale at the base" (Clark, 1928, p. 177).

The Storrs Tongue lies 150 feet above the top of the Panther with sandstone ranging between 15 and 30 feet thick. The Spring Canyon Tongue lies 100 to 125 feet above the Storrs and is 150 feet thick in Spring Canyon. Both units thin eastward. The base of the tongues is usually gray siltstone, transitional from Mancos-like shales. The matrix is usually clay, rich in organic particulate matter and may constitute 50 percent of the rock. The grains are dominantly quartz with abundant dolomite. For the most part the tongue consists of a fairly sorted fine- to medium-grained cross-bedded sandstone. Cementation is with calcite and individual beds are separated by a shaley argillaceous sandstone. The sandstones are resistant, often forming a cliff.

The coal beds occur in the next formation, the Blackhawk Formation, consisting of cliffy sandstone beds and lagoonal sediments. According to Clark (1928, p. 118):

> The coal-bearing member of the Blackhawk Formation ranges through a thickness of 900 to 1,300 feet of strata, consisting of massive gray to buff sandstone, sandy shale, shale and coal beds, with the sandstone in excess of the other rocks. The sandstone is composed mainly of semirounded fine and coarse quartz grains cemented in most places by carbonate of lime. It is reasonably well consolidated, but not highly indurated, except in some of the fine-grained and highly calcareous beds. The shale is generally more or less sandy, but in places thinly laminated shale occurs, and adjacent to the coal beds much of it contains some carbonaceous material. . .The lower half of the coal-bearing division of the Blackhawk Formation contains three economically important coals or coal groups, each of which has a thick cliff making sandstone at its base.

The lower coal group is known as the Spring Canyon and is underlain by the Spring Canyon Tongue of the Star Point Sandstone. The coal occurs in an interval of 60 to 100 feet. Then the Aberdeen Member consisting of 80 feet of sandstone and 100 feet of lagoonal beds follows. The Aberdeen Sandstone is a cliffy littoral unit making an easily recognized key bed. The lagoonal beds contain three to four valuable coal beds. In the upper part of the Blackhawk no additional diagnostic sandstone beds and no additional thick valuable coal seams occur. The interval is marked by lenticular sandstone, shale, thin coal beds and a little carbonaceous shale. Coal beds are often burned at the outcrop and associated rocks have been melted, fused and altered in color, usually to red. The Blackhawk has a total thickness of about 1,200 feet in the quadrangle and forms a step-like outcrop with the risers more prominent than the planars.

The Castlegate Sandstone is a single bed of massive sandstone about 450 to 500 feet high. It is medium- to coarse-grained and disconformably overlies the Blackhawk. Mostly the color is gray to yellow-gray but on weathered surfaces may be brown. It contains no coal and usually crops out along the top of the Book Cliffs. The mountains continue to rise above the Castlegate but not as steeply as the Star Point-Blackhawk-Castlegate sequence. Above the Castlegate are 900 to 1,000 feet of sandstone, shale and sandy shale beds. The sandstones are resistant, cliffy and yellow-gray to white; the shales are gray to olive-green and slope formers. This unit is known as the Price River Formation.

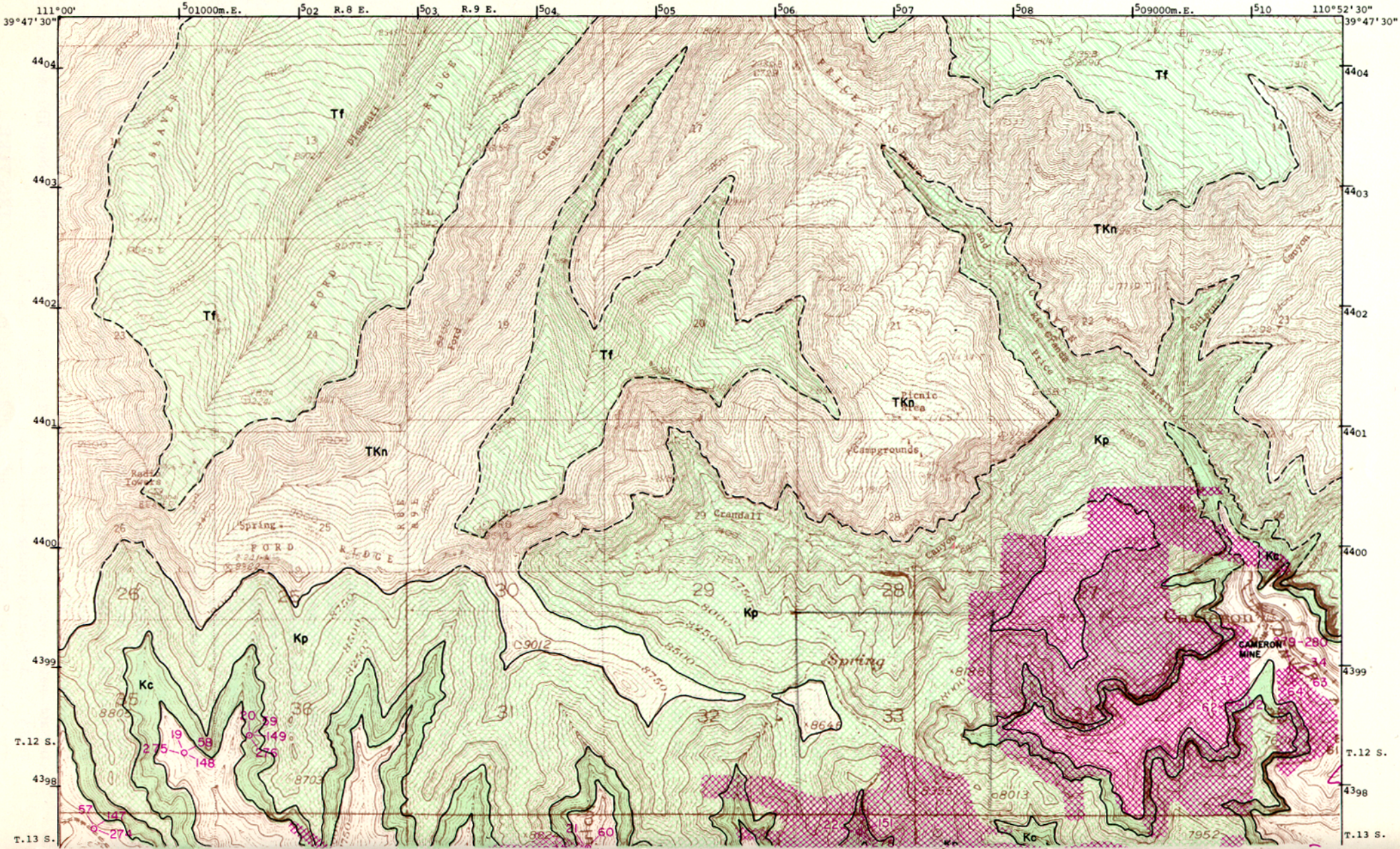
Clark (1928, p. 120) notes the contact between the North Horn Formation and the Price River Formation is unconformable in places indicated by a basal conglomerate. Gross (1961, p. 32) states that no evidence of a lithologic or time break between the two units exists and he places the base of the North Horn below a fairly thick and continuous green-gray shale overlying thick tan and light gray sandstones interbedded with thin shales and siltstones. Young (1955, p. 187) indicates that the North Horn-Price River contact is gradational in the Castlegate area and drawn where redbeds first appear. The North Horn consists of variegated shale, sandstone with subordinate conglomerate and freshwater limestone. In Price Canyon the unit is 2,200 feet thick and contains thin beds of poor coal. The lower part of the North Horn is Cretaceous in age and the upper part Paleocene.

The youngest consolidated unit on the Castlegate-Kyune quadrangle is probably the Flagstaff Limestone exposed as a hard cap holding up northward-dipping cuestas in the north part of the area. It consists of thin-bedded limestone, shale and sandstone. The microcrystalline lime beds resemble a compacted limy spring deposit. The shales are variegated and the less prominent sandstones are fine- to medium-grained, calcareous and red-brown. The unit is about 500 feet thick on the quadrangle.

STRUCTURE

The regional dip is northward and the coal beds drop 450 to 600 feet per mile or 4 to 6 degrees. The steeper (6 degree-) dips

CASTLEGATE — KYUNE QUADRANGLE



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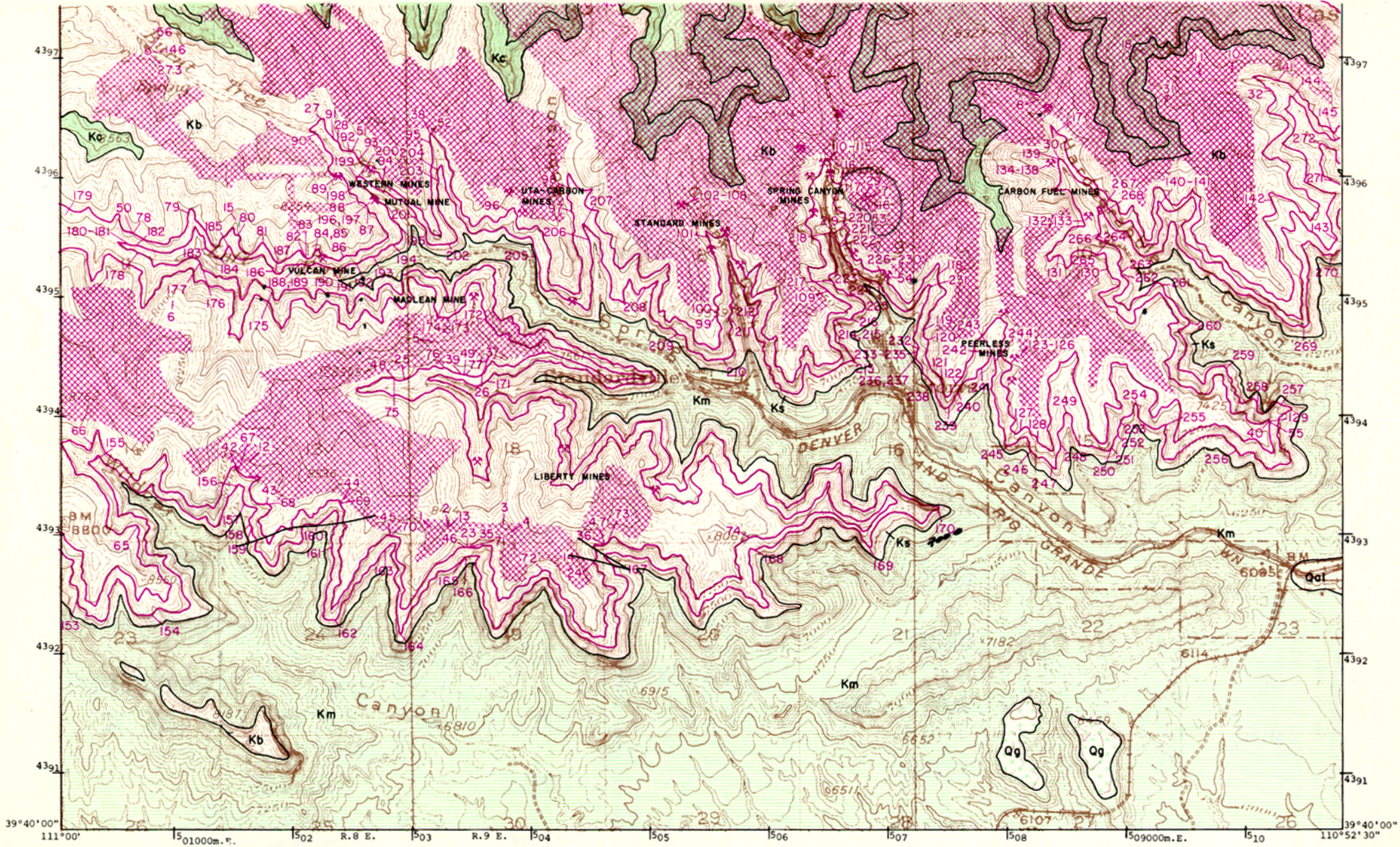


TOPOGRAPHY BY
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SCALE 1:42240

Geology and coal data by F. R. Clark, 1928, USGS.

Figure 24. Coal and geology map, Castlegate-Kyune quadrangle (explanation pages 332-333).

occur at a flexure trending north, north of Hardscrabble Canyon. A shallow anticline lies to the west and a shallow syncline to the east. Faults present in a few places are of small displacement. The fault in SW 13-13S-8E has a throw ranging up to 25 feet. The faults in NW 20-13S-9E have displacements ranging up to 14 feet and the fault in 12-13S-8E (Spring Canyon) has a maximum displacement of 13 feet.

PROPERTY CONTROL

Ownership of lands in the Castlegate-Kyune quadrangle is divided as follows: private property 55.4 percent, Bureau of Land Management 38.4 percent and Utah state land 6.2 percent.

Almost all the coal outcrops fall on private lands but behind the outcrop scattered state and BLM properties lie. The land below the cliffs is controlled by BLM. Practically all lands with less than 1,000 feet of overburden are currently (1970) held as private coal land. Most coal land with 1,000 to 2,000 feet of overburden is held by current leases, federal and state. In essence only the coal lands in the north third of the Kyune portion of the quadrangle are open. Companies, individuals or organizations that control lands are: Carbon Development, Carbon-Emery Bank, Duvels, Inc., Liberty Fuel Co., North American Coal, Royal Coal Co., Spring Canyon Coal Co., Western Coal and Vulcan Fuel.

COAL

Surface Information

At least eight coal beds are of sufficient thickness to mine on the Castlegate-Kyune quadrangle. They are not consistent throughout the area so in each locality, only two to five are of interest. The beds are lenticular, thin and thicken or disappear altogether and often split into several benches. The condition of the beds is represented by 280 measured sections (figure 25). The position of each bed in the stratigraphic column follows:

		Feet
Upper beds (within 325 ft above the Kenilworth bed)		
	Individual beds	0-4
Kenilworth (Castlegate "D") bed		0-5
Castlegate Group 145-170 feet	Interval including Kenilworth Sandstone	70
	Castlegate "C" bed	0-7
	Interval	45-70
	Royal Blue bed	0-4
	Interval	25-30
	Castlegate "B" bed	0-9
	Interval	20-60
	Castlegate "A" bed	1-17
Spring Canyon Group 100-125 feet	Interval including Aberdeen Sandstone	80-170
	Spring Canyon c sub 1	1-7
	Interval	15-30
	Spring Canyon b sub 2	1-7
	Interval	25-75
	Spring Canyon a sub 3	0-8
Spring Canyon Sandstone (Star Point)		

The Spring Canyon coal group is the lowest sequence on the quadrangle. In the Scofield NE quadrangle, immediately to the west, this interval is represented by the Hiawatha bed and perhaps the Gordon bed. In 23-13S-8E where the Hiawatha enters the Castlegate-Kyune quadrangle the bed is 5 feet thick: In sec. 15 of the same township a bed 7 feet thick lies 45 feet above the Hiawatha and in sec. 16 the easternmost measurement of the Gordon bed shows 4.4 feet of badly split coal. On this quadrangle the interval including these three beds is represented by a maximum of five beds, at least two of which are workable. In the west part of the quadrangle the interval containing the Spring Canyon Group is sandwiched between two prominent sandstones, the lower Spring Canyon and the upper Aberdeen, which are 100 to 125 feet apart. The interval between the two diminishes eastward and somewhat east of the Price River the sandstones merge, eliminating the coal. The area of best development is in Hardscrabble and Spring canyons. The coal beds are usually divided into three—upper, lower and those that fall between. The lowest bed is known as the Sub 3 bed and correlates with the Hiawatha to the west. The bed ranges

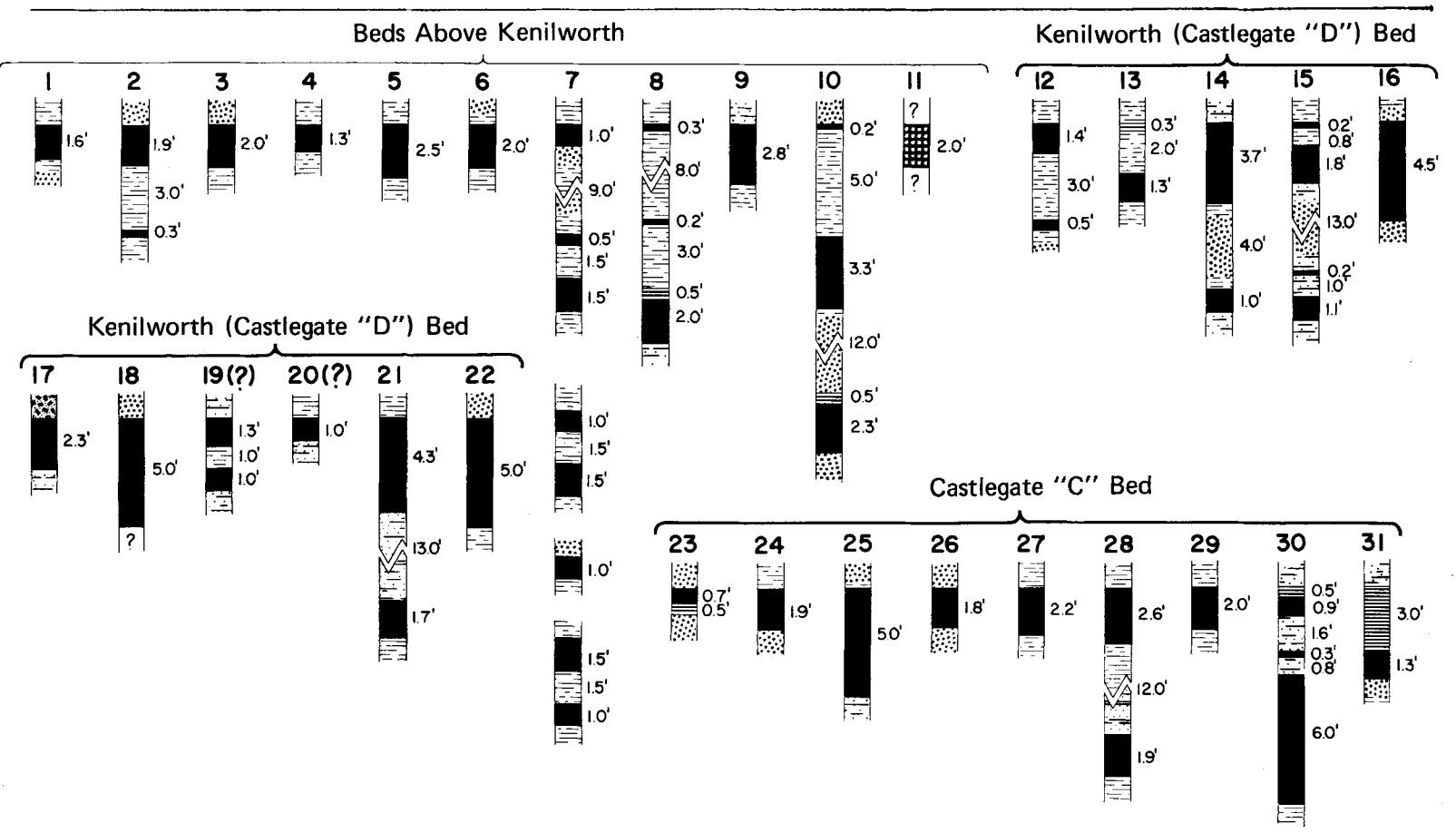
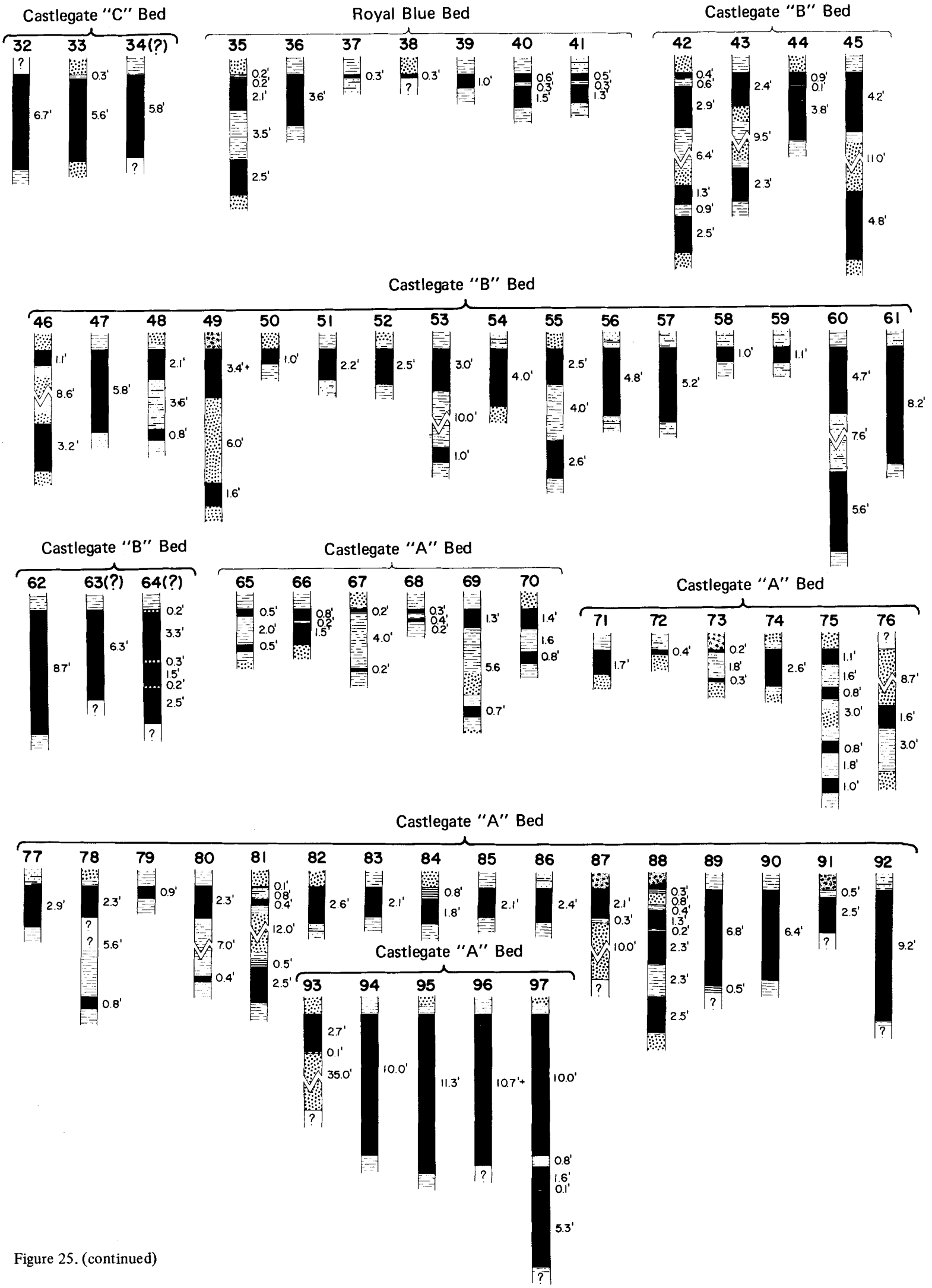


Figure 25. Coal sections of Castlegate–Kyune quadrangle (vertical scale: 1 inch = 8 feet).



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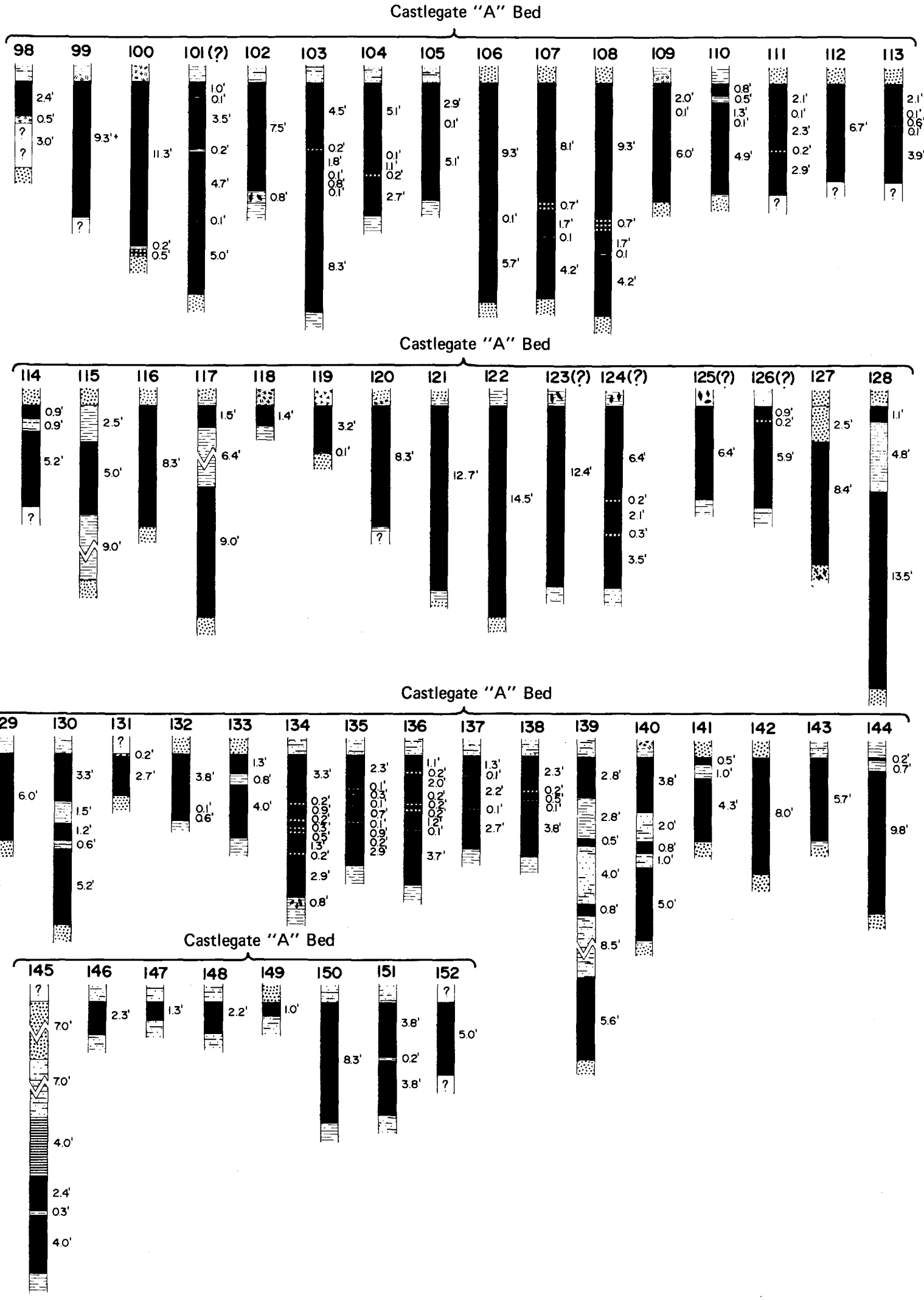

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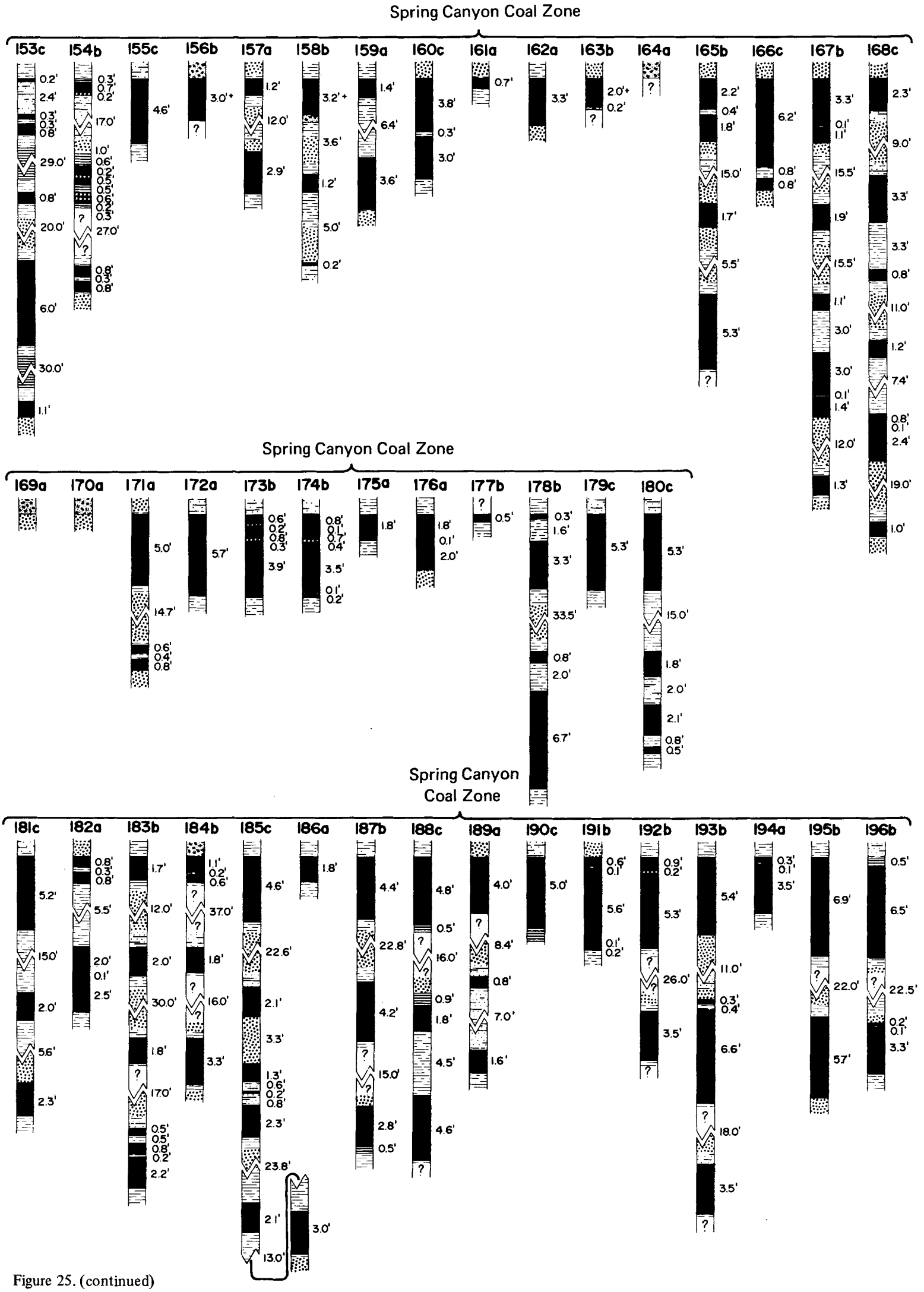

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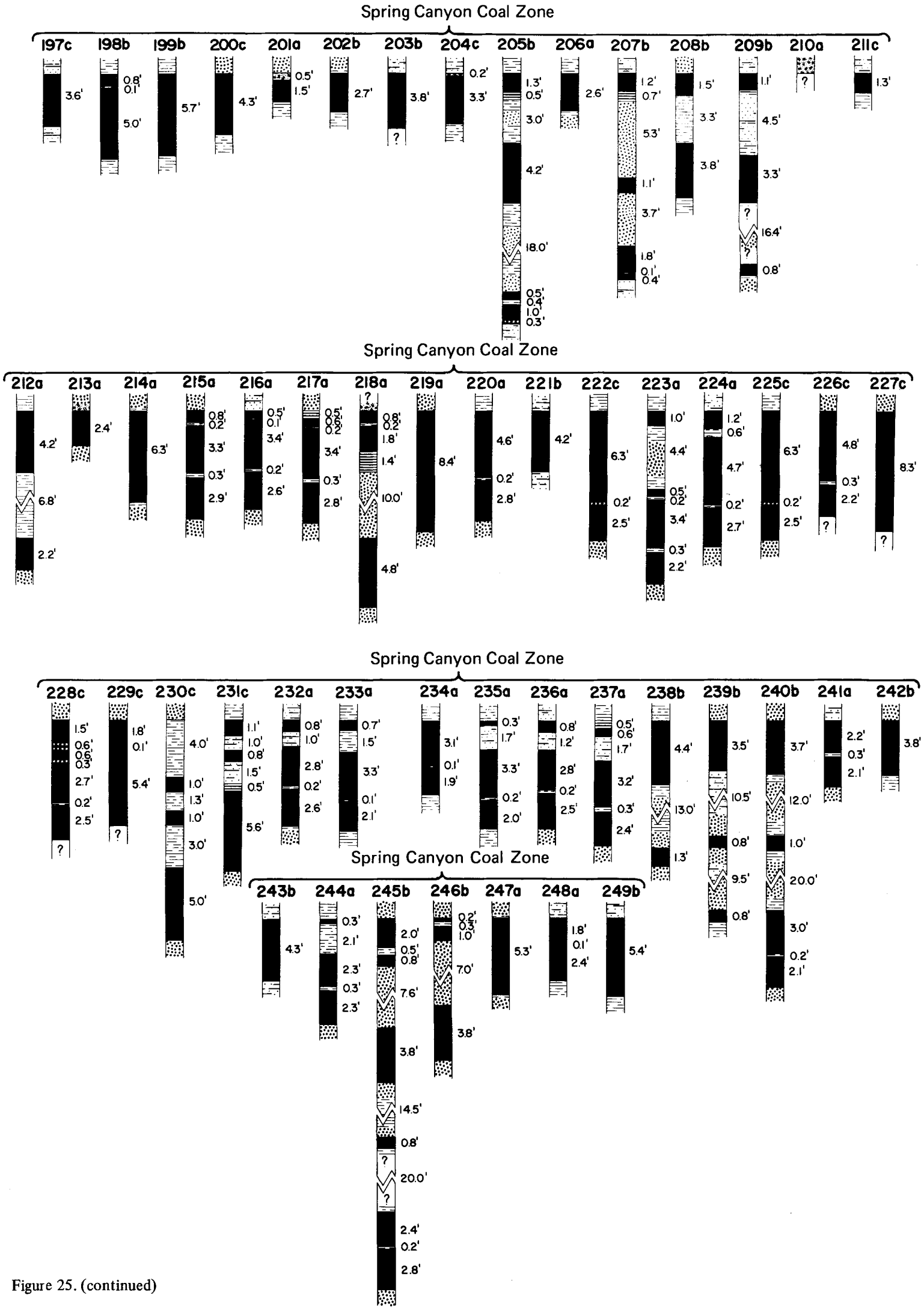


Figure 25. (continued)

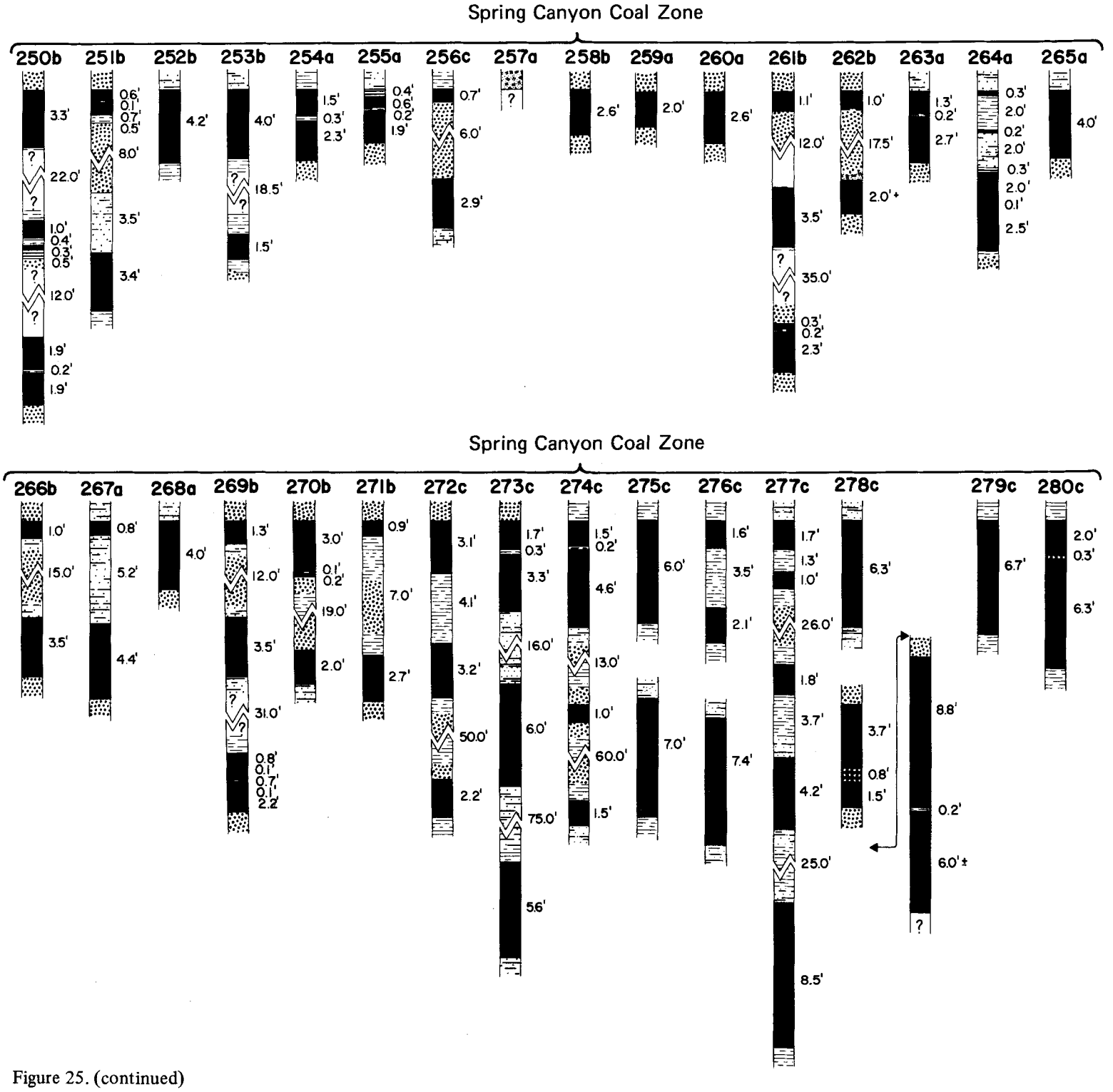


Figure 25. (continued)

from 8 inches to 7 feet 4 inches in surface exposures. The thickest section is in Sowbelly Gulch and the bed thins gradually east and west.

The Sub 2 bed or beds are in the middle, often with three benches. The aggregate thickness of the coal ranges between 1 foot 2 inches and 7½ feet and individual seams occur up to 7 feet. Thicker individual seams are generally in the west half of the quadrangle. The highest bed (Sub 1 bed) is irregular in value, usually marginal except at the west end of Spring Canyon where it averages a little less than 5 feet and attains a maximum thickness of nearly 7 feet. Pockets of minable coal of the Sub 1 bed have been located elsewhere. According to Clark (1928, p. 161) the aggregate thickness of beds in Spring Canyon in T. 12 S., R. 8 E. is 15 feet, in T. 13 S., R. 8 E., 17½ feet, in T. 12 S., R. 9 E., nearly 11 feet and in T. 13 S., R. 9 E., 11.7 feet. The Spring Canyon coal has been mined extensively and contains perhaps the most valuable group of beds on the quadrangle.

The Castlegate Group has up to five important beds present (from bottom to top): the Castlegate "A", Castlegate "B", Royal Blue, Castlegate "C" and Kenilworth or Castlegate "D". The Castlegate "A" has been correlated with a bed extending far to the west in the Wasatch Plateau field; it is found throughout the quadrangle although not always of minable thickness. The bed continues eastward as well and at Kenilworth reaches 19 feet thick. The thickest section measured on Castlegate-Kyune is 17 feet and the bed reaches its best development in Spring Canyon. The Castlegate "B" is generally thin in outcrop and only locally is it thick enough to mine. The bed thickens northward and has been mined in the subsurface. The bed is 5.8 feet in its thickest exposure at the surface at location 47 near the Liberty mines. In drill holes to the north it attains a maximum of 8.7 feet.

The Royal Blue bed is thin and of no value on the quadrangle. The thickest section, 3.6 feet at location 36, is in the same area as the thickest surface Castlegate "B" exposure. The Castlegate "C" is best developed in and around the north, at least along the east edge of the quadrangle.

The Kenilworth or Castlegate "D" is the highest important bed. The thickest exposure is in the gulch east of Hardscrabble

Canyon. The bed was mined in the Cameron (Royal) mine and thickens eastward.

No beds above the Kenilworth are shown to be thicker than 4 feet and it is assumed that no important beds will be more than locally workable.

Subsurface Information

Several drill holes have probed the condition of coal north of the outcrops and mining has extended up to 2 miles behind the outcrop. Good seams of coal were discovered in the Spring Canyon Group completely across the map (locations 273 to 280).

Sufficient data indicate that at least one seam of the three groupings continues in a workable condition northward. The Castlegate "A" is represented by measured sections 146 to 152 and the best section was located at the head of Robinson Gulch. The bed is too thin westward and thins eastward as well but maintains a workable thickness in that direction. Measured sections 56 to 64 are on the Castlegate "A". It is about 5 feet thick along the west edge of the quadrangle and thick in the east half. Sections between are too thin. At the head of Sowbelly Gulch and in the canyon near Cameron the bed exceeds 8 feet.

Towards the north the cover over the coal continues to increase and near the north boundary of T. 12 S. it is 3,000 feet (table 13).

Table 13. Classification of lands according to overburden, Castlegate–Kyune quadrangle.

Overburden (feet)	Percent	
	Total land	Coal land
Greater than 3,000	3.1	–
2,000-3,000	25.5	34.4
1,000-2,000	19.6	26.5
0-1,000	28.9	39.1
Noncoal	22.9	–

The approximate locations of coverlines are given in the Book Cliffs coal field overburden map. In the north two tiers of sections of T. 12 S., between 110°52'30" and 111°00' W. long. (north of map), about 60 percent of the land have 2,000 to 3,000 feet of overburden and 40 percent exceed 3,000 feet if extended contours and formation thicknesses were properly calculated.

Quality of Coal

More than 500 analyses indicate the quality of coal originating on the Castlegate-Kyune quadrangle (table 4). The analyses came from many mines, but most represented are the Cameron (Royal), Carbon Fuel (Hardscrabble Canyon), Liberty and Spring Canyon mines. Many of the samples taken were from tipples and since many mines have operated in more than one bed, it is difficult to separate these by seam. An examination of the analyses indicates little differences and they are averaged together (table 14):

Table 14. Average proximate analyses of coal, Castlegate–Kyune quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	563	4.1	0.62-24.5
Volatile matter	514	43.2	31.4 -48.5
Fixed carbon	514	45.9	33.9 -52.9
Ash	534	6.8	4.3 -13.2
Sulfur	498	0.59	0.2 - 2.1
Btu/lb	551	12,863	7,045-13,530

Walker and Hartner (1966, p. 36-37) subdivided sulfur into its forms for several of the analyses (table 15).

Table 15. Sulfur content of coal, Castlegate–Kyune quadrangle.

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Bills and Killgore	Castlegate	0.54	0.02	0.06	0.46
Day (Mutual)	Castlegate	1.26	0.00	0.50	0.76
Hardscrabble	Castlegate	0.46	0.03	0.10	0.33
Liberty	Castlegate	0.84	0.01	0.26	0.57
Liberty	Liberty (Spring Canyon)	0.58	0.00	0.17	0.41
MacLean	Spring Canyon	0.64	0.01	0.14	0.49
Peerless	Castlegate	0.62	0.01	0.11	0.50
Peerless	Sub 2	0.77	0.00	0.16	0.61
Rains No. 2	Castlegate	0.55	0.00	0.07	0.48
Royal	?	0.32	0.01	0.03	0.28
Royal No. 2	Castlegate	0.36	0.01	0.04	0.31
Spring Canyon	?	1.29	0.02	0.50	0.77
Standard	?	0.79	0.01	0.19	0.59
Uta No. 2	Castlegate	0.56	0.01	0.07	0.48
Vulcan	Castlegate	1.45	0.01	0.77	0.67
Western	Liberty	2.01	0.00	1.34	0.67

Figure 26 plots the number of coal analyses against percent sulfur and demonstrates that 40 percent fall between 0.3 and 0.5 percent. The curve quickly rises to this maximum and then gradually tapers off. Examination of the sulfur forms (table 15) indicates that where sulfur is higher than normal, the amount of pyritic sulfur increases.

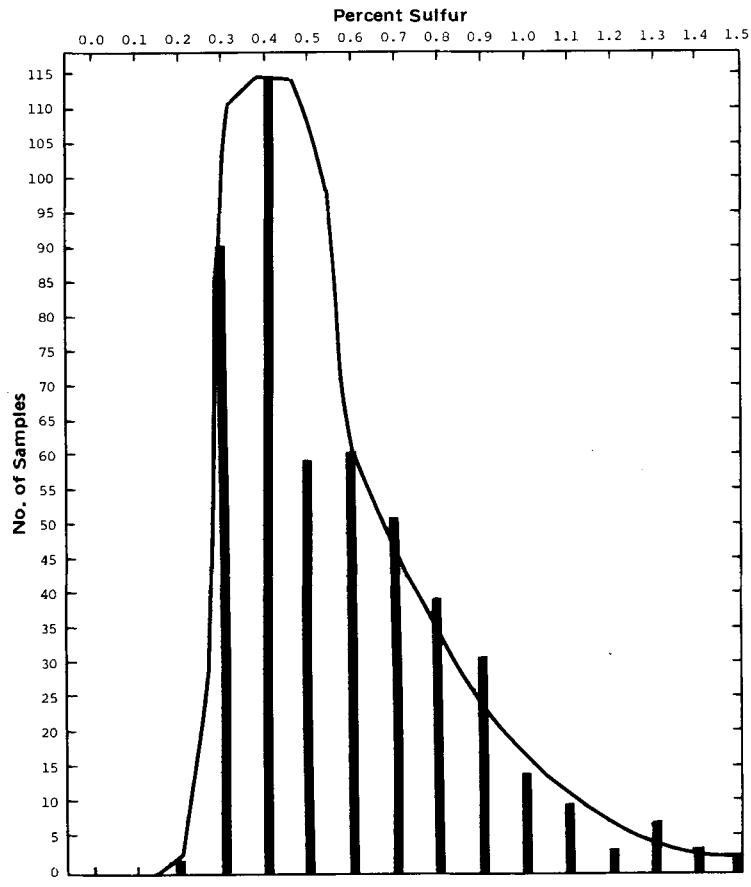


Figure 26. Percent sulfur content versus number of coal analyses, Castlegate–Kyune quadrangle.

In a report of the Utah Conservation and Research Foundation (1939, p. 75) low-temperature carbonization of coal from the Sub 3 seam, Spring Canyon zone of the Liberty mine, was evaluated (table 16).

Similar tests were run by the U. S. Bureau of Mines (Gomez and others, 1967) using an end carbonization temperature of 500° C (table 17).

Mines and Development

Many mines have been opened on the Castlegate-Kyune quadrangle (table 18), but in 1969 only two were active–the Car-

Table 16. Carbonization product yields, Sub 3 seam bed, Liberty mine, Castlegate–Kyune quadrangle.

	Vertical Retort									Rotary Retort			
	External Heating							Internal Heating		External Heating			
Carbonizing Temperature °C (Products Weight Percent)	450	550	650	650	650	750	850	550	650	450	550	650	650
Char	78.5	67.2	62.0	62.4	67.1	60.2	58.7	70.2	65.0	70.1	63.6	60.8	59.9
Gas	1.4	3.6	9.0	8.0	7.5	10.0	10.7	2.3	4.2	3.4	7.6	7.8	8.8
Tar	7.0	12.5	12.0	13.1	9.1	12.3	12.3	11.3	11.9	13.7	14.3	14.6	14.9
Light Oil	0.3	0.5	0.8	0.5	0.4	0.8	0.7	0.4	0.6	0.3	0.4	0.5	0.4
CO_2	1.1	1.7	1.5	1.7	1.9	2.2	1.6	1.4	1.6	1.1	1.2	2.2	0.8
Tar Liquors[1]	9.9	11.8	12.0	12.2	9.8	13.8	12.4	–	–	10.6	12.8	13.6	12.6
Total	98.2	97.3	97.3	97.9	95.8	99.3	96.4	–	–	99.2	99.9	99.5	97.4
Gas, cu ft	491	1,515	3,519	3,659	3,748	5,136	6,398	846	1,883	1,138	2,585	3,706	3,860
Tar, Gallons	16.8	30.1	28.6	31.5	21.9	29.3	29.3	26.7	27.9	33.0	33.2	35.1	35.6
Light Oil, Gallons	0.9	1.6	2.3	1.6	1.3	2.6	2.1	1.4	1.9	1.0	1.2	1.5	1.2
$(NH_4)_2SO_4$ Pounds Total	3.4	6.4	8.9	8.2	7.1	16.0	18.9	7.5	10.0	3.8	4.8	8.9	8.3

[1] Contains phenol, 0-cresol, m,p-cresol and xylenol.

Table 17. Calculated carbonization product yield (maf coal in weight percent; at 500° C).

Mine	Char	Water of decomposition	Tar and oil	Gas	Gas volume	Heat value Btu/scf
Bills and Killgore	71.0	5.0	18.5	4.8	0.925	804
Carbon Fuel	70.1	5.6	18.0	5.4	0.990	774
Carbon Fuel No. 1	70.4	5.1	19.9	4.3	0.891	827
Day	68.8	4.8	20.9	4.7	0.897	812
Day	68.3	4.7	21.7	4.4	0.873	825
Hardscrabble	71.1	5.1	18.2	4.8	0.939	803
MacLean	70.2	4.9	19.7	4.7	0.902	810
Peerless	71.3	5.1	18.0	5.2	9.957	782
Rains No. 2	69.1	4.8	21.0	4.2	0.862	831
Rains No. 3	69.9	5.6	18.3	5.2	0.976	782
Royal	69.7	4.8	20.4	4.4	0.874	816
Royal No. 2	70.9	4.9	19.0	4.4	0.892	820
Spring Canyon No. 5	66.6	5.1	22.0	4.7	0.898	811
Standard	68.8	4.9	20.6	4.3	0.888	827
Vulcan	67.9	5.0	21.2	4.8	0.915	807
Western	68.4	4.7	21.2	4.3	0.890	829

Table 18. Mines in the Castlegate–Kyune quadrangle.

Mine		Location	Remarks
Bills and Killgore (Castlegate, Rains, Mutual)			Active 1941-1948
Cameron mine (Royal mine)		NE.NE.NW.35-12S-9E 4,399,040m.N. 510,460m.E.	Active 1912-1962
Carbon Fuel mine (Hardscrabble Canyon, Carbon King)			Active 1896-1970
	No. 1	C.N.SE.SW.3-13S-9E 4,396,570m.N. 508,360m.E.	
(Lolly mine)	No. 2	NW.NW.NW.NE.10-13S-9E 4,396,110m.N. 508,390m.E.	
(Helper Coal Co., Martin, Blaze mine)	No. 3	SW.SW.SW.NE.10-13S-9E 4,395,660m.N. 508,690m.E.	
Liberty mines	No. 1	SW.NE.SE.7-13S-8E 4,395,060m.N. 503,750m.E.	Active 1919-1967; abandoned
(Maple Creek)	No. 3	NE.NE.SE.18-13S-9E 4,393,750m.N. 503,460m.E.	
(Greek mine)	No. 4	NE.SW.SW.17-13S-9E 4,393,790m.N. 505,840m.E.	
	No. 5	NE.NE.SW.18-13S-9E 4,393,750m.N. 503,690m.E.	
MacLean mine (Western)		SW.NE.SW.7-13S-8E 4,395,000m.N. 503,480m.E.	Active 1922-1966; abandoned
Mutual mine		NW.SE.NE.12-13S-8E 4,395,660m.N. 502,540m.E.	Active 1921-1938; abandoned
Peerless mine	No. 1	C.W.SW.SW.10-13S-9E 4,394,710m.N. 507,900m.E.	Active 1915-1954; abandoned
	No. 2	E.NW.NW.NW.15-13S-9E 4,394,470m.N. 508,070m.E.	
	No. 3	E.SW.NW.NW.15-13S-9E 4,394,230m.N. 508,050m.E.	
Spring Canyon mines (Spring Canyon-Royal, Storrs)			Active 1900-1970
(Rhodes)	No. 1	NE.NE.SW.9-13S-9E 4,395,180m.N. 506,930m.E.	
	No. 2	SW.SE.NW.9-13S-9E 4,395,400m.N. 506,680m.E.	
	No. 2½	SE.SW.NW.9-13S-9E 4,395,370m.N. 506,490m.E.	
(Pratt mine)	No. 3	SE.NE.NW.NW.9-13S-9E 4,395,480m.N. 506,530m.E.	
	No. 4	NW.NW.SE.NW.9-13S-9E 4,395,720m.N. 506,700m.E.	

(continued on page 350)

Table 18. (continued)

Mine	Location	Remarks
No. 5	C.W.SE.SW.4-13S-9E 4,396,340m.N. 506,680m.E.	
No. 7	SW.SW.SW.SW.4-13S-9E 4,396,200m.N. 506,210m.E.	
No. 8	C.SW.NW.NW.9-13S-9E 4,395,840m.N. 506,400m.E.	
Standard mines		Active 1913-1954
No. 1	NE.SE.NW.8-13S-9E 4,395,660m.N. 505,300m.E.	
No. 2	SW.SW.NE.8-13S-9E 4,395,340m.N. 505,480m.E.	
No. 2½	NE.NW.SE.8-13S-9E 4,395,280m.N. 505,670m.E.	
No. 3	SE.SW.SW.NE.8-13S-9E 4,395,450m.N. 505,600m.E.	
Uta-Carbon mine (Rains, Hi-Heat mine)		Active 1914-1956; abandoned
No. 1	NW.NW.NE.7-13S-9E 4,396,050m.N. 503,850m.E.	
No. 2	SW.NW.NE.7-13S-9E 4,395,880m.N. 503,850m.E.	
No. 3	7-13S-9E	
Vulcan mine	NW.NW.SE.12-13S-8E 4,395,310m.N. 502,450m.E.	Active 1944-1957; abandoned

bon Fuel mine in Hardscrabble Canyon (356,882 tons) and the Spring Canyon mine in Sowbelly Gulch (218,281 tons). The total production from the quadrangle in 1969 was 575,163 tons.

Several other mines named in the literature and in unpublished reports were alias names or were later incorporated by the larger mines. Three names not included in the list of mines include the Lamph & Johnson, Day's Mutual and the Wildcat, all believed located somewhere in Spring Canyon.

By far the most productive mine or mines have been the Spring Canyon. Up to and including 1969 about 15.4 million tons were produced. Production started in 1912 and all minable seams were developed. For instance the No. 1 mine is opened on the Sub 3 seam, the No. 2 on the Sub 2 seam, the No. 2½ on the Sub 1 seam, the No. 3 on the Castlegate "A", the No. 4 on the Castlegate "B" and the No. 5 on the Kenilworth bed. Two other mines, Nos. 7 and 8, open on the Kenilworth and Castlegate "A". During the years an intricate maze of overlapping mined-out areas has developed. Mining has produced an average of 5,238 tons per acre or 47 percent recovery. The average thickness of each seam is listed below:

	Feet
Kenilworth	5
Castlegate B	6
Castlegate A	6
Sub 1	4
Sub 2	4
Sub 3	8

The Standard mines which have produced approximately 8.1 million tons were active 1913 to 1954 and are located on Gilson Gulch north of abandoned Standardville. The four individual mines were numbered exactly as those of the Spring Canyon mines and entered the same beds. All three subseams were developed plus the Castlegate "A". The average thickness of the beds was the same as those in the Spring Canyon mines but the mines produced 5,406 tons per acre or 51 percent recovery.

The Liberty mines located mostly on the south side of Spring Canyon operated from 1919 to 1967. All the important seams are believed mined out and the mines are believed abandoned for good. Production figures range between 6,170,000 to 8,816,000 tons; the discrepancy is attributed to predecessors with alias names that were incorporated by the Liberty mines. The Liberty No. 1 mine is in the Sub 2 seam, the No. 3 in the Sub 3 seam, the No. 4 in the Sub 1 seam and No. 5 in the Castlegate "B" seam. Average thicknesses of individual seams are not available except for the Sub 2 (5 feet) but 5,138 tons per acre indicate a 58 percent recovery if the higher production figure is considered.

The ghost town of Cameron or Royal on the west side of Price Canyon about 1½ miles north of Castlegate marks the location of the Royal or Cameron mine. The entryways are above the coal beds and the mine was first developed by driving two rock tunnels 740 feet in length to the coal. Several beds were developed in the Castlegate Group and Kenilworth. The period of activity extended from 1912 to 1962 when 7.1 million to 7.4 million tons were produced. About 6,200 tons per acre were won with a 44 percent recovery. The coal seams mined averaged 8 feet.

Uta-Carbon mines, sometimes known as the Rains mines, are located in the upper part of Spring Canyon just below the point where Burnt Tree Fork and Left Fork join. Activity extended from 1914 to 1930 and from 1935 to 1956. Principal seams included the Castlegate "A", averaging 6 feet and the Sub 2, averaging 5 feet. About 4,122 tons per acre were realized with a 43 percent recovery. Total production figures range from 3.1 million to 4.1 million tons and the discrepancy again may be the result of incorporating figures of adjoining older mines.

The Peerless mines are located between Storrs and Helper near the mouth of Spring Canyon. They operated in the Castlegate "A", Sub 2 and Sub 3 seams between 1915 and 1954. The "A" averaged 6 feet and each of the other two averaged 4 feet. Six thousand eighty-one tons per acre were realized with a recovery of 76 percent. All-time production figures range between 3.4 million and 3.7 million tons.

The Carbon Fuel mine which operates in Hardscrabble Canyon has incorporated the area formerly included with earlier mines. Hardscrabble Canyon was one of the earlier producers commencing in 1896. Early production was small and serious efforts in mining began in 1955. Prior production was usually less than 10,000 tons per year. Total production figures range between 2.9 million and 3.1 million tons. The most important seam mined is the Castlegate "B" which averages 8 feet thick. About 5,635 tons per acre are realized with a recovery of 41 percent.

Two other mines have produced more than 1 million tons. The first is the Mutual near the confluence of Burnt Tree and Left forks of Spring Canyon. Production was mostly from the Sub 1 and Sub 2 and extended from 1922 to 1938 and totalled 2.4 million tons. This figure probably was included in the high calculation for the Liberty mine. The second mine is the MacLean or Western mine, active from 1922 to 1966 and producing about 1.8 million tons.

Other mines and their production which may or may not be included in the estimates of the big producers are:

	Tons
Maple Creek	228,195
Lone Pine or Vulcan	210,885
Day's Mutual	157,913

Total production for the quadrangle amounts to approximately 53 million tons. Overall recoverability has been about 50 percent so that 106 million tons of original coal are now unavailable.

Tomlinson (1932) made a study of some of the hazards encountered in mining coal in the Book Cliffs field and elaborated on the condition of each seam including information about roof and floor. The lower subseam (Sub 3) has coal that is bright, hard and breaks in large oblong blocks. It burns with a light red ash and does not clinker. It is softer than the Castlegate "A" coal, but is a premium domestic coal. The bed has the greatest variety of

roof of any in the field. It varies from fine-grained sandstone to sandy shale and shale and has the characteristics of draw slate being quite treacherous. Practically everywhere a seam of hard to soft shale caps the coal 1 to 12 inches in thickness. This presents the greatest danger to miners at the face from roof falls.

The second subseam (Sub 2) has bright and hard coal that breaks into large cubical blocks. It has been regarded as a fine domestic coal. Its roof is usually a bed of hard sandy shale 12 to 20 feet thick that has bedding planes and makes a good roof. Occasionally some carbonaceous shale lies between the sandstone and coal which can cause treacherous conditions when moist.

The upper subseam (Sub 1) coal breaks in large irregular blocks and is abundantly endowed with a resinous material. It is termed an excellent domestic and railroad coal, burns with a light red ash leaving little clinker. Its roof has been a bed of hard dark shale 8 inches to 3 feet thick which forms a good roof in most places.

The Castlegate "A" coal is massive, brittle and bright but contains dull bands of coal and numerous partings of bone and shale. The bed shows few or no marks of bedding, has prominent joints and locally has streaks of resin and sulfur balls in it. It normally has a good roof–a fine-grained sandstone 4 to 6 feet thick.

The next important bed, the Kenilworth, is generally softer than the Castlegate "A" with otherwise the same physical characteristics. The dull bands have a higher ash percentage. The roof is a sandstone bed 40 to 60 feet thick, but often a sandy shale or hard shale lies between the coal and sandstone. A definite bedding plane, 1 to 12 inches above the coal bed creates problems; the rock underneath is usually treacherous and brittle.

Reserves

Clark (1928, p. 161) calculated reserves for the entire Castlegate quadrangle. None of his figures extend into the Kyune portion of the presented map. His estimate is based on 1,800 tons per acre-foot and includes all beds over 14 inches. His reserves are here modified to fit only the Castlegate NW portion of the quadrangle and excludes all groups, beds or seams whose calculated average thickness is less than 4 feet (table 19).

Table 19. Original coal reserves in the Castlegate–Kyune quadrangle (in short tons).

Location	Bed or group	Average thickness (feet)	Acres est.	Tonnage
T.12S. R.8E.	Coal beds above Kenilworth	4.2	1,280	10,000,000
	Spring Canyon Group	15.0	1,408	35,000,000
T.13S. R.8E.	Coal beds above Kenilworth	4.2	1,280	10,000,000
	Castlegate Group	4.0	2,720	20,000,000
	Spring Canyon Group	17.5	3,136	99,000,000
T.12S. R.9E.	Coal beds above Kenilworth	4.2	3,840	29,000,000
	Castlegate Group	5.0	3,480	34,500,000
	Spring Canyon Group	10.8	3,840	74,500,000
T.13S. R.9E.	Coal beds above Kenilworth	4.2	5,120	38,000,000
	Castlegate Group	7.9	6,208	88,000,000
	Spring Canyon Group	11.7	6,144	129,000,000
			Total coal	567,000,000

The Kenilworth bed in T. 12 S., R. 9 E. averages 3½ feet and in T. 13 S., R. 9 E. averages 3¾ feet. It has been mined in places, however, and is probably thicker. On the other hand if the average thickness ascribed to coal beds above the Kenilworth is divided into two or more seams, none would be considered economical. Hopefully these differences average out. Since much of the area is mined out, these reserves can all be classed as measured or estimated (Classes I and II).

In a study of land holdings of remaining coal, the following figures were calculated (table 20). They cover most of the area north and through the lower third of T. 12 S.

Table 20. Estimated reserves by companies and seam, Spring Canyon district, Castlegate–Kyune quadrangle.

	Class	Thickness (feet)	Acreage	Tonnage	Bed
Royal Coal Co.					
28-31, 12S-9E	II	5	2,240	19,600,000	Kenilworth
Spring Canyon Coal					
33-12S-9E, 4-6, 13S-9E	I	5	1,300	11,375,000	Kenilworth
31, 32-12S-9E, 6-13S-9E	II	5	960	8,408,000	Kenilworth
5, 6-13S-9E,	I	6	600	6,300,000	Castlegate "B"
30, 31-12S-9E	II	6	1,120	11,760,000	Castlegate "B"
5-13S-9E	I	6	100	1,050,000	Castlegate "A"
31-12S-9E,	II	6	320	3,360,000	Castlegate "A"
35, 36-12S-8E	I	7	1,280	15,680,000	Sub 2
5, 6-13S-9E,	I	8	450	6,300,000	Sub 3
31-12S-9E.	II	7	550	6,737,000	Sub 3
Carbon Fuel					
32, 33-12S-9E, 3-5, 13S-9E,	I	6	360	3,780,000	Castlegate "B"
33-12S-9E, 3-13S-9E,	I	6	1,240	13,020,000	Sub 3
32, 34-12S-9E.	II	6	1,040	10,920,000	Sub 3
Western Fuel					
2-13S-8E,	II	4	560	3,920,000	Castlegate "B"
2-13S-8E.	I	4	320	2,240,000	Sub 1
Uta-Carbon					
1-13S-8E	II	4	400	2,800,000	Castlegate "B"
			Total coal	127,250,000	

[1] Tonnage estimates on other seams omitted because of lack of information.

Spieker (1931, p. 204) calculated reserves for the deep coal in T. 12 S., R. 9 E. and for that part of T. 12 S., R. 8 E. that is a part of the Kyune portion of the quadrangle. In the east township he estimated an average thickness of 20 feet for all workable beds and excluded sections 1, 2 and 3 where the coal is more than 3,000 feet deep. To this township of 20,920 acres he assigned 753 million tons. In the west township he calculated an average thickness of 17 feet. Part of this township extends into the Soldier Summit quadrangle so that all the acreage cannot be included. About 5,120 acres can be included or 156.5 million tons of reserve. According to Spieker (p. 79):

> At least one and probably more of these beds (beds of the Castlegate and Spring Canyon districts) may be expected to persist northward into the Price River area, and the probability of disclosing workable coal there by prospecting with the diamond drill is great. Comparison of the stratigraphic sections in surrounding districts indicates that the Castlegate "A" bed is probably present and over 30 inches thick and the Castlegate "D" or Kenilworth bed is probably present in the southern part of the area. The Hiawatha (Sub 3) and other beds of the Spring Canyon group should be present according to the evidence in Spring Canyon, but the absence of the Hiawatha bed in the Pleasant Valley district suggests that it may habitually disappear westward, and its meager showing in the Castlegate district suggests that the Price River area may be near its northern limit. The Castlegate "A" bed is the most likely of the group to be present, with the Castlegate "D" (Kenilworth) and the Hiawatha beds second and third respectively.

Subsurface data in the Spring Canyon district do not confirm Spieker's theory that the Hiawatha may disappear northward. The indication is that coal beds shrink to the east and west respondent to the ancient shorelines which created lagoons behind them. Thus there would be no coal at Pleasant Valley, very little at Kenilworth, but to the north a continuation is expected. Conditions in Cretaceous time possibly were not as favorable north or south of Spring Canyon for the formation of coal, but the change is more apt to be gradual than severe.

Depth to the coal is based on average dips but northward, changes in the thicknesses of formations unknown to the calculator may occur. Thus without deep drilling, assumptions become more and more speculative farther away from the outcrop. In the Kyune portion of the map no areas with less than 1,000 feet of overburden exist. Except for small fringe areas such as in Beaver Creek Canyon most of the area has at least 2,000 feet of cover. Exceptions are Crandall, Price and Beaver Creek canyons where the overburden is between 1,000 and 2,000 feet. In the northeast corner of the map the cover is greater than 3,000 feet under a small patch on Ford Ridge. The 3,000-foot coverline west of Price Canyon is believed near the Carbon-Utah County line (township line). For the purposes of this report that portion of township 12S-8E and 12S-9E between 110°52'30" and 111°00' W. long. and north of 39°47'30" N. lat. is considered a Class IV reserve being at least 5 miles distant from a reliable control point. The part between 39°45' and 39°47'30" N. lat. between the aforementioned longitudinal limits is considered inferred.

In summary the reserves as presented by Clark and Spieker, which are modified to fit more of the requirements of this report, eliminate areas with more than 3,000 feet of cover and seams with less than 4 feet of thickness. Clark and Spieker both used beds less than 4 feet in their reserve summations and worked with average thicknesses on a township basis. Their figures and reserves are used where the averages are more than 4 feet (table 21), but locally these beds may be less; it is hoped that thicknesses in excess of the average will compensate.

This reserve may include coal that is unretrievable because of closeness of seams. The acreage involved in burned outcrop coal and in geologic inconsistencies such as splits, wants, fault shear zones, etc. will certainly cut down on the total recoverable. Mining

Table 21. Original coal reserves in the Castlegate–Kyune quadrangle (more than 4 feet thick; in short tons).

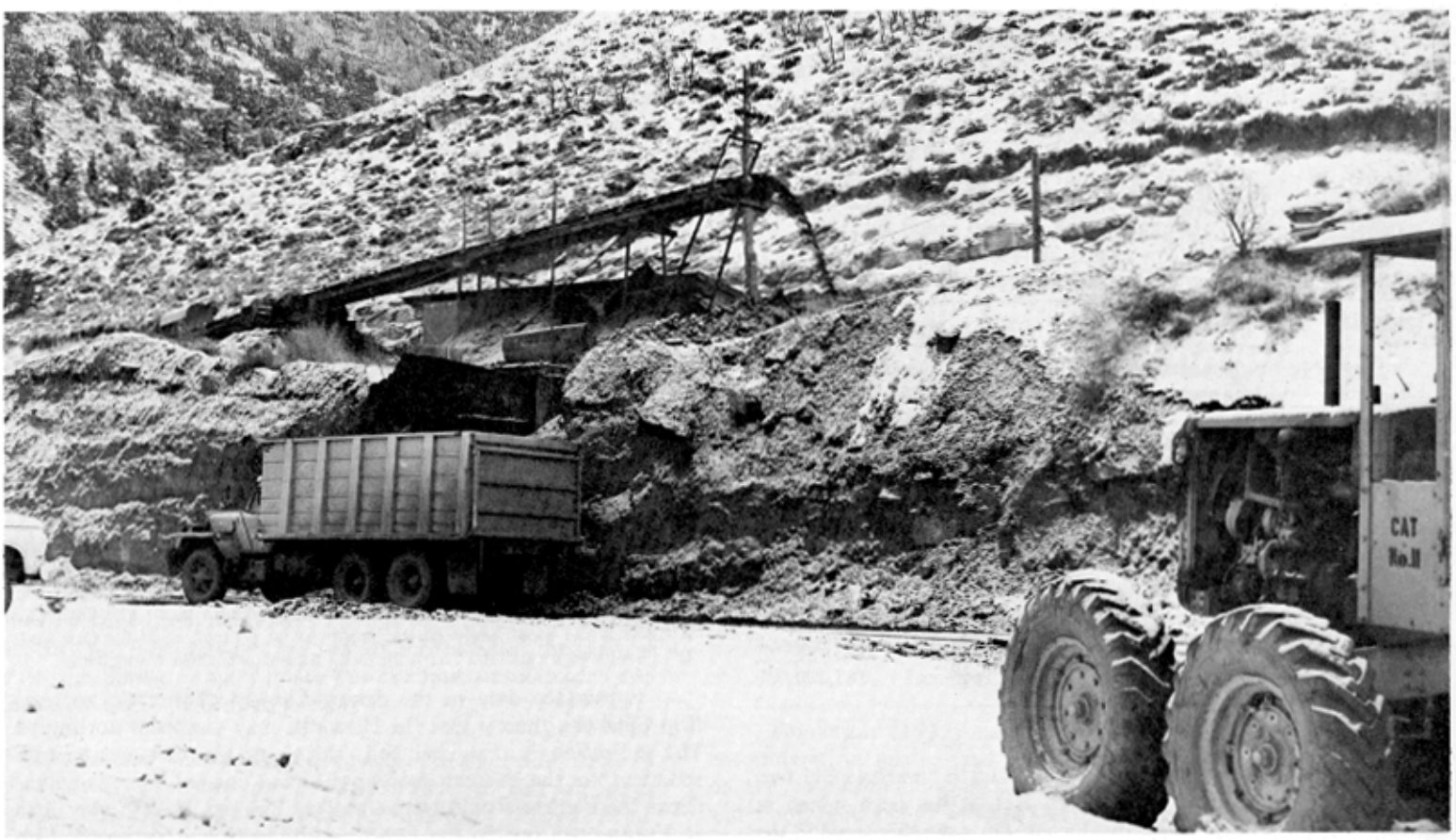
Cover (feet)	Classes I and II	Class III	Class IV	Total
Less than 1,000	377	–	–	377
1,000-2,000	148	100	–	248
2,000-3,000	42	268	127	437
Totals	567	368	127	1,062

[1] Includes area north of this quadrangle with less than 3,000 feet of cover.

experience has dictated a 50 percent recoverability in the acreage mined, but a seam above may now be unminable because of safety conditions. For example in the Spring Canyon district, reserves estimated for the Class I and II remaining are 127 million tons or 63.5 million tons recoverable. One hundred and six million have already been mined or lost due to mining. This area covers at least 75 percent of Clark's area in which he calculated 567 million tons of reserve. Therefore under today's conditions only 155.3 million tons may be won from the Castlegate portion of the quadrangle. Then only 27.4 percent of this reserve are recoverable which, for all classes of reserves, amounts to 291 million tons. On a budget basis 53 million have already been removed, leaving 238 million tons recoverable.

PRINCIPAL WORK

The principal investigator of this area was Clark (1928). Significant additional contributions were made by Spieker (1931) and by much U. S. Bureau of Mines analytical work, published and unpublished. Some additional work was added directly through this study. References are listed at the end of this report.



Spring Canyon mine, Castlegate–Kyune quadrangle. The mine presently is closed, but operated in multiple seams in the Spring Canyon coal group (Hiawatha).

CASTLEGATE–MATTS SUMMIT QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Castlegate-Matts Summit (figures 19 and 27) is a composite quadrangle prepared by matching the south one-third of Matts Summit U. S. Geological Survey 7½-minute quadrangle and the north two-thirds of the Castlegate NE quadrangle. The purpose is simple: the south part of the Castlegate NE quadrangle exposes no coal and important coal reserves extend into the Matts Summit area. The mouth of Price Canyon occurs along the west map margin and the town of Helper is located in the southwest corner. Two other coal-mining towns locate here, Kenilworth in the south central map area and Castlegate, just north of the Castlegate mines in Price Canyon.

Along the south map margin are the foothills of the Book Cliffs and trending east-west just north of Kenilworth are the cliffs themselves. The cliffs are indented by numerous short canyons and at Kenilworth the base of the cliff is about 6,700 feet and the top about 8,000 feet above sea level. The two major canyons are Price Canyon and Willow Canyon. Both carry major highways to the north. In the uplands the quadrangle is mountainous and only in a few places is it plateau-like. The very north part is an evenly inclined dip slope or cuesta supported by the Flagstaff Limestone. The highest elevation is almost 8,800 feet and located on a prominence just south of Emma Park along the east map edge. The coal crops out from about 6,100 feet in the area of Castlegate to more than 7,400 feet near Kenilworth.

The main line of the Denver & Rio Grande Western Railway follows Price Canyon from Helper to Soldier Summit and a spur connects Kenilworth to Helper. U. S. Highway 50-6 parallels the main line of the railroad and is the major link with Salt Lake City. A paved road connects Helper with Kenilworth and Utah Highway 33 starts at Castlegate, continues through Willow Creek Canyon and eventually leads to Duchesne 45 miles to the northeast. Occasional poorly maintained dirt roads provide access to other areas at the foot of the Book Cliffs from below. Only poorly defined trails occur above the cliffs.

STRATIGRAPHY

Bedrock units exposed on the Castlegate-Matts Summit quadrangle range from the upper part of the Mancos Shale to the Flagstaff Limestone. The Emery Sandstone Member of the Mancos is exposed about a half mile south of Helper and consists of three thin beds of sandstone separated from each other by 50 feet of Mancos-like shales. From bottom to top their thicknesses are 25, 15 and 5 feet made up of massive sandstone toward the top and grading downward into thin-bedded or shaley sandstone. The sands are gray to yellow-tan-gray. The beds eventually pinch out north of Price a few miles to the east.

Along Price River Canyon the Masuk Tongue of the Mancos is 700 feet thick and consists mainly of drab blue-gray shales. The outcrop area covers most of the ground below the cliffs. In geologic history a pediment formed below the cliffs and gravels was deposited on the surface. The base level has since been lowered and the pediment exists presently as scattered remnants. The gravels consist mainly of cobbles, pebbles and sand of rock units of the Mesaverde Group or higher strata. The upper part of the Mancos contains thin siltstone and sandstone beds and is supported as a badland cliff by the more resistant Mesaverde Group rocks in the Book Cliffs.

The Mesaverde Group has been subdivided into four mappable units on this quadrangle. The outcrops are associated with the Book Cliffs and form its steepest surfaces. The first unit is highly resistant forming vertical cliffs and is the littoral sandstone known as the Star Point. It actually consists of several sandstone tongues interfingering into the Mancos to the east. Three tongues have been named, from bottom to top, the Panther, Storrs and Spring Canyon. They all thin eastward: the lower and upper are best developed. Each tongue is massive near the top and grades downward into thin-bedded sandstones and siltstones.

The next unit, the Blackhawk, is the coal-bearing formation. From Panther Canyon westward the initial part of the Blackhawk is the Spring Canyon lagoonal sequence that contains coal which is followed above by the Aberdeen Sandstone. To the east the Aberdeen merges with the Spring Canyon Tongue at the expense of the lagoonal deposits. Above the Aberdeen are more lagoonal deposits, the coals of which belong to the Castlegate Group. At least one more discernible cycle is known as the Kenilworth Sandstone and Kenilworth coal-bearing deposits. All the important coal beds are located within 400 feet of the base of the Blackhawk. Above the Kenilworth are lenticular beds of sandstone, shale, thin coal beds and carbonaceous shale. Along the east edge of the map some of the higher coals begin to thicken; the most important bed is the Lower Sunnyside. The entire Blackhawk averages 800 feet thick. The sandstones are resistant and are separated by soft shales, shaley sandstone and coal which produces a step-like topography.

The Castlegate Sandstone and the town of Castlegate derive their names from a steep erosional landform in Price River Canyon that appears much like the gate of an ancient castle wall complete with turret. At one time a pair of "castle gates" extended from each side of the canyon, but one was removed to improve the highway in the canyon during the early 1960's. The Castlegate Sandstone is one single bed of massive sandstone forming a nearly vertical cliff 250 to 300 feet thick along the east part of the map to 350 to 400 feet thick at the west end. The contact between Blackhawk and Castlegate is believed disconformable and the lagoonal rocks below are replaced by fluvial, coarser-grained sandstones above. The Castlegate is succeeded by the Price River Formation which is composed of sandstone, shale and sandy shale. Again the unit alternates between soft and hard beds forming cliff and slope topography. One 100-foot sandstone bed, usually white, is found near the middle of the unit. The Price River thickens westwardly and is about 900 feet thick in this area.

The variegated shales, impure limestones and subordinate sandstone and conglomerates of the North Horn Formation follow. The lower part of the North Horn is youngest Cretaceous and the upper part is Paleocene in age. Although the unit contains some resistant beds it tends to be a slope former. The topographic contours reveal the North Horn to vary between 700 and 800 feet on the quadrangle. The final unit is incompletely exposed and is a resistant cream-gray limestone unit. The beds are thin- to medium-bedded and form a cuesta-like dip slope at the north end of the map. Interbedded with the shales are subordinate variegated shales and reddish brown sandstones.

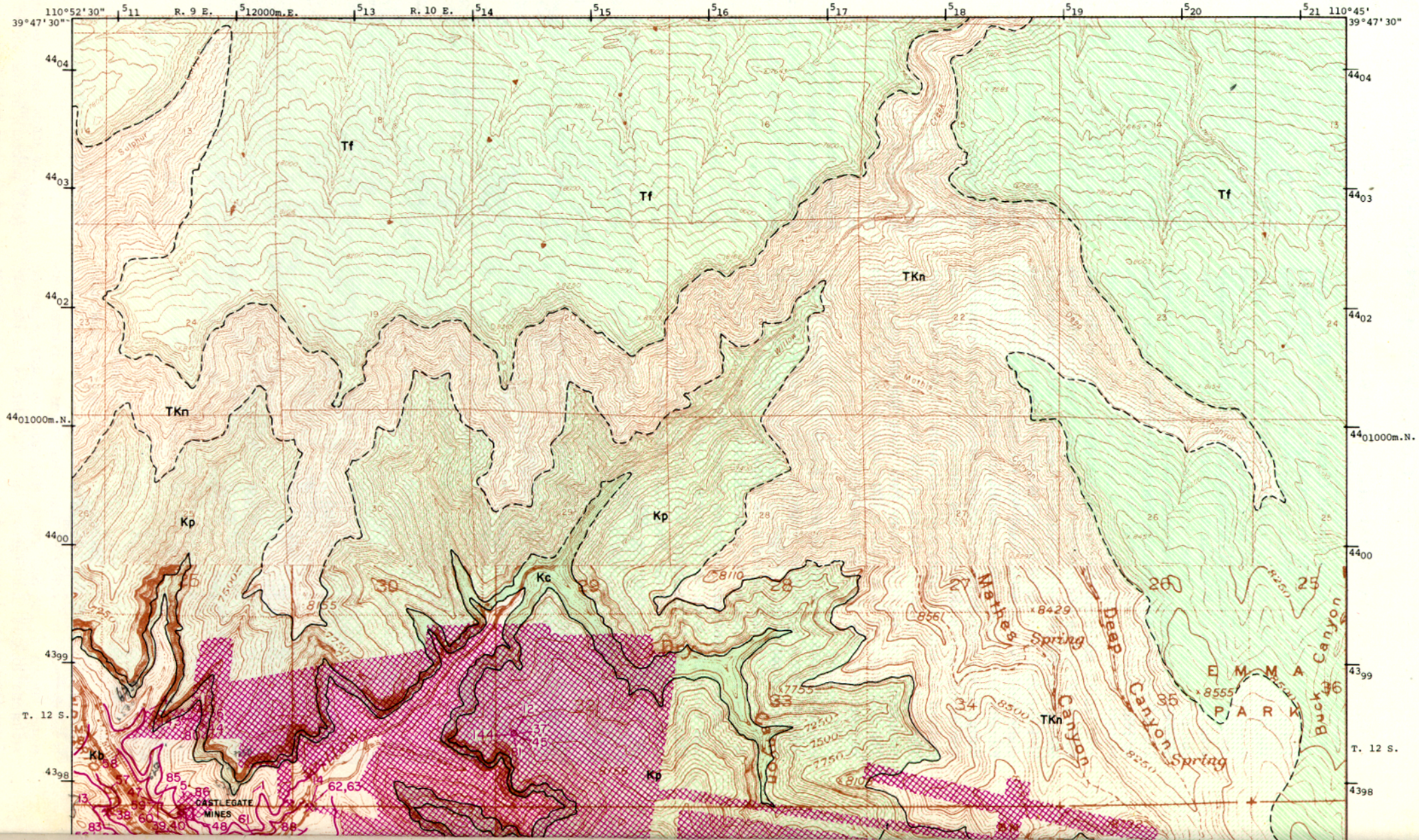
STRUCTURE

The structure of the Castlegate-Matts Summit quadrangle is simple. The structure contours are spaced regularly in an east-west trend dropping 500 feet each mile to the north. This represents a dip of about 5½ degrees. Faults are practically nonexistent but one 1½ miles long appears on the State Geologic Map of Utah, NE quarter (Stokes and Madsen, 1961). Nothing more is known about the fault or its displacement. Coal mining should not be affected by it in the future as the area south of its outcrop appears mined out. Any faults that occur on the quadrangle are expected to be of small displacement.

PROPERTY CONTROL

The lands shown on this quadrangle are owned privately (60.5 percent), by the Bureau of Land Management (36.0 percent) and the state of Utah (3.5 percent). An examination of the Land

CASTLEGATE—MATTS SUMMIT QUADRANGLE



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972

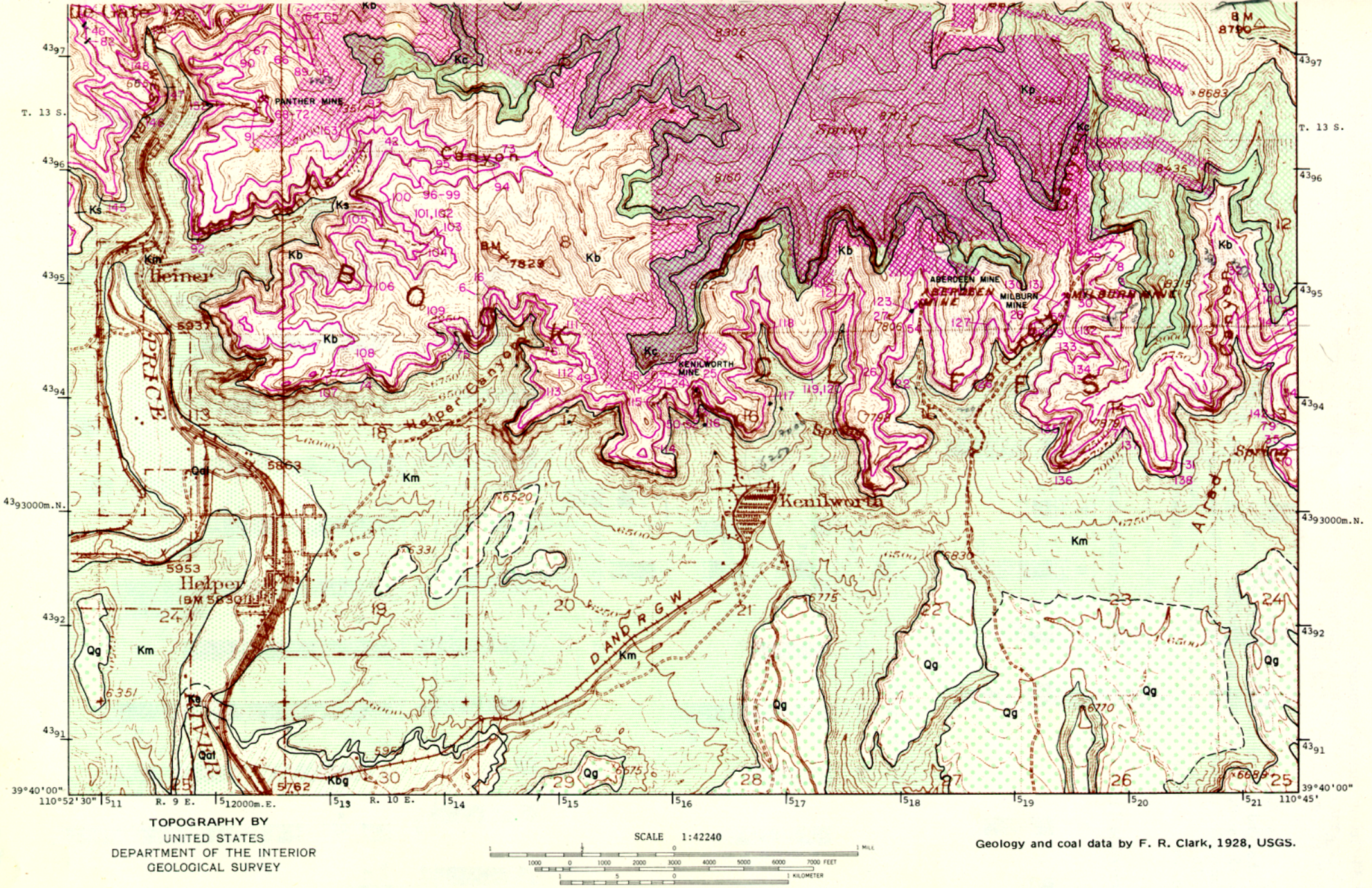


Figure 27. Coal and geology map, Castlegate-Matts Summit quadrangle (explanation pages 332-333).

Ownership Map (figure 14) reveals that most outcrop areas are privately held, but that large areas of BLM land lie on coal lands behind the cliff. About half the state lands are on coal land.

A good percentage of the lands is currently held for the purpose of mining coal. This land is leased mainly from the BLM or held privately. Figure 15 indicates the extent of such holdings as of January 1, 1970. Companies and individuals holding this land include: C. Bertola, W. Mathis, North American Coal Corp., J. Peperakis, Royal Coal Co. and J. R. White.

Most of the land is controlled by the North American Coal Corp. operating the Castlegate and Kenilworth mines.

COAL

Surface Information

Eight beds or groups of beds are located on the map area. The sequence of beds is indicated below in a generalized section. Coal sections from the Castlegate-Matts Summit quadrangle are illustrated in figure 28.

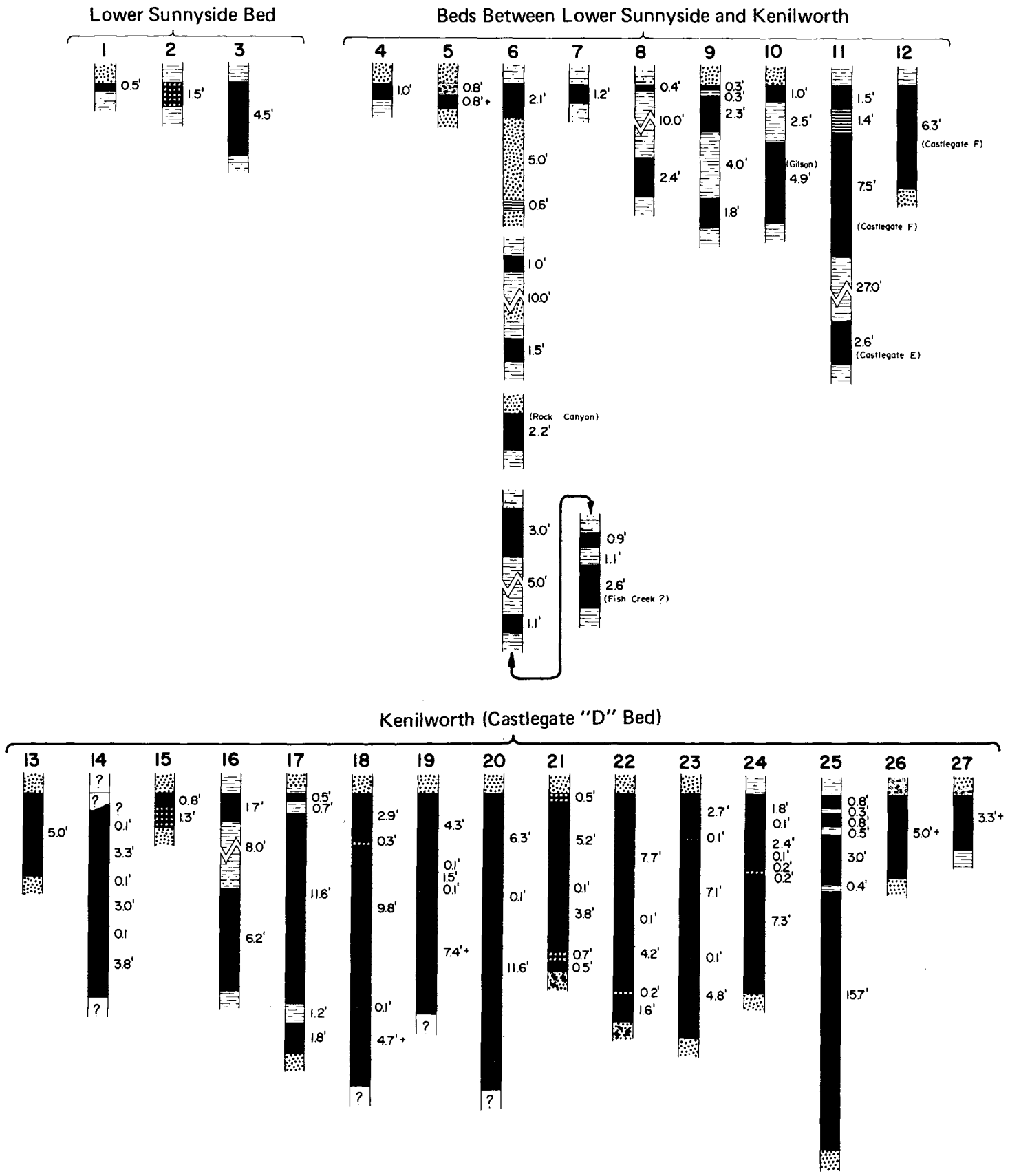


Figure 28. Coal sections of Castlegate–Matts Summit quadrangle (vertical scale: 1 inch = 8 feet).

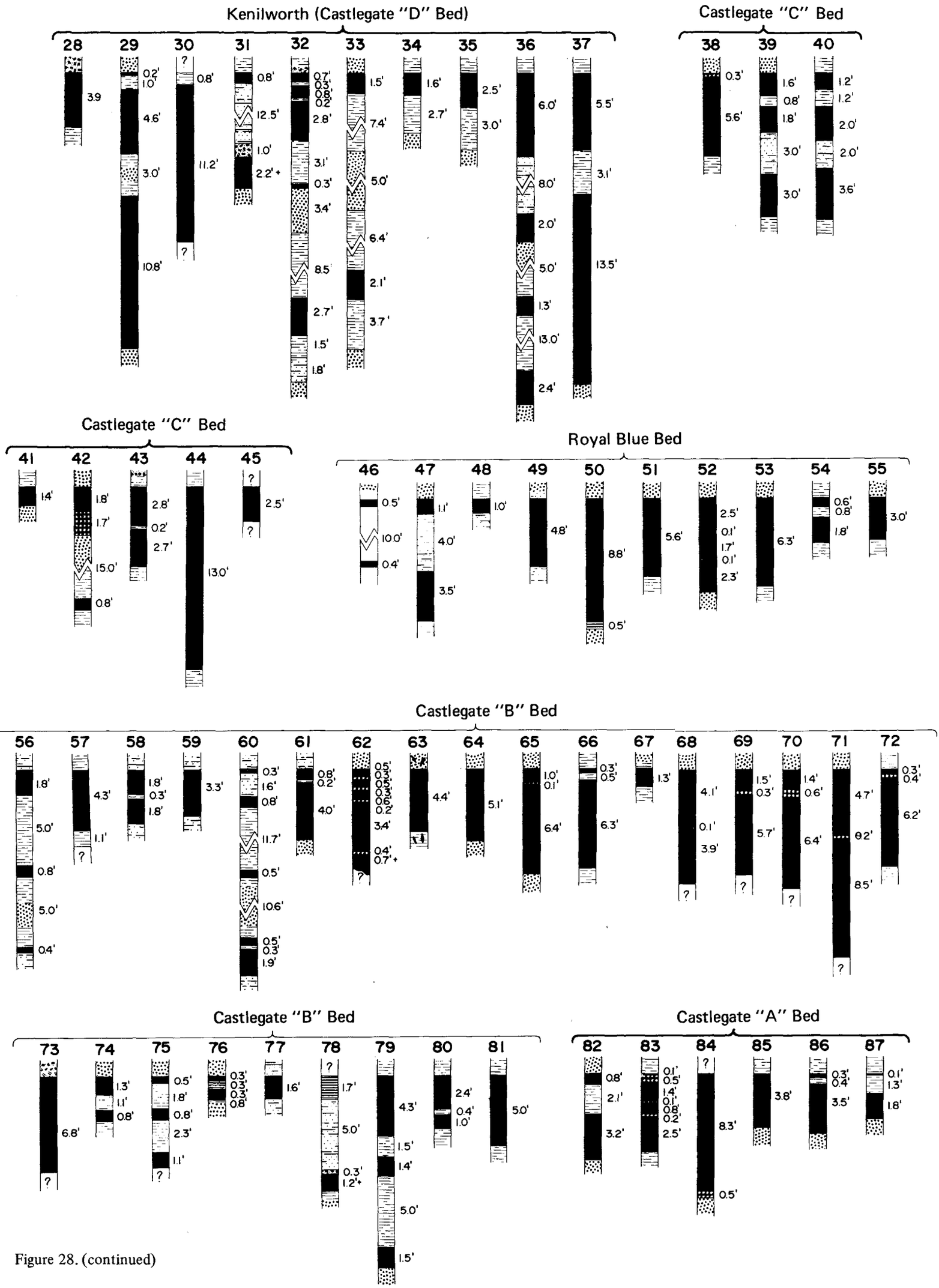


Figure 28. (continued)

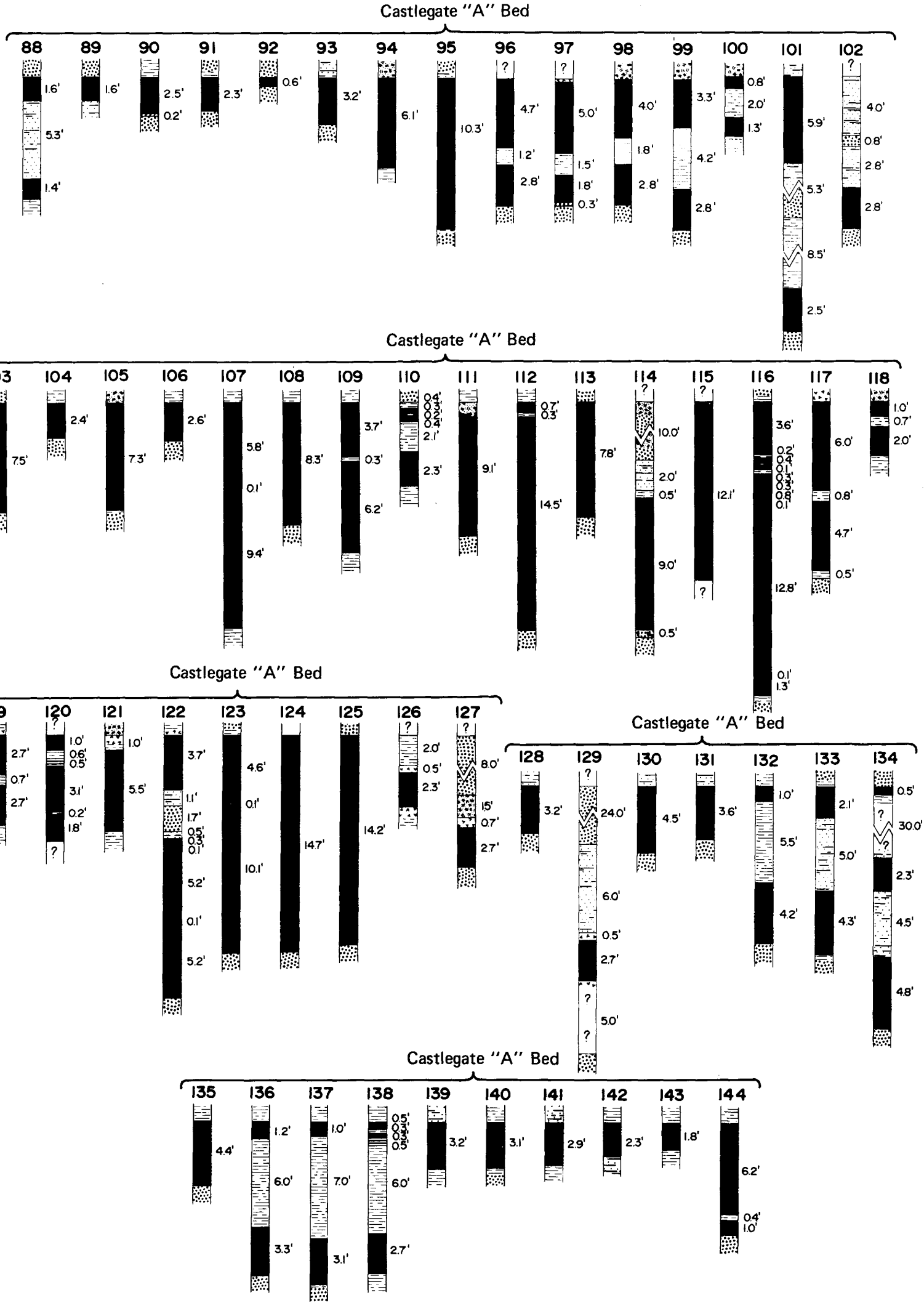


Figure 28. (continued)

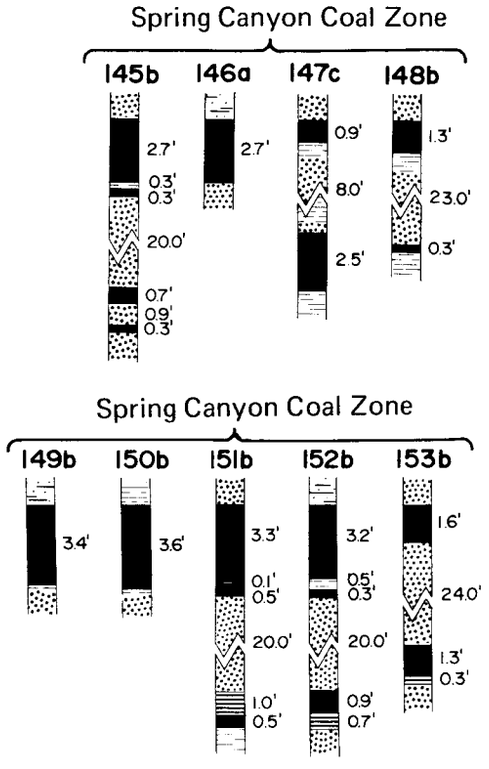


Figure 28. (continued)

	Feet
Lower Sunnyside bed	0-5
Coal beds in the 325-foot interval between Lower Sunnyside and Kenilworth beds	0-8 (325)
Kenilworth bed	1-20
Interval (Kenilworth Ss.)	35-55
Castlegate "C"	0-13
Interval	45-60
Royal Blue	0-9
Interval	25
Castlegate "B"	1-13
Interval	40
Castlegate "A"	1-20
Interval (Aberdeen Ss.)	100-210
Spring Canyon Group-several beds	0-100
Interval	0-4
Spring Canyon Tongue-Star Point Sandstone	

The lowest exposed coal is in the Spring Canyon Group represented by sections 145 to 153. All of these are located in the westernmost part of the Castlegate-Matts Summit quadrangle. None of the beds exceeds 4 feet thick and the group is not considered important. To the east the coal-bearing interval disappears completely in a merger of Spring Canyon and Aberdeen sandstones.

One of the more important beds is the Castlegate "A" resting upon the Aberdeen Sandstone. A thick 8.3-foot section was measured on the west side of Price River Canyon but in most sections west of Panther Canyon it is unworkable. Good sections persist up to location 135 in Cordingly Canyon and the best development appears between locations 111 and 117 (Kenilworth area) and between 122 and 125 near the Aberdeen mine. East of Cordingly Canyon the bed thins and finally disappears in the next quadrangle.

The Castlegate "B" bed is represented by locations and sections 56 to 81. The bed is lenticular and fluctuates between 4 feet thick or less. The best development is between locations 65 and 73 between Panther and Willow canyons. The Royal Blue bed is also lenticular, but is only important in the immediate area of Kenilworth where it achieves a maximum thickness of 8.8 feet. The Castlegate "C" bed is important in the immediate vicinity of Castlegate only; elsewhere it is too thin to mine.

The Kenilworth bed is perhaps the most important bed of the quadrangle and is represented by coal sections 13 to 37. It becomes important just east of Price River Canyon, reaches its maximum development at Kenilworth and begins to thin, becoming unworkable east of Cordingly Canyon. Maximum development of the seam is believed thicker than 20 feet. Several beds present above the Kenilworth achieve greater importance in quadrangles to the east: the Fish Creek, Rock Canyon, Gilson, Castlegate F and Lower Sunnyside beds. Of these the only beds to achieve 4 feet or greater thicknesses in outcrop are near the east edge of the quadrangle.

Tomlinson (1932) made a study of some of the hazards encountered in mining coal in the Book Cliffs field and discussed the physical characteristics and roof conditions of the Castlegate "A" and Kenilworth beds:

> It [Castlegate "A"] varies from 4 to 19 feet in thickness and is massive, brittle, and bright; it also contains thin shale, boney partings and dull bands of coal, and shows few or no marks of bedding. The bed has prominent joints and in places contains streaks of resin and sulphur balls.
>
> The Castlegate D bed, also known as the Kenilworth. . . varies from 6 to 26 feet in thickness and is generally softer than the Castlegate A coal. It is brittle and massive, contains no visible bedding planes, and is characterized by bands of dull coal which contain a higher percentage of ash than the brighter coal, by boney and shale partings, and by streaks of resin and sulphur. . .
>
> . . .The roof of the Castlegate A coal is a bed of fine-grained sandstone, 4 to 6 feet thick, which forms a good roof wherever exposed. The roof of the Castlegate D (Kenilworth) is a bed of sandstone 40 to 60 feet thick. Intermediate between the roof and the coal bed, a layer of hard shale, and in some localities of sandy shale, from 6 to 48 inches thick occurs. It has a pronounced bedding plane, varying from 1 to 12 inches above the coal bed, which is termed cap rock. It is brittle and when exposed is treacherous, due to the fact that this coal bed is more than 12 feet thick in nearly all localities.

Subsurface Information

Two drill holes give data concerning conditions of the coal behind the outcrop. Also extensive mining indicates what happens to the coal farther north.

Mine records show the coal in the mines was thicker than at the surface. In the Castlegate mine the Kenilworth reached 25 feet and in the Kenilworth mine the same bed reached 22 feet. The drill holes are located in the area of the Castlegate mines. Sections 143 and 144 are on the Castlegate "A" and only the east hole showed workable coal, 7.2 feet split by 0.4 feet, 1 foot from the base. Sections 80 and 81 are on the Castlegate "B", coal thickening eastward with 5 feet of clear coal at the best location. Coal sections 36 and 37 show good Kenilworth coal thickening eastward as expected. The east hole indicates 19 feet of coal in two benches separated by 3 feet of shale. These holes hit another bed above the Kenilworth called the Castlegate "F" that may correlate with beds to the east. It lies 50 to 90 feet above the Kenilworth and is thicker to the west. Coal section 11 shows 7.5 feet of clear coal.

Depth to the coal increases rapidly in a northward direction, hence mining costs increase in that direction. A goodly proportion of the shallow overburden coal proved unminable because of outcrop burning or other geologic hazards and much of the coal with 1,000 to 2,000 feet of overburden has already been extracted. Table 22 classifies the lands of the Castlegate-Matts Summit quadrangle with respect to overburden. Reference is made to the top of the Aberdeen Sandstone.

The location of the 1,000-foot coverline is approximated near the top of the Castlegate Sandstone. The 2,000-foot coverline nearly follows the North Horn-Price River contact. In places 3,000 feet of cover occur just above the North Horn-Flagstaff contact, but the inconsistency in the thickness of the North Horn proves this an unreliable datum.

Table 22. Classification of land according to overburden, Castlegate–Matts Summit quadrangle.

Overburden (feet)	Percent	
	Total land	Coal land
Greater than 3,000	13.4	–
2,000-3,000	21.8	37.6
1,000-2,000	18.7	32.2
0-1,000	17.5	30.2
Noncoal land	28.6	–

Quality of Coal

Over 300 individual analyses (table 4) have been run on coal from the Castlegate-Matts Summit quadrangle and most represent samples from the Castlegate and Kenilworth mines. Little difference exists between coals from one bed to the next or from one area on the map to another. Table 23 lists average proximate analyses.

Table 23. Average proximate analyses of coal, Castlegate–Matts Summit quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	312	4.7	2.5-10.4
Volatile matter	306	41.7	35.7-64.3
Fixed carbon	306	47.2	28.3-52.1
Ash	311	6.3	3.8-12.7
Sulfur	295	0.44	0.1- 0.8
Btu/lb	303	12,755	11,840-13,370

Walker and Hartner (1966, p. 36 and 37) took the sulfur of several coals and subdivided it into three categories (table 24).

Table 24. Sulfur content of coal, Castlegate–Matts Summit quadrangle.

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Arronco	Kenilworth	0.46	0.01	0.07	0.38
Arronco	Kenilworth	0.50	0.01	0.03	0.46
Castlegate No. 2	Castlegate C, D	0.37	0.01	0.05	0.31
Kenilworth	Castlegate "A"	0.46	0.01	0.02	0.43
Kenilworth	Kenilworth	0.39	0.01	0.03	0.35

The sulfur content of the coal in the 295 samples plotted against the number containing an increment percent range yields a curve that quickly rises to the average and then gradually tapers off (figure 29).

Forrester (1905, p. 43) provides an analysis of ash obtained from coal in the Castlegate mine.

	Percent
Sesquioxide	22.01
Silica	38.18
Alumina	21.87
Protoxide of manganese	2.34
Lime	9.26
Magnesia	2.67
Undetermined	3.67

Further data on the ash (table 25) are supplied by Abernethy, Peterson and Gibson (1969a, p. 7). The two analyses are believed from the Castlegate and Kenilworth areas and are of Kenilworth coal.

Spectrochemical analyses of the same samples of coal ash were made (table 26) and reported by the same authors (Abernethy, Peterson and Gibson, 1969b, p. 23) to determine the presence of trace elements.

Table 25. Analyses of ash content, Kenilworth coal, Castlegate–Matts Summit quadrangle.

	Sample No. 1	Sample No. 2
Percent of maf coal ash	8.1	9.6
Percent of maf coal sulfur	0.4	0.5
Percent of ash		
S_1O_2	50.5	48.7
Al_2O_3	10.3	15.1
Fe_2O_3	4.9	4.9
T_1O_2	0.9	1.0
P_2O_5	0.62	0.62
CaO	17.2	13.3
MgO	7.6	6.0
Na_2O	0.4	0.5
K_2O	0.4	0.6
SO_3	6.6	8.3
Ash softening temp.	2,260° F	2,260° F

Before 1905 the Castlegate coal was used in coking and provided Utah's principal supply. At least 200 coke ovens were operating in the area of Castlegate at the turn of the century. Eventually the Castlegate coke was replaced with the product from Sunnyside which was greatly superior. Forrester (1905, p. 42) compared an analysis of Castlegate coke with that of the Sunnyside (table 27).

Johnson (1953) notes that the existence of coking and noncoking coal in adjacent areas of the same coal bed is indicated by chemical analyses and confirmed by physical tests. Apparently coking coal occurs only in areas of relatively stagnant groundwater below the water table. Noncoking coal is found in active circulation areas near or above the water table. The destruction of the coking properties is blamed on oxygen absorption from circulating groundwaters.

In a report of the Utah Conservation and Research Foundation (1939, p. 74) low-temperature carbonization of coal from the

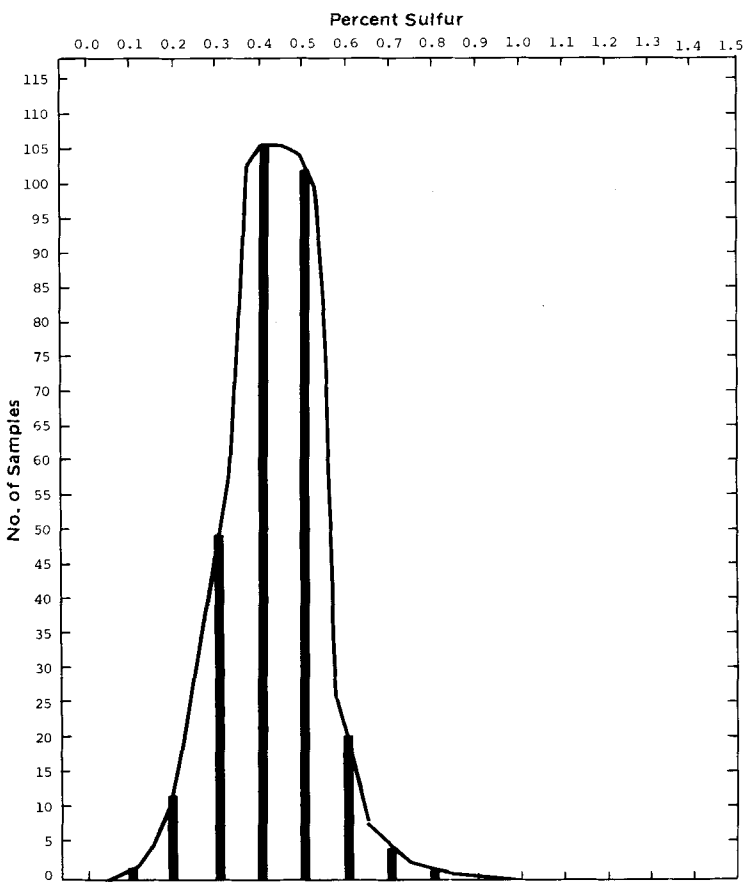


Figure 29. Percent sulfur content versus number of coal analyses, Castlegate–Matts Summit quadrangle.

Table 26. Trace-element content of coal, Castlegate–Matts Summit quadrangle.

	Sample No. 1	Sample No. 2
Percent of maf coal ash	8.1	9.6
Percent of ash		
As	0	0
B	.05	.04
Ba	.12	.12
Be	.0002	.0002
Co	.003	.005
Cr	.005	.005
Cu	.002	.002
Ga	.001	.002
Ge	0	.0005
La	0	0
Li	.003	.003
Mn	.007	.005
Mo	.001	.001
Nb	.005	.005
Nd	0	0
Ni	.001	.002
Pb	.001	.001
Rb	0	.008
Sc	.002	.002
Sn	.001	.001
Sr	.1	.1
V	.005	.01
Y	.003	.003
Zn	.01	.005
Zr	.08	.07

Table 27. Comparison of analyses of coke from Sunnyside and Castlegate areas, Castlegate–Matts Summit quadrangle.

	Moisture	Volatile matter	Fixed carbon	Ash
Sunnyside	0.28	1.68	89.6	8.5
Castlegate	0.80	2.70	86.8	9.8

Castlegate "A" bed in the Aberdeen mine was tested and the results are repeated in table 28.

Similar tests were run by the U. S. Bureau of Mines (Gomez, Landers and Boyd, 1967) using an end carbonization temperature of 500° C (table 29).

Table 29. Calculated carbonization product yields (maf coal in weight percent; at 500° C), Castlegate–Matts Summit quadrangle.

Mine	Char	Water of decomposition	Tar and oil	Gas	Scf/lb gas value	Heat value of gas Btu/scf
Castlegate No. 2	70.7	5.3	18.0	5.2	0.960	787

Mines and Development

Several mines have been opened on the Castlegate-Matts Summit quadrangle (table 30), but essentially only the Castlegate and Kenilworth mines have been important and only the Kenilworth was active in 1969. The total production of 627,423 tons for the quadrangle in 1969 came from the Kenilworth mine delivered through the Castlegate mine portals.

The Kenilworth has absorbed the Aberdeen, Bull Canyon prospects, Cordingly Canyon prospect and Milburn mine. The Castlegate has incorporated the Peacock and the Ketchum mines. Presently the two giants join underground and it is difficult to define their boundary. The only other mine was the Panther, which was abandoned in 1938.

The earliest mine to open was the Castlegate in 1889. From the beginning the coal was used to make a low-grade coke. Coking ended in 1907 as Sunnyside coal proved superior in quality. Between 1890 and 1907, 1,590,332 tons of coal were consumed to produce 720,843 tons of coke. Four to five seams have been

Table 28. Carbonization product yields, Castlegate "A" bed, Aberdeen No. 1 mine, Castlegate–Matts Summit quadrangle.

	Vertical Retort									Rotary Retort			
	External Heating							Internal Heating		External Heating			
Carbonizing Temperature °C (Products Weight Percent)	450	550	650	650	650	750	850	550	650	450	550	650	650
Char	80.1	69.5	64.8	64.2	67.4	62.2	61.9	74.4	67.8	71.2	66.5	63.2	62.6
Gas	2.0	5.3	8.5	10.8	7.2	10.2	12.4	2.1	5.6	4.0	7.5	10.0	8.5
Tar	6.4	10.7	10.2	10.6	9.0	10.7	10.7	8.8	9.6	12.3	12.2	12.0	12.9
Light oil	0.3	0.5	0.6	0.5	0.4	0.6	0.6	0.5	0.6	0.3	0.4	0.6	0.4
CO_2	1.1	1.4	2.0	1.9	1.9	2.7	2.3	1.7	1.5	0.8	2.0	1.4	2.0
Tar liquors[1]	8.0	10.4	11.3	11.3	11.8	11.1	11.2	–	–	10.0	9.9	11.0	11.6
Total	97.9	97.8	97.4	99.3	97.7	97.5	99.1	–	–	98.6	98.5	98.2	98.0
Gas, cu ft	666	2,116	4,072	3,770	3,705	5,151	6,830	778	2,421	1,379	2,690	4,470	4,340
Tar, gallons	15.4	25.5	24.3	25.5	21.7	25.6	25.4	20.4	22.1	29.6	29.4	29.0	31.0
Light oil gallons	1.0	1.6	1.9	1.4	1.2	1.8	1.7	1.5	1.8	1.0	1.4	2.0	1.3
$(NH_4)_2SO_4$ pounds total	2.4	8.8	12.8	9.2	6.1	18.3	12.3	9.3	15.9	4.6	–	8.8	10.5

[1]Contains phenol, o-cresol, m,p-cresol and xylenol.

Table 30. Mines in the Castlegate–Matts Summit quadrangle.

Mine	Location	Remarks
Aberdeen (Bollinger, Price Trading Co.)	SE.SW.10-13S-10E 4,394,810m.N. 518,190m.E.	Active 1898-1916 Portal abandoned
Bull Canyon prospects	C.S.½.9-13S-10E	
Peacock mine (Castlegate mine)	NE.SW.SW.NE.1-13S-9E 4,397,760m.N. 510,900m.E.	Old
Cordingly Canyon prospect	C.NW.14-13S-10E	
Kenilworth (Portal) (Rock Tunnel) (Independent, Four Points, Wade and Lowley)	SE.NE.SW.NW.16-13S-10E NW.NE.SW.16-13S-10E 4,394,110m.N. 516,190m.E.	Active 1906-1970
Castlegate mine (Peacock, Ketchum)		Active 1890-1970
No. 1	NW.NW.NW.NW.1-13S-9E 4,397,050m.N. 511,980m.E.	
No. 2	SE.SW.SW.SW.31-12S-10E 4,397,810m.N. 512,550m.E.	
No. 3	SE.NW.NE.35-12S-9E	
No. 4	SE.SE.SE.SE.36-12S-9E 4,397,820m.N. 512,495m.E.	
Milburn mine (Arronco, Cordingly Canyon)	NE.SW.SW.11-13S-10E 4,394,910m.N. 519,440m.E.	Active 1936-1949
Ketchum mine (Castlegate mine)	NE.NE.NE.NW.1-13S-9E 4,397,050m.N. 511,980m.E.	Active 1911-1916
Panther mine (Heiner, U. S. Fuels)	NE.SE.SE.1-13S-9E 4,396,650m.N. 512,400m.E.	Active 1913-1938

mined involving the Castlegate coal group, Kenilworth and Castlegate "F". In 1901 it was the largest mine in the state of Utah. In 1922 the first shaft mine in Utah was the Castlegate No. 3. Production reports are confusing since in later years the Kenilworth joined with the Castlegate. Some reports indicate a production total of 27.4 million tons through 1969; others report 34.0 million tons. The reports with the smaller figure for the Castlegate mine have larger figures for the Kenilworth and conversely. As expected the two compensate and are nearly equal when added.

The Kenilworth mine started production as the Four Points mine in 1906 or 1907. Most of the coal has come from the Castlegate "A" and Kenilworth beds but other beds were mined including the Royal Blue. In one analysis the mines produced 36.2 million tons and in another 27 million tons through 1969. The mine is presently (1970) active. The easy coal in the Kenilworth mines was quickly extracted and soon mining was under heavy cover. This cover creates tremendous pressure on pillars and during their removal, crushes them into powdery coal. The mines were classed as gassy by the Safety Division of the Industrial Commission of Utah. Jackson and Meritts (1951) report how water infusion reduced the dust to safe limits. In this process the pillars are infiltrated with water preventing dust production during mining. The ratio of volatile matter to total combustible, an index to the explosibility of coal dust, is 0.475. The Bureau of Mines states that a ratio exceeding 0.12 is explosive and that the explosibility increases as the ratio increases.

The Panther mine was active from 1913 to 1938 mainly in the Castlegate "B" seam which ranges in thickness from 6 to 8 feet. About 1.4 million tons were removed before the mine was closed for good. It is estimated that 65 million tons have been removed from the mines in the quadrangle through 1969.

Reserves

Clark (1928, p. 161) calculated the reserves for the Castlegate portion of the quadrangle. His estimates are on the basis of 1,800 tons per acre-foot and include all beds over 14 inches. His reserves are here modified to fit only the Castlegate NE portion of his quadrangle and excludes all groups, beds or seams whose calculated average thickness is less than 4 feet (table 31). It is hoped that where Clark includes total coal in groups with individual seams less than 4 feet thick, omitted beds, such as the Royal Blue which averages less than 4 feet but contains considerable reserve locally, will compensate.

Table 31. Original coal reserves in the Castlegate–Matts Summit quadrangle (more than 4 feet thick).

Location	Bed or Group	Average thickness (feet)	Acres est.	Tonnage
T.12S. R.9E.	Castlegate Group	5.0	960	8,600,000
	Spring Canyon Group	10.8	960	18,700,000
T.12S. R.10E.	Coal above Kenilworth	5.0	3,840	29,000,000
	Kenilworth bed	8.3	4,416	66,000,000
	Castlegate Group	5.4	4,416	43,000,000
T.13S. R.9E.	Castlegate Group	7.9	512	7,300,000
	Spring Canyon Group	11.7	704	14,800,000
T.13S. R.10E.	Coal above Kenilworth	5.0	6,400	58,000,000
	Kenilworth bed	12.2	6,976	153,000,000
	Castlegate Group	10.3	7,552	131,000,000
			Total coal	529,400,000

A separate study of the remaining coal in land holdings revealed that many acres are unavailable as a result of heavy outcrop burning. Tomlinson (1932, p. 5) states that sometimes coal has been burned from the outcrop 2,000 feet from the surface and under cover to a depth of 800 feet. A minimal estimate of 1,300 acres is eliminated because of outcrop burning. Recoverable reserves calculated in this study cover the entire quadrangle northward to and including the second tier of sections in T. 12 S. Measured reserves (Class I) amount to 43.8 million tons and estimated reserves (Class II) amount to 67.3 million tons. These reserves include only the Castlegate "A" and Kenilworth beds. The total recoverable figure may be enlarged by including the reserves of other beds where data are lacking to come up with a meaningful figure. Mining experience has proven about 53 percent recoverability of a seam of coal. If this recoverability is maintained, a total of 174 million tons will have been extracted when the quadrangle south of 39°45′ N. lat. is mined out. To compare this with Clark's (1931, p. 161) total reserve of 529 million tons roughly proves a true recoverability of 32.9 percent. This new figure should compensate for all reserve reductions as a result of geologic hazards, burned seam and multiple seam problems.

The north part of the Castlegate-Matts Summit quadrangle has not been evaluated in terms of reserve. It is close enough to infer the presence of good coal throughout the entire area and limited only by the 3,000-foot coverline. This area involves 7,150 acres. Fifteen feet of minable coal are assumed present in two seams with an inferred (Class III) reserve of 188 million tons (table 32). If 32.9 percent are recoverable, then 61.7 million tons of this coal could be extracted.

Table 32. Original coal reserves in the Castlegate–Matts Summit quadrangle according to overburden.

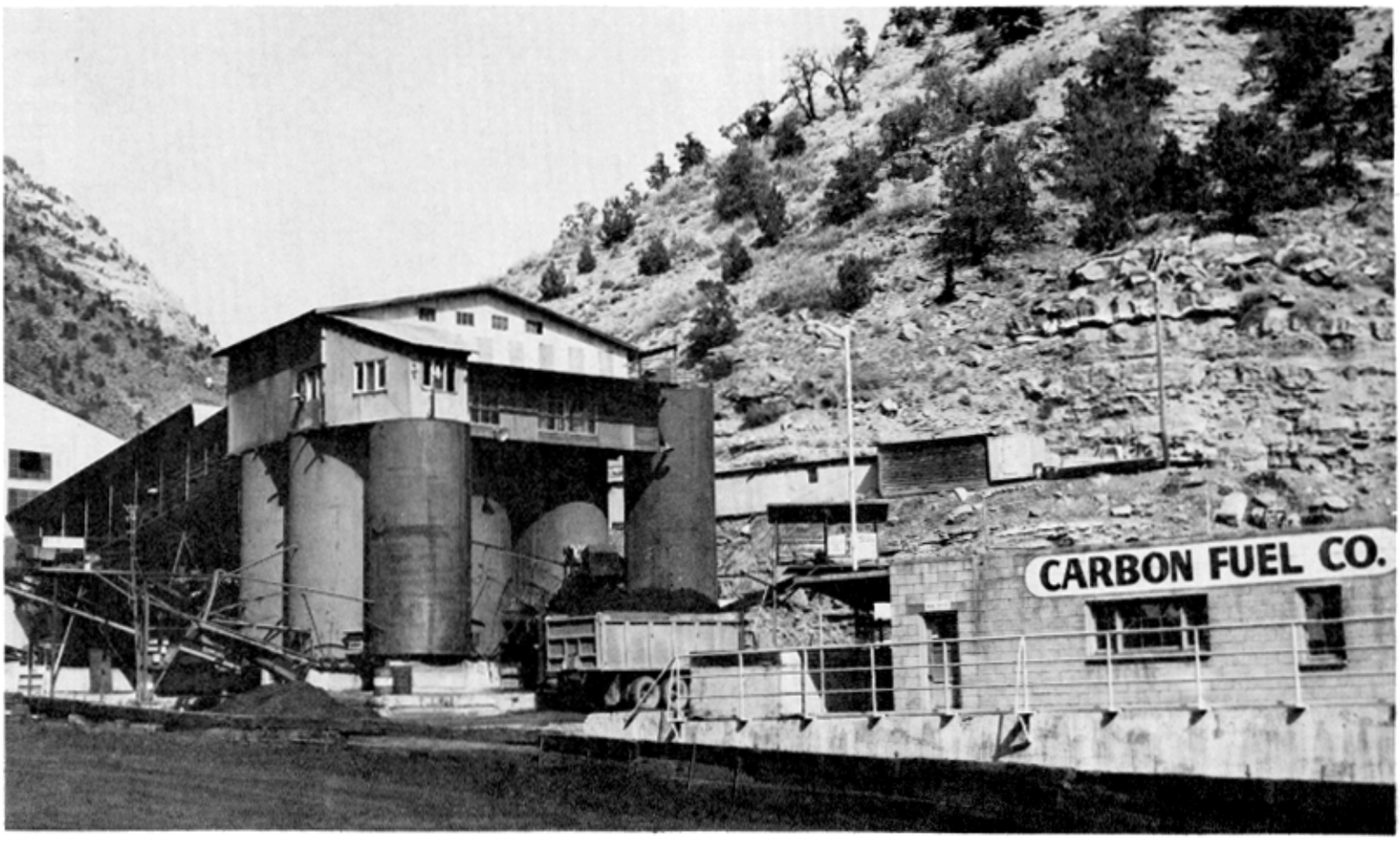
Cover (feet)	Class II	Class III	Total
Less than 1,000	241.4	–	241.4
1,000-2,000	188.5	47.9	236.4
2,000-3,000	99.5	140.1	239.6
	529.4	188.0	717.4
	Minable (32.9 percent) recoverability		236.0
	Mined up to January 1, 1970		65.0
	Recoverable coal remaining		171.0

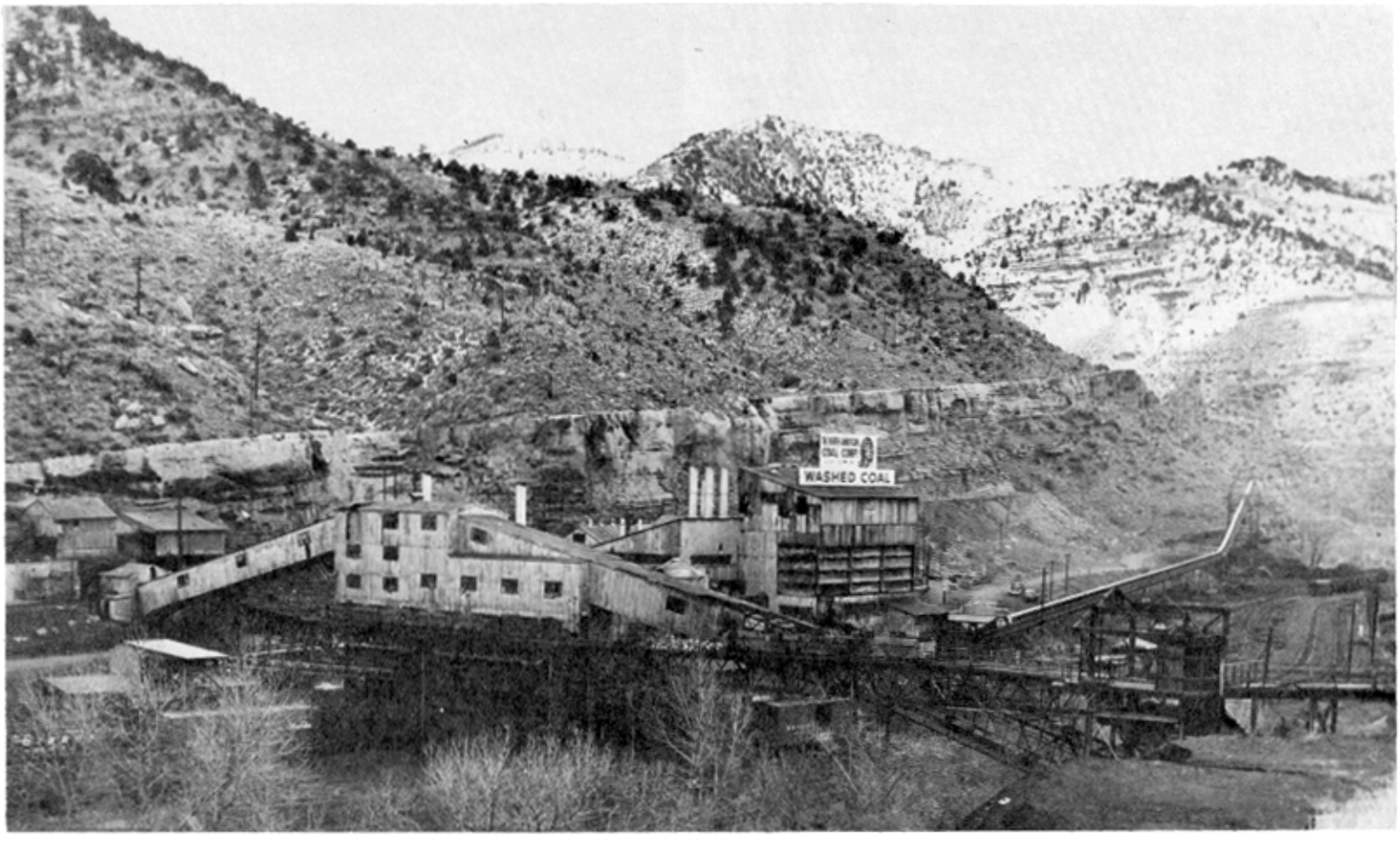
Little acreage north of the mapped quadrangle has less than 3,000 feet of cover so that any Class IV reserve would be small.

PRINCIPAL WORK

Most of the data were derived from Clark (1928) with significant amounts from various authors of the U. S. Bureau of Mines, especially in the area of analyses. Much new data were collected to finalize the study. All references are listed at the end of this report.

Top: Hardscrabble Canyon Carbon Fuel mine near Helper, Castlegate-Kyune quadrangle. *Bottom:* Coal from Castlegate and Kenilworth mines processed at the North American Coal Corp. tipple, Castlegate, Utah. Long conveyor (right) supplies coal to Utah Power & Light Carbon power plant.

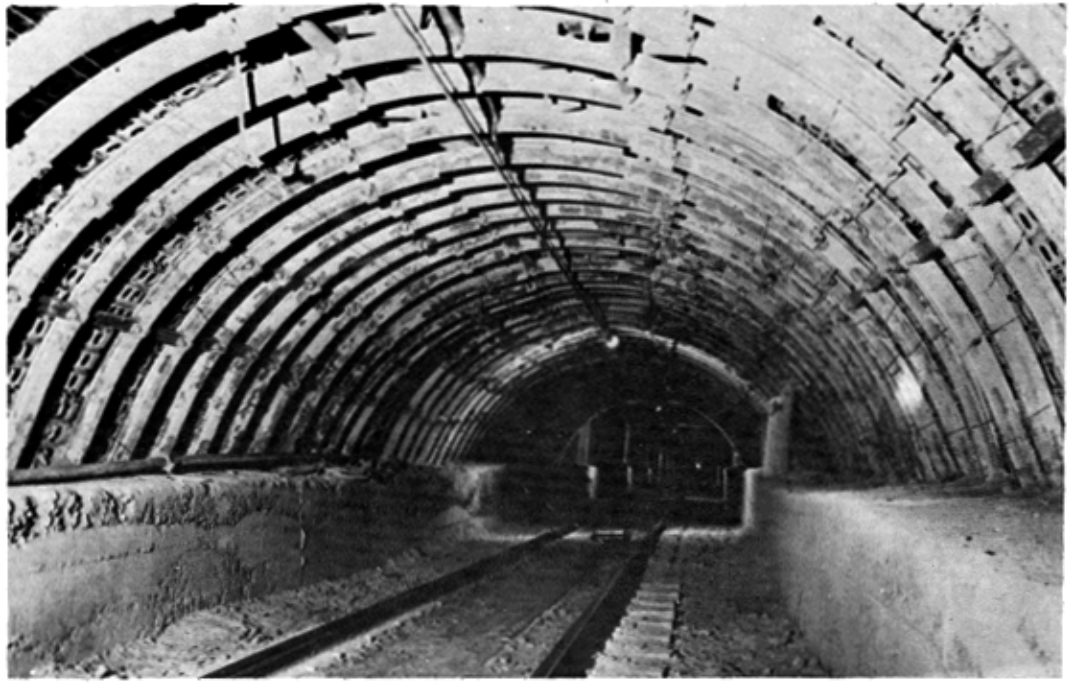




Early Utah coal mining town in the Castlegate area. Photo from Helper Mining Museum original.

Abandoned workings of the Liberty mines in Spring Canyon, Castlegate–Kyune quadrangle. Lower Blackhawk Formation in background at top of hill.

Collapse of roof at Sunnyside; note closely spaced roof bolts. Photo from Helper Mining Museum original.



Main slope, Sunnyside No. 1, in 1957. Photo from Helper Mining Museum original.

GUNNISON BUTTE W QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The U. S. Geological Survey Gunnison Butte 15-minute quadrangle is located at the mouth of Gray Canyon where the Green River emerges through the Book Cliffs out of the Uinta Basin (figures 19 and 30). The Green River marks the arbitrary boundary between the Book Cliffs coal field and the Sego coal field to the east. Gunnison Butte W is that part of the quadrangle west of the Green River. The town of Green River is located 6 to 9 miles south of the canyon mouth on the major transportation routes of U. S. Highway 50-6, Interstate 70 and the Denver and Rio Grande Western Railway. The Green River is the major tributary of the Colorado River in Utah with an average annual natural flow of 2.4 million cfs-days at Green River (6,575 cfs).

Access north of Green River is poor. A good road parallels the river on its east bank northward to a few miles beyond the confluence with the Price River. On the west bank a similar road fallen into disrepair north of Gunnison Butte is impassable even with four-wheel drive vehicles. Access to lands of the Beckwith Plateau is only on foot or horseback.

Elevation of the Green River at the mouth of Gray Canyon is 4,100 feet and rises to about 4,250 feet at the north end of the quadrangle. The base of the Book Cliffs is about 4,400 feet and the top of the Beckwith Plateau ranges from 5,600 feet at its east end to 6,500 feet along the west map margin. The highest map elevation is on the plateau and is a little less than 6,800 feet. The coal horizons are along the cliffs and on the canyon walls that cut into the Beckwith Plateau from the east at elevations ranging from 5,000 to 6,400 feet being lowest in Gray Canyon and highest to the southwest. In contrast to the other quadrangles produced for the Book Cliffs coal field, this one is presented at a reduced scale. The area shown marks the east edge of the coal field and was deemed less important inasmuch as the coal seams are mostly thin and subcommercial.

STRATIGRAPHY

The oldest stratigraphic unit exposed on the quadrangle is the Mancos Shale. The outcrop area covers all the flat lowlands of Gunnison Valley, extends northward and includes the lowermost part of the Book Cliffs escarpment. The drab medium to dark gray shale often has thin layers of sandstone or limestone in it. It is nonresistant and plastic when wet. Dirt roads become impassable during wet weather. The Mancos is believed to be about 3,500 feet thick at this location. The Blackhawk Formation forms much of the cliff north of Green River. It is difficult to place a lower boundary to the unit but the lowermost massive sandstone bed on the cliff is assigned to the Blackhawk and represents the featheredge of the Kenilworth Sandstone. It is not mapped east of the Green River. This is followed by a thick tongue of the Mancos Shale. The upper part of the Blackhawk consists of a cliffy sandstone bed followed by a slightly less resistant sequence of shaley sandstone and shale. Any coal is usually associated with the upper part of the cliff-forming sandstone or the softer units above. All coal beds are within 225 feet of the base of the overlying Castlegate Sandstone. Coal in the cliff-forming sandstone is correlated with the Sunnyside horizon and that of the uppermost sandy and shaley beds of the Blackhawk are correlated with the Beckwith coal zone. In places this upper member contains cliffy sandstones as well. Young (1955, p. 186) calls these upper beds the Grassy Member of the Blackhawk; when cliffy sandstones appear at the top they are known as the Desert Member. In a section measured along the west edge of the quadrangle the entire Blackhawk is 697 feet. Of this 171 feet are the Kenilworth Sandstone and 148 feet the Mancos Tongue above it. The sandstones associated with the Sunnyside coal are 224 feet thick and the upper beds are 154 feet thick.

The easy-to-recognize Castlegate Sandstone lies above the Blackhawk and the contact appears conformable. The Castlegate is a single massive cliff 75 to 100 feet high. The sandstone is fine- to medium-grained, very light gray in color, weathering medium tan-brown usually to darker shades than the Blackhawk. Above the Castlegate the Price River Formation in this locality can be divided into members. An incomplete section of 490 feet occurs on the Beckwith Plateau, the formation covering most of the upland surface. North of the Price River the entire thickness of the formation is present; it has not been measured but contours indicate a thickness of about 1,000 feet. The initial member of the Price River Formation on the Beckwith Plateau is the Buck Tongue of the Mancos Shale, about 100 feet thick, which in turn is overlain by the cliffy Sego Sandstone that resembles the Castlegate. The Sego is about the same thickness as the Castlegate as well. Two members follow: the Neslen coal-bearing member and the barren Farrer Member. Both consist of alternating resistant sandstones, shaley sandstones, shale and carbonaceous shale. The Neslen Member forms the basis of the Sego coal field to the east but on the Beckwith Plateau contains coaley beds or lenses usually less than 6 inches thick. The thicknesses of the individual members are undetermined in this quadrangle.

The youngest consolidated units, the Tuscher and North Horn formations like the North Horn Formation to the west, are believed to straddle the Cretaceous-Tertiary time line. They are exposed only north of the Price River in the area of the Big Horn benches. Fisher (1936) describes the Tuscher as a series of non-fossiliferous light gray sandstones separated by thin beds of shale. Only generalities are known about the Tuscher in the quadrangle. It first appears near Horse Canyon to the north and thickens gradually eastward.

The foothills of the Book Cliffs are often covered by bench gravels and the meander zones of both the Green River and Price River often are filled with alluvium. Some slumping and landsliding are evident around the base of the cliffs.

STRUCTURE

The strata of the quadrangle dip gently about 3 degrees to the northeast. No faults have been mapped.

PROPERTY CONTROL

Ownership of lands on the Gunnison Butte W quadrangle west of the Green River is as follows: Bureau of Land Management 81.7 percent, state of Utah 12.1 percent and private property 6.2 percent.

All the private lands are farms along the Green River and do not fall along the cliffs. No land is currently (1970) held for coal in leases or permits.

COAL

Surface Information

The lands of the Gunnison Butte W quadrangle are marginal coal lands and mark the east edge of Blackhawk coal. To the east emphasis shifts to the Neslen Member of the Price River Formation. About twelve coal sections are available, seven from the Sunnyside horizon and the remainder from the Beckwith zone (figure 31). The Sunnyside appears to be missing east of R. 15 E. which probably indicates a pinching out in that direction. The best thickness is at location 11 west of Blue Castle Butte where two benches of coal, one 3 feet thick, the other 2¼ feet thick, are separated by almost 4 feet of shale. Fisher (1936, p. 69) expects the coal to thin rapidly westward and considers it unimportant. He

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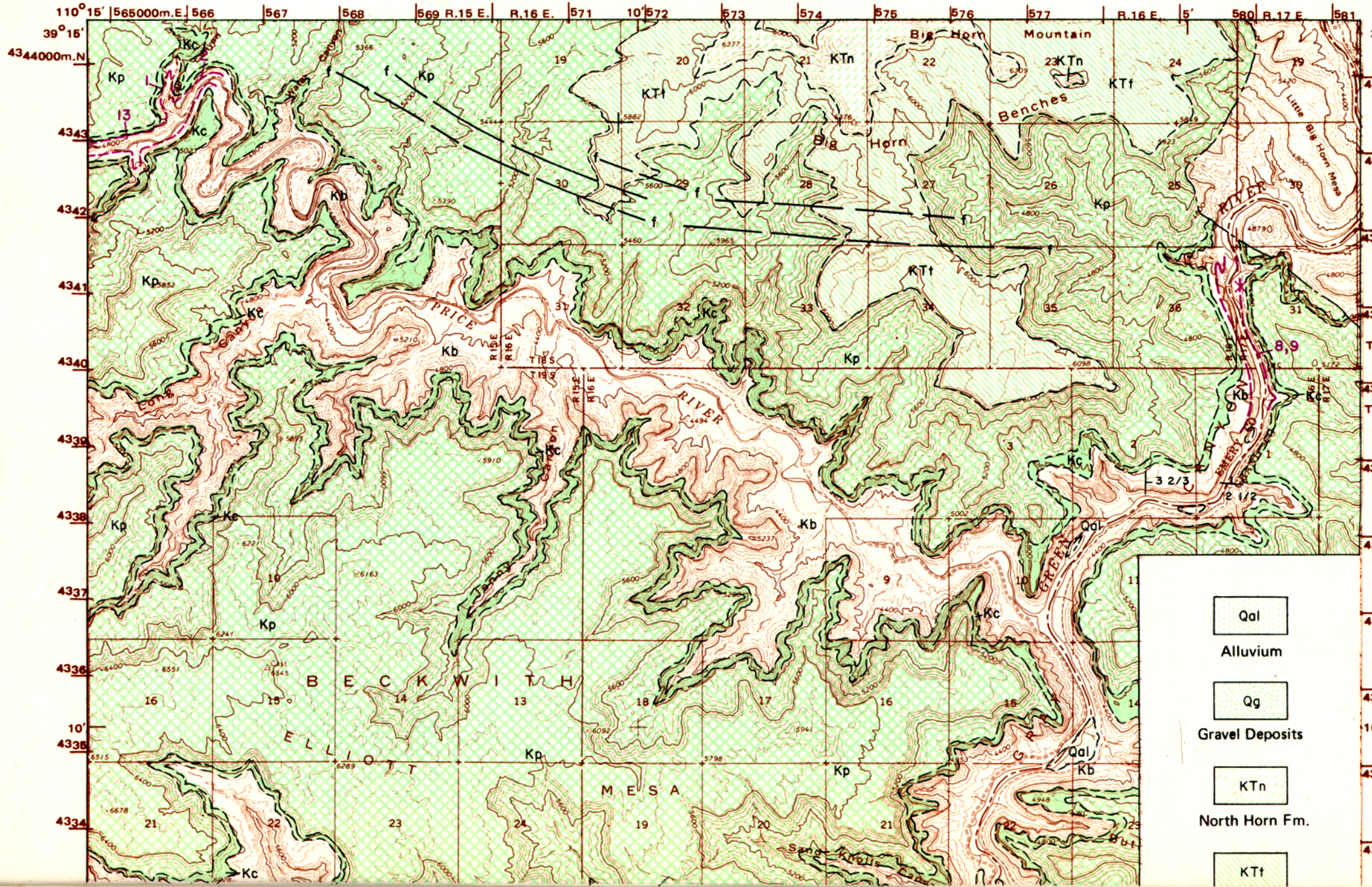
GUNNISON BUTTE QUADRANGLE
UTAH



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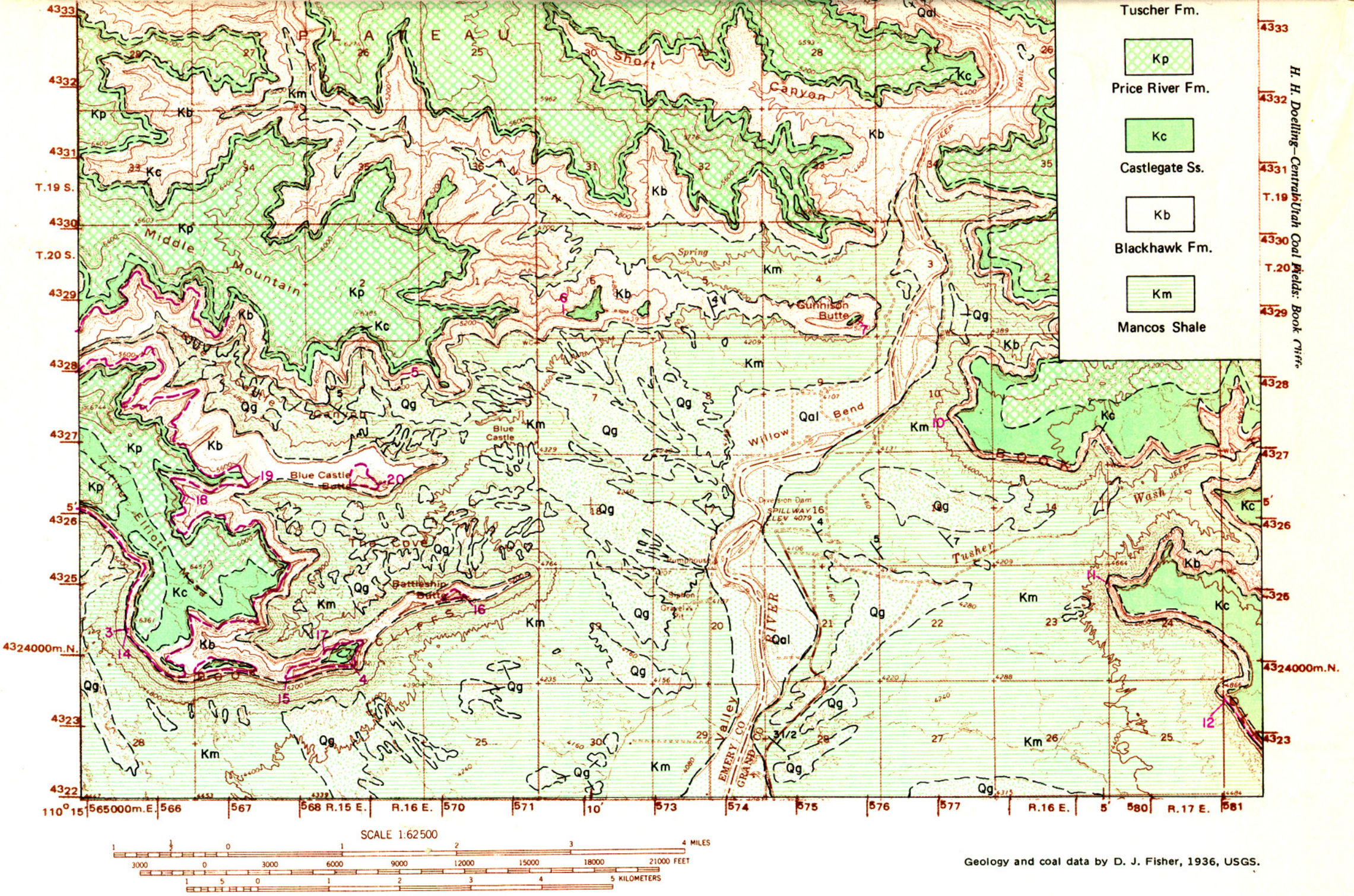


Figure 30. Coal and geology map, Gunnison Butte W quadrangle (explanation pages 332-333).

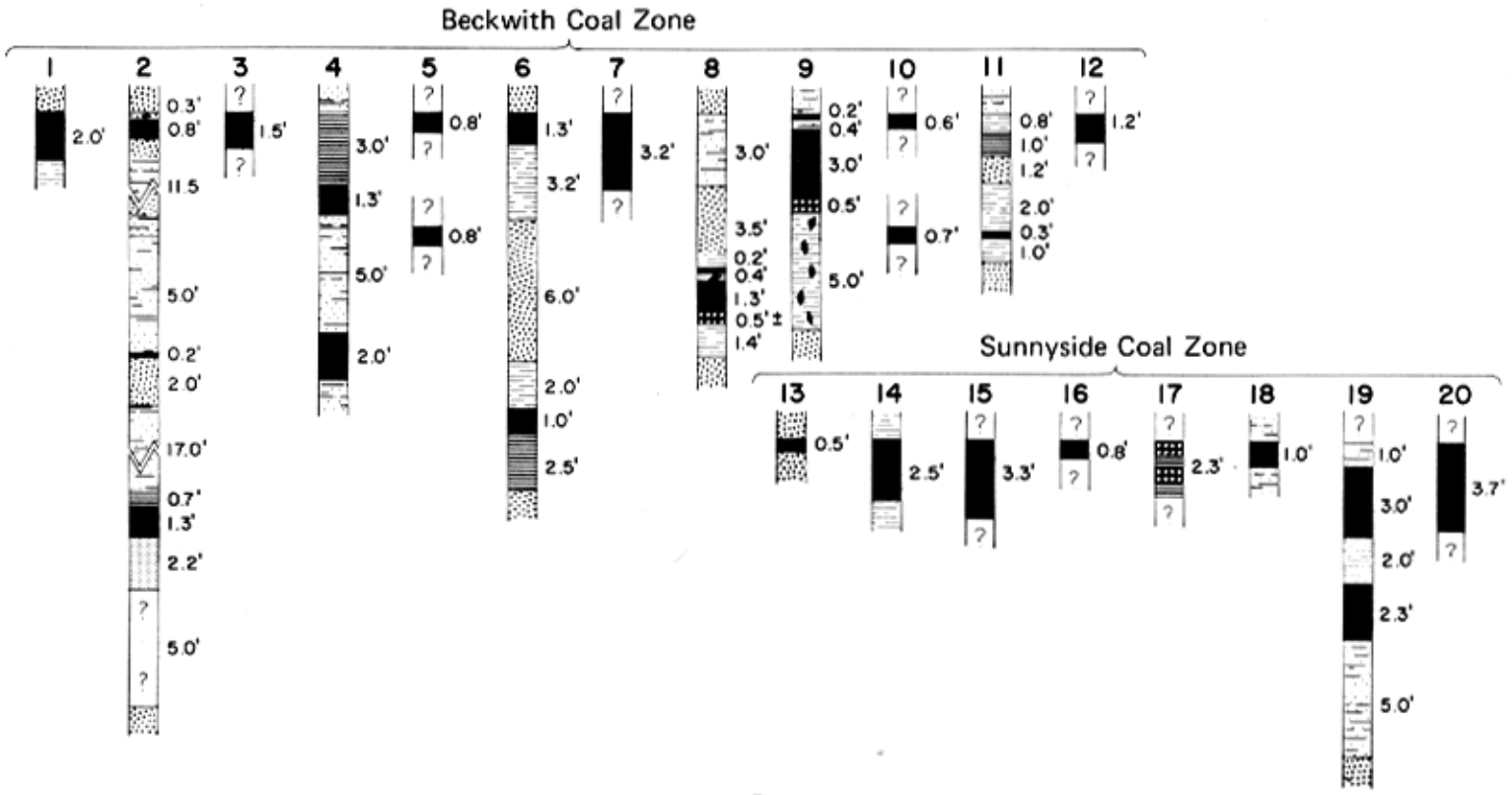


Figure 31. Coal sections of Gunnison Butte W quadrangle (vertical scale: 1 inch = 8 feet).

considers the coal of Sunnyside to average 14 inches in T. 20 S., R. 15 E. The upper Beckwith coal is lenticular and probably not continuous. The thickest bed was noted on Gunnison Butte just west of the Green River. The bed appears a little more than 3 feet thick.

To the present, investigations of the coal north of Elliott Mesa, especially along outcrops in the Price River Canyon, have been nil. It is thought, however, that the beds will average less than 4 feet thick.

Subsurface Information

Coal has not been drilled for on the quadrangle. Depth to the coal on the Beckwith Plateau should not exceed 1,000 feet. North of the Price River the 1,000-foot coverline is presumed in the Farrer Member of the Price River Formation. The cover should not exceed 2,000 feet anywhere.

Quality of Coal

No analyses of coal samples are available for the Gunnison Butte W quadrangle.

Mines and Development

No mines and no development for coal are known on the quadrangle.

Reserves

On the basis of a minimum 4-foot thick seam, no coal reserves exist on this quadrangle. However, local pockets of coal may be uncovered in the unexplored parts of the quadrangle.

PRINCIPAL WORK

All of the data presented for the Gunnison Butte W quadrangle were derived from Fisher (1936).

Looking southeast towards Woodside down U. S. Highway 50-6. Book Cliffs lie to the east with the Mancos Shale making the valley floor and Blackhawk and Castlegate sandstones rimming the tops of the cliffs. Lowermost sandstone is the Kenilworth; the next is the Sunnyside. This is followed by alternating shales and sandstones of the Beckwith coal zone. The uppermost massive sandstone is the Castlegate.

SUNNYSIDE NW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

This part of the Book Cliffs field is situated northeast and includes the Bear Canyon-Rock Canyon sector along the cliffs (figures 19 and 32). Most of the area portrayed is the rugged mountainous country above the cliffs. The base of the cliffs lies at 7,000 feet of elevation and the tops average 8,200 and 8,500 feet. The average elevation behind the cliffs, however, increases to 9,000 feet, the highest prominence being Mt. Bartles at 10,047 feet. The coal crops out along the cliffs between 7,000 and 7,700 feet.

The remote area is accessible by dirt roads and jeep trails. Such accessways are above and below the cliffs, but none cross them. The mouth of Rock Creek is 10 to 12 miles from U. S. Highway 50-6 and the junction of Left Fork and Right Fork of Whitmore Canyon is about 6 miles north of the town of Sunnyside.

STRATIGRAPHY

Consolidated units exposed on the quadrangle start with the Mancos Shale below the cliffs; the Blackhawk, Castlegate and Price River formations make up the cliff and the North Horn, Colton and Green River formations produce the uplands. The entire northeast half of the map area consists of Green River outcrops.

The oldest unit, the Aberdeen Sandstone, is a tongue of the Blackhawk within the Mancos about 275 feet below the top of the marine shale. In Rock Canyon the Aberdeen is about 100 feet thick, thickening westward. In Bear Canyon it is thin consisting of bedded sandstone, sandy shale and limy concretions. The main body of the Blackhawk overlies the Mancos and contains the coal beds. Of the several seams, the more important are the Gilson, Rock Canyon and Lower Sunnyside. The Blackhawk is dominated by massive gray to yellow-gray cliff-forming sandstones which are interbedded with shaley sandstone, shale and coal beds. The Blackhawk is about 750 feet thick on the Sunnyside NW quadrangle.

The Castlegate Sandstone, here about 150 feet thick, lies atop the Blackhawk and forms its usual nearly vertical cliff. The Castlegate is overlain by the Price River which is composed of two or more thick beds of sandstone interbedded with thinner beds of shale and sandy shale. The upper surface of the Price River underwent subaerial erosion before deposition of succeeding beds which created a surface of moderate relief. The average thickness is estimated about 500 feet.

The succeeding formations are Tertiary in age, except for the lower part of the North Horn. The North Horn Formation is a sequence of shales, sandstones, minor conglomerates and freshwater limestone and is about 500 feet thick. Above the North Horn is the Colton Formation. The lower part consists of about 140 feet of thin-bedded limestones, variegated shales and calcareous reddish brown sandstone. In the upper part the limestones disappear and lenticular shales and sandstones make up the unit. The Colton has a maximum thickness of 2,000 feet near Sunnyside and thins westward, intertonguing and grading into the Green River Formation. The thickness on this quadrangle has not been ascertained, but is assumed between 1,000 and 2,000 feet.

The youngest unit is the Green River Formation, composed of greenish gray and white claystones and shale. It contains minor amounts of sandstone, marlstone and algal reefs. The shales are often rich in organic material tending to change the color to brown and black. No estimate is made of its thickness.

STRUCTURE

The strike of the beds is northwest and the dip is northeast. The drop in beds is 600 feet per mile or 6 to 7 degrees. Several north- by northwest-trending faults cut coal beds in the west central map area but little is known about them. The displacements are assumed small, but locally shear zones undoubtedly will cut down on the recoverable reserve.

PROPERTY CONTROL

The lands of the Sunnyside NW quadrangle are owned privately (57.6 percent), by the Bureau of Land Management (34.8 percent) and the state of Utah (7.6 percent). Much of the private land does not include coal rights and is administered by the BLM. All the shallow coal under 2,000 feet of cover is held as leases by Kennecott Copper, Kaiser Steel and U. S. Steel corporations.

COAL

Surface Information

The area between Rock and Bear canyons has been investigated and 46 measured sections indicate the condition of the coal (figure 33). Four coal beds have sections indicating they are greater than 4 feet thick. The position of these coal beds is given in a generalized section below:

	Feet
Upper Sunnyside bed	0-4
Interval	25-30
Lower Sunnyside bed	1.5-7
Interval	135-140
Rock Canyon bed	2-6
Interval	40-75
Gilson bed	2-6
Interval	45
Kenilworth bed	0-2
Kenilworth Sandstone	

The Kenilworth bed is too thin to be of value on the Sunnyside NW quadrangle. The Gilson coal is thickest along the west map margin and gradually thins to unminable proportions in T. 14 S. The thickest measured section is almost 6 feet (location 32) but Clark (1928, p. 57) states that the average thickness for T. 13 S., R. 13 E. is about 7 feet. An apparent northward thickening of coal beds lends confidence to Clark's prediction. In his reserve estimates, however, he had little confidence that this average thickness would extend under the deeper parts of the township and he calculated with an average of 3.75 feet.

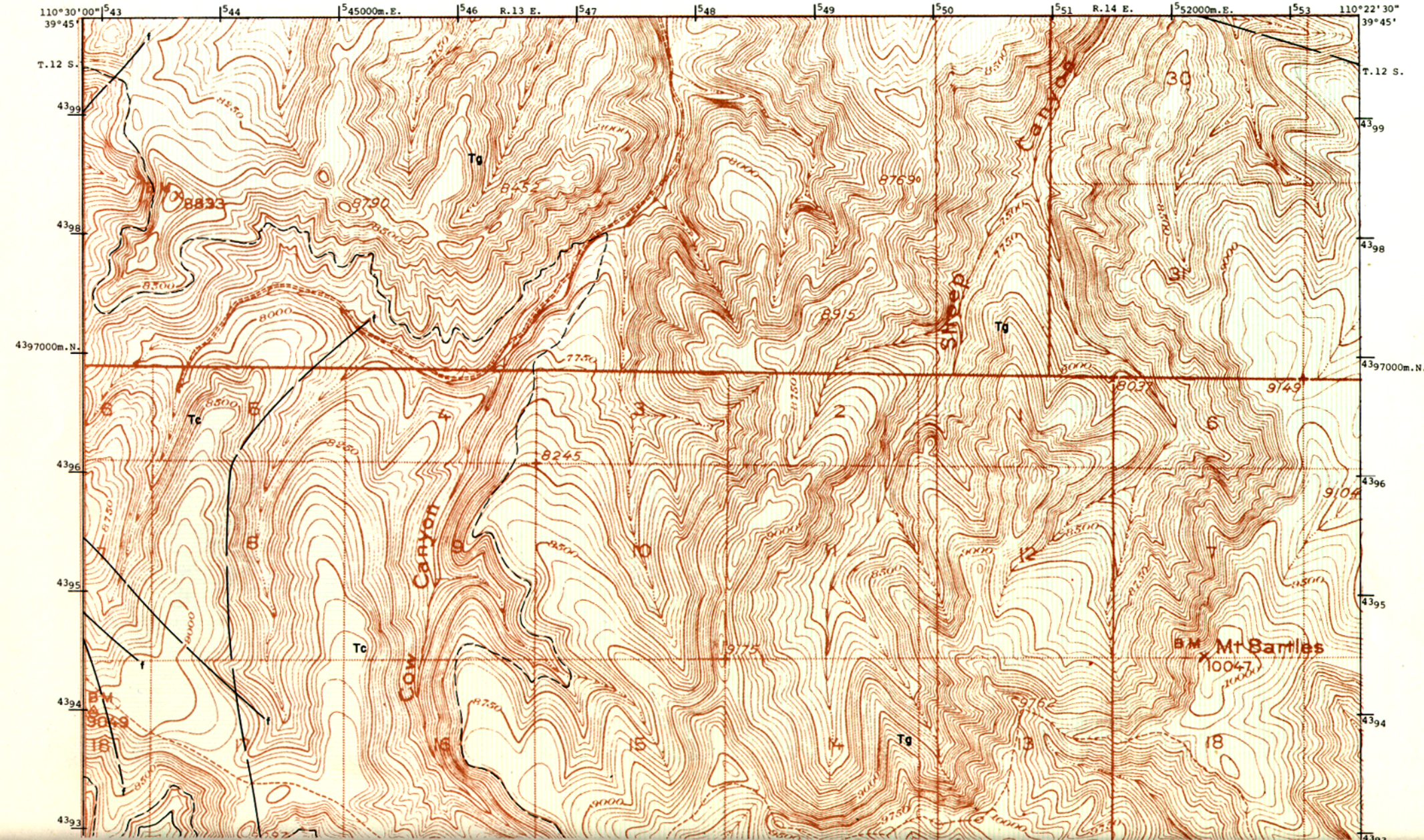
The Rock Canyon bed (with one thin measurement at Bear Canyon as an exception) maintains a 5- to 6-foot bed along the outcrop. The Bear Canyon sections are less than 4 feet thick. Clark notes (1928, p. 59) that although the Gilson is the thickest bed at the outcrop, it will not yield as great a tonnage since the area of thick coal is less.

The Lower Sunnyside is the most persistent and perhaps the most valuable bed on the quadrangle. The bed is extensively burned in outcrop but the zone of burning is thick indicating the continuance of a thick seam. Thicknesses seem to improve slightly southeastward.

Subsurface Information

The only drill-hole data are from the Pace Canyon site, measured sections 8, 15 and 31. The Lower Sunnyside is 3.9 feet, the Rock Canyon 5.2 feet and the Gilson bed 6.3 feet. Property-holding companies base their reserve estimates on an average of 4 feet of Lower Sunnyside coal, 5.4 feet of Rock Canyon coal and 7.0 feet of Gilson coal. Overburden data indicate that only

SUNNYSIDE N.W., UTAH



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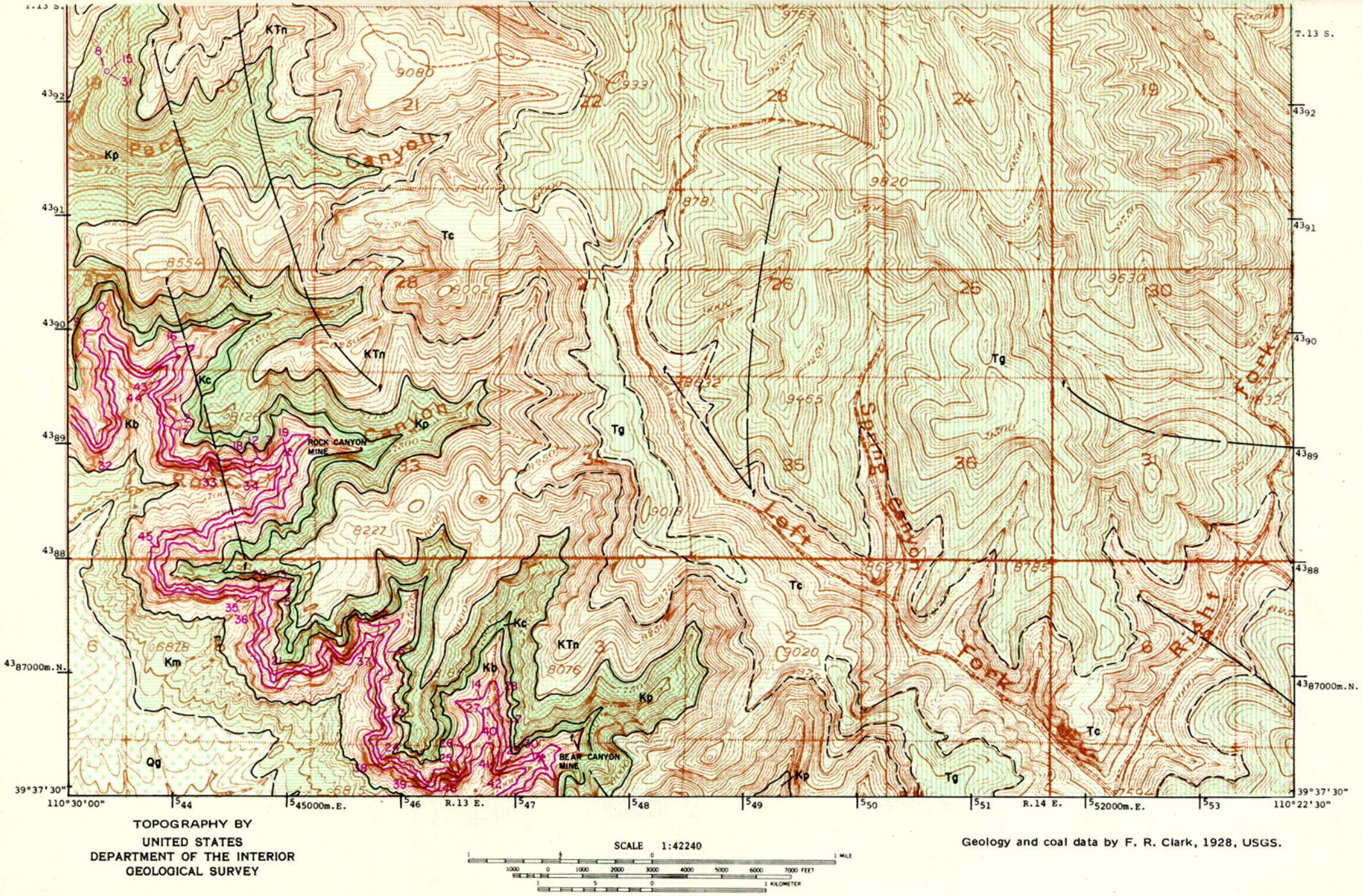


Figure 32. Coal and geology map, Sunnyside NW quadrangle (explanation pages 332-333).

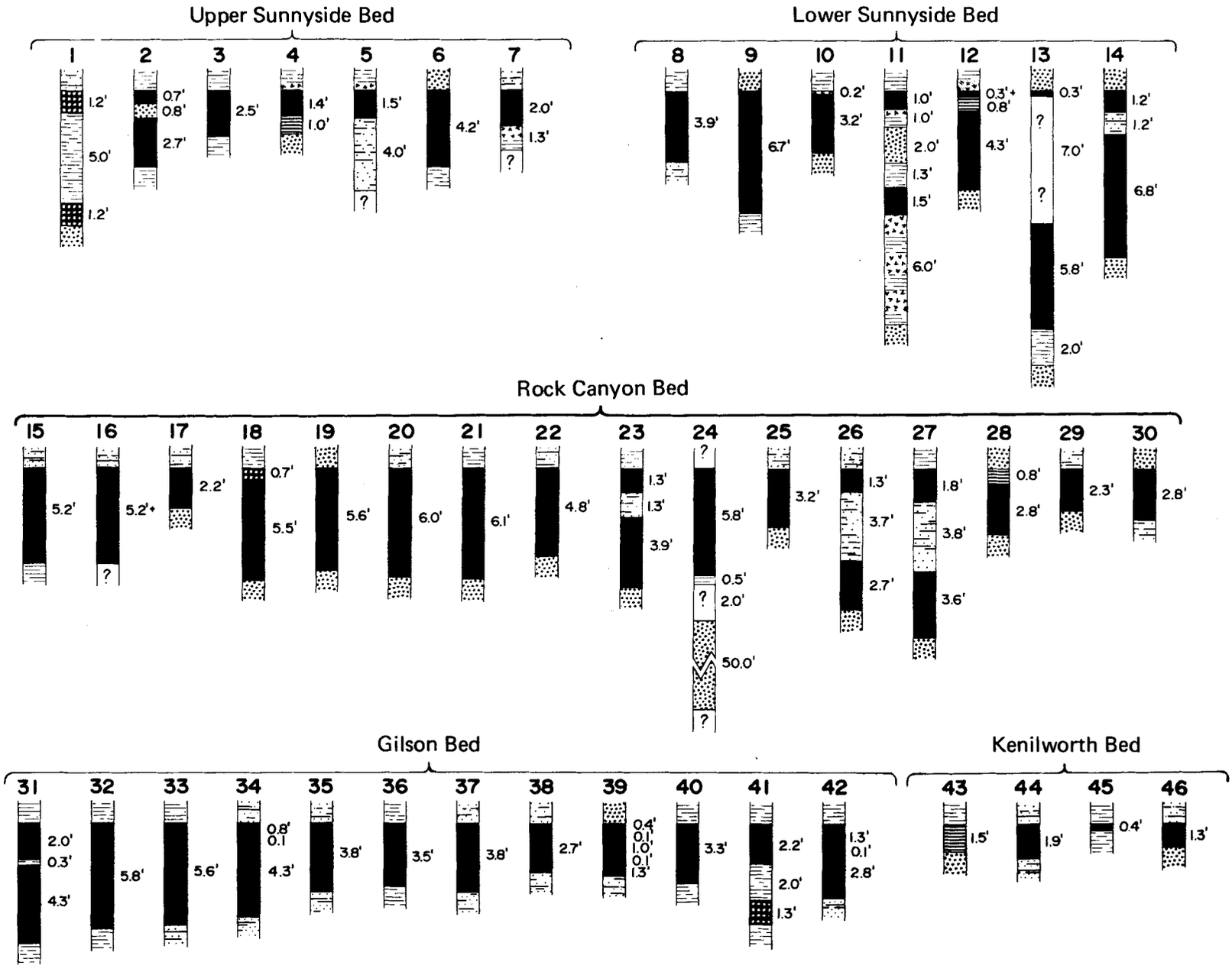


Figure 33. Coal sections of Sunnyside NW quadrangle (vertical scale: 1 inch = 8 feet).

46.3 percent of the quadrangle area can be considered coal land, the remainder being too deep to mine (table 33).

Table 33. Overburden data, Sunnyside NW quadrangle.

Overburden (feet)	Percent	
	Total land	Coal land
Greater than 3,000	49.7	–
2,000-3,000	30.2	65.2
1,000-2,000	9.9	21.3
0-1,000	6.2	13.5
Noncoal land	4.0	–

Quality of Coal

Six analyses, all from the Rock Canyon mine and probably all from the Rock Canyon bed, show the quality of coal in the quadrangle (table 34).

Of interest is the high-sulfur content of the Rock Canyon seam. The average quality of washed coal from the general Sunnyside area has the following approximations: Upper Sunnyside 0.60 percent, Lower Sunnyside 0.85 percent, Rock Canyon 0.94 percent and Gilson 0.68 percent. Much of the sulfur is believed in pyritic form which will make mining difficult because of hard sulfur balls and sulfurous fumes which affect miners' eyes and lungs. The coal lands are being held to produce metallurgical quality coal.

Table 34. Average proximate analyses of coal, Sunnyside NW quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	6	5.2	3.1- 7.9
Volatile matter	6	38.8	37.2-40.0
Fixed carbon	6	49.0	48.4-49.7
Ash	6	7.0	5.2- 7.9
Sulfur	6	1.82	1.0- 2.4
Btu/lb	6	12,512	11,880-12,940

In tests made of the Rock Canyon coal with respect to coking, the following was concluded:

1. Laboratory analyses, as well as full-scale oven coking tests, showed poor coking properties for the Rock Canyon coal.

2. Substitution of 20 percent Rock Canyon coal for Sunnyside coal in the plant mix showed a decrease in coke physical quality, particularly in the tumbler test stability and hardness factors. The Rock Canyon coal as tested was essentially fresh coal.

3. Chemical analyses of the Rock Canyon coal showed approximately 1 percent higher ash and 0.4 percent higher sulfur content than Sunnyside coal.

Gieseler plastometer tests were run on each sample of Rock Canyon coal (table 35). On arrival the coal showed maximum fluidities of 12 to 14 divisions per minute. Samples taken in subsequent full-scale testing, however, showed maxima of 3.7 to 8.0 divisions per minute. The temperature of occurrence of the maximum fluidity, as well as the solidification temperature, was somewhat lower for the Rock Canyon coal indicating this coal is less amenable to blending with higher rank coals.

Table 35. Comparison of Sunnyside and Rock Canyon coal (Gieseler plastometer test data).

Sample	Ash (percent)	First move. °C	0.1 D/M move. °C	Max. move. °C	Solidification	Max. Move. div/min
Sunnyside						
Fresh coal, avg.	6.7	333	361	427	458	30-200
Stock coal						
1	6.6	333	372	424	456	35
2	8.4	329	367	424	457	75
3	6.8	341	366	424	455	25
4	10.0	336	369	425	457	30
Rock Canyon coal						
As-received						
5	7.2	338	364	427	452	14
6	7.9	332	368	422	452	12
Test coal						
7	7.4	323	375	419	451	4.8
8	7.4	329	372	424	448	8.0
9	7.1	337	372	424	451	6.0
10	7.1	328	371	421	450	3.7

Full-scale oven tests of 100 percent Rock Canyon coal and Sunnyside coal were run on successive days. Coke from the Rock Canyon coal was definitely smaller and showed much more -5/8-inch breeze. Although the usual +2-inch index of the shatter test was higher than coke from the Sunnyside coal, the ½-inch fines were decidedly higher, illustrating the poor fusion of the coke. The tumbler test showed weaker coke from the Rock Canyon coal both for stability and hardness. Inspection of the coke showed generally poor fusion in the green ends with considerable areas of agglomerated but not fully fused particles and considerable pebbly seam separation. Coke from Sunnyside coal shows the same fingery structure but decidedly less pebbly seam and other poorly fused coke. Some blend tests with Rock Canyon coal were run as well and the results are given in tables 36 and 37.

Mines and Development

Two mines are known to have been opened on the Sunnyside NW quadrangle and both are presently inactive (table 38). Of these only the Rock Canyon mine produced appreciable coal. The area was first prospected in 1906 and mining took place in the 1950's on an intermittent basis. The mine was operated by Heiner Coal Co. from 1950 to 1960 when the property passed to the Pacific Steel Corp. and finally transferred to Kaiser Steel in 1965. Entries were driven into the Rock Canyon and Lower Sunnyside beds. Total production is about 93,000 tons. Nothing is known about the activity of the Bear Canyon mine except its location.

Reserves

The reserves listed in table 39 are those of Clark (1928, p. 102) modified slightly to fit the quadrangle and to exclude a small area thought to have more than 3,000 feet of cover. Clark used all beds 14 inches or more thick.

In the Kaiser Steel Rock Canyon leases of more than 5,300 acres, three seams are considered minable: the Gilson, Rock Canyon and Lower Sunnyside seams. The rock interval between the lower two averages 40 to 60 feet and the rock interval between

Table 36. Carbonization conditions and coke physical test results.

Percent Sunnyside	0	100	60	60	55		80	80	80
Percent Rock Canyon	100	0	20	20	20		0	0	0
Percent medium volatile			13	13	25		13	13	10
Percent low volatile			7	7	0		7	7	10
Test No.	1	2	3	4	5	Plant Avg.	Plant Coke	Plant Coke	Plant Coke
Coal pulverization									
1/4 inch	12.7	18.4	17.2	15.7	14.7				
1/8 inch	67.4	59.7	62.9	63.3	70.8				
Coal moisture percent	3.8	4.5	5.5	4.7	5.5				
Bulk density, oven	54.3	52.0	52.2	52.5	49.7				
Flue temp. °F	2,360	2,320	2,380	2,260	2,290				
Coking time, hrs.	16:20	15:42	15:40	17:10	18:29				
P. max., mix, D/M	8.0	75	16	12	16				
Coke screen test									
4 inch	.6	.7	6.6	3.6	1.6	–	6.5	4.7	7.4
2 inch	24.3	35.4	72.3	67.5	70.4	63.9	64.1	67.0	75.0
5/8 inch	9.2	4.6	3.0	4.3	4.1	4.3	5.4	5.4	3.0
1/8 inch	3.6	1.3	1.2	1.7	1.6	–	-	–	–
Shatter test									
2 inch	20.9	14.6	58.4	54.2	64.0	55.6	55.0	56.6	50.6
1/2 inch	8.7	6.0	3.0	2.8	3.2	3.1	3.2	4.2	2.8
Tumbler test									
Stability	3.1	5.4	31.7	37.2	36.2	39.8	37.1	38.3	38.6
Hardness	66.0	71.7	66.7	67.3	66.8	69.2	67.7	68.4	68.7
Porosity									
App. sp. gr.	.82	.84	.86	.84	.88	.85	.87	.84	.84
True sp. gr.	1.79	1.85	1.87	1.85	1.83	1.89	1.87	1.85	1.85
Percent cells	54.2	54.6	54.0	54.6	51.9	55.4	53.5	54.6	54.6
Physical fuel value	13.9	15.1	42.9	45.1	46.6	46.7	44.6	46.2	45.7
CPI	8	17	63	68	71	71	66	70	70

Table 37. Comparative data on Sunnyside district coals.

	Rock Canyon coal (washed at Castlegate)	Rock Canyon coal (washed at Castlegate)	Rock Canyon coal (table washed)	Lila area (table washed)	B-Canyon coal (table washed)
Date of coking test	6-21-59	6-16-59	6-23-59	6-24-59	6-22-59
Distance from outcrop line (feet)	500	500	500	4,500	2,000
Cover - approximate (feet)	900	900	900	2,000	1,000
Seam conditions:	Good, no support req.	Good, no support req.	Good, no support req.	Good, roof bolting req.	Good, roof bolting req.
Thickness (feet)					
Top	–	–	–	–	6
Separation	–	–	–	–	15
Bottom	5½	5½	5½	16	8-9
Sample location	NW ¼ NE ¼ 32-13S-13E	NW ¼ NE ¼ 32-13S-13E	NW ¼ NE ¼ 32-13S-13E	SW ¼ NE ¼ 14-16S-14E	NW ¼ SW ¼ 13-14S-13E
Coal proximate analysis (dry basis, percent):					
Moisture	1.8	–	–	2.6	2.7
Volatile matter	39.3	40.8[1]	39.2	38.8	38.3
Fixed carbon	53.4	51.9	54.8	55.1	54.9
Ash	7.3	7.3	6.0	6.1	6.8
Sulfur	1.47	1.51	1.35	.82	.63
Fluidity:					
Initial soft. temp. (°C)	338	329	344	350	332
Max. fluidity temp.	398	422	390	398	397
Dial div. per min.	6.2	3.7-8.0 (range)	4.4	1.5	3.1
Solidification temp.	428	450	419	426	429
Coke proximate analysis (dry basis, percent):					
Volatile matter	1.0	.8	1.2	1.1	1.2
Fixed carbon	89.2	88.1	89.5	89.3	88.5
Ash	9.8	11.1	9.3	9.6	10.3
Sulfur	1.33	1.28	1.10	.75	.63
Coke sieve (percent):					
Plus 1 inch	92.2	N.A.	90.5	84.5	93.0
Minus ½ inch	3.5	N.A.	6.0	11.0	4.0
Coke tumbler:					
Stability +1 inch (percent)	10.5	3.1	8.5	11.5	8.5
Hardness +¼ inch	71.0	66.0	65.5	62.0	72.0

[1] Average of 4 tests.

N.A. - Not available in terms comparable to other samples. Following sizes reported: "Screen test" +4 inch, .6 percent; +2 inch, 24.3 percent; -5/8 inch, 9.2 percent.

Table 38. Mines in the Sunnyside NW quadrangle.

Mine	Location	Remarks
Bear Canyon mine	N ½.10-14S-13E 4,386,260m.N. 547,220m.E.	
Rock Canyon mine	SE.NE.32-13S-13E 4,388,960m.N. 544,950m.E.	Prospected 1906; active 1952-1960

Table 39. Original coal reserves in the Sunnyside NW quadrangle (in short tons).

Location	Bed or zone	Average thickness (feet)	Acres est.	Tonnage
T.12S. R.13E.	Lower Sunnyside	2.8	2,048	10,300,000
	Rock Canyon	3.0	720	3,900,000
	Gilson	2.5	3,160	6,100,000
T.12S. R.14E.	All coal beds are considered too deep in this twp.			
T.13S. R.13E.	Upper Sunnyside	2.0	2,560	9,000,000
	Lower Sunnyside	4.8	11,450	98,900,000
	Rock Canyon	4.0	4,736	34,100,000
	Gilson	3.8	7,936	54,300,000
T.13S. R.14E.	Lower Sunnyside	4.0	300	2,100,000
T.14S. R.13E.	Upper Sunnyside	2.2	2,720	10,800,000
	Lower Sunnyside	7.8	2,880	40,400,000
	Rock Canyon	3.0	1,280	7,000,000
	Gilson	3.0	1,920	10,000,000
T.14S. R.14E.	Upper Sunnyside	3.0	1,200	6,500,000
	Lower Sunnyside	9.8	1,200	21,100,000
			Total coal	314,500,000
			Coal averaging 4 ft or more	196,000,000

the upper two averages 130 feet. Thus all three seams should be minable. The lower Sunnyside is expected to average 4 feet, the Rock Canyon 5.4 feet and the Gilson 7 feet. Compare this with Clark's averages for T. 13 S., R. 13 E. and T. 14 S., R. 13 E. Because thinner seams are minable by the long-wall method and separation between seams is wide, a relatively high percentage of recovery probably will be achieved. Management estimates that recoverable tonnages by long-wall, room and pillar and slope entries will total 60.7 million tons. This estimate does not take into consideration variables such as appearance of splits, thinning of some seams below the limit in which the equipment can operate, the distance behind the outcrop to which natural burn and oxidation has progressed, possible high-sulfur content and other quality problems. Thus a safety factor diminishes the reserve by 20 percent, which reduces the minable reserve of that property to 48.6 million tons. About 9,000 tons per acre of ground would be recoverable from all minable seams. By similar calculation, an assumed 8,200 tons per acre are recoverable from U. S. Steel lands just south of those of Kaiser's holdings. If an arbitrary average minable tonnage of 8,000 tons per acre were set for the entire quadrangle in the area with less than 3,000 feet of cover (about 17,000 acres), then a recoverable reserve of 136 million tons could be realized. If Clark's figures for coal more than 4 feet are used with an estimated 50 percent recovery, which would undoubtedly be realized with advanced mining techniques, the recovery would only be 98.3 million tons.

The small acreage north of the quadrangle under less than 3,000 feet of overburden is not considered important enough to include in the reserves of the field at this time.

PRINCIPAL WORK

The geology and surface coal data are mainly derived from Clark (1928). Additional data were gathered by consultants in investigations conducted for this presentation.

SUNNYSIDE SE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The north-south dividing line of this quadrangle, Patmos Mountain, has prominences rising to almost 10,000 feet (figures 19 and 34). The lands east and west appear mountainous despite their plateau-like inner structure. East of Patmos Mountain and paralleling it is Range Creek Canyon, the lower (south) part of which drops to less than 7,000 feet. A second ridge east of Range Creek also rises to nearly 10,000 feet. To the west Patmos Mountain is indented by closely spaced canyons mainly tributary to Whitmore Canyon which trends north-south along the west central map margin. The Book Cliffs front is exposed only in the southwest map corner. The top of the cliffs proper is at an elevation of about 8,500 feet and the base of the cliff is about 6,500 feet above sea level. The coal beds are exposed only along the cliff face between 6,800 and 7,100 feet.

Mountain roads passable by four-wheel drive or high clearance vehicles occur on the main ridges. The mines located along the cliff faces are served by Utah state highways connecting with U. S. Highway 50-6. A spur of the Denver and Rio Grande Western Railroad ends at the Sunnyside mines with a branch extending just to the west of the map area south of Sunnyside and connecting with the Horse Canyon mine farther south.

STRATIGRAPHY

The major part of the Sunnyside SE quadrangle is the area above the cliff exhibiting Tertiary outcrops. Cretaceous beds occur only along the west map edge, along or closely paralleling the Book Cliffs. The drab gray shales of the Mancos lie below and form the lower 200 to 300 feet of the cliffs. The shales of the Mancos are superseded by the sandstones of the Kenilworth Member of the Blackhawk Formation. The lower part of the sands are thin-bedded but for the most part are massive, building a cliff 180 feet high. Fisher (1936, p. 13) subdivides the Blackhawk into members based on their resistance to erosion. From top to bottom these members are: upper shaley member (220 feet), middle sandstone member (130 feet), middle shale member (130 feet) and lower sandstone member (200 feet); they total 680 feet.

The first coal bed, the Kenilworth, is located just above the lower sandstone member. The other important coal beds are near the top of the middle sandstone. The sandstone members were formed as great coastal plain deposits that extended from the highlands on the west into the edge of the Mancos sea. According to Fisher these sandstones become more fine-grained to the east where they finally grade into the Mancos Shale. The shaley members consist of alternating sandstone, shale, carbonaceous shale and coal and are deposits of coastal swamps and lagoons.

The Castlegate Sandstone and Price River Formation overlie the Blackhawk and crown the cliff. The Castlegate Sandstone is a sandstone cliff about 180 feet thick and the Price River Formation consists of alternating sandstone and shale 500 feet thick. The Price River is 70 percent sandstone but the shales are often carbonaceous with occasional layers of bone coal. No commercial coal has been located in the Price River around Sunnyside. Mountains continue to rise above the Price River but the gradient is not as steep as at the Book Cliffs proper.

The Tertiary beds are made up of the North Horn, Colton, Wasatch and Green River formations. Relationships between the first two are unclear and mapping over the major part of the area shows them as a single formation. The lower part of the North Horn is considered Cretaceous in age. The North Horn is mainly a unit of alternating sandstone and shale. To the south the Wasatch appears above the North Horn. It consists of interbedded red and green shales with a conglomerate at the base. Some geologists feel that this Wasatch is the same as the Colton to the north; others feel it is a tongue of the Wasatch which thickens rapidly eastward. The major part of the upland surface exposes the Green River Formation, the youngest consolidated unit. The unit is thick, consisting mostly of greenish gray and white claystones and shale. Between 2,500 and 3,000 feet of the unit are exposed on the quadrangle.

STRUCTURE

The structure contours strike north-south in the south half of the quadrangle and veer slightly northwest in the north. Over much of the area the beds drop 500 feet per mile to the east but near the cliffs the drop increases to as much as 700 feet per mile (dips from 5 to 8 degrees).

Several faults cut the coal beds, most parallel this strike. The displacements are generally under 100 feet although in a few places they exceed this. Locally they have produced shear zones cutting down the minable reserve. For the most part they are spaced widely enough apart so as not to seriously impede mining.

PROPERTY CONTROL

The lands of the Sunnyside SE quadrangle are mostly privately owned (75.8 percent), much of which is held as coal land. The rest is divided by the Bureau of Land Management (18.3 percent) and the state of Utah (5.9 percent). Most of the coal properties held are private fee lands; only a small acreage is leased. The larger block of property is held by Kaiser Steel Corp.; along the south map margin, property is held by U. S. Steel Corp. Small acreage is held by L. Hawthorne in the north central map area (figure 15). No land is open except the area with less than 3,000 feet of cover around Range Creek.

COAL

Surface Information

Measured coal sections are available from the Kenilworth, Lower Sunnyside and Upper Sunnyside beds (figure 35). Of these the Sunnyside beds are the only ones of appreciable thickness. The positions of these beds in the stratigraphic column are listed below:

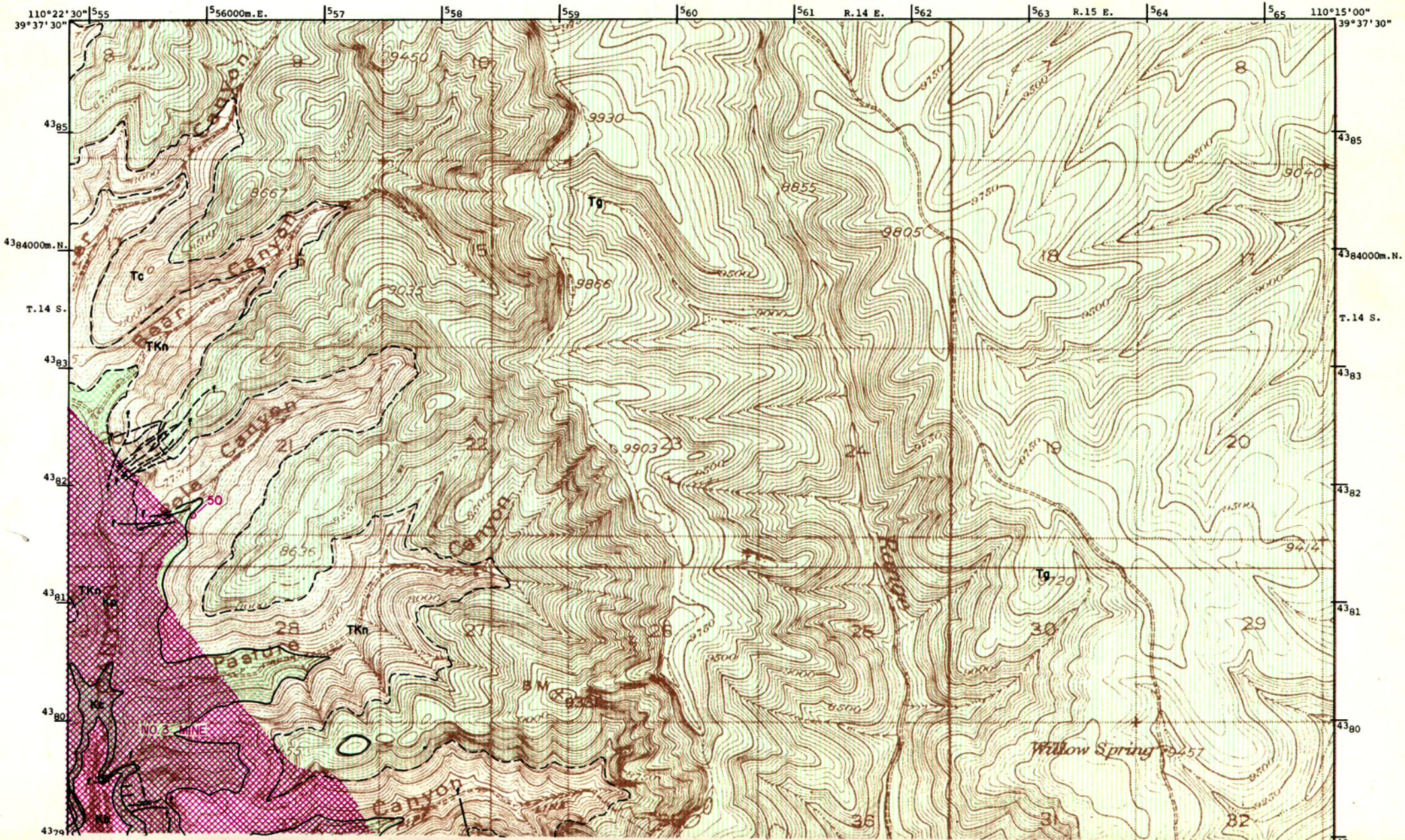
	Feet
Upper Sunnyside	2-6.5
Interval	3-40
Lower Sunnyside	5-14
Interval	220-240
Kenilworth	0-2.5
Kenilworth Sandstone	

The Kenilworth bed is of no value when the lower limit is 4 feet. It averages 2 feet along the outcrop, in some places resting directly on a massive sandstone or separated from it by up to a few feet of clay or sandy shale.

The Lower Sunnyside is the most valuable bed; all the included sections average 9 feet thick and the coal bed is thought to be of value everywhere. The bed normally occurs in a single bench with several exceptions, most notably in 5-15S-14E. The Lower Sunnyside generally rests on a massive ledge-making sandstone.

The Upper Sunnyside bed is represented by locations 1 to 14. The bed reaches its best development in the coal field on this quadrangle. The coal is usually present in a single bench. One problem with this bed is its proximity to the Lower Sunnyside. In Kaiser's Sunnyside No. 1 mine the interval is about 39 feet. In Water Canyon in the NW quadrangle corner, it is about 15 feet; in NE 16-15S-14E, it is 6 feet. The bed averages about 5 feet thick.

SUNNYSIDE S.E., UTAH



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972

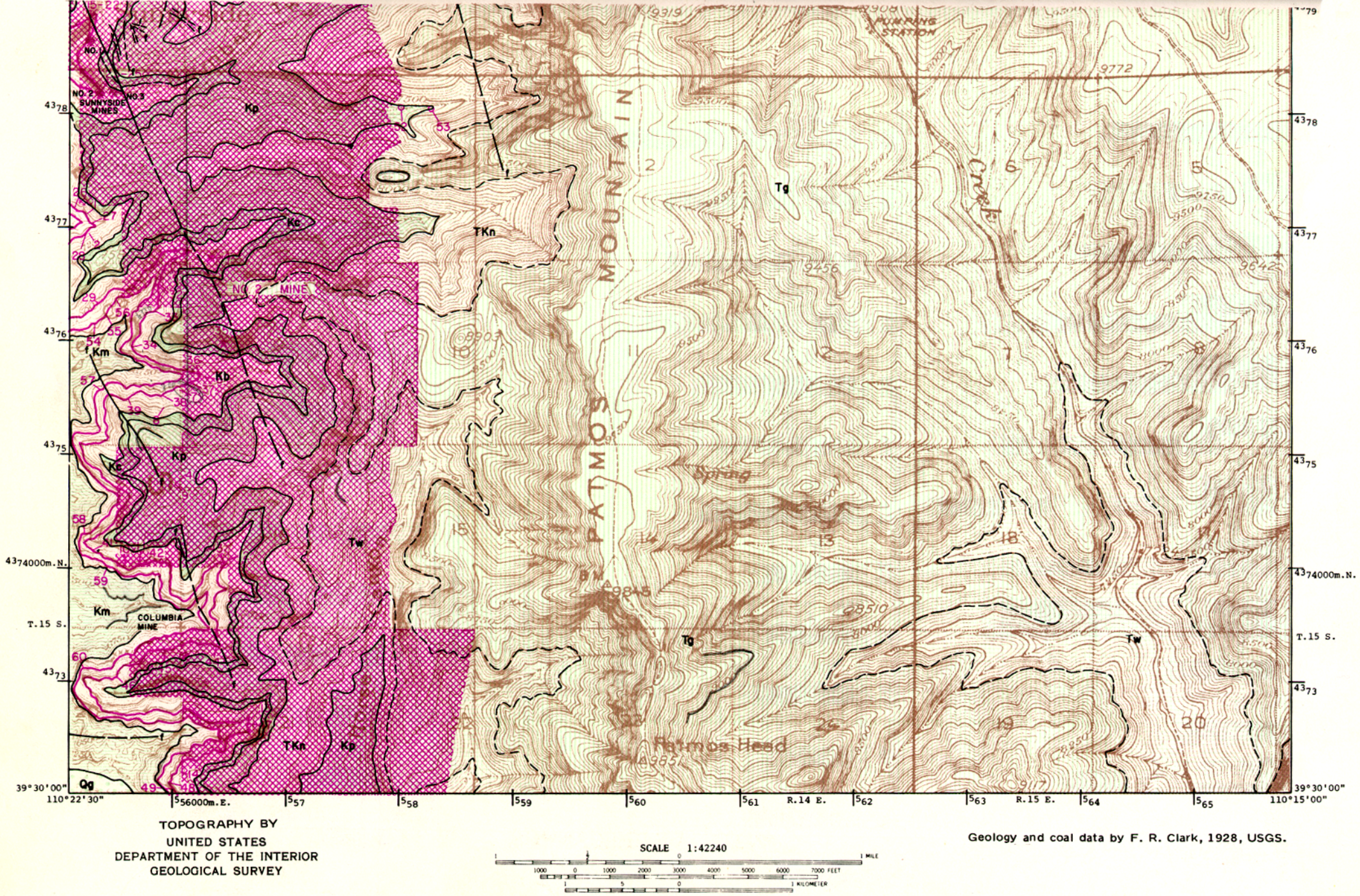


Figure 34. Coal and geology map, Sunnyside SE quadrangle (explanation pages 332-333).

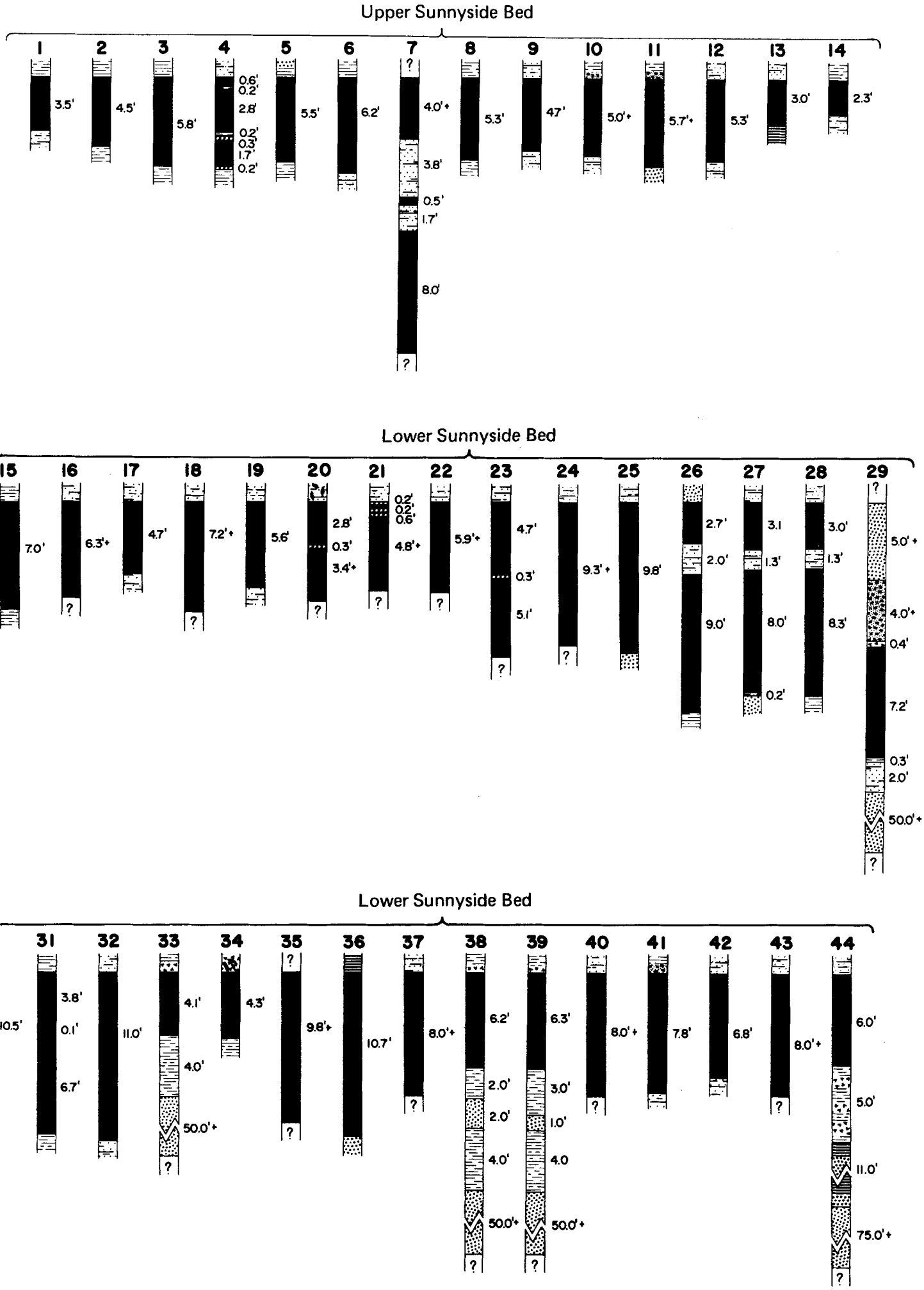


Figure 35. Coal sections of Sunnyside SE quadrangle (vertical scale: 1 inch = 8 feet).

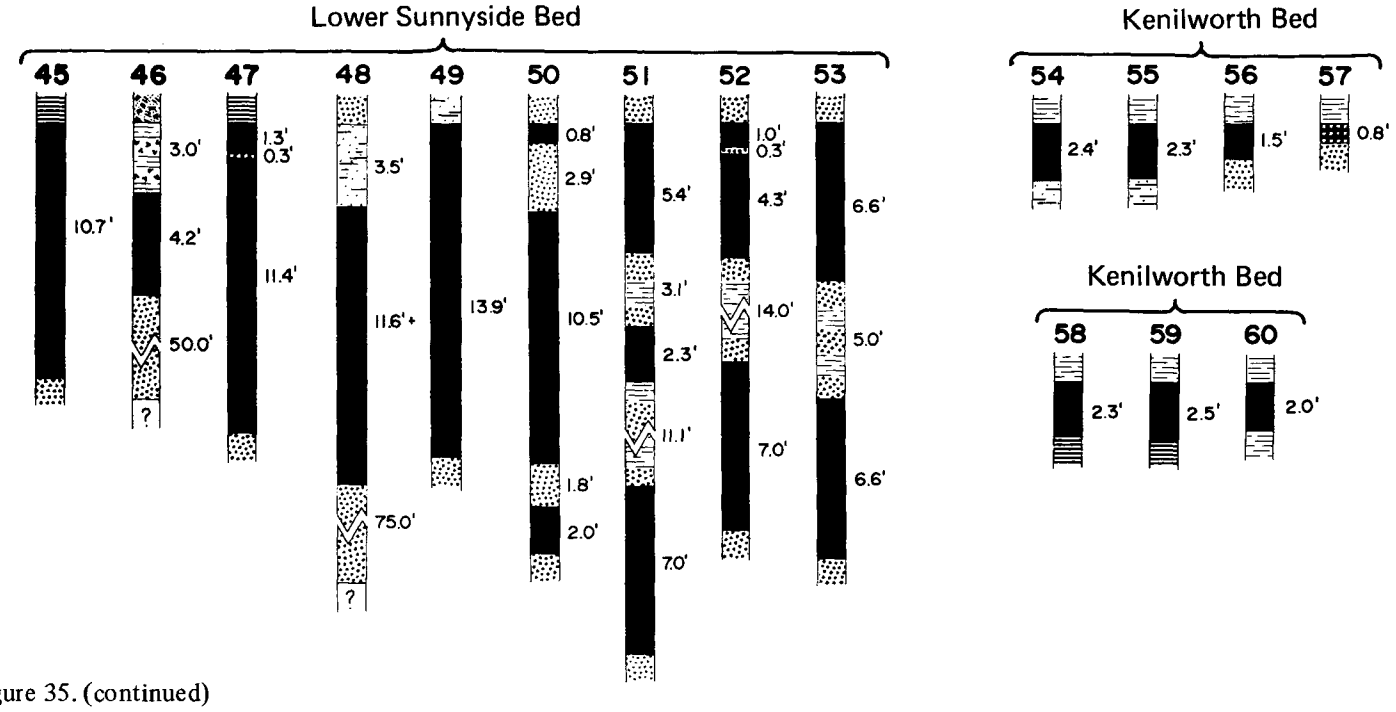


Figure 35. (continued)

Subsurface Information

Several drill holes shown as locations 50 to 53 indicate the condition of the Sunnyside seams. The coal beds are thick and with the exception of drill-hole 50 are split into two important benches 5 to 16 feet apart. The upper bench probably represents the Upper Sunnyside.

Approximately 98.5 percent of the Sunnyside SE lands are underlain by coal, but 56.4 percent have coal buried under more than 3,000 feet of overburden. The datum is the Lower Sunnyside (table 40).

Table 40. Overburden data, Sunnyside SE quadrangle.

Overburden (feet)	Percent	
	Total land	Coal land
Greater than 3,000	56.4	–
2,000-3,000	19.7	46.8
1,000-2,000	12.5	29.7
0-1,000	9.9	23.5
Noncoal land	1.5	–

Most the lands with less than 2,000 feet of overburden have been mined out. In the south half of the quadrangle at least half of the reserve between 2,000 and 3,000 feet has been mined.

Quality of Coal

The 61 analyses (tables 4 and 41) for the quadrangle were collected from the Lower and Upper Sunnyside beds from the Sunnyside and Columbia mines.

Table 41. Average proximate analyses, Sunnyside SE quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	61	5.1	3.1-15.2
Volatile matter	56	38.1	33.9-42.9
Fixed carbon	56	50.6	44.8-54.2
Ash	61	6.3	4.2-11.9
Sulfur	60	1.02	0.5- 3.0
Btu/lb	51	12,906	9,530-13,660

Walker and Hartner (1966, p. 37) further investigated the sulfur content of the coal (table 42).

Table 42. Sulfur content of coal, Sunnyside SE quadrangle.

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Columbia	Lower Sunnyside	0.94	0.02	0.28	0.64
Sunnyside No. 1	Lower Sunnyside	1.19	0.02	0.34	0.83
Sunnyside No. 1	Lower Sunnyside	1.22	0.02	0.29	0.91
Sunnyside Nos. 1 and 2	Lower Sunnyside	0.94	0.02	0.23	0.69

The sulfur content in the Sunnyside area is somewhat higher than at Columbia or Horse Canyon to the south. It varies depending on the particular seam or split mined; in practice, however, all coals are washed to metallurgical standards for both sulfur and ash content.

The coal from this area is a coking coal. In general the coal in the Sunnyside No. 1 and No. 3 mine areas has superior coking qualities as compared to coal from the south (Sunnyside No. 2) part of the Kaiser properties and is mostly better than any south extension of the Sunnyside seams into the Columbia area. The superior coking quality of the No. 1 and No. 3 mine coal has long been known; during operation of the beehive ovens (approx. 50 years) it was always preferred to the No. 2 mines coal or southerly extensions at Columbia or Horse Canyon. Deeper coal, that located farthest from the outcrops, has better coking quality than the near-outcrop coal, apparently because of the lower oxygen content of the deeper coal. Table 43 illustrates differences in analyses and coking properties because of general location and distance from the outcrop.

Various tests comparing coking quality between Rock Canyon seam coal at Rock Canyon and Sunnyside coal were made. The results and conclusions are submitted in the Sunnyside NW quadrangle report.

Landers, Gomez and Boyd (1967) reported on the coking properties of selected Utah coals and blends. To produce industrially acceptable coke the Sunnyside coal must be blended with low- and medium-volatile blending coals from other sources. Kaiser Steel blends 82.5 to 85 percent of their coal with other medium- and low-volatile coals. A summary of some of the properties of the coal as reported is given below:

Sunnyside coal carbonized in 50-lb retort:

Coke average size	1.85 inches
1-inch tumbler index	433
Net resultant coke factor	0.49
Coke strength index	110

Table 43. Comparison of coking coals analyses in Sunnyside and East Carbon areas.

	Sunnyside No. 1 mine	Sunnyside near outcrop	Columbia mine	Geneva mine	Drill hole Sunnyside SW (53)
Seam thickness (feet)	5-12	7	10-14	10-14	14'-6" incl. splits
Depth from surface (feet)	1,000-2,000	1,180	1,000-2,000	1,000-2,000	1,225
Distance down pitch (feet)	6,000	1,410	5,000	5,000	7,900
Oxygen content (maf, percent)	10.3	10.8	11.2	11.4	8.9
Ash content (dry, percent)	6.5	8.8	7.6	8.0	7.2
Sulfur content (dry, percent)	1.20	1.79	1.10	0.80	0.70
Btu/lb content (maf)	14,680	14,530	14,650	14,580	14,860
Ash softening temp. (°C)	2,650	2,510	2,550	2,510	2,400
Free swelling index	5½	2½	4-4½	3-4½	6.25
Agglutinating (15:1)	2.9-5.4	2.8	2.9-4.2	2.9-4.2	
Gieseler plastometer dial div/min	12.3-30.0		2-4	1-4	
Coke sieve (+1 inch)	90		80	77	
Coke tumbler:					
Plus 1 inch	14		11	9	
Minus ¼ inch	33		33-39	40	
Proximate analysis dry (percent):					
Ash	6.5	8.8	7.6	8.0	7.2
Volatile matter	39.7	38.5	39.2	39.1	39.5
Fixed carbon	53.8	52.7	53.1	52.9	53.3
Sulfur	1.20	1.79	1.10	0.80	0.70
Btu/lb	13,725	13,251	13,537	13,413	13,790

Forrester (1905, p. 43) provides an analysis of ash obtained from coal in the Sunnyside area and compares it with ash from the Castlegate mine (table 44).

Table 44. Comparison of ash content of coal from the Sunnyside area and the Castlegate mine.

	Percent	
	Sunnyside	Castlegate
Oxide of iron	23.99	–
Sesquioxide of iron	–	22.01
Silica	45.40	38.18
Alumina	20.19	21.87
Protoxide of manganese	–	2.34
Lime	6.00	9.26
Magnesia	trace	2.67
Undetermined	4.42	3.67

In a report of the Utah Conservation and Research Foundation (1939, p. 79) low-temperature carbonization of coal from the Lower Sunnyside bed in the Columbia mine were tested; the results are repeated in table 45.

Similar tests were run by the U. S. Bureau of Mines (Gomez, Landers and Boyd, 1967) using an end carbonization temperature of 500° C (table 46).

The physical appearance of the Lower Sunnyside coal, both macroscopically and microscopically, was well documented by Thiessen and Sprunk (1937). Macroscopically it is a hard, tough, bright coal lacking definite fracture lines, breaking into large irregular lumps. Microscopic analyses revealed the components to consist of 30 percent anthraxylon, 61 percent translucent attritus, 6 percent opaque attritus and 3 percent fusain; resins are conspicuous in the anthroxylon portion of the coal. In summary the Sunnyside coal is a uniform attrital-anthraxylous bright coal largely derived from small plant materials such as small stems, twigs, roots and leaves.

Mines and Development

Four mines open on the Sunnyside SE quadrangle (table 47).

The Sunnyside group of mines are all owned by Kaiser Steel Corp. and all portals are located near the mouth of Whitmore Canyon. Each of the mines has a large mined out area. Sunnyside No. 1 area extends mainly into the Sunnyside SW quadrangle and is located north of the portal, the No. 3 mine is immediately east of the portal area and the No. 2 mine is to the south. All three mines were listed as active in 1970. In 1969 the No. 1 mine produced 959,730 tons, the No. 2 produced 116,443 tons and the No. 3 produced 115,129 tons for a total of 1,191,302 tons. For 1969 the Sunnyside No. 1 mine was the largest producer in the state of Utah. As of December 31, 1969, a total of 44,885,000 tons of coal had been extracted from the mines. Of this amount roughly 13 million tons are estimated to have come from Sunnyside SW. From the acreage mined out an average of 7,760 tons per acre are calculated recovered. With an average of 10 feet of minable coal in each acre, a recoverability of 44.5 percent has been realized. It is uncertain how far extraction can proceed under heavy cover (some has already been removed with more than 2,000 feet of cover). The management at Sunnyside believes remaining reserves on this segment of Kaiser's properties will exceed 25 million tons. To extend the 7,760 tons per acre over the remaining holdings raises the expected tonnage to 39.4 million tons. Coal mine bumps which plague the mining operation at Sunnyside are probably related to the heavy overburden. The bumps are spontaneous and often inflict violent energy releases on rock and coal along the floors, roofs and faces. The problem has existed since the first opening of the mines. These bumps are frequent, increase in number during working days and range in intensity from small ones that release only small amounts of coal or rock to large ones that damage equipment and injure miners. Clark (1928, p. 80) notes, "the unweathered coal is brittle and hard to pick and

Table 45. Carbonization product yields, Lower Sunnyside bed, Columbia No. 1 mine, Sunnyside SE quadrangle.

	Vertical Retort							Rotary Retort			
	External Heating						Internal Heating	External Heating			
Carbonizing Temperature °C (Products Weight Percent)	450	550	650	650	750	850	650	450	550	650	650
Char	82.6	72.4	67.3	67.0	66.0	64.3	79.4	73.0	67.4	63.8	63.8
Gas	1.4	3.8	6.4	7.1	9.3	8.1	3.8	3.0	8.9	–	13.2
Tar	5.4	8.7	9.9	10.0	9.3	10.7	6.7	11.9	12.5	10.4	13.1
Light oil	0.2	0.5	0.6	0.5	0.6	0.7	0.5	0.4	0.6	–	0.4
CO_2	0.8	1.0	1.4	1.6	1.8	1.3	1.9	0.7	1.5	–	0.8
Tar liquors[1]	7.4	11.2	12.0	11.0	13.0	11.8	–	9.6	10.1	9.8	11.3
Total	97.8	97.6	97.6	97.2	100.0	96.9	–	98.6	101.0	–	102.6
Gas, cu ft	446	1,693	3,320	3,507	5,250	6,224	2,034	989	2,460	3,890	4,060
Tar, gallons	13.0	20.7	23.5	24.0	21.8	25.4	15.3	28.6	30.0	25.1	31.5
Light oil, gallons	0.6	1.6	1.8	1.5	1.9	2.1	1.5	1.1	1.7	–	1.3
$(NH_4)_2SO_4$ pounds total	2.5	7.5	11.3	7.7	17.9	22.6	20.4	3.4	4.9	–	7.6

[1] Contains phenol, o-cresol, m,p-cresol and xylenol.

Table 46. Calculated carbonization product yields (maf coal in weight percent; at 500° C), Sunnyside SE quadrangle.

Mine	Char	Water of decomposition	Tar and oil	Gas	Scf/lb gas value	Heat value of gas Btu/scf
Columbia	74.8	4.5	16.9	4.1	0.873	834
Sunnyside No. 2	74.0	4.4	17.4	4.1	0.873	837
Sunnyside No. 1	74.9	4.2	16.9	3.2	0.856	854

Table 47. Mines in the Sunnyside SE quadrangle.

Mine	Location	Remarks
Columbia mine (U. S. Steel mine)	NW.NW.NW.21-15S-14E 4,373,250m.N. 556,090m.E.	Active 1922-1967
Sunnyside mine (Kaiser mine)		Active 1899-1970
No. 1	SE.NE.SE.SW.32-14S-14E 4,378,650m.N. 555,140m.E.	
No. 2	NW.NE.5-15S-14E 4,378,210m.N. 555,360m.E.	
No. 3	NW.NE.5-15S-14E 4,378,210m.N. 555,360m.E.	

has a metallic ring when struck with the hammer. While mining is going on the working faces are continually snapping and splintering."

According to Osterwald and Dunrud (1966, p. 107):

Results to date from the seismic investigations indicate that many tremors in the Sunnyside mining district are related to large-scale mining of coal in the district. Many tremors occur above, below or beside a given mine, but the occurrence of bumps in the mines is related to the occurrence of tremors. Small amplitude tremors are most abundant during the middle of the work week. Large tremors are most common weekends in the northern part of the district, and perhaps more common during the middle of the week in the southern part of the district.

The Columbia mine in the south part of the quadrangle is owned by U. S. Steel and is presently inactive. The mine was opened in 1923 and closed May 1967 because of poor working conditions in deep coal served by a mile-long rock tunnel. The dip of the coal seam increased unexpectedly to more than 25 percent in places making use of heavy mechanical equipment difficult and costly. Whether the mine ever will be reopened is uncertain. The Lower Sunnyside is the only seam that averages more than 4 feet thick, estimated in the mine at about 12 feet. The range has been 10 to 15 feet. About 17.3 million tons were mined during the active period. Part of this was extracted from that part of the mine that extends into the Woodside NE quadrangle. In the Sunnyside SE area an estimated 7.3 million tons were removed. Recovery rate has averaged 38.6 percent. Total coal removed from the quadrangle is approximately 39,155,000 short tons.

Reserves

The major part of the reserve lies in the Lower Sunnyside coal bed. The total reserve for the quadrangle is not as high as others but just as important because of the coking capabilities of the product. Clark (1928, p. 102) calculated a reserve for the area and his figures are modified to fit the area of the quadrangle under 3,000 feet or less of cover (table 48). Clark used all coal 14 inches or more thick.

Table 48. Original coal reserves in the Sunnyside SE quadrangle (in short tons; 14 inches or more thick).

Location	Bed or zone	Average thickness (feet)	Acres est.	Tonnage
T.14S. R.14E.	Upper Sunnyside	3.0	3,024	16,300,000
	Lower Sunnyside	9.8	6,850	120,800,000
T.15S. R.14E.	Upper Sunnyside	4.0	5,504	39,600,000
	Lower Sunnyside	12.0	7,375	159,300,000
	Kenilworth	2.0	400	1,400,000
T.15S. R.15E.	Lower Sunnyside	10.4	2,075	38,800,000
			Total coal	376,200,000
		Coal averaging 4 ft or more		358,500,000

Recoverable coal is related to the amount of overburden expected above the mined seam. At best 40 percent might be achieved up to the 3,000-foot coverline. Total recoverability would thus be 143.4 million tons. It is estimated that a little more than 36 percent of the coal land were mined out to produce 39 million tons; actual recoverability, which includes oxidation, burn and geologic condition losses, is 30 percent, provided Clark's average thicknesses are correct. Part of the problem may be that nonretrievable Upper Sunnyside coal is too close to the Lower Sunnyside.

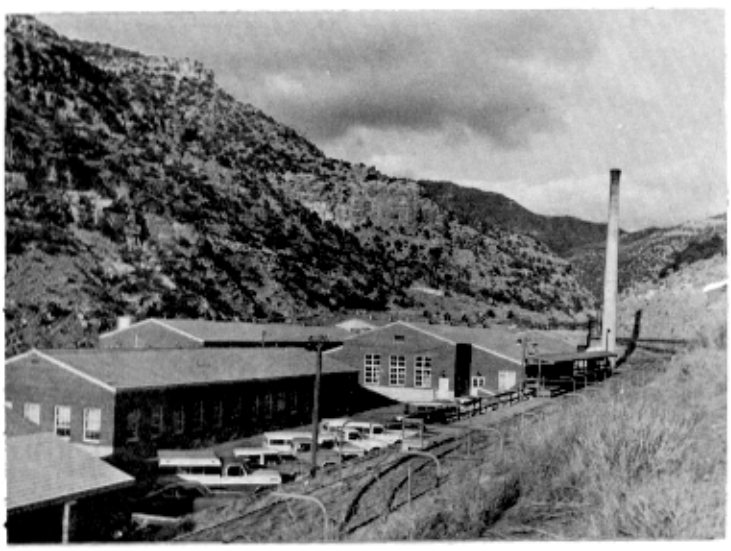
In addition Clark lists townships clearly in areas where the overburden exceeds 3,000 feet (table 49). These tonnages may someday be mined but under present economics and mining conditions it seems doubtful; they are considered a resource, not a true reserve (Class IV). The tabulation includes areas in Sunnyside NW, NE, SW and SE that fall in this category. Beds averaging less than 4 feet have been omitted. All reserves are from the Lower Sunnyside bed.

Table 49. Class IV reserves (more than 3,000 feet of overburden), Sunnyside SE quadrangle.

Location	Average thickness (feet)	Acres est.	Tonnage
T.12S. R.14E.	4.0	7,680	55,000,000
T.12S. R.15E	4.0	2,560	18,000,000
T.13S. R.13E.	4.8	5,120	44,000,000
T.31S. R.14E.	5.3	20,480	195,000,000
T.13S. R.15E.	6.0	7,040	76,000,000
T.14S. R.14E.	9.8	7,680	135,000,000
T.14S. R.15E.	8.0	7,680	111,000,000
T.15S. R.14E.	12.0	2,560	55,000,000
T.15S. R.15E.	10.4	5,120	96,000,000
		Total coal	785,000,000

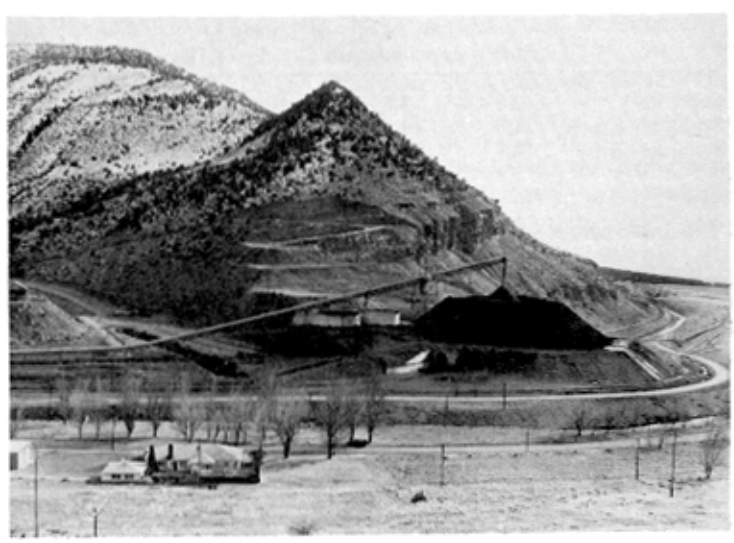
PRINCIPAL WORK

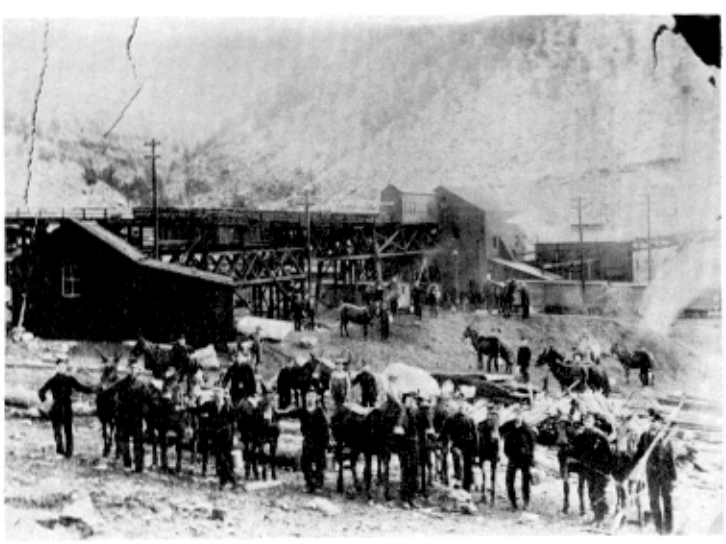
Clark (1928) provided the majority of the information and numerous supplementary works brought the information to date.



South view near the mouth of Whitmore Canyon at Sunnyside; shows unit-train loading facility of Kaiser Steel.

View easterly into Horse Canyon shows buildings of U. S. Steel's Geneva coal mine. Blackhawk Formation exposed on the canyon wall.





Tipple at Royal or Castlegate and miners and mine mules, pre-1920. Photo from Helper Mining Museum original.

SUNNYSIDE SW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Sunnyside area is central to the Book Cliffs coal field as designated in this report (figures 19 and 36). The portion of the Book Cliffs represented by this quadrangle includes the sector between Bear Canyon on the northwest to Whitmore Canyon on the southeast. Most of the map area is of Clark Valley, the area below the cliffs. Here the surface consists of gravel benches intermittently dissected by the drainages which cut through the gravel into shale. Elevations range from less than 5,500 feet to 7,000 feet at the foot of the cliff. The face of the cliff is quite steep and re-entrants are shallow making them inaccessible. The cliffs rise to the crest of West Ridge with a maximum elevation of 9,030 feet. Whitmore Canyon (about 7,500 feet) parallels the ridge to the east. The coal seams are exposed along the cliff front mostly above 7,000 feet.

The base map on which the geology has been drawn is old and the alignment of Utah Highway 123 is not correctly shown (figure 36). The map also fails to show the towns of Sunnyside and Dragerton and the road extending south from Dragerton to Columbia and Horse Canyon. Columbia is located in the southeast map corner, Dragerton in the vicinity of secs. 2 and 11, T. 15 S., R. 13 E. and Sunnyside in sec. 6, T. 15 S., R. 14 E.

The mouth of Whitmore Canyon is served by a spur of the Denver and Rio Grande Western Railway. A branch extends southerly from Sunnyside to Horse Canyon (not shown).

STRATIGRAPHY

The major part of the Sunnyside SW quadrangle lies below the cliffs and exhibits outcrops of the Mancos Shale or the bench gravels that often cover them.

The greater part of the surface of the Mancos Shale was at one or more times buried beneath sheets of gravel spread evenly over it by torrential streams that drained and eroded the adjoining uplands. The character of the surface of the Mancos Shale at many places suggests that erosion prior to the deposition of the gravel had partly base-leveled the region. At least three sets of terraces at different levels are now indicated by remnants of alluvial fans. The gravel varies in thickness, but in general it is thickest near the place of origin, the Book Cliffs. At many places close to the Book Cliffs the gravel is 50 feet thick and the largest boulders are 10 feet or more in diameter . . . (Clark, 1928, p. 22).

The drab gray shales of the Mancos rise several hundred feet up the cliffs and the entire unit is estimated to exceed 4,000 feet. At this location the Aberdeen Sandstone has practically disappeared and the shales above it are mapped with the Mancos. The initial bed of the Blackhawk is the Kenilworth Sandstone. The lower part of the cliffy member is thin-bedded and divided by shale partings but the major part builds a nearly massive body 130 feet high. The total Kenilworth is about 180 feet thick.

The coal-bearing beds of the Blackhawk Formation commence above the Kenilworth. They can be divided roughly into three members as recognized by Fisher (1936, p. 13). The lower sequence consists of alternating sandstone, shaley sandstone, shale and coal including the Kenilworth, Gilson and Rock Canyon seams. The next division is dominated by massive cliff-forming sandstone near the top of which are some lagoonal beds carrying the Sunnyside coal horizon. The upper beds are a sequence of shaley sandstone, shale and thin coal beds. The entire Blackhawk is estimated about 700 feet thick.

The Castlegate Sandstone cliff overlies the Blackhawk, is about 180 feet thick and is mainly a fine- to medium-grained quartzose sandstone of mostly light gray color. The Price River Formation which overlies it is about 500 feet thick and consists of interbedded sandstone and shale. The sandstones are light gray to tan, fine- to medium-grained, slightly calcareous to argillaceous, thin- to massive-bedded and the shales are medium to dark gray, carbonaceous and silty with occasional layers of bone coal present. The Price River is 70 percent sandstone and forms alternating ledges and slopes.

The Tertiary is represented by the North Horn, Colton and Green River formations with a total thickness on West Ridge of about 1,250 feet. The beds are mainly alternating sandstone and shale beds of fluvial origin forming ledge and slope topography.

STRUCTURE

The strike of the beds is to the northwest and the beds dip 6 to 12 degrees eastward and northeastward. The coal bed drop to the east is about 800 feet per mile which represents an average dip of about 8½ degrees. Several faults with displacements sometimes exceeding 100 feet cut the strata just south of Bear Canyon and just north of the mouth of Whitmore Canyon. Details of structure in the area of West Ridge are shown on Osterwald's (1962) preliminary lithologic and structural map of Sunnyside No. 1 mine area at the superior scale of 1:6000. These faults are usually widely spaced and have not impeded mining excessively in the area.

PROPERTY CONTROL

The lands of the Sunnyside SW quadrangle are mostly owned by the Bureau of Land Management (56.5 percent). Private property makes up 36.7 percent and Utah state lands 6.8 percent. Most of the coal land is private property but large blocks of BLM land also occur in the area. Coal lands amount to only 19.9 percent of the quadrangle of which practically all is held by two companies (1970): U. S. Steel Corp. and Kaiser Steel Corp.

COAL

Surface Information

Eighty-nine coal sections are shown on figure 37 and marked as to location on the quadrangle map (figure 36). Five beds or groups of beds in the stratigraphic column are represented as follows:

	Feet
Upper Sunnyside	1-5
Interval	25-30
Lower Sunnyside	4-12.5
Interval	135-140
Rock Canyon bed (present only along north map margin where it consists of 1.8 feet of boney coal)	
Interval	40-75
Gilson bed	0-3.7
Interval	45
Kenilworth	1-4.6
Kenilworth Sandstone	

The lowest bed is the Kenilworth which averages almost 4 feet thick between locations 72 and 81. All these measurements occur in one square mile area just north of the mouth of Whitmore Canyon. It is thin or missing elsewhere and does not constitute an important resource on this quadrangle.

The Gilson bed is present in mostly thin beds rarely exceeding 2 feet; the Rock Canyon lies only along the north edge of the quadrangle and each is therefore unimportant.

The most valuable bed is the Lower Sunnyside. The measured sections that have not been affected by outcrop burning yield an average of 8.2 feet. The Lower Sunnyside is somewhat lenticular but thick sections appear everywhere present. Occasionally the

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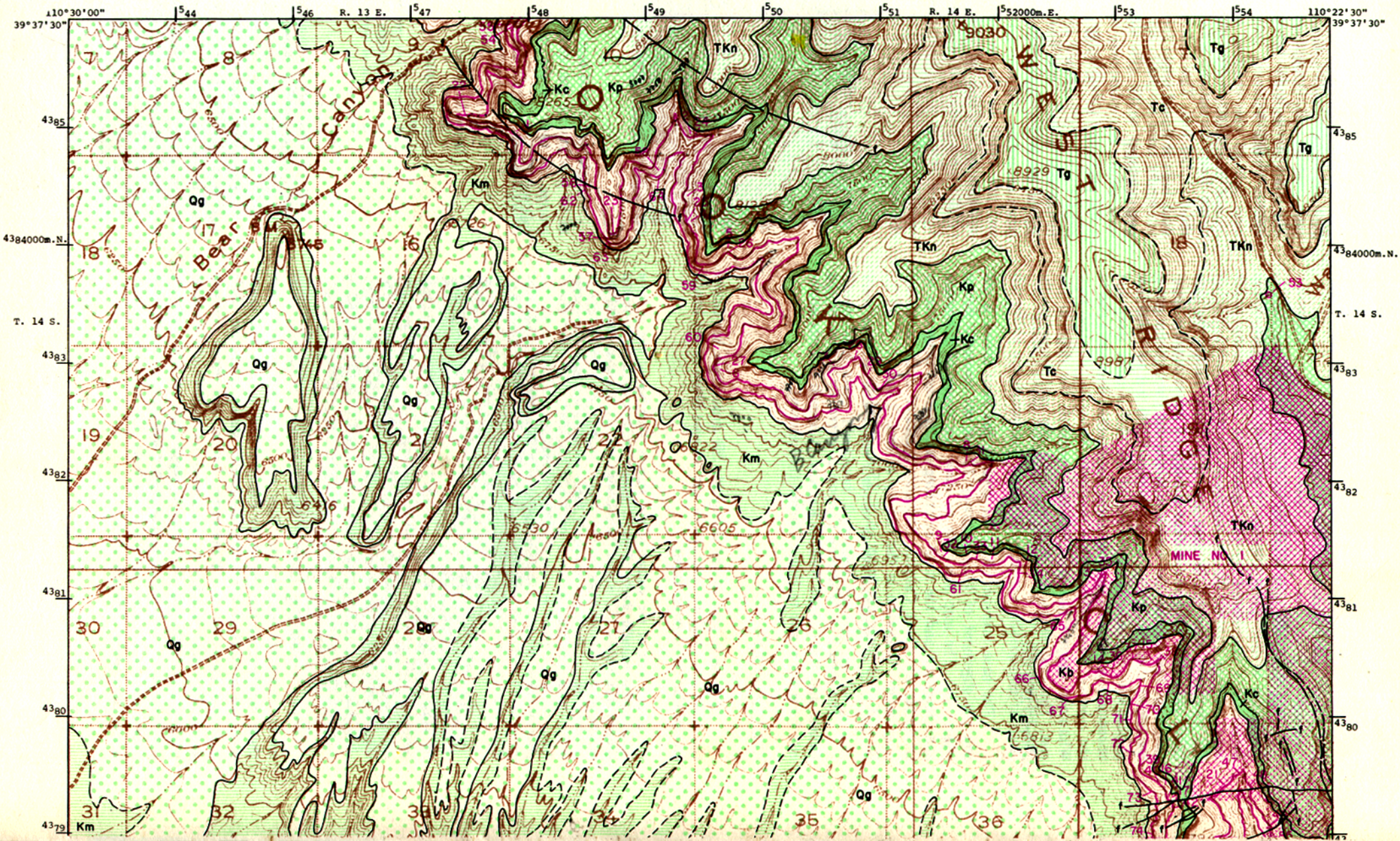

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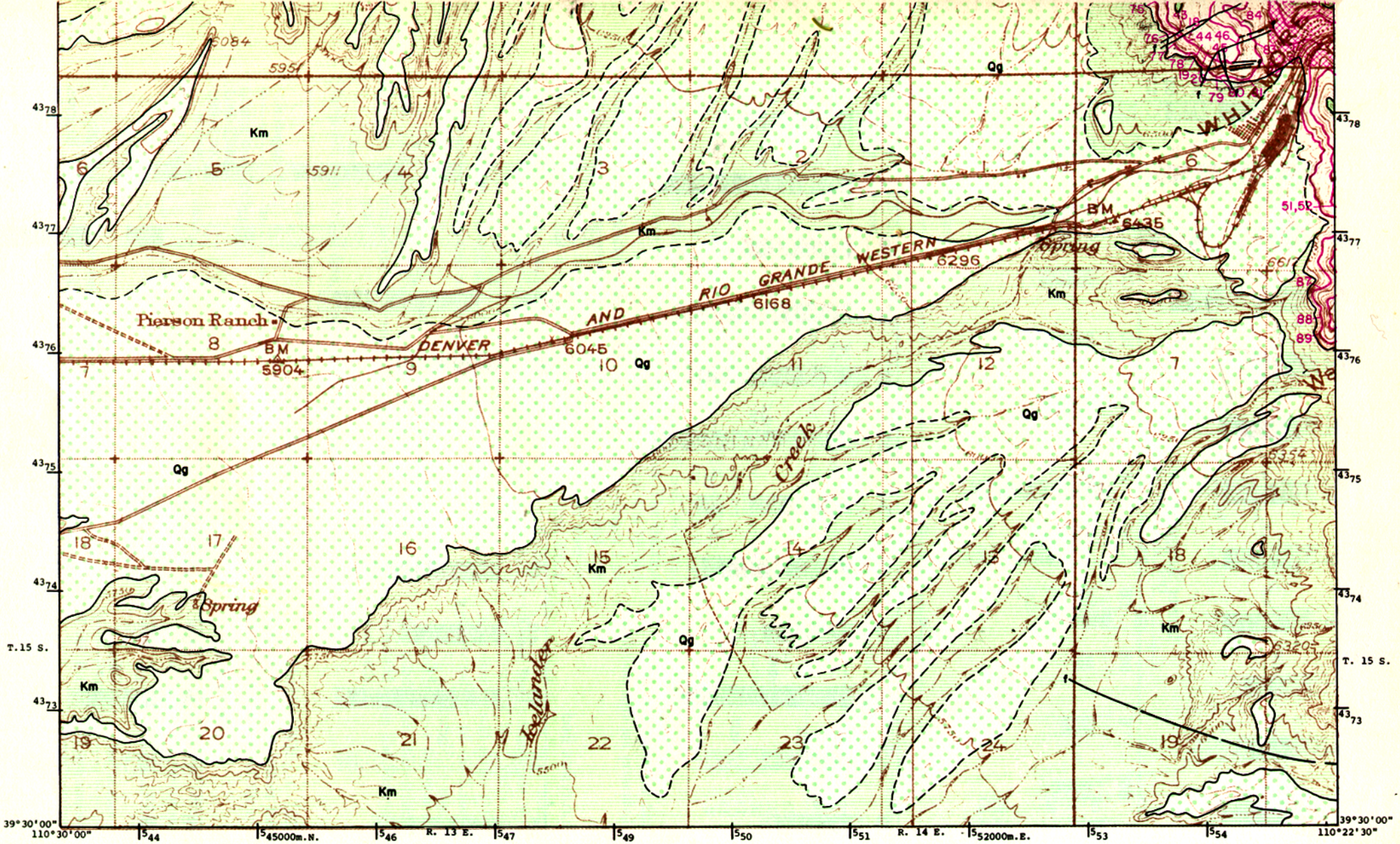

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Geology and coal data by F. R. Clark, 1928, USGS.

Figure 36. Coal and geology map, Sunnyside SW quadrangle (explanation pages 332-333).

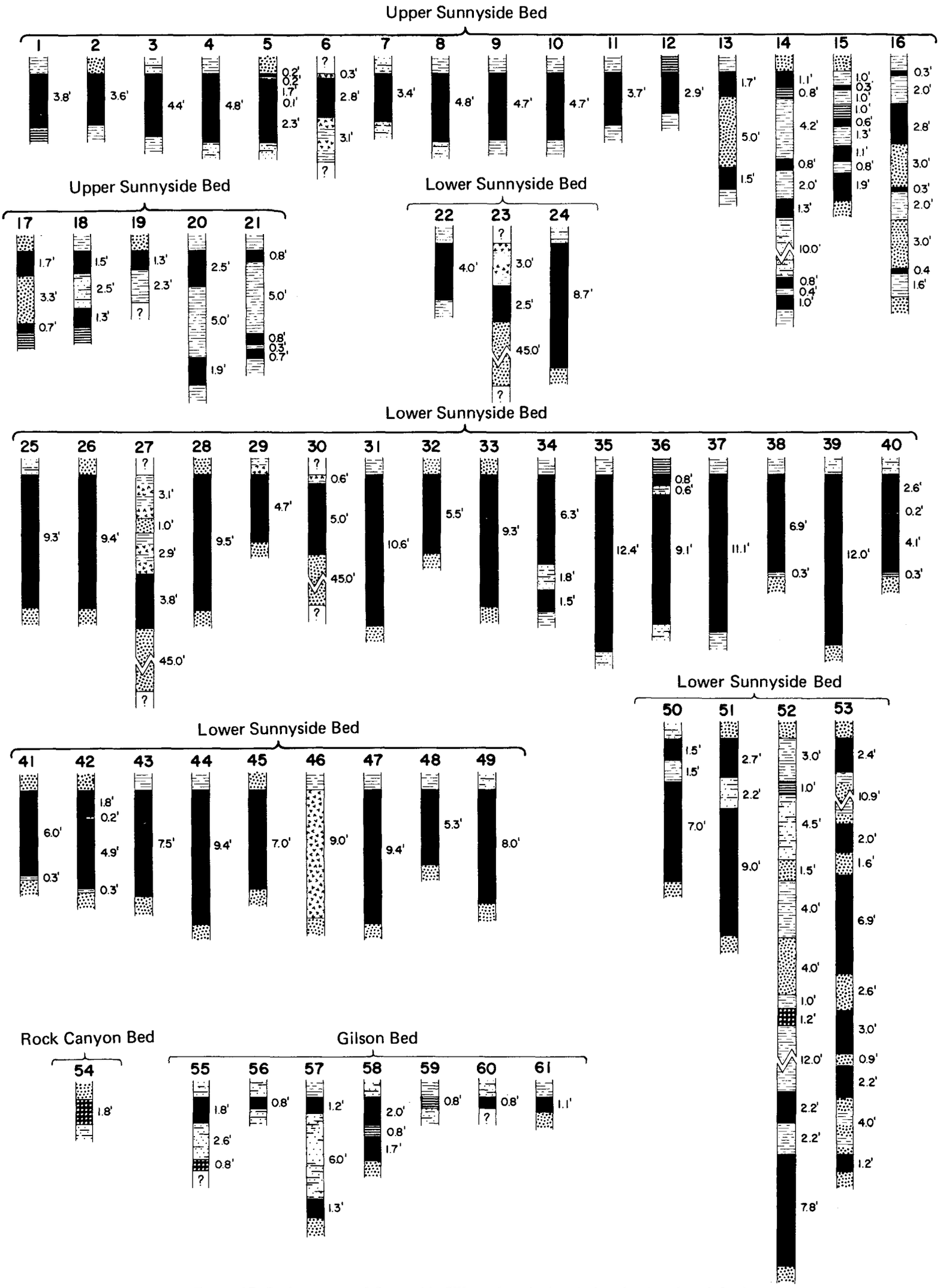


Figure 37. Coal sections of Sunnyside SW quadrangle (vertical scale: 1 inch = 8 feet).

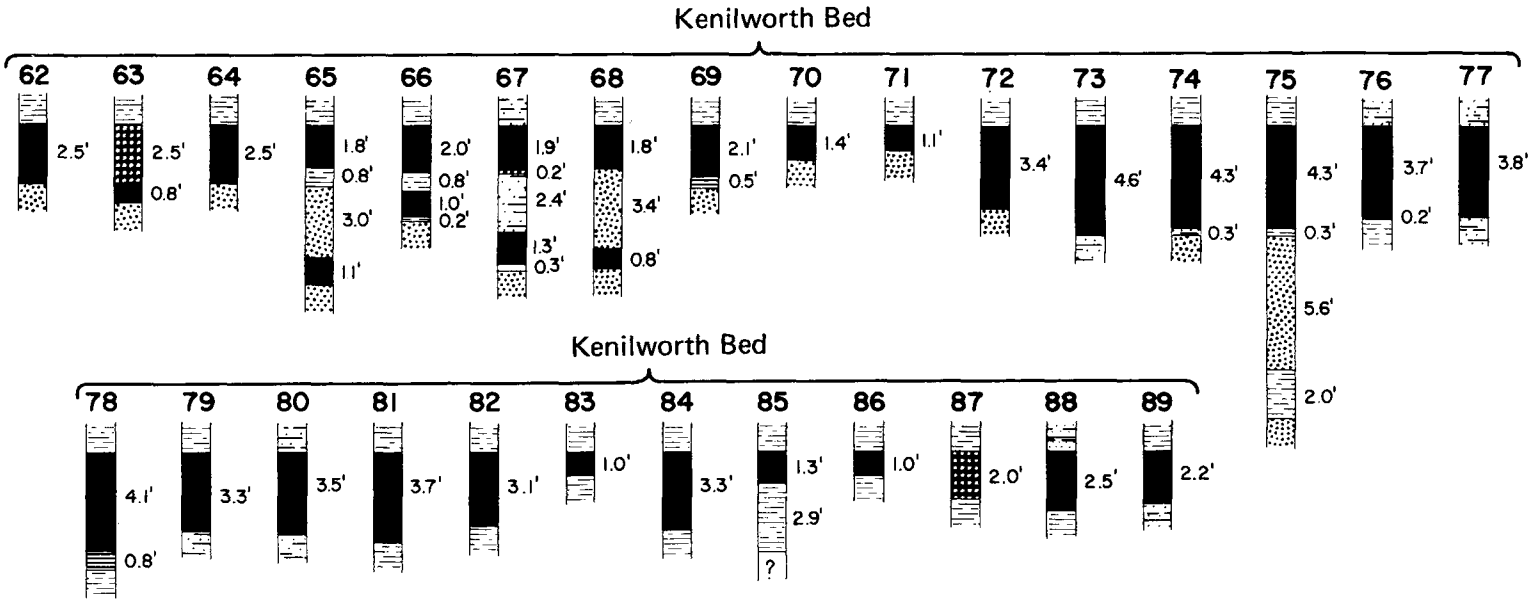


Figure 37. (continued)

bed is split and often subsidiary seams lie a few feet above and below the main one.

The Upper Sunnyside may be of value between locations 3 and 10 where the average thickness is 4 feet. Elsewhere the bed is too thin or too badly split to mine.

Subsurface Information

The one available drill hole is located in SE 18-14S-14E. The drill hole tested the Sunnyside interval and the log is shown as location 53. In this hole more than 17 feet of coal were discovered in six seams in an interval of about 31 feet. The thickest seam was 6.9 feet. Coal seam condition and thickness is known from exploration within mines. The Upper Sunnyside averages 5 to 12 feet. Rock separation between seams is not adequate and it is practically impossible to extract coal from more than one seam or workable split at any location making overall recovery low. Rock formation between the Lower and Upper Sunnyside is mostly interbedded shale and sandsone. Roof conditions are generally bad, requiring close timbering and/or roof bolting. Where mining is conducted in split and soft shale floor areas, it is a detriment to good extraction with long-wall roof support systems.

There are no lands where the Sunnyside coals have more than 3,000 feet of overburden (table 50). Only 19.9 percent of the total land area of the quadrangles are underlain with coal.

Table 50. Overburden data, Sunnyside SW quadrangle.

Overburden (feet)	Percent	
	Total land	Coal land
Greater than 3,000	–	–
2,000-3,000	3.7	18.6
1,000-2,000	8.4	42.1
0-1,000	7.8	39.3
Noncoal land	80.1	–

Quality of Coal

No analyses have been made from coal samples collected from the outcrops of this quadrangle; one is available, however, from the drill hole located in SE 18-14S-14E (table 4). Certainly other samples were collected from the Sunnyside No. 1 mine which underlies part of the area; these are reported with the Sunnyside SE quadrangle where the main mine portal is located. An average of proximate values for the Sunnyside No. 1 mine is listed in table 51.

Table 51. Average proximate analyses of coal, Sunnyside SW quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	12	4.3	3.1- 6.0
Volatile matter	10	38.0	36.8-39.0
Fixed carbon	10	51.3	48.2-52.8
Ash	12	6.4	4.2-11.9
Sulfur	12	1.21	0.5- 3.0
Btu/lb	9	13,058	12,420-13,660

The coal from the Sunnyside No. 1 is coking quality; more analytical data are presented with the Sunnyside SE quadrangle.

Mines and Development

No mines have main portals opening on the quadrangle. Kaiser Steel's Sunnyside No. 1 mine is located underground in the south half of West Ridge. Several square miles are mined out and the mine is still active (1970). The total production for this and the remainder of the Kaiser No. 1, which projects into the Sunnyside SE quadrangle, is given with that report. Production from the Sunnyside No. 1 in 1969 was 959,730 tons mostly from lands of this quadrangle. An estimated 13 million tons of coal have been extracted from the Sunnyside SW quadrangle from the Sunnyside coal beds.

Reserves

Clark's (1928, p. 102) reserves were calculated to include coal down to 14 inches thick. His figures are repeated but modified to fit the area of the quadrangle (table 52).

Table 52. Original coal reserves in the Sunnyside SW quadrangle (in short tons; 14 inches or more thick).

Location	Bed or zone	Average thickness (feet)	Acres est.	Tonnage
T.14S. R.13E.	Upper Sunnyside	2.2	2,720	10,800,000
	Lower Sunnyside	9.0	3,857	62,500,000
	Kenilworth	2.0	640	2,300,000
T.14S. R.14E.	Upper Sunnyside	3.0	3,456	18,700,000
	Lower Sunnyside	9.8	3,456	60,900,000
	Kenilworth	2.5	1,200	5,600,000
		Total coal		160,800,000
		Coal averaging 4 ft or more		123,400,000

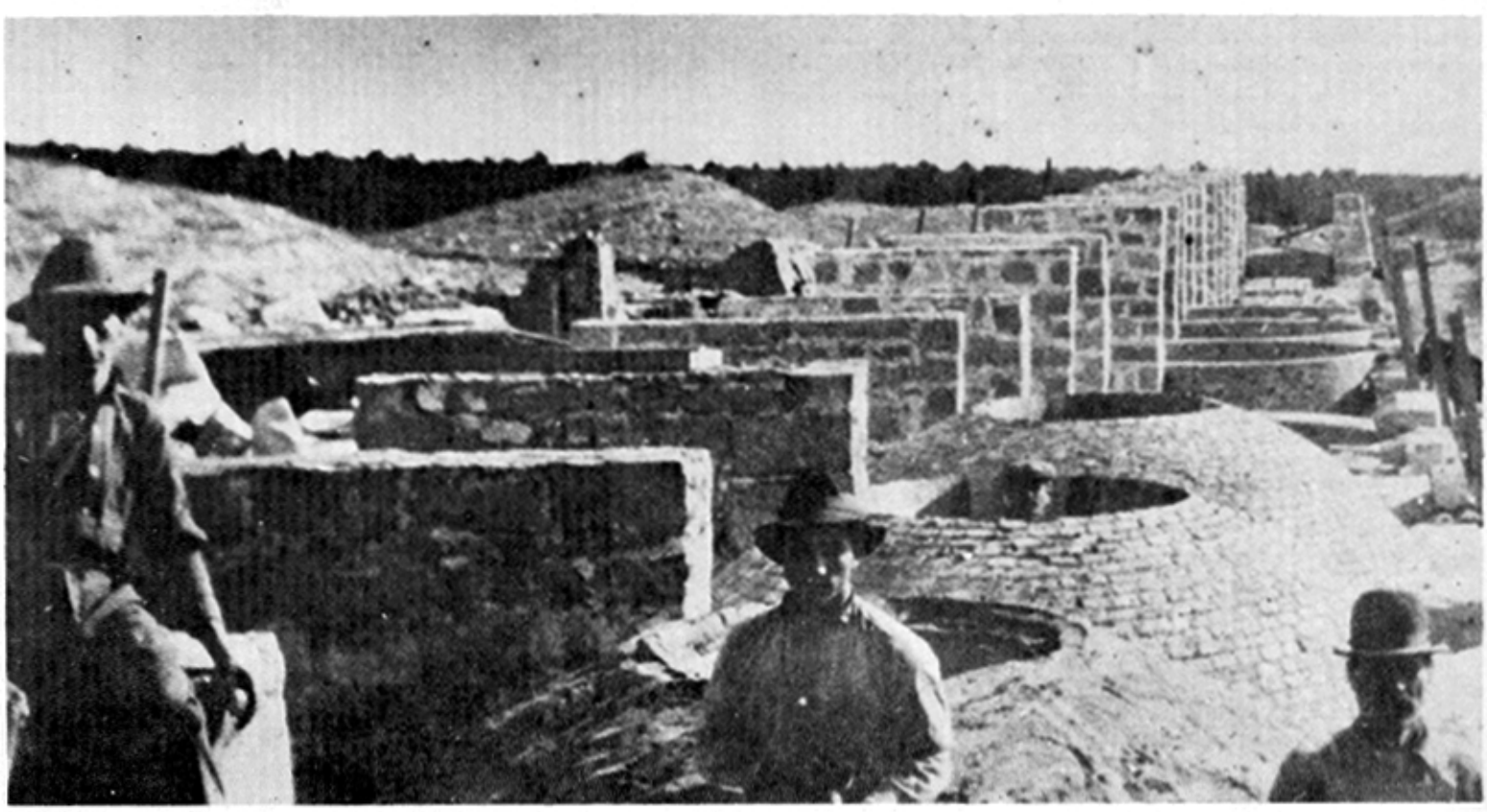
The Upper Sunnyside has been mined at times and so constitutes a valid reserve even though its average in the township may be less. Unforeseen geologic hazards, oxidation of coal and other mining problems undoubtedly will make up for eliminating the Upper Sunnyside in the total coal evaluation. Recoverability in the mine has been 44.5 percent so that a recoverable reserve of 54.9 million tons is expected. Thirteen million tons already have been extracted leaving a remainder of 41.9 million tons to be mined. All the coal is believed to be under less than 3,000 feet of overburden and most of the coal is within 1½ miles of a control point so that all can be considered measured or indicated (Class I or II). If one considers the percentage of land with respect to cover (above Lower Sunnyside) then 29.9 (23.0) million tons of coal are under 2,000 to 3,000 feet of cover, 67.7 (52.0) million tons are under 1,000 to 2,000 feet of cover and 63.2 (48.4) million tons are under less than 1,000 feet of cover. The figure in parentheses indicates the coal over 4 feet thick; the other is Clark's total figure.

PRINCIPAL WORK

Most of the original data presented are from Clark (1928), supplemented by several Bureau of Mines analyses and by a small amount of information from the mining operations collected for this report.

Kaiser Steel Corp. tipple at Sunnyside, Utah, looking east. Long conveyor unloads coal (to the south) for a unit-train arrangement. Canyon directly behind tipple has portals to Sunnyside No. 2 and 3 mines. No. 1 mine is to the north and on the west side of the canyon.

View looking up (northwesterly) Price River Canyon towards town of Castlegate. The Utah Power & Light Carbon plant is in the foreground. North American Coal Corp. tipple which supplies the plant and its conveyor is just to the right of the D&RGW railroad tracks and Castlegate is behind it. U. S. Highway 50-6 is to the left.



Beehive coke oven building near Castlegate prior to 1900. Photo from Helper Mining Museum original.

WELLINGTON–MINNIE MAUD W QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Wellington-Minnie Maud W quadrangle is a composite of the north two-thirds of the U. S. Geological Survey Wellington NW quadrangle and the south third of the Minnie Maud W quadrangle (figures 19 and 38). The south end of the map area is located about 8 miles north of Wellington, U. S. Highway 50-6 and the Denver and Rio Grande Western Railway. The quadrangle covers that portion of the cliffs from Deadman Canyon to Soldier Creek. The foothills and benches below the Book Cliffs are known as Clark Valley, which has an elevation as high as 6,750 feet. The cliffs rise to about 8,500 feet and behind the cliff a dip slope drops the elevation to about 7,400 feet before the elevations rise again onto the Roan Cliffs. The dip slope is gently inclined. The area behind the cliffs has been designated as parks; Whitmore Park is located in the east part of the quadrangle. The coal is exposed along the cliffs at elevations ranging between 6,700 and 7,700 feet.

STRATIGRAPHY

Formations exposed in the Wellington-Minnie Maud W quadrangle include the following stratigraphic units:

	Thickness (feet)
Green River Formation	Incomplete
Colton Formation	~800
Flagstaff Limestone	~300
North Horn Formation	600
Price River Formation	1,000
Castlegate Sandstone	250
Blackhawk Formation	1,000
Mancos Shale	~5,000

General descriptions of the units are given in the field report. Of these the coal-bearing unit is the Blackhawk. In the Castlegate quadrangles it is underlain by the Star Point Sandstone. This unit consists of three sandstone tongues separated by two thick gray shale beds reminiscent of the Mancos. Along the west edge of the quadrangle, the middle sandstone (Storrs) disappears. The other two continue easterly to Soldier Canyon where they too disappear. Along the west edge of the quadrangle they are each 150 feet thick and may have 150 feet of shale between them. These sandstone tongues have not been mapped and are included as a part of the Mancos Shale.

More shale lies above the upper sandstone tongue. The initial Blackhawk Member is known as the Aberdeen Sandstone. Above the Aberdeen are a series of alternating sandstones and shales with coal beds. According to Clark (1928, p. 19):

> The coal-bearing part of the Blackhawk Formation consists of massive beds of gray to buff sandstone, alternating with smaller amounts of sandy shale, shale and coal beds. The sandstone is composed largely of semirounded quartz grains cemented by carbonate of lime and is reasonably well consolidated but not greatly indurated except some of the fine-grained and highly calcareous beds. The shale, as a rule, is more or less sandy and adjacent to the coal beds usually contains some carbonaceous material. The coal beds have been extensively burned at the surface, and the associated rocks are greatly altered in character and composition. At many places where coal beds have burned, the rocks overlying them have fused, and everywhere they are predominantly red instead of gray and buff, their original colors.
>
> The dominant feature of the coal-bearing part of the Blackhawk Formation consists of the massive, cliff-forming beds of sandstone, which lie beneath many of the principal coal beds. Some of these sandstone beds are exposed for 20 to 30 miles in east-west extent.

In the Wellington-Minnie Maud W quadrangle there are at least seven named coal beds. Not all of these have workable seams. Further discussion on the individual coal beds is given in the Surface Information section. The coal outcrops are located high on the Book Cliffs and are almost inaccessible except in the V's of the short canyons which cut into the cliffs.

STRUCTURE

The structure between Deadman Creek and Soldier Canyon is relatively simple. Structure contours are aligned basically east-west but very slightly northwest. Northward dips lower the coal beds 100 feet each 1,000 feet on the average (6 degrees). The few faults are of small displacement and should be of little consequence in mining.

PROPERTY CONTROL

Lands of the Wellington-Minnie Maud W quadrangle are mostly privately owned (73 percent); the remainder is shared by the Bureau of Land Management (24.2 percent) and the state of Utah (2.8 percent). Practically all the coal land is privately owned, but much has the coal reserved to the U. S.

The lands are held by various individuals and companies for the purpose of coal extraction. About 75 percent of the land with cover less than 2,000 feet have been appropriated. The coal operators include: Kennecott Copper Corp., R. B. Crandall, North American Coal Corp., Premium Coal Co., L. D. Sutton and Zions Securities Corp. Figures 14 and 15 show the location of holdings.

COAL

Surface Information

Many coal seams are exposed on the quadrangle and their position in the column is expressed below:

	Feet
Upper Sunnyside bed	0-3
Interval	3-40
Lower Sunnyside bed	1-5
Interval, incl. some thin coal beds	90-140
Rock Canyon bed	0-5
Interval	10-35
Fish Creek bed	0-5
Interval	25-60
Gilson bed	2.5-9.5
Interval	12-15
Kenilworth	0.5-3.5
Interval	60
Royal Blue bed (?)	0-1.5
Interval	90-130
Castlegate "B" (?)	0-4.5
Interval	7-35
Castlegate "A"	2.5-6
Aberdeen Sandstone	

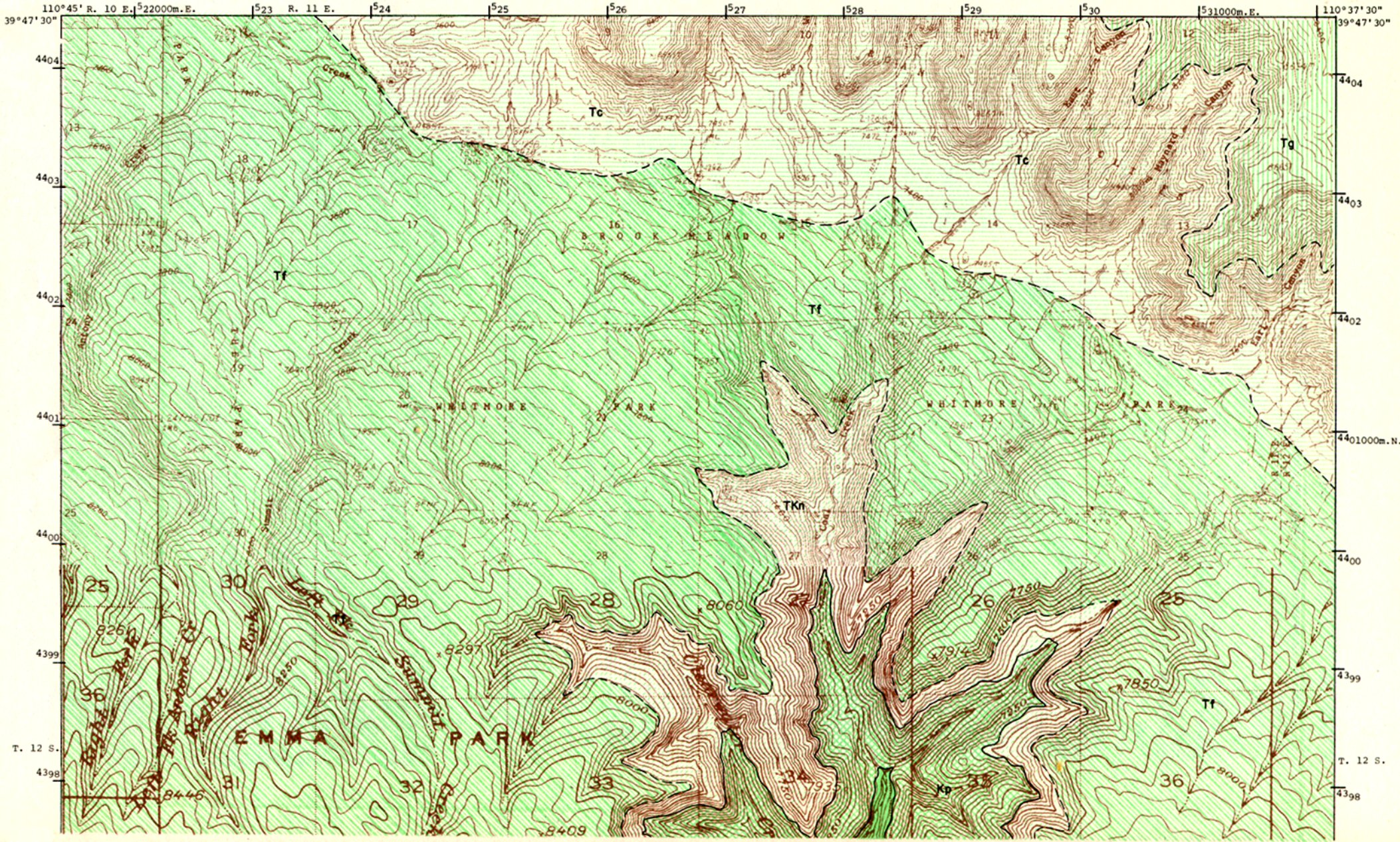
Seventeen sections for the Castlegate "A" bed ranging from 1.3 to more than 5.8 feet were measured. The average thickness is 3.2 feet. The bed is thicker than 4 feet between the Right Fork of Deadman Creek and Straight Canyon. It thins farther to the east and at location 134 on the east side of Coal Creek Canyon is 1.3 feet.

Five sections are available for the Castlegate "B" bed. The bed is local in extent and mostly thin. Midway between Deadman Creek and Straight Canyon it thickens to 4.3 feet. All sections of the Royal Blue bed (?) are thin (less than 2 feet).

The Kenilworth is thick in the quadrangle to the west, but is here thin and lenticular. The 23 sections (figure 39) indicate an average of 2 feet. The bed is present along the entire length of outcrop.

Perhaps the most valuable bed on the quadrangle is the Gilson bed. The thickness ranges from 2.4 to 9 feet and averages 4.8 feet. The bed is workable between locations 64 to 76 or between Deadman Creek and Coal Canyon. Eight sections for the Fish Creek bed attain the 4-foot minimum at two of these loca-

WELLINGTON — MINNIE MAUD W., UTAH



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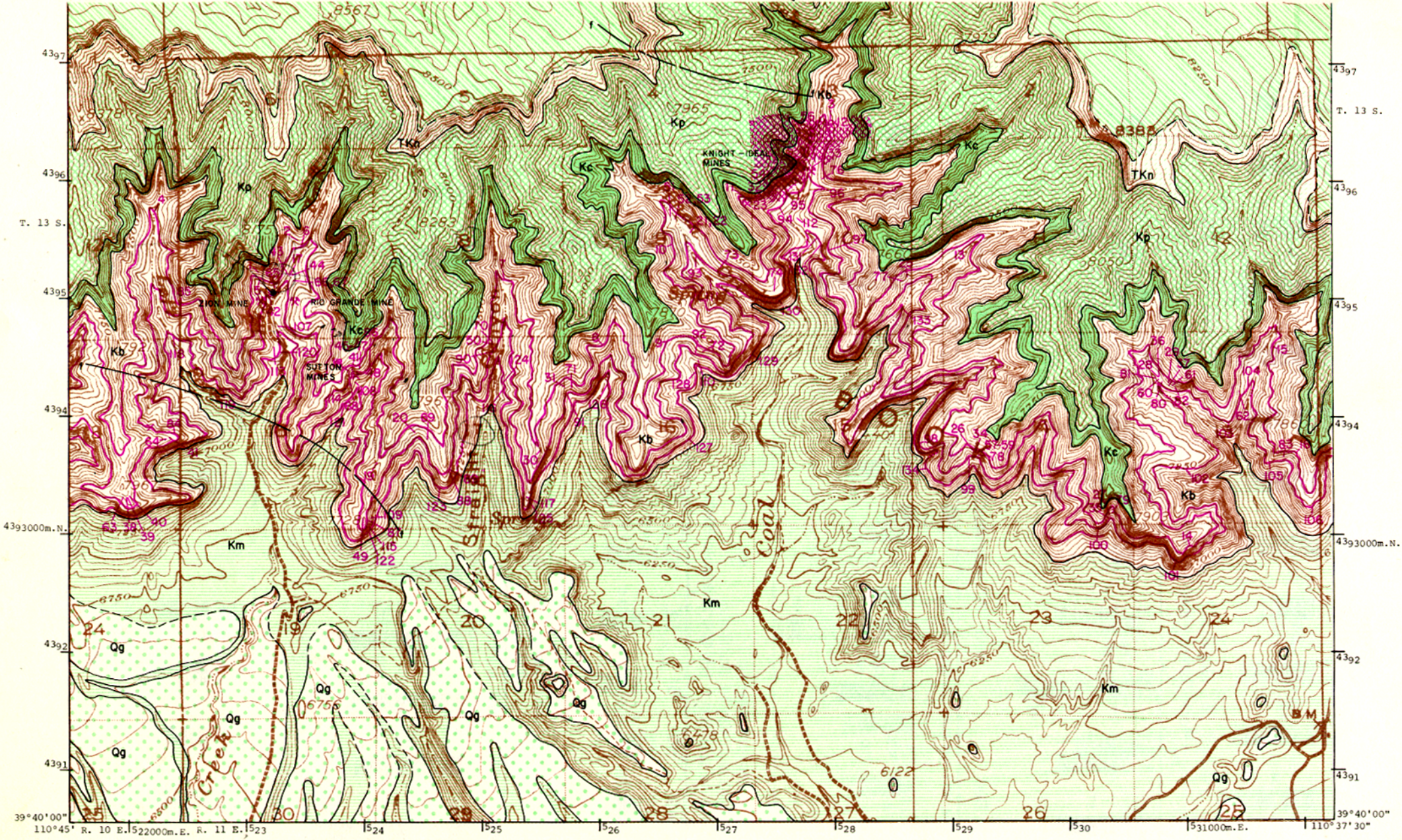

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Geology and coal data by F. R. Clark, 1928, USGS.

Figure 38. Coal and geology map, Wellington-Minnie Maud W quadrangle (explanation pages 332-333).

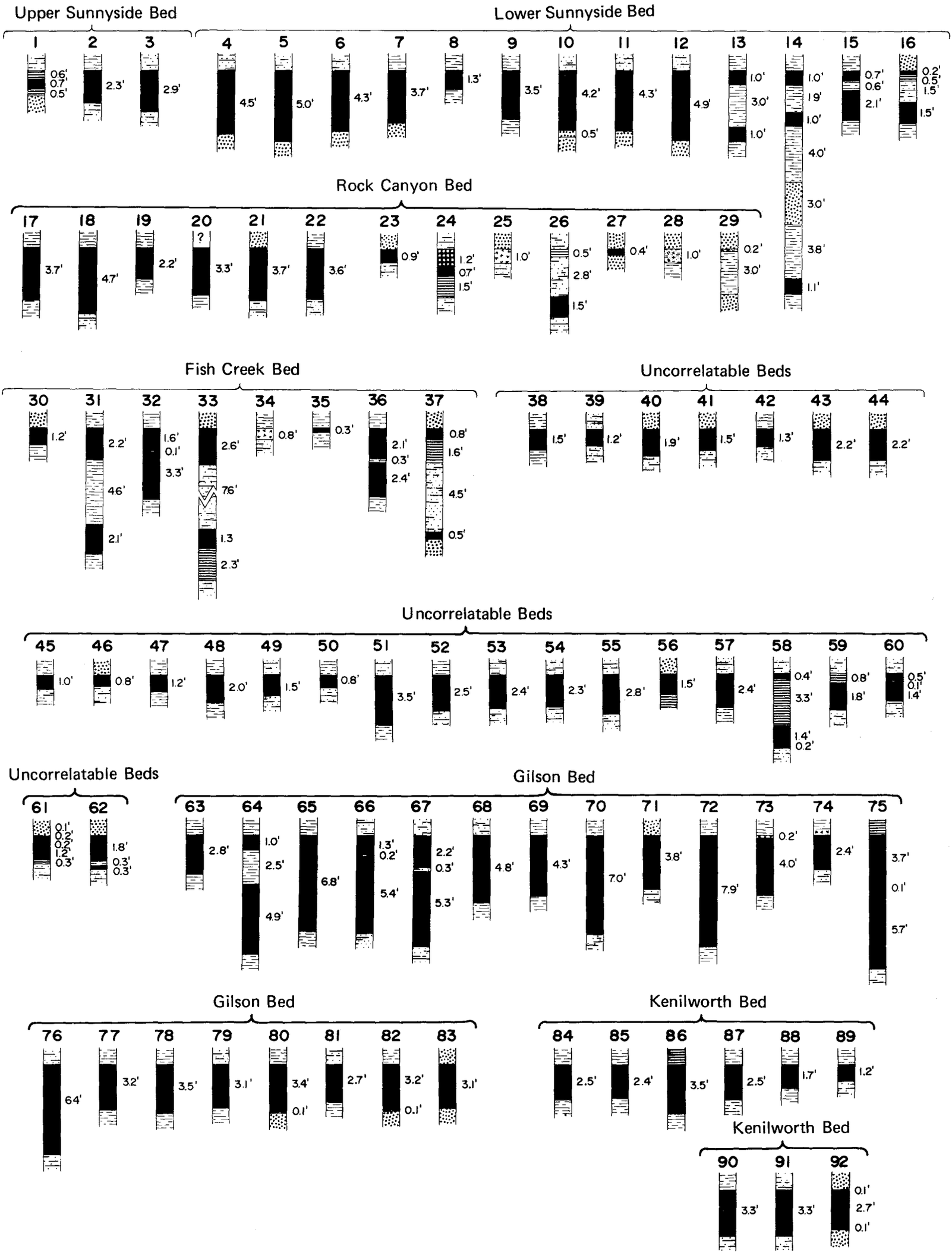


Figure 39. Coal sections of Wellington–Minnie Maud W quadrangle (vertical scale: 1 inch = 8 feet).

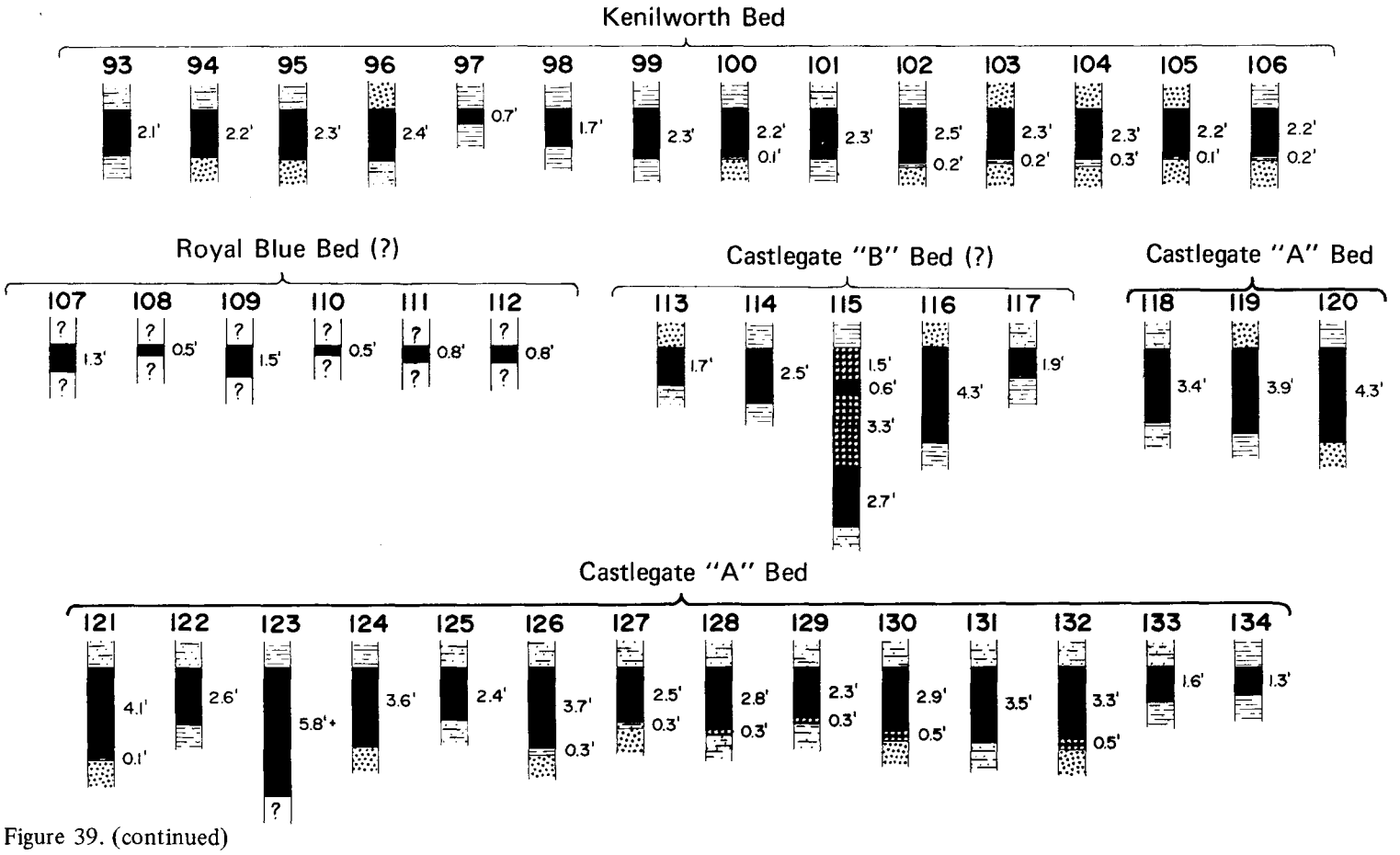


Figure 39. (continued)

tions (32 and 36). One of these locations is along Coal Creek, the other in the Left Fork of Soldier Creek.

The Rock Canyon bed is present in mostly thin sections. It reaches 4 feet thick only in the vicinity of Coal Creek. The Lower Sunnyside bed is the second most valuable. It is best developed in the deep re-entrants of Coal and Deadman creeks and may indicate an improvement of the bed to the north. Most sections are a little more than 4 feet thick. The Upper Sunnyside bed appears too thin to be mined.

Subsurface Information

Only the Coal Creek area has been extensively mined. The next important mine area is just to the east of the map area in Soldier Creek. The Gilson seam is most important in the Coal Creek area and is the only one that has been mined. Four typical sections from the Knight-Ideal mine (Coal Creek) are as follows:

SE.SE.3-13S-11E

	Feet
Coal	3.0
Bone	0.6
Shale	0.2
Coal	0.8
Bone	0.6
Coal	1.8
Total coal	5.6
Partings	1.4

NW.NW.10-13S-11E

	Feet
Coal	3.9
Bone	9.0
	–
Coal	1.0
Bone	0.1
Coal	3.8
Total coal	8.7
Partings	1.0

SW.SW.3-13S-11E

Coal	5.7
Shale	0.3
Coal	5.0
Total coal	10.8
Partings	0.3

NE.NE.9-13S-11E

Black shale	0.3
Coal	2.0
Bone	0.3
Coal	0.8
Bone	0.2
Coal	3.2
Total coal	6.0
Partings	0.8

In the Coal Creek area boney seam splits and steep pitches of coal beds make mining difficult and costly. No additional drill-hole information is available.

Coal land amounts to 70.1 percent of the quadrangle. About one-fourth of this is under 1,000 feet of cover. Most lies between 1,000 and 2,000 feet of cover with the majority under close to 2,000 feet of overburden (table 53). Datum is the Lower Sunnyside coal.

Table 53. Overburden data, Sunnyside SW quadrangle.

Overburden (feet)	Percent	
	Total land	Coal land
Greater than 3,000	2.0	–
2,000-3,000	9.1	12.8
1,000-2,000	43.8	61.7
0-1,000	18.1	25.5
Noncoal land	27.0	–

The 3,000-foot limit runs parallel and along the Roan Cliffs and the 2,000-foot line runs in the lower area between the Book Cliffs and the Roan Cliffs.

Quality of Coal

The number of available analyses for the Wellington-Minnie Maud W quadrangle totals 137 (table 4). Most of the analyses are from the Knight-Ideal mine and from the Gilson bed. Averages and ranges are listed in table 54.

Table 54. Average proximate analyses of coal, Wellington–Minnie Maud W quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	136	4.8	2.2- 8.4
Volatile matter	124	38.6	30.9-45.7
Fixed carbon	124	48.7	44.0-52.6
Ash	128	7.5	3.4-12.6
Sulfur	110	0.49	0.3- 1.0
Btu/lb	132	12,451	11,700-13,000

Walker and Hartner (1966, p. 36 and 37) subdivided the sulfur percentage of the coals of some of the mines into the sulfate, pyritic and organic categories (table 55).

Table 55. Sulfur content of coal, Wellington–Minnie Maud W quadrangle.

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Blue Flame	Castlegate A	0.38	0.00	0.04	0.34
Blue Flame	Castlegate A	0.56	0.00	0.08	0.48
Knight-Ideal	Gilson	0.36	0.00	0.03	0.33
Zion Sec. No. 1	Gilson	0.46	0.01	0.18	0.27

Tests were run by the U. S. Bureau of Mines (Gomez, Landers and Boyd, 1967), to determine what yields of char, tar, light oil, gas and other constituents could be expected from coal at a carbonization temperature of 500° C. Several Wellington-Minnie Maud W mines were included (table 56).

Table 56. Calculated carbonization product yields, Wellington–Minnie Maud W quadrangle (maf coal in weight percent; at 500° C).

Mine	Char	Water of decomposition	Tar and oil	Gas	Gas vol. scf/lb	Heat value of gas Btu/scf
Blue Flame	72.8	5.5	15.8	5.6	0.999	766
Coal Creek	73.1	5.3	15.9	5.3	0.978	779
Rio Grande	72.2	5.9	15.3	6.0	1.054	745

Mines and Development

Mines in the vicinity of Castlegate were first developed in the 1890's and in the early 1900's practically the entire Book Cliffs had been prospected (table 57). Mines in the Wellington-Minnie Maud W area, however, were not seriously active until the 1940's because the cliffs were less accessible and the coal beds were thinner. In 1970 all mines with portals opening on the quadrangle were closed.

Table 57. Mines and prospects in Wellington–Minnie Maud W quadrangle.

Mine	Location	Remarks
Blue Flame (Sutton, Star Point, Crandall)	NE.SE.NE.18-13S-11E 4,394,370m.N. 523,940m.E.	Active 1945-1964
Knight-Ideal mine	E½.NW.10-13S-11E 4,396,090m.N. 527,790m.E.	Active 1906, 1940-1965
Olson prospect	SE.NE.13-13S-10E 4,393,910m.N. 522,180m.E.	
Rio Grande mine (Olson, McAlpine)	W.NW.SW.SE.7-13S-11E 4,394,950m.N. 523,400m.E.	Opened 1925 as Rio Grande; prospected 1900's, active 1940-1956
Zion mine (Zion Securities, Jesse Knight)	SE.SW.7-13S-11E 4,395,000m.N. 523,100m.E.	Prospected 1906; active 1925-1948

The most productive group of mines are the Knight-Ideal mines–two mines located in Coal Creek Canyon. They have changed hands often and many names carry over. Initial prospecting took place in 1906, but serious mining began in 1946 and ended in 1958. During that period 1,680,000 tons of coal were mined. Operations were in the Gilson bed.

Three mines in the Deadman Canyon area include the Zion, Rio Grande and Sutton (Blue Flame) mines. The first two operated in the Gilson seam and the last in the Castlegate "A". Production figures are not reliable and merely estimates. As little as 216,000 tons and as much as 720,000 tons may have been removed from the Sutton mines. The Rio Grande mine is believed to have produced 18,000 tons and the Zion mine about 240,000 tons. The last figure is unreliable.

The total amount of coal removed from the quadrangle is thus assumed between 2 and 3 million tons.

Reserves

Clark (1928, p. 101) estimated the reserves for the Wellington portion of the quadrangle drawing his line at 39°45′ N lat. His reserves are based on a minimum of 14 inches of coal and are reproduced here (table 58); the small area of R. 12 E. is excluded and is reported with the Wellington NE summary.

Table 58. Original coal reserves in Wellington–Minnie Maud W quadrangle (in short tons; 14 inches or more thick).

Location	Bed or zone	Average thickness (feet)	Acres est.	Tonnage
T.12S. R.10E.	All beds	–	–	13,000,000
T.12S. R.11E.	Lower Sunnyside	4.0	6,223	44,800,000
	Rock Canyon	3.0	3,200	17,000,000
	Gilson	4.0	6,223	45,000,000
	Kenilworth	2.0	6,223	22,500,000
	Castlegate "A"	3.0	5,120	28,000,000
T.13S. R.10E.	All beds	–	–	31,000,000
T.13S. R.11E.	Lower Sunnyside	3.8	5,440	37,000,000
	Rock Canyon	3.2	5,760	33,000,000
	Gilson	4.2	6,720	50,000,000
	Kenilworth	2.3	6,208	26,000,000
	Castlegate "A"	3.2	4,224	24,000,000
	Other beds	5.0	448	4,000,000
			Total coal	375,300,000
			Coal averaging 4 feet or more	174,900,000

From table 59 it can be assumed that the north part of the quadrangle, which has an area of 11,500 acres, is underlain by 8 feet of coal in beds 4 feet or more thick or an additional 161 million tons. Between 110°37′30″ and 110°45′ W long., north of the Wellington-Minnie Maud W quadrangle, is an area of 2,500 acres in which depth to the coal is less than 3,000 feet for an additional 30 million tons. Experience in mining shows that the coal is split badly, thus is naturally high in ash. The undulatory nature of coal seams also has presented mining and recovery difficulties so that only 40 percent recovery can be expected (table 58). Of the 365.9 million tons in the quadrangle and the area to the north, only 146.4 million tons can be extracted. In the Castlegate quadrangle recoverability has been 50 percent. When compared to mining experience, recoverability is only about 30 percent of Clark's reserve. If this basis is used, recoverable tonnage drops to 110 million.

Table 59. Original coal reserves according to overburden, Wellington–Minnie Maud W quadrangle.

Overburden (feet)	Classes I and II	Class III	Class IV	Total
Less than 1,000	66.5	–	–	66.5
1,000-2,000	60.4	169	5	234.4
2,000-3,000	–	40	25	65.0
	126.9	209	30	365.9
			Minable 40 percent recoverability	146.4
			Minable 30 percent recoverability	110.0
			Mined up to January 1, 1970	2.5

PRINCIPAL WORK

Most of the data were derived from Clark (1928) with significant data procured from the U. S. Bureau of Mines, especially with respect to analyses.

WELLINGTON NE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Wellington NE quadrangle covers that part of the Book Cliffs between Soldier Creek and Rock Canyon in the central part of the coal field (figures 19 and 40). The main access road is Utah Highway 53 which connects Wellington on the south with Myton to the north and traverses through Soldier Creek Canyon. The mouth of the canyon is about 14 miles north of Wellington, the closest town. The highway provides access to areas above the cliffs. Gravel and dirt roads lead to the base of the cliffs at numerous places, especially to the mouths of the more prominent canyons.

Clark Valley below the cliffs slopes upward to about 6,750 feet. From there the cliffs rise to about 8,200 feet. A dip slope gradually lowers the elevation northward into Whitmore Park to about 7,450 feet and then the Roan Cliffs raise the surface to more than 9,000 feet. The coal measures are exposed between 6,700 and 7,800 feet above sea level along the cliffs and canyon walls.

STRATIGRAPHY

All the area below the cliffs consists of outcrops of the Mancos Shale and outcrops of bench gravels. Only the upper part of the 4,000- to 5,000-foot Mancos appears and it is made up of somber gray nodular-weathering shale with occasional thin-bedded tan to brown sandstone layers. During its erosional history a temporary base level was achieved and the surface was veneered with gravel. Since that time the base level has been lowered and the more important creeks and gullies have cut through the gravel exposing the Mancos Shale.

Above the marine Mancos are first the littoral sandstones which are followed by the lagoonal coal-bearing deposits of the Blackhawk Formation. The initial bed of the Blackhawk is the littoral Aberdeen Sandstone Member. In the Wellington NE quadrangle it is split into two main masses separated by an eastward-projecting tongue of the Mancos Shale. The lower sandstone is about 100 feet thick in Rock Canyon along the east map margin where it is overlain by 275 feet of Mancos Shale. The upper sandstone is 60 feet thick in Pace Canyon and it too has a Mancos Tongue above it, 150 feet thick. The sandstone tongues are massive, well cemented toward the top and cliff forming. Toward the bottom they grade into thin-bedded sandstone, shaley sandstone and sandy shale.

The upper coal-bearing part of the Blackhawk consists of massive yellow-gray cliff-forming sandstone alternating with sequences of shaley sandstone, sandy shale, gray shale, carbonaceous shale and coal. Some of the sandstone beds are as prominent as those of the Aberdeen. The better coal beds usually lie immediately above these or are separated from them by thin layers of shale or shaley sandstone. Six beds of coal have been recognized and named with other uncorrelatable coal beds as well. The entire Blackhawk is about 750 feet thick on the quadrangle. It thickens westward and thins eastward.

The Blackhawk and the succeeding Castlegate Sandstone form the major part of the Book Cliffs. The gray to tan sandstone of the Castlegate forms a vertical cliff above the Blackhawk which is more step-like in its habit, 100 feet or more high. The entire Castlegate is about 225 feet thick.

The Castlegate is the basal sandstone of the Price River Formation. The Price River is composed of two or more thick beds of sandstone interbedded with mostly thin-bedded shale and sandy shale. The thick sandstones often form cliffs 100 feet high as did the Castlegate. The Price River appears to be approximately 500 feet thick on the quadrangle. The thickness is not uniform, however, and near Soldier Canyon the unit is 150 feet thick, thickening to the east and to the west.

The North Horn Formation succeeds the Price River and is believed to straddle the Cretaceous-Tertiary time line. The North Horn is a sequence of gray, green-gray and dark green shale, tan, yellow-gray, fine-grained sandstone and tan and argillaceous limestones with minor amounts of conglomerate. The unit thins west to east in the Book Cliffs field and in the Wellington NE quadrangle appears to be 400 to 500 feet thick.

The northward-pitching dip slope of the Book Cliffs is capped by the Flagstaff Limestone, predominantly thin-bedded limestone, shale and sandstone. The limestones are lacustrine and microcrystalline. The shales are varicolored and the sandstones are generally reddish brown and fine- to medium-grained. Sandstone is not plentiful in the Flagstaff. The unit thins rapidly eastward so that only a thin division between the North Horn and the overlying Colton Formation exists along the east map edge. Average thickness of the unit on the quadrangle is an estimated 250 feet.

The northeast map corner exposes the Roan Cliffs and the Colton Formation. In the immediate corner is the Green River Formation. The Colton consists of reddish and brownish lenticular sandstone, shales and siltstones at least 1,000 feet thick. The Green River Formation, with its greenish gray and white claystones and shale, is the youngest exposed formation.

STRUCTURE

The structure contours follow the trend of the cliff front, west by northwest. The northward-dipping rocks drop 500 feet per mile for an average of about 6 to 7 degrees. Occasional faults may cut the coal beds, but these are believed to be of small displacement and should not appreciably affect mining. The State Geologic Map of Utah, NE quarter, shows several northwest-trending faults along the Roan Cliffs which might create problems if mining proceeds this far behind the outcrop.

PROPERTY CONTROL

The lands of the Wellington NE quadrangle are 54.8 percent privately owned, 36.0 percent owned by the Bureau of Land Management and 9.2 percent state owned. Most of the private land is behind the cliffs. The cliffs are equally divided as private property and BLM land.

Some of the leased lands superimpose upon private lands indicating that the coal is reserved to the federal government. Practically all the outcrop area is leased. The leases extend back to cover most of T. 13 S., R. 12 E. and the locations of such lands are shown on figure 15. Holders of such lands include: Kennecott Copper Corp., Island Creek Coal Co. (Heiner), Premium Coal Co. and Kaiser Steel Corp.

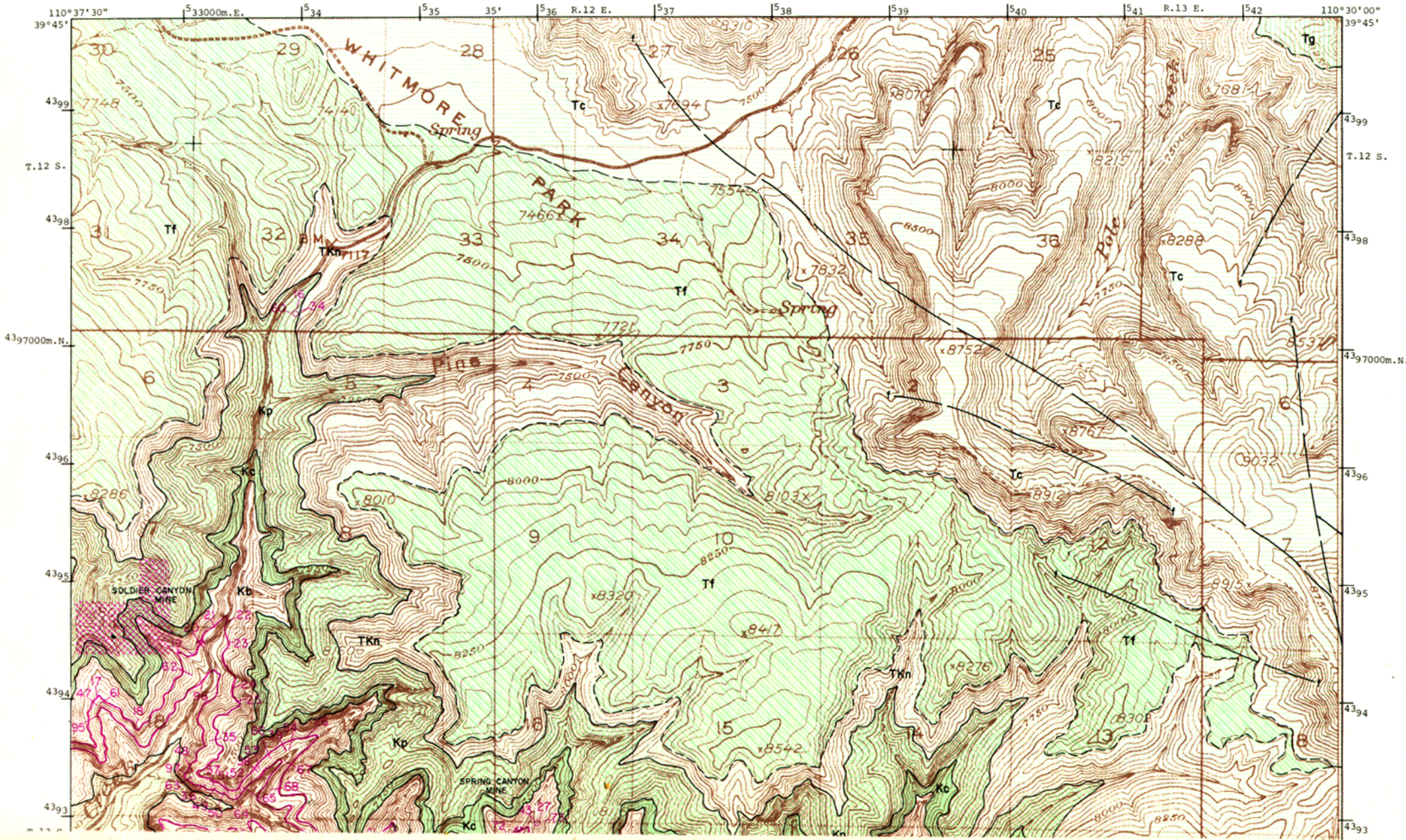
COAL

Surface Information

The coal beds exposed on the Wellington NE quadrangle are shown in their stratigraphic positions below:

	Feet
Castlegate Sandstone	
Coal beds above Upper Sunnyside	0-3
Upper Sunnyside bed	0-6
Total interval above Lower Sunnyside to base of Castlegate Sandstone	175-250
Lower Sunnyside bed	1-9
Interval	55-180
Rock Canyon bed	1-9
Interval	50
Fish Creek bed	0.8-5.2
Interval	25-60
Gilson bed	1-13
Interval	50
Kenilworth bed	1-2.7
Kenilworth Sandstone	

WELLINGTON N.E., UTAH



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972

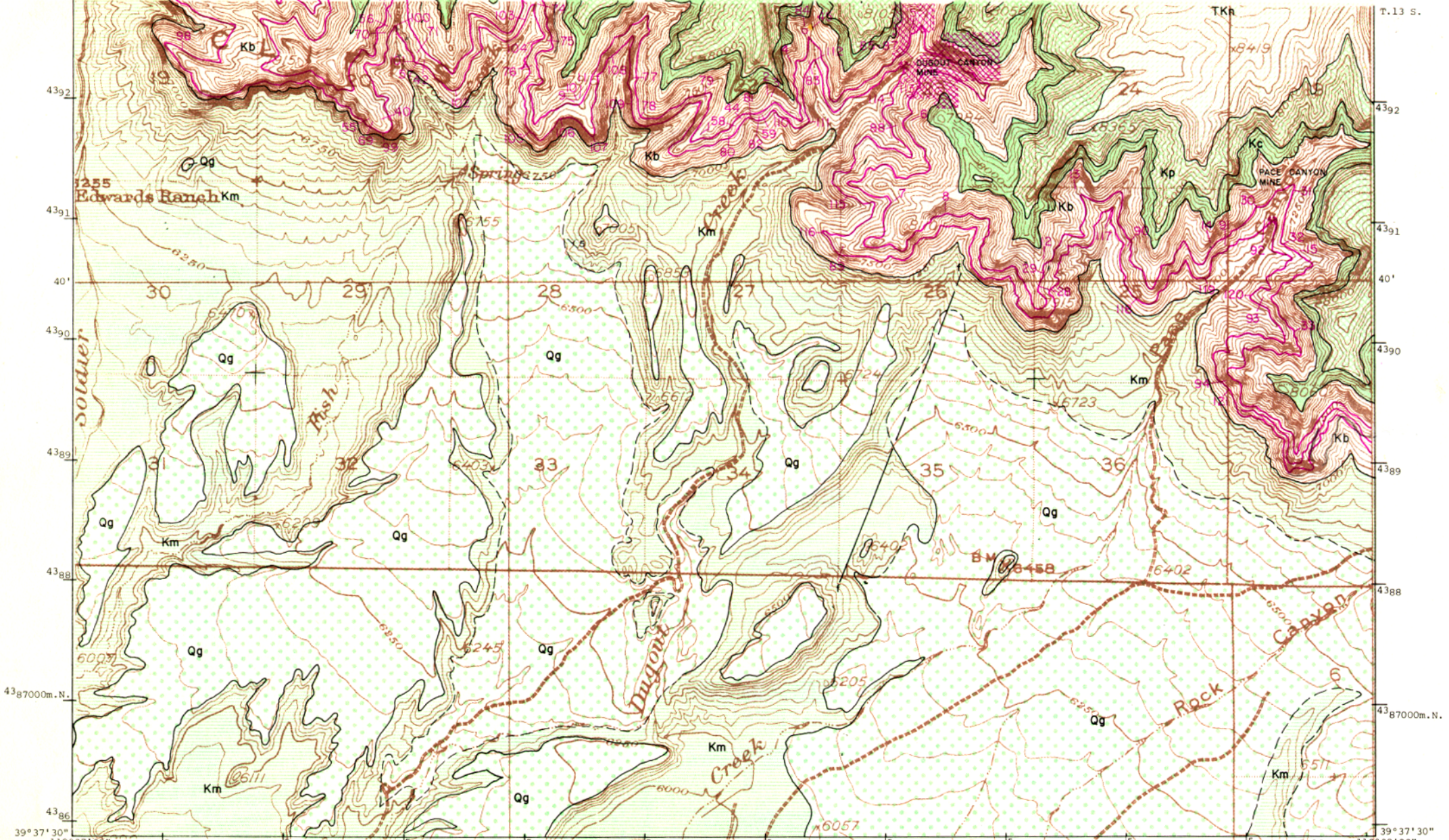


Figure 40. Coal and geology map, Wellington NE quadrangle (explanation pages 332-333).

The lowermost Kenilworth bed probably averages 2 feet thick over the entire quadrangle and is consistent. According to Clark (1928, p. 49):

> The Kenilworth bed is generally overlain by shale or sandy shale, with a sandstone about 5 to 10 feet above the coal, but in some places sandstone rests directly on coal. . .The coal rests on a massive sandstone from 100 to 125 feet thick or is separated from it by a few inches to a few feet of shale or sandy shale. . .It appears to be the only coal not seriously reduced in thickness or affected in character in the vicinity of Soldier Creek. . .There is a considerable area in secs. 29, 30, 31 and 32, T. 13S., R. 13E., where the Kenilworth bed is probably thin or absent . . .

The Gilson bed is probably the most valuable on the quadrangle but is variable in thickness (figure 41). To the west near Soldier Canyon it is lenticular and badly split. East of sec. 20, T. 13 S., R. 12 E. the bed does not thin to less than 3 feet. Much of the coal is seriously burned at the outcrop and has probably ruined the coal within 200 feet of the outcrop. The zone of burning is usually less where outcrops cross stream channels.

The Fish Creek bed, thought to be a split of the Rock Canyon bed above, achieves its best development in Fish Creek Canyon. The average thickness of the bed is 3 feet 3 inches and locally it thickens to more than 4 feet. In local areas the bed should be minable. Clark (1928, p. 51) notes this bed is of good thickness throughout a considerable area on the north where it is under deeper cover.

The Rock Canyon bed is valuable on the Wellington NE quadrangle. It is irregular in thickness with occasional shaley partings. In one bench the thickness ranges from 3.5 to nearly 3 feet. The thickness over much of the quadrangle averages 5 feet. Most of the surface exposures are burned.

The Lower Sunnyside coal is mostly thin in outcrop and marginal to the 4-foot limit. It rests on the Sunnyside Sandstone which is easily traced. Much of the bed, however, has been burned along the outcrop. The average thickness is 2.4 feet in surface exposures. All upper beds, including the Upper Sunnyside, are thin

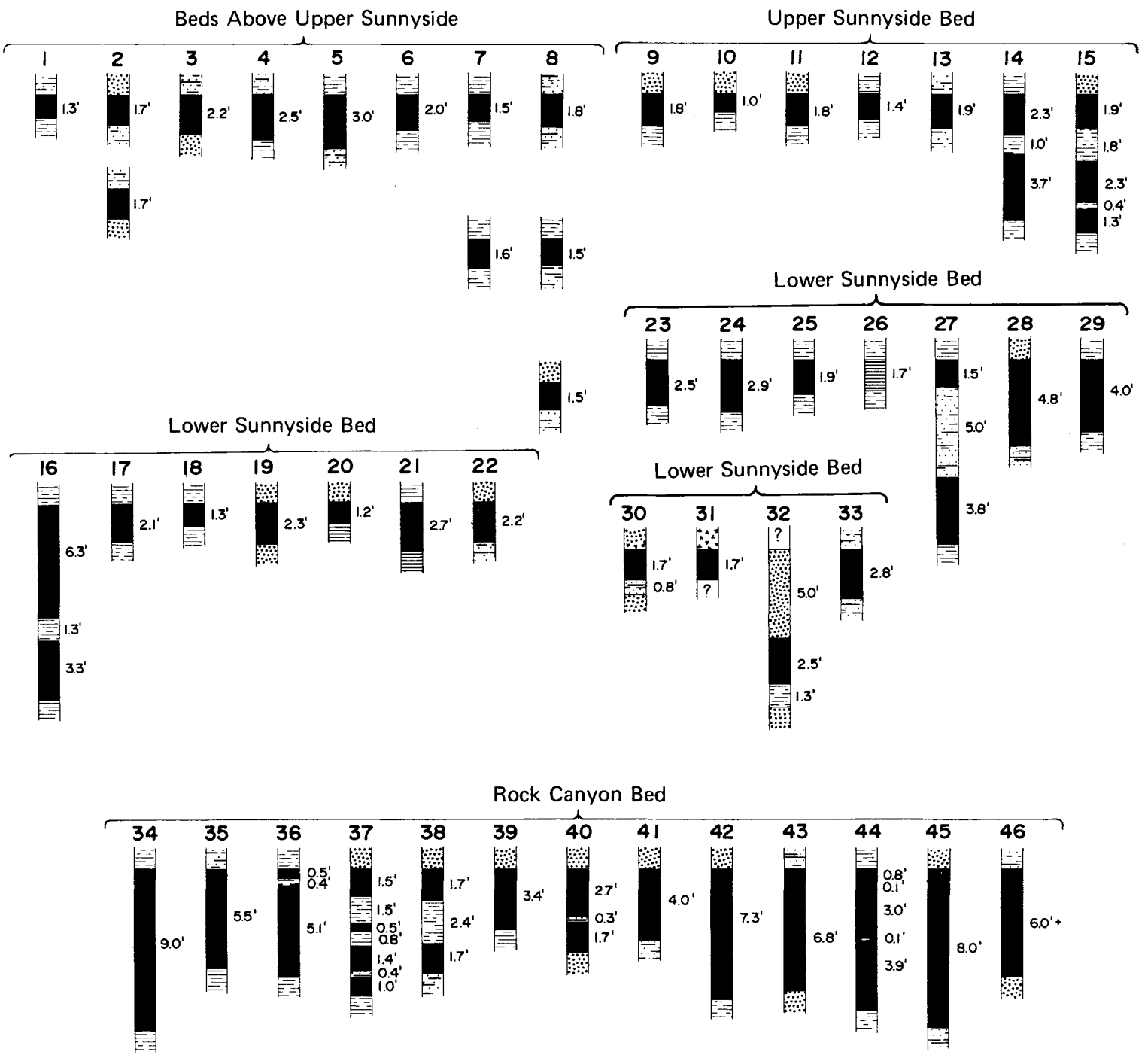


Figure 41. Coal sections of Wellington NE quadrangle (vertical scale: 1 inch = 8 feet).

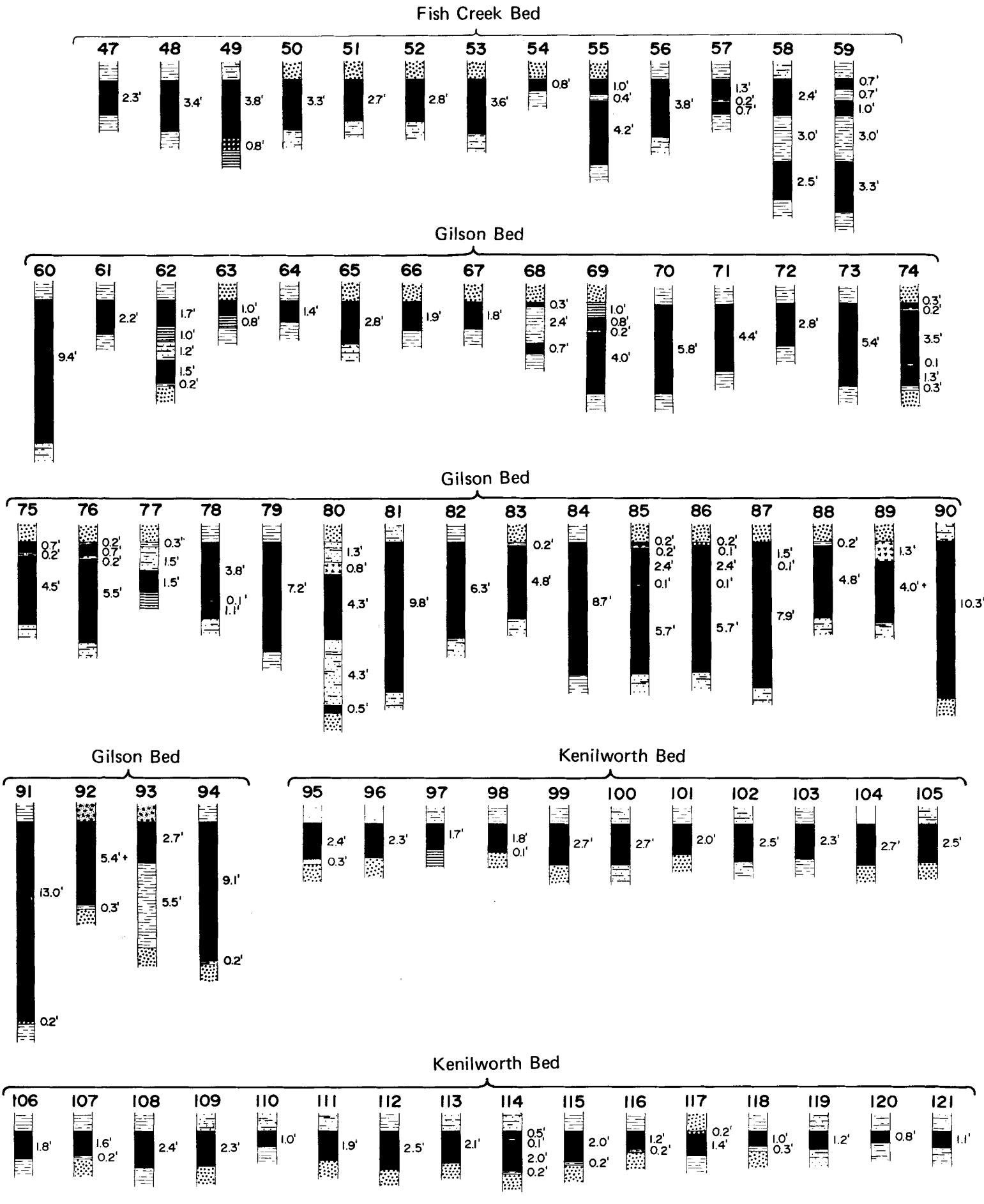


Figure 41. (continued)

and no sections show 4 feet of clear coal. Along the east map edge the Upper Sunnyside thickens to 6 feet but is split by partings.

Subsurface Information

Subsurface data from drill hole and mines are summarized below (table 60):

Table 60. Drill-hole and mine subsurface data, Wellington NE quadrangle.

	Average thickness (feet)		
	Gilson	Rock Canyon	Lower Sunnyside
Kaiser leases (east map margin)	7.0	5.4	4
Kennecott (Pace to Dugout Canyon)	11.0	8.0	–
Island Creek 22-13S-12E	8.7	8.0	–
21-13S-12E	5.4	6.8	3.8
17-13S-12E	2.0	3.0	–
Drill hole 32-12S-12E	9.4	9.0	9.6
Premium mine	4.8	12.0	3.0

The three 9-foot seams in north Soldier Creek Canyon may indicate a thickening trend to the north. Overburden data are as follows (table 61):

Table 61. Overburden data, Wellington NE quadrangle.

Overburden (feet)	Percent	
	Total land	Coal land
Greater than 3,000	0.1	–
2,000-3,000	14.2	24.2
1,000-2,000	28.0	47.9
0-1,000	16.3	27.9
Noncoal land	41.4	–

By projecting structure contours, north of the quadrangle an estimated additional 500 acres of coal land will occur with 1,000 to 2,000 feet of overburden and almost 5,000 acres with 2,000 to 3,000 feet of overburden. The 3,000-foot limit lies high on the Roan Cliffs.

Quality of Coal

Coal analyses are summed up in table 62. The available analyses for the Wellington NE quadrangle total 97 (table 4).

Table 62. Average proximate analyses of coal, Wellington NE quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	97	4.9	3.1- 8.5
Volatile matter	94	38.6	37.4-40.1
Fixed carbon	94	50.1	45.2-52.9
Ash	97	6.4	3.7-11.5
Sulfur	96	0.49	0.3- 0.82
Btu/lb	93	12,645	11,390-13,390

Results of select analyses from the two most important mines on the quadrangle are given in table 63.

Gomez, Landers and Boyd (1967, p. 8) calculated carbonization product yields from three Utah coals mined from this quadrangle (table 64).

Mines and Development

Four groups of mines have been opened across the quadrangle (table 65), each in a major re-entrant of the Book Cliffs.

Table 63. Average proximate analyses of coal from the Dugout and Premium mines, Wellington NE quadrangle.

	Washed Coal Basis		
	Dugout mine		Premium mine
	Gilson	Rock Canyon	Rock Canyon
Moisture (air dried, percent)	2.1	2.0	3.2
Ash (dry, percent)	5.0	5.3	6.4
Volatile matter, percent	40.7	38.7	39.7
Fixed carbon, percent	54.3	56.0	53.9
Sulfur, percent	0.4	0.6	0.5
Btu/lb	13,750	13,700	13,360
Ash soft temp.	2,160	2,500	2,360
Free swelling index	2½	1½	1½
Grindability	46	41	48
Oxygen (maf)	10.2	11.2	?

Table 64. Calculated carbonization product yields (weight percent of maf coal at 500° C), Wellington NE quadrangle.

Mine	Char	Water of decomposition	Tar and oil	Gas	Gas vol. scf/lb	Heat value of gas Btu/scf
Dugout No. 2	73.5	5.0	16.4	4.7	0.939	809
Knight-Ideal No. 2	74.3	5.5	15.7	4.7	1.309	806
Soldier Canyon	74.2	5.2	14.8	5.3	0.978	781
Rock Canyon core near Soldier Canyon	74.2	5.2	14.8	5.4	0.984	778

Table 65. Mines in the Wellington NE quadrangle.

Mine	Location	Remarks
Dugout Canyon mine (ESO, Branch Bros., Knight-Ideal)	SE.SE.NW.23-13S-12E 4,392,320m.N. 539,080m.E.	Active 1906; 1920-1953
Pace Canyon mine (Snow mine)	NW.NW.30-13S-13E. C.SW.½ S19 4,391,060m.N. 542,150m.E.	Active 1906; 1932-1940
Soldier Canyon mine (Premium mine)	NW.NE.18-13S-12E 4,394,480m.N. 533,220m.E.	1906 some prospecting 1931-1970 active
Spring Canyon mine	NE.NW.21-13S-12E 4,392,900m.N. 535,980m.E.	Active 1906-1910

In Soldier Canyon the Premium Coal Co. mine is presently (1970) active and in 1969 produced 143,093 short tons of coal. Only the Rock Canyon seam is mined. The roof is generally hard but requires bolting; the floor is hard and about 2 feet of bottom coal are left to eliminate a 3-inch rock split. The seam thins noticeably both east and west of Soldier Canyon in surface outcrops. Coal production from the mine began in the 1930's and totals about 1.2 million tons to January 1, 1970.

The Spring Canyon mine in Fish Creek Canyon was opened at the time of the initial investigations into the area in 1906. The coal bed contained 5.3 feet of coal 50 feet above the lowest seam. The seam had a 4-inch parting at the top. If any bona-fide production was achieved, it was small.

Dugout Canyon mines and the Knight-Ideal successors operated in Dugout Canyon from both the Gilson and Rock Canyon seams. Mining was intermittent at first but steadied in the 1940's. Truck mining was conducted during the 1940's and the property was subsequently acquired by Knight-Ideal Coal Co. This company together with its predecessors extracted approximately 1,326,000 tons of coal until September 1965 when the property was closed down. It was sold to Kennecott Copper Corp. for fuel insurance purposes. The dip of the coal seams in the mines averages 6 degrees and the strike is N 68° W. Mining operations were con-

ducted in both the Rock Canyon and Gilson seams using the room and pillar method and, where possible, pillars in the Rock Canyon seam were superimposed over pillars in the Gilson seam. Mining originally began in the thicker and lower Gilson. Recovery was about 39.5 percent. The roof is tender and shaley in the Rock Canyon seam and a hard sandstone roofs the Gilson. A sandy shale floor occurs under the Rock Canyon and a hard sandstone under the Gilson.

The Pace Canyon mine was originally opened by cutting a 50-foot tunnel through a naturally burned seam. No production figures are available and the mine may never have exceeded the prospect stage. Any production is assumed to have been small.

Total production from mines with entries opening on the quadrangle amounts to a little less than 2.6 million short tons of coal.

Reserves

Clark (1928, p. 101 and 102) calculated reserves for the quadrangle by townships including coal 14 inches thick or more. They are reproduced here (table 66) and include a thin strip of R. 12 E., extending into the Wellington-Minnie Maud W quadrangle.

Table 66. Original coal reserves in Wellington NE quadrangle.

Location	Bed or zone	Average thickness (feet)	Acres est.	Tonnage
T.12S. R.12E.	Lower Sunnyside	2.0	6,400	23,000,000
	Rock Canyon & Fish Creek	6.0	6,400	69,100,000
	Gilson	4.0	6,400	46,100,000
	Kenilworth	1.5	6,400	17,300,000
T.12S. R.13E.	Lower Sunnyside	2.8	1,200	6,000,000
	Rock Canyon	3.0	1,200	6,500,000
	Gilson	2.5	1,200	5,400,000
T.13S. R.12E.	Lower Sunnyside	2.5	11,520	52,000,000
	Rock Canyon	4.0	10,880	78,000,000
	Fish Creek	3.3	5,760	35,000,000
	Gilson	4.7	12,160	102,000,000
	Kenilworth	2.0	12,160	44,000,000
T.13S. R.13E.	Lower Sunnyside	4.9	4,200	37,000,000
	Rock Canyon	4.0	4,200	30,200,000
	Gilson	3.8	4,200	28,700,000
			Total coal	580,300,000
			Coal averaging 4 ft or more	293,300,000

Clark lacked drill-hole data in 32-12S-12E where 9 feet of coal were found in each of the Gilson, Rock Canyon and Lower Sunnyside seams. At least in that township the coal is thicker and some adjustment should be made; it is misleading to think that the entire township contains these coal thicknesses as an average, however. A new average thickness is calculated incorporating Clark's data and drill-hole data. Thus, on an inferred basis, the Lower Sunnyside averages 4.5 feet, the Rock Canyon 5 feet and the Gilson 5.8 feet. The others remain thin. Using Clark's acreage for T. 12 S., R. 12 E. the Lower Sunnyside will have a 51.8-million ton reserve, the Rock Canyon 57.6 million tons and the Gilson seam 66.8 million tons. This adds 130.1 million tons to the coal averaging 4 feet or more.

Studies of reserves for the mining properties indicate a recoverability of about 40 percent with 6,000 tons per acre per seam. At least two seams 4 or more feet thick are everywhere minable except in the lower part of Soldier Canyon. With 2,800 acres in this area, reserves for the entire quadrangle might be calculated in this fashion:

2,800 x 6,000 tons =	16,800,000
18,650 x 12,000 tons =	223,800,000
	240,600,000
Less 15 percent burn, oxidation and other geologic inconsistencies	36,100,000
Recoverable and minable coal	204,500,000
Production plus mining loss	6,500,000
Remaining and recoverable	198,000,000
40 percent of Clark's modified 4 feet or thicker coal	169,400,000

In addition reserves to the north of the Wellington NE quadrangle might be contemplated. About 5,200 acres of ground contain coal with less than 3,000 feet of overburden. The overburden datum is placed on the Lower Sunnyside. It is assumed that about 4,000 acres of Rock Canyon and 3,000 acres of Gilson seam would be minable. Most of this area involves the south two tiers of sections in the quadrangle to the north (Minnie Maud Creek E; table 67) or the area south of the Roan Cliffs. The resource is close enough to drill holes to be classed as an inferred reserve (Class III).

Table 67. Original coal reserves in the Minnie Maud Creek E quadrangle (cover less than 3,000 feet).

	Average thickness (feet)	Acres est.	Tonnage
Lower Sunnyside	4.5	5,200	41,000,000
Rock Canyon	5.0	4,000	35,000,000
Gilson	5.8	3,000	30,500,000
		Total coal	106,500,000
		30 percent recoverability	32,000,000

The recoverability is calculated 10 percent less in this sector because of the great depth. The coal reserve for both quadrangles is summarized below for coal over 4 feet thick (table 68). If one assumes 35 percent recoverability for all the coal then the minable tonnage varies between 185 and 230 million tons which may be possible considering the good separation between seams.

Table 68. Original coal reserves in Wellington NE quadrangle (more than 4 feet thick; in short tons).

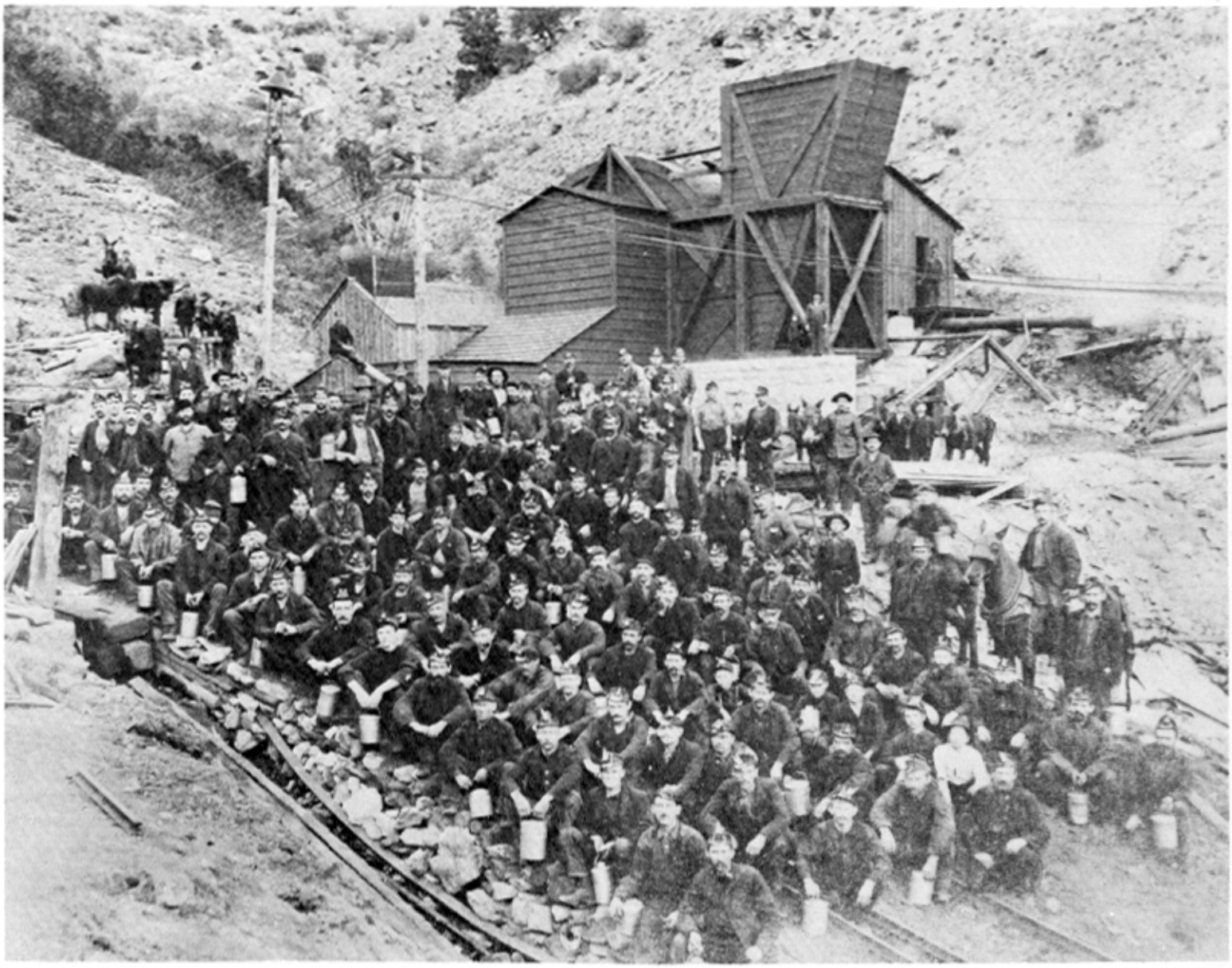
Overburden (feet)	Classes I and II	Class III	Total
Less than 1,000	81.8	–	81.8
1,000-2,000	228.9	32.3	261.2
2,000-3,000	12.5	174.4	186.9
	323.2	206.7	529.9

PRINCIPAL WORK

The geologic mapping and the procurement of measured sections were mainly done by Clark (1928). Supplemental data were principally secured from Bureau of Mines published and unpublished information (especially for the analyses) and from special investigations made for this study by consultants.

Soldier Canyon mine (Premium coal mine) in 1970. The mine is cut in the Rock Canyon seam, Wellington NE quadrangle.

Tipple of the Spring Canyon mines in 1970, shortly before the mines closed.



Miners and mine mules in the Royal area between 1912 and 1920. Photo from Helper Mining Museum original.

WOODSIDE NE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Woodside NE quadrangle is located about 6 miles south of Sunnyside and covers that portion of the Book Cliffs from Columbia to Williams Draw (figures 19 and 42). The actual location of the town of Columbia is about 1 mile north of the north map edge. The area below the cliffs consists of gravel benches or exposures of shale rising from about 5,000 feet to 6,000 feet at the base of the cliff. Toward the north the base of the cliff is a little higher, about 6,500 feet. The top of the cliffs ranges from about 7,000 feet to the south to more than 8,000 feet to the north. The coal beds are exposed along the cliffs between 6,500 and 7,250 feet above sea level. The upland area behind the cliffs is rugged and mountainous but the slopes are less steep than along the cliff front. A ridge, the south extension of Patmos Mountain, parallels the cliffs 2½ miles to the east and the peaks surpass 9,000 feet in elevation. Farther east the altitude drops toward Range Creek. Few canyons have indented the cliff front to any degree. The deepest canyons are Horse and Lila canyons.

Access along the base of the cliffs is good and paved roads extend from U. S. Highway 50-6 to Horse Canyon directly or from Sunnyside. Gravelled and four-wheel drive roads extend up Horse Canyon and provide access to the upland region.

STRATIGRAPHY

The only consolidated unit exposed below the Book Cliffs (and forming the lower 500 feet of the cliff) is the Mancos Shale. Estimated as being more than 4,000 feet thick, it consists of drab medium to dark gray shales that are generally limy and without pronounced fissility. The shales are often nodular weathering and carry veinlets of gypsum and occasionally calcite. The Mancos is quite impervious to water and the surface becomes slick and muddy after a rain. The moisture dissolves the chemical matter and whitish efflorescences often are seen on its surface after it dries. At one time a gravel surface developed on the Mancos. Remnants of this surface are plentiful and are more conducive to vegetative growth. The gravels occur up to 50 feet thick.

The Mancos is overlain by the Blackhawk Formation which is exposed only along the cliffs and canyon walls. The Blackhawk is the important coal bearer and in this location carries coal in one bed, the Lower Sunnyside. The Blackhawk may be divided into four members on the basis of resistance to erosion; this system was the basis for mapping by Fisher (1936): upper shaley member ±270 feet, middle sandstone member ±120 feet, middle shaley member ±150 feet and lower sandstone member 175 to 200 feet. The Lower Sandstone and Middle Shale members are known as the Kenilworth Member (Young, 1955). The Kenilworth coal bed usually lies just above the sandstone. The sandstone is usually a massive cliff former composed of littoral fine- to medium-grained rock, the lower part of which is thin-bedded and split by many shale partings. The upper part consists of alternating sandstone, shale, carbonaceous shale and coal. Toward the south, shale constituents dominate, making the unit appear more and more like the Mancos. The Middle Sandstone Member corresponds to Young's Sunnyside Member. The lower part mimics the Kenilworth Sandstone. The important Sunnyside coal beds lie in the upper third. The upper shaley beds are like the shaley beds of the Kenilworth except that the sandstones dominate and there is a greater percentage of carboniferous shale. Young termed this interval the Desert and Grassy members but in mapping they are best grouped into one. The coal beds therein are called the Beckwith zone in this report.

Rimming the cliff above the Blackhawk is the Castlegate Sandstone, a massive, cross-bedded cliff maker, tan-brown to light gray in color. The quartz grains are mainly cemented by calcite. Often small concretions occur near the top of the unit. The Price River has been subdivided into various members by Fisher (1936, p. 25 and 26): Farrer noncoal-bearing member (?), Neslen coal-bearing member (354 feet), Sego Sandstone (177 feet) and Buck Tongue of Mancos Shale (137 feet).

The Buck Tongue is reminiscent of the Mancos and is a westward-projecting part of that unit. The Sego Sandstone is mostly cliffy sandstone, shale being prominent only in the gradational zone with the underlying member. The Neslen coal-bearing member consists of alternating sandstone, shale and coal. The coal beds are thin in this area, but the member forms the basis of the Sego coal field east of the Green River. The Farrer Member is similar to the Neslen but has no known development of coal beds in Utah. The exact thickness of the member has not been ascertained but the entire formation is expected to be less than 800 feet at Horse Canyon. Thickness range is probably wide on the quadrangle varying between 500 and 1,000 feet.

Little is known about the succeeding Tuscher, North Horn, Wasatch and Green River formations but their general descriptions are found on figure 5.

STRUCTURE

The structure contours parallel the cliffs and the rocks dip from 4 to 12 degrees eastward. The average dip is about 7 degrees. The dips decrease eastward, at least at the surface, to average 4 degrees. According to Fisher (1936, p. 58) the only observed dislocations are those in the southeast corner of T. 16 S., R. 14 E. The northernmost one is a shear zone with 50 feet of displacement, the next one has a maximum displacement of 200 feet, the third 120 feet and the last 200 feet.

PROPERTY CONTROL

Woodside NE quadrangle is owned by the Bureau of Land Management (62.0 percent), privately (20.0 percent) and the state of Utah (18 percent). There is a large grouping of state acreage in the north central map area. Most of the private land is located to the west of the state land. The south part of the quadrangle presents the normal BLM lands with a sprinkling of state sections (figure 14). All the best coal lands are held for coal extraction and these leases and private holdings extend almost to Patmos Ridge. Control of these properties is dominated by U. S. Steel and Kaiser Steel corporations. The land held by the Book Cliffs Coal Co. is mined out and a small acreage is held by Bank of America. The areas are located on figure 15.

COAL

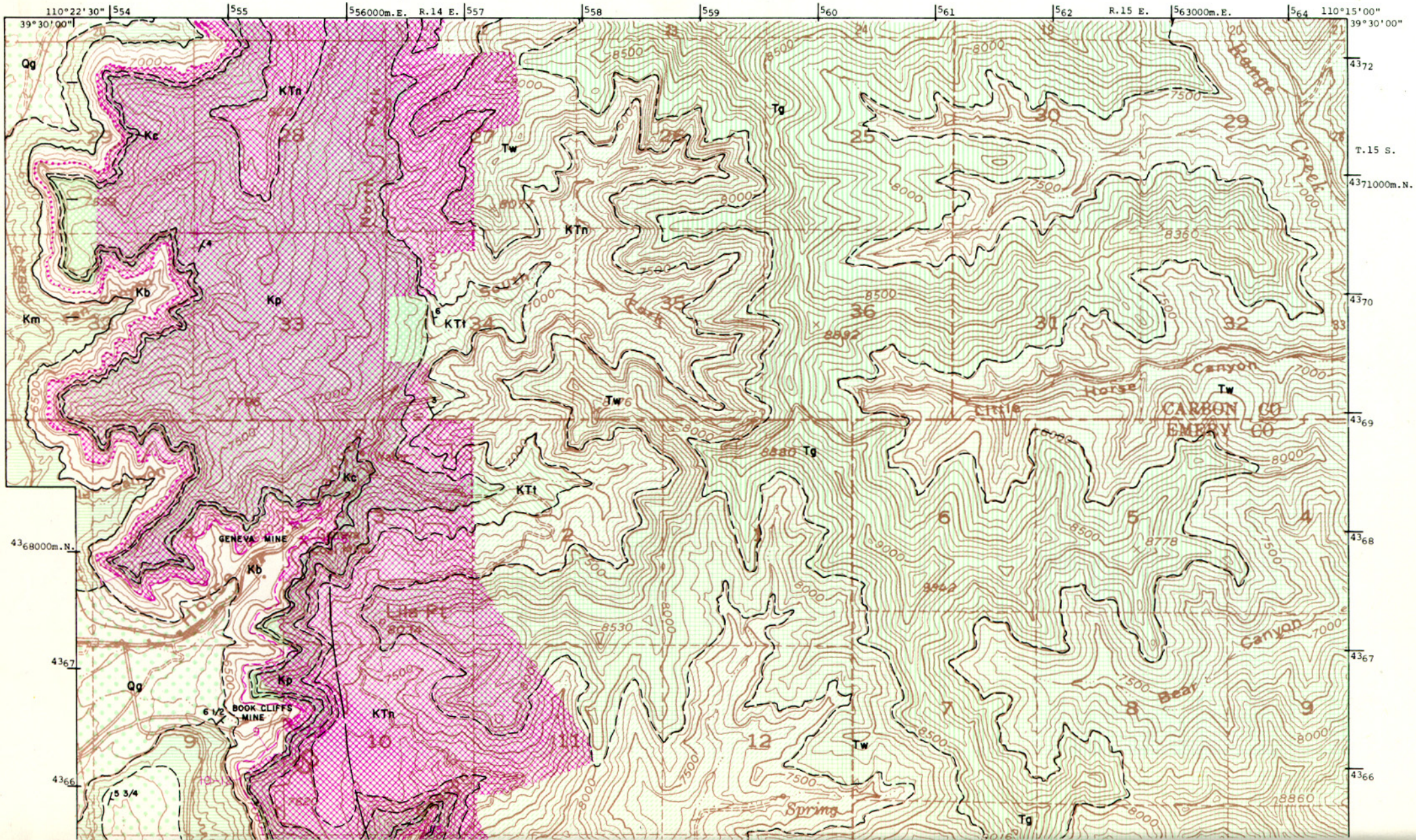
Surface Information

The lowest coal bed on the Woodside NE quadrangle probably is the Kenilworth. No measured sections are available but the bed is believed to average less than 2 feet and is probably missing over part of the area. The most important bed is the Sunnyside ranging from 5 to 18 feet thick. The averages listed by Fisher (1936, p. 56) are 13 and 14 feet. He indicates the average thickness to thin to 6 feet in the south two tiers of sections of the quadrangle. In the north map area an upper bench of coal outcrops 2 to 4 feet above the main seam and is thought to represent the Upper Sunnyside bed. Nothing is reported about the upper beds but they are expected to be thin and inconsequential. The Sunnyside coal beds lie about 325 feet below the base of the Castlegate Sandstone. Coal sections for Woodside NE quadrangle are shown in figure 43.

Subsurface Information

Data from three drill holes are shown as locations 24 to 26, each indicating thick coal in the Lower Sunnyside. The holes confirm the presence of minable coal eastward at least to the 2,000-foot coverline (table 69).

WOODSIDE N.E., UTAH



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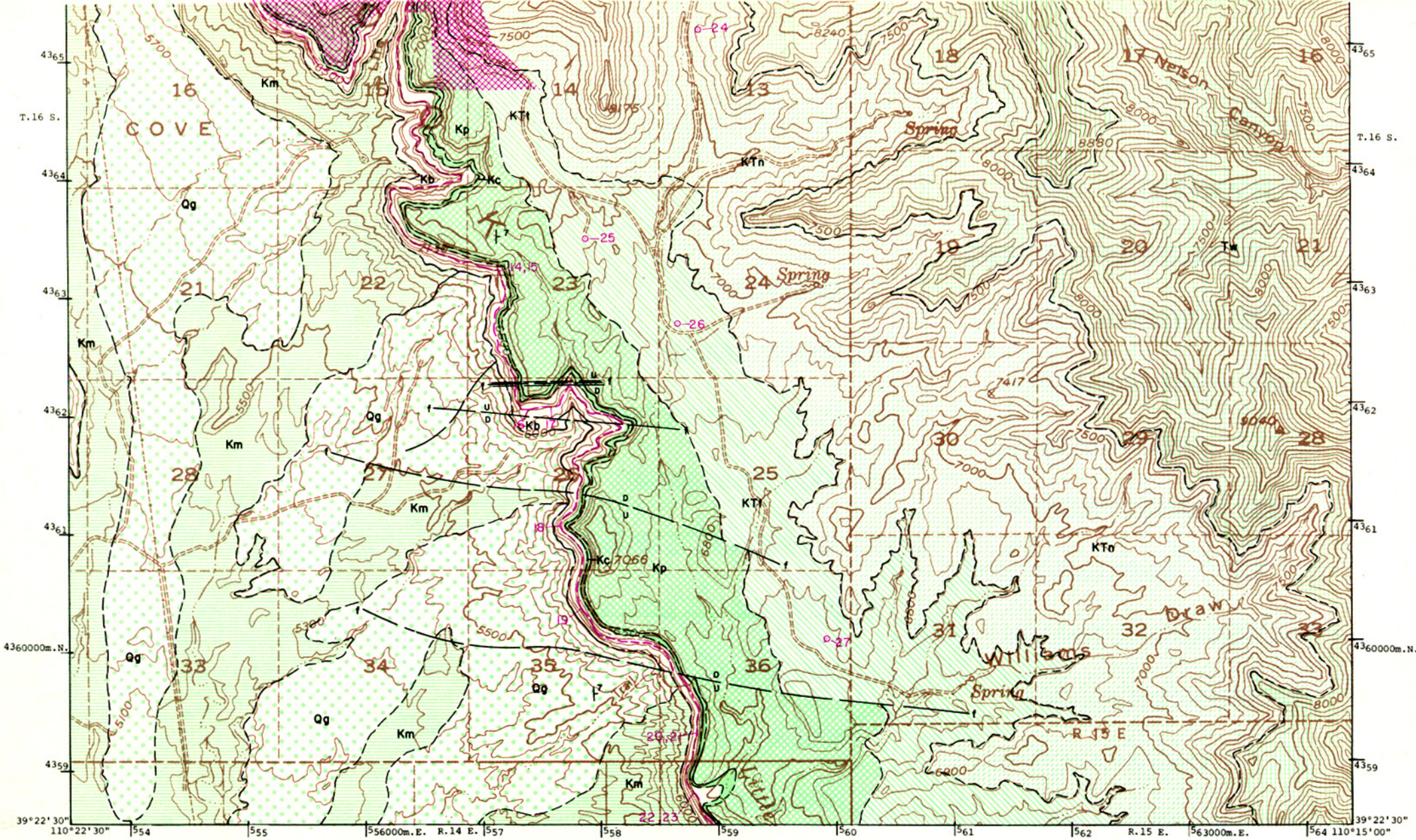

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SCALE 1:42240

1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
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Geology and coal data by D. J. Fisher, 1936, USGS.

Figure 42. Coal and geology map, Woodside NE quadrangle (explanation pages 332-333).

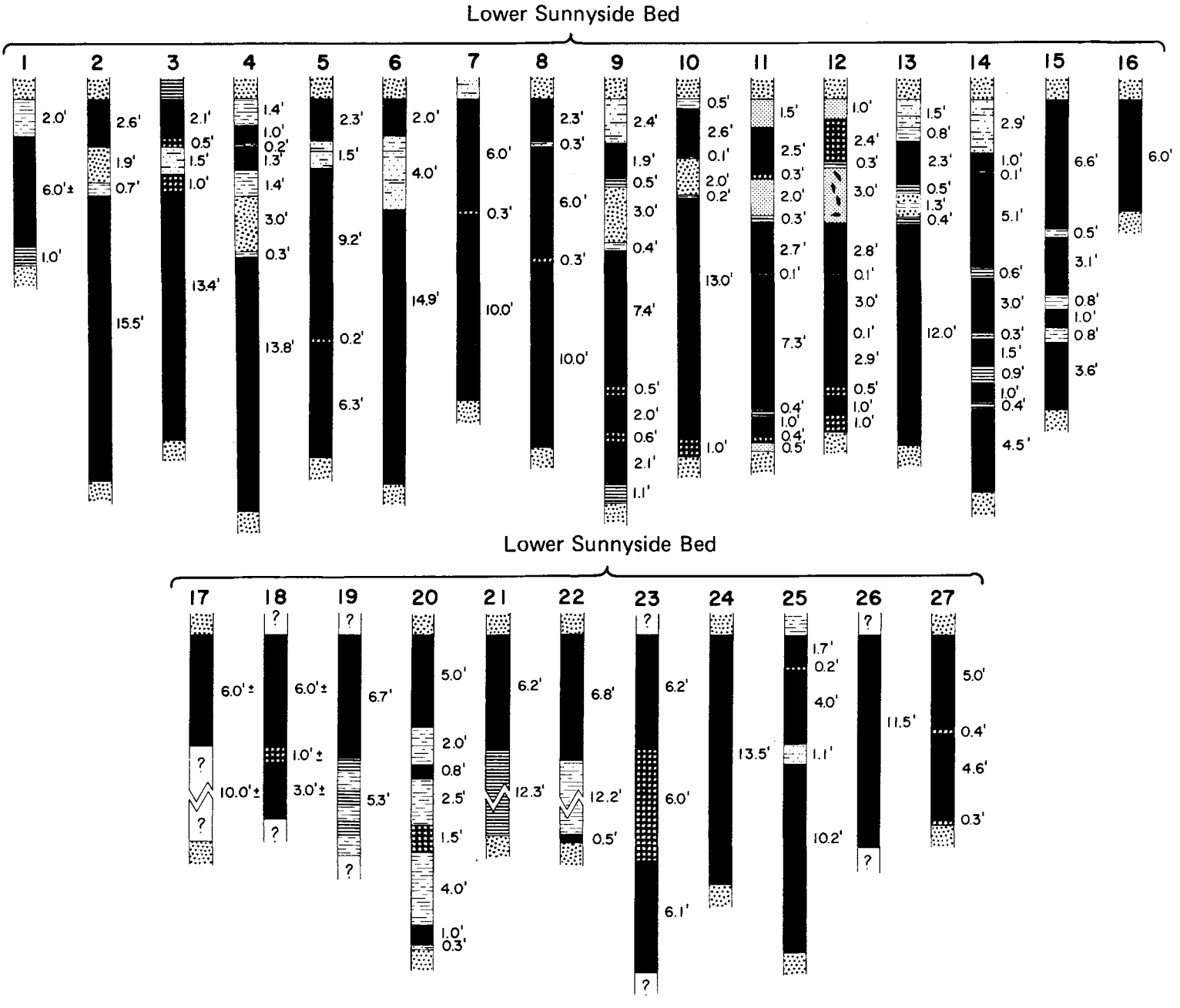


Figure 43. Coal sections of Woodside NE quadrangle (vertical scale: 1 inch = 8 feet).

Table 69. Overburden data, Woodside NE quadrangle.

Overburden (feet)	Percent	
	Total land	Coal land
Greater than 3,000	10.5	–
2,000-3,000	25.8	39.2
1,000-2,000	22.5	34.1
0-1,000	17.6	26.7
Noncoal land	23.6	–

Table 70. Average proximate analyses of coal, Woodside NE quadrangle.

	No. Analyses	Percent	
		Average	Range
Moisture	110	5.5	1.9- 9.8
Volatile matter	96	37.5	16.4-44.7
Fixed carbon	96	50.1	41.6-74.3
Ash	99	6.7	3.8-10.7
Sulfur	91	0.70	0.5- 1.1
Btu/lb	105	12,664	10,860-14,220

Almost 66 percent of the shown area are coal land. The 3,000-foot coverline is close to the Green River-Wasatch Formation contact if estimates on formation thicknesses are correct. The Range Creek area has the Sunnyside coal buried under 2,000 and 3,000 feet of cover.

Quality of Coal

More than 100 analyses are available for the Woodside NE quadrangle (table 4) mostly from the Book Cliffs mine and all from the Lower Sunnyside bed. Average data are as follows (table 70).

Walker and Hartner (1966, p. 37) further investigated the sulfur content of the coal in three samples (table 71):

Table 71. Sulfur content of coal, Woodside NE quadrangle.

Mine	Bed	Percent			
		Total Sulfur	Sulfate	Pyritic	Organic
Book Cliffs	Lower Sunnyside	0.86	0.01	0.35	0.50
Columbia	Lower Sunnyside	1.37	0.08	0.35	0.94
Geneva	Lower Sunnyside	0.71	0.02	0.19	0.50

The drill holes in the center of the quadrangle have retrieved coal where the sulfur increases to as high as 1.42 percent as com-

pared with about 0.70 percent for the present Geneva mine. Mine experience shows local areas where the sulfur content increases considerably. Washing of the product generally reduces the coal to metallurgical grade.

The coal is of coking grade but not considered as good as that in the Sunnyside area. An estimate of the coal indicates an average free swelling index of 4 to 5, ash softening temperature of 2,410° F and a grindability of 51. Comparisons of the various coking characteristics in the Sunnyside-Horse Canyon area are given in the Sunnyside SE quadrangle report. Gomez, Landers and Boyd (1967) reported on the coking properties of selected Utah coal and blends. The Lower Sunnyside coal of this area must be blended with 15 to 20 percent low- and medium-volatile coals from other sources to produce an industrially acceptable coke.

No analyses of the major ash constituents are available but Abernethy, Peterson and Gibson (1969, p. 22) list two spectrochemical analyses of coal ash from the Lower Sunnyside for trace elements. The point of collection is unknown and may be from the Sunnyside quadrangles. They are, nevertheless, repeated here (table 72):

Table 72. Trace-element content of coal, Woodside NE quadrangle.

	Sample No. 1	Sample No. 2
Ash, percent of dry coal	6.2	6.9
Percent of ash		
Arsenic	0	0
Boron	0.1	0.3
Barium	0.3	0.1
Beryllium	0.0002	0.0001
Cobalt	0.008	0.008
Chromium	0.008	0.01
Copper	0.004	0.002
Gallium	0.005	0.01
Germanium	0.001	0.001
Lanthanum	0.03	0.02
Lithium	0.05	0.15
Manganese	0.02	0.03
Molybdenum	0.01	0.002
Niobium	0.004	0.008
Neodymium	0	0.05
Nickel	0.003	0.008
Lead	0.005	0.005
Rubidium	0.005	0
Scandium	0.005	0.008
Tin	0.002	0.001
Strontium	0.2	0.2
Vanadium	0.02	0.015
Yttrium	0.01	0.01
Zinc	0.01	0.015
Zirconium	0.1	0.1

Tests were run by the U. S. Bureau of Mines (Gomez, Landers and Boyd, 1967) in the field of carbonization. Their data are based on an end carbonization temperature of 500° C (table 73).

Table 73. Calculated carbonization product yields (maf coal in weight percent; at 500° C).

Mine	Char	Water of decomposition	Tar and oil	Gas	Gas vol. scf/lb	Heat value of gas Btu/scf
Blue Diamond	72.6	5.1	16.5	5.4	0.975	776
Book Cliffs	73.8	5.0	16.0	5.0	0.954	793
Geneva	74.7	4.6	16.5	4.2	0.887	826
Geneva	73.8	5.3	15.4	5.5	1.002	767

Mines and Development

Two important mines have been developed on the Woodside NE quadrangle. The others are old prospects now engulfed by the operations of the former (table 74).

Table 74. Mines and prospects in the Woodside NE quadrangle.

Mine	Location	Remarks
Book Cliffs mine (Prentiss, Utah Blue Diamond, Blue Diamond, Heiner)	SW.SW.SW.NW.10-16S-14E 4,366,540m.N. 555,390m.E.	Intermittently active 1938-1948; active 1949-1966
Calkins prospect	SE.10-16S-14E 4,365,600m.N. 556,610m.E.	Activity unknown
Geneva mine (U. S. Steel mine)	NW.SW.3-16S-14E	Active 1941-1970
Adit 1	4,368,200m.N. 555,500m.E.	
Adit 2	4,368,100m.N. 555,550m.E.	
Lila Canyon prospect	C.N.15-16S-14E 4,365,420m.N. 556,110m.E.	Activity unknown
Prentiss prospect	SE.9-16S-14E 4,366,180m.N. 555,250m.E.	Activity unknown

The northernmost mine opens on the Sunnyside SE quadrangle and is the Columbia mine of U. S. Steel; it is presently closed but it is estimated that 10 million tons were removed from the Woodside NE portion of the mine.

The Geneva mine of U. S. Steel is presently active (1970) and in 1969 produced 843,362 tons of coal. The mine began operating in 1943 to supply high-volatile coking coal to the Geneva Steel Plant of U. S. Steel Corp. located near Provo, Utah. Production through 1969 totalled 23,425,000 tons. The average extraction rate has been 10,709 tons per acre and compared with an average of 14 feet thickness, indicates a 43 percent recovery rate.

The properties of the Book Cliffs mine are mined out. The main production period extended from 1950 to 1966 during which time 1,698,513 tons were removed. Another mine, known as the Blue Diamond, began production in 1938 and operated intermittently during the 1940's but only 14,500 tons production are recorded. The location is the same as that of the Book Cliffs mine and was probably incorporated by it.

Total production of coal from the Woodside NE quadrangle is a little less than 33.5 million tons.

Reserves

Fisher (1936, p. 56) estimated reserves for the area in the part covered by his maps. His average thicknesses are here maintained (table 75), but the areas are extended to cover the coal lands up to 3,000 feet of overburden.

Table 75. Original coal reserves in the Woodside NE quadrangle (in short tons).

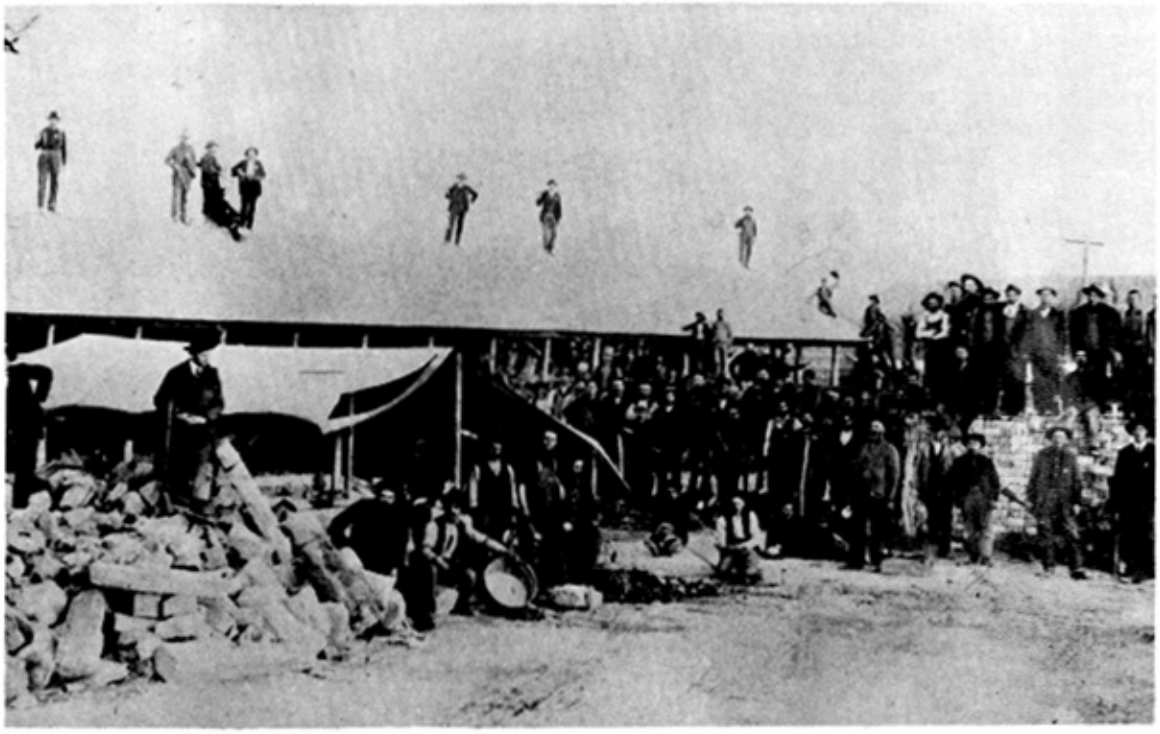
Location	Bed or zone	Average thickness (feet)	Acres est.	Tonnage
T.15S. R.14E.	Sunnyside bed	14.0	4,800	120,900,000
T.16S. R.14, 15E.	Sunnyside bed			
N.2/3 Twp.		13.0	9,094	212,800,000
S.1/3 Twp.		6.0	3,834	41,400,000
T.17S. R.14, 15E.	Upper Sunnyside	4.0	1,504	10,800,000
	Lower Sunnyside	5.0	1,504	13,500,000
			Total coal	399,400,000

This acreage does not include the Range Creek area where the coal is buried beneath 2,000 and 3,000 feet of cover. The coal thins in an easterly direction south of the quadrangle so that any estimate of coal thickness is speculative. About 93.6 million tons,

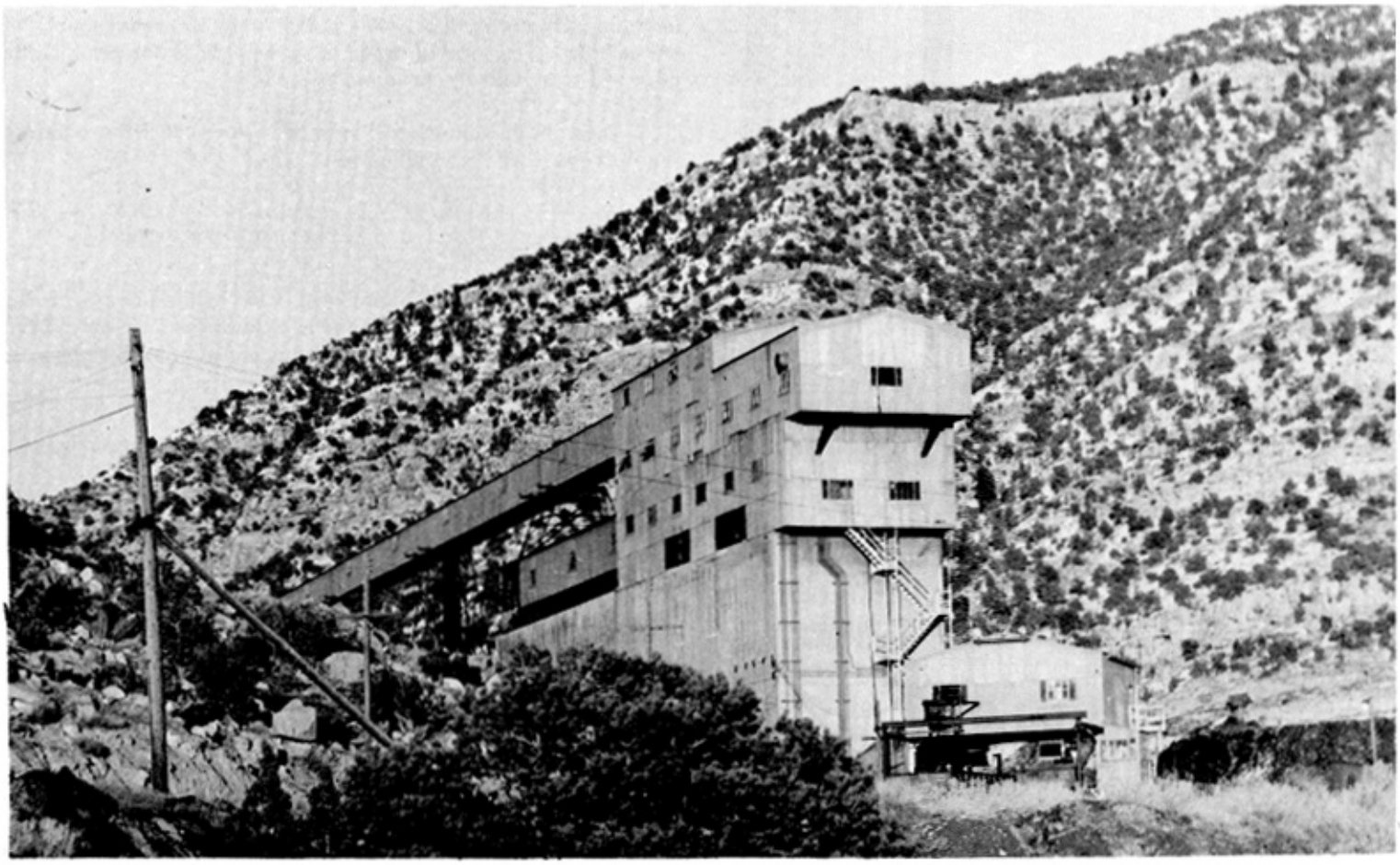
however, may be available on a Class IV potential reserve basis. The Range Creek coal area extends into the Range Creek quadrangle but this area is not included in the reserve. From the experience gained in nearby mines, 40 percent recoverability might be expected so that 159.8 million tons are available not counting the Range Creek area. Discounting the 33.5 million tons already mined leaves an available 126.3 million short tons.

PRINCIPAL WORK

The map work is a modification of Fisher (1936). He also provided many of the measured coal sections. Other data were gleaned from several references.



Castlegate, Utah, during the early 1900's following Butch Cassidy's robbery of the coal mine payroll. Men are armed awaiting a recurrence. Photo from Helper Mining Museum original.



Conveyor and tipple, Geneva coal mine, Horse Canyon.

WOODSIDE SE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Book Cliffs bisect the Woodside SE quadrangle into east and west halves (figures 19 and 44). The area on the west half is nearly flat to hummocky except immediately below the cliffs and where washes have cut deeply into the soft rocks and soil. The drainages, which are nearly always dry, flow southerly into the Price River along the south map edge. The town of Woodside is located where U. S. Highway 50-6 and the Denver and Rio Grande Western Railway cross the Price River. Woodside is 24 miles northwest of Green River.

There has been no cultural development of lands on the east side of the Book Cliffs. The uplands range in elevation from 6,000 to 6,500 feet except in the northwest map corner where the hills rise to 7,750 feet. The upland is plateau-like and rises to the north. The relief along the cliff is about 1,000 feet. Exposures of coal are seen in the upper third of the cliff from the highway.

No roads exist with only a few trails on the upland surface. A few dirt roads lead to the base of the cliff from the highway. The cliff is unscalable on foot except along a trail in 25-17S-14E. The only other access to the uplands from below is to proceed up the canyon of the Price River (Gray Canyon) and climb a tributary canyon to the top.

STRATIGRAPHY

Fisher (1936) mapped the cliffs geologically and for coal in a preliminary manner. The uplands behind the cliffs were not examined. The strata exposed include the Mancos Shale, Blackhawk Formation, Castlegate Sandstone and Price River Formation.

Most of the area below the Book Cliffs exposes the Mancos Shale. The weathering and erosion of this formation has produced a nearly flat surface except along the cliff where rounded knobs and knolls are common. The upper part of the Mancos rises to as much as 500 feet on the cliff and is supported by the harder and more resistant sandstones of the Blackhawk Formation. Badlands are often present along the base of the cliff. The formation is probably 4,000 feet thick near Woodside. The major part of the Mancos is a drab gray shale, but thin sandstone beds occasionally occur within it. These form cuestas, whose prominence depends upon the local dip and the thickness and resistance of the bed.

Part of the Blackhawk was measured by Fisher (1936, p. 22), probably in sec. 24 or 25, T. 17 S., R. 14 E.

Blackhawk Formation (in part):
Upper member (not measured)

Middle sandstone member	Feet
14. Sandstone, massive, very light gray	15±
13. Sandstone, thick-bedded buff layers alternating with medium- to thin-bedded carbonaceous layers	25±
12. Sandstone, massive	3
11. Sunnyside coal zone	18
10. Sandstone, massive, very light gray	22
9. Sandstone, massive, cross-bedded, gray and buff, coarse-grained; mainly quartz, but contains 10 percent of dark mineral grains; thin films of carbonaceous material between the bedding planes	38
8. Shale and siltstone; soft, thin-bedded, gypsiferous, very carbonaceous	8
7. Sandstone, thick-bedded, buff	38
Total middle sandstone member	167±
Middle shale member	
6. Shale, gray with thin layers of interbedded siltstone and sandstone; highly carbonaceous	121
Lower sandstone member	
5. Sandstone and siltstone with minor interbedded layers of finely laminated gray-black shale, in part carbonaceous; sandstone is massive, cross-bedded, very light gray, coarse- to fine-grained	98
4. Shale, dirty gray, gypsiferous, in part silty and limy, with fragments of carbonized wood	17
3. Siltstone, light gray, thin-bedded	33
2. Sandstone and shale, interbedded; sandstone, buff, medium- to thin-bedded, with a few sandy limestone layers; shale like Mancos	73
Total lower sandstone member	221
	509±

Gradational contact
Mancos Shale

The lower sandstone is correlated with the Kenilworth Sandstone to the west. The middle shale is much like the Mancos and the middle sandstone is the Sunnyside Sandstone. Above the middle sandstone is an upper sequence of beds called by Young (1955, p. 186) the Grassy and Desert members of the Blackhawk. A section of these rocks appears below (NW. 19, T. 18 S., R. 15 E.):

Castlegate Sandstone
Disconformity?

Blackhawk Formation	Feet
Sandstone with thin carbonaceous shales	6-10
Interbedded sandstone, shale and coal (thickest coal is 0.5 feet thick)	8
Sandstone, fine-grained with pyrite nodules	5
Carbonaceous shale	1
Coal (Beckwith Group)	6.5
Shaley sandstone, carbonaceous shale and thin coal seams (thickest 1.2 feet)	40
Carbonaceous shale	2
Coal	1.3
Carbonaceous shale	0.5
Shaley sandstone	10

Sunnyside Sandstone

The upper 6 to 10 feet are probably the beginnings of the Desert Member and the remainder belongs to the Grassy Member. The two added sections indicate the Blackhawk to be almost 600 feet thick.

The Castlegate Sandstone lies above the Blackhawk and may be in a disconformable relationship with it. The Castlegate is usually a single massive bed of sandstone, forming a cliff 75 to 125 feet high. The Price River beds lie above it and consist of alternating shale and sandstone similar in appearance to the Blackhawk beds. They have not been looked at in detail in this quadrangle.

STRUCTURE

The beds of this quadrangle dip eastward 4 to 6 degrees in most places, but locally they steepen to as much as 12 degrees. Several low displacement faults mostly trending east-west cut the cliffs. Six of these faults have throws between 70 and 175 feet; others have less than 50 feet of displacement.

PROPERTY CONTROL

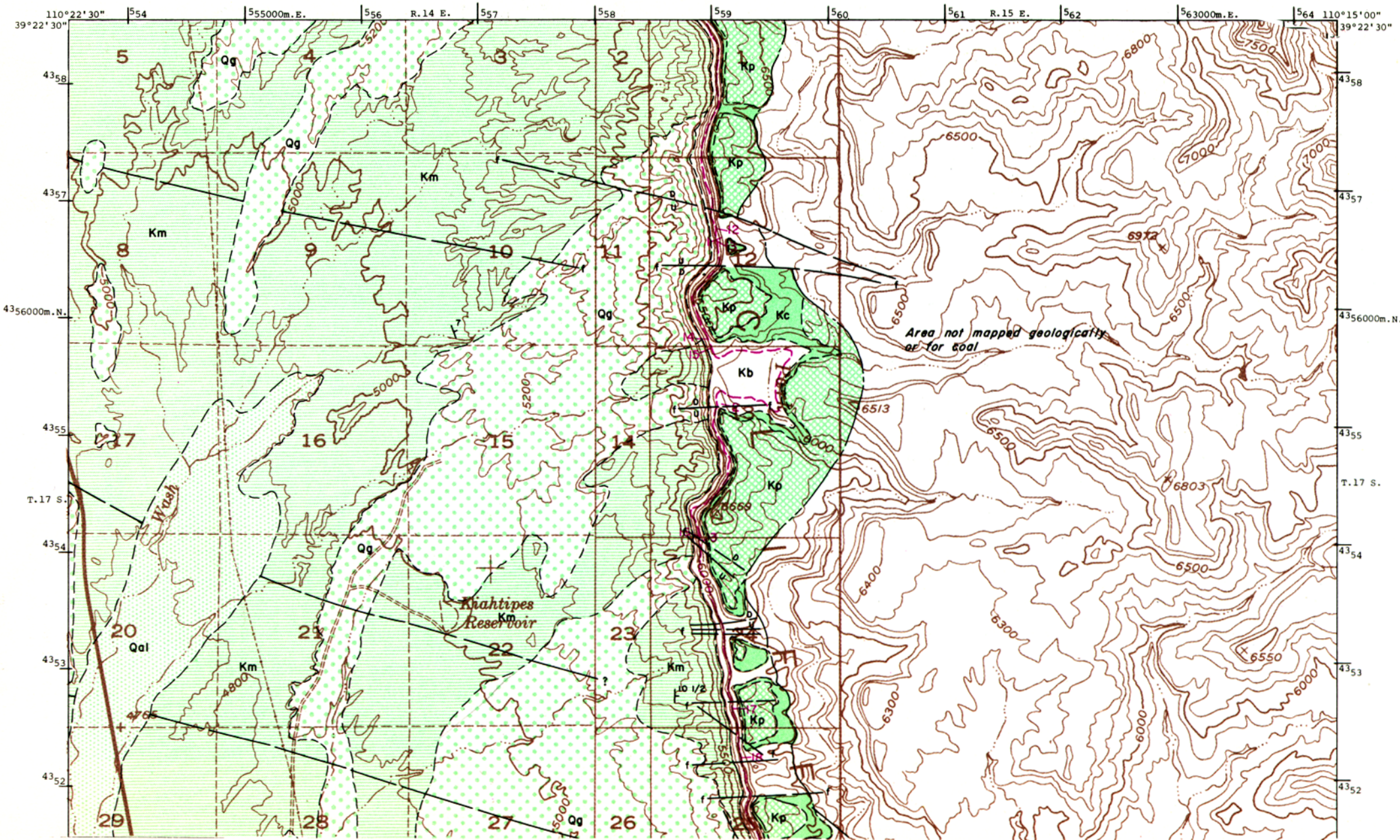
The Bureau of Land Management owns most of the lands of the Woodside SE quadrangle (86.6 percent). The state of Utah owns its usual sprinkling of sections (9.8 percent) and a few parcels of land along the Price River are privately held (3.6 percent). Secs. 5 to 8, T. 17 S., R. 15 E., and part of secs. 1 and 12, T. 17 S., R. 14 E. are currently held in leases by Kaiser Steel Corp. (1970). The remainder of the quadrangle is open land (Jan. 1, 1970).

COAL

Surface Information

Measured sections (figure 45) indicate the presence of at least two zones of coal. The uppermost coal lies in a zone 6 to 10

WOODSIDE S.E., UTAH



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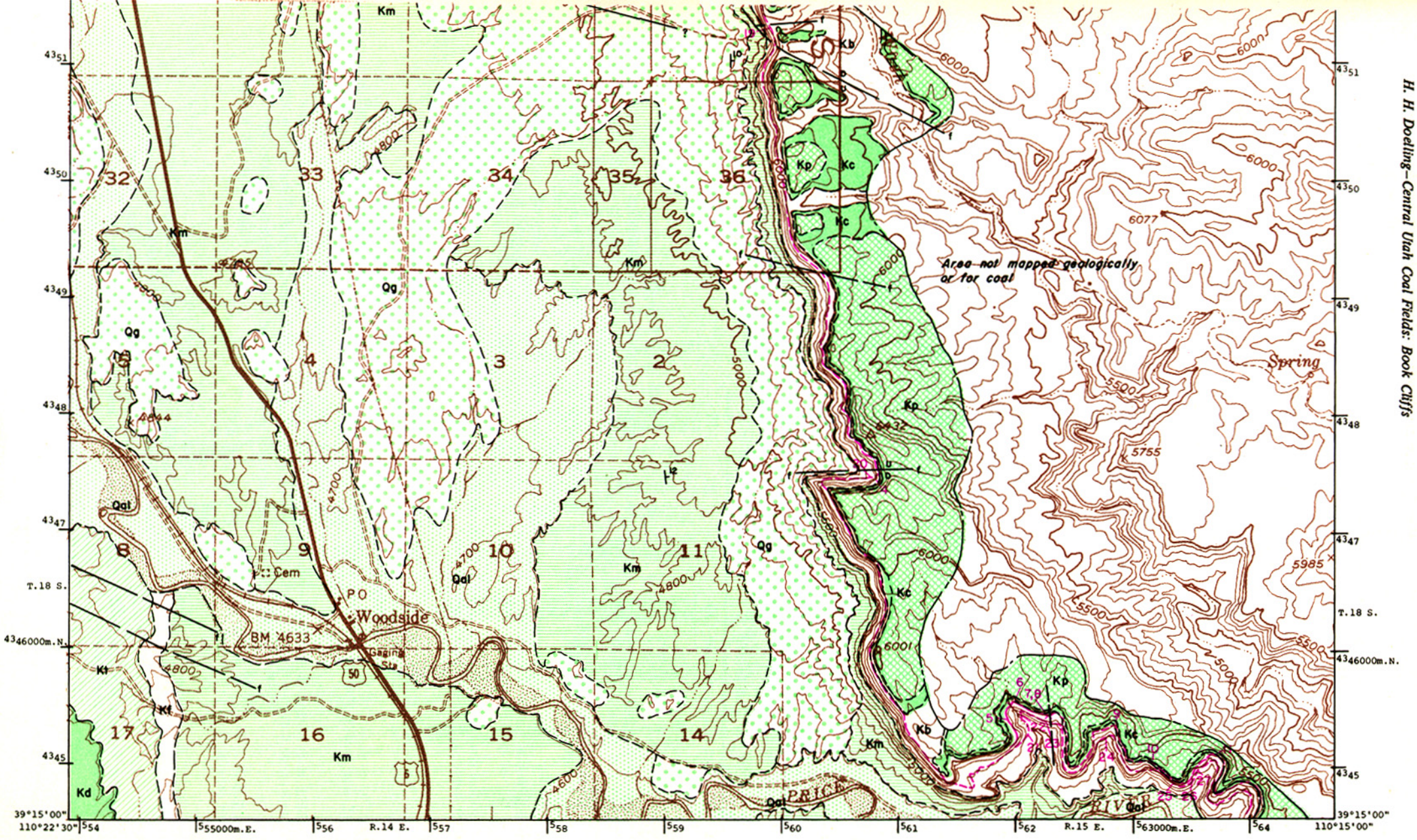

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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SCALE 1:42240

1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 5 0 1 KILOMETER

Geology and coal data by D. J. Fisher, 1936, USGS.

Figure 44. Coal and geology map, Woodside SE quadrangle (explanation pages 332-333).

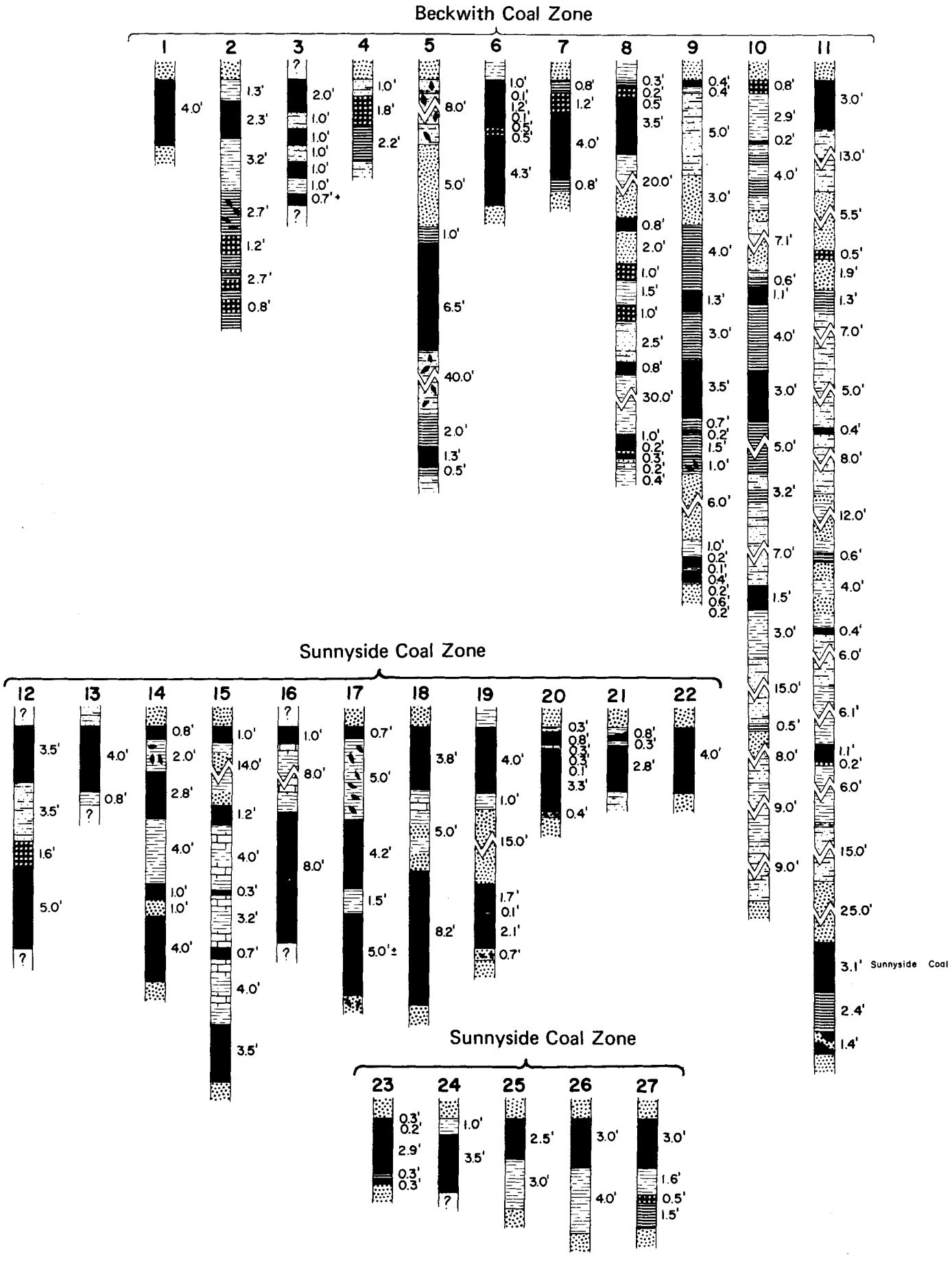

Figure 45. Coal sections of Woodside SE quadrangle (vertical scale: 1 inch = 8 feet).

feet below the base of the Castlegate Sandstone. The zone, called the Beckwith, is at least 70 feet thick and usually contains several seams of coal. At location 1 the thickest bed is 2 feet 4 inches and at location 3, it is 6.5 feet thick. Data about the coal in between is sparse except for location 2 where the thickest beds are 2 feet. The bed is presumed to be more than 4 feet thick at least locally and it might be profitably mined. The lower zone is the Sunnyside and indications are that it gradually thins from north to south. It is 60 feet below the Beckwith zone. In the north half of the quadrangle coal, although often split by shale, bone or sandstone dividers, is usually 8 feet. Only a few sections give information of the coal in the south half of the quadrangle, but a 4-foot section was measured near the south map edge. According to Fisher (1936, p. 63) the Sunnyside coal averages 5½ feet in T. 17 S. and 3½ feet in T. 18 S.

Subsurface Information

Two drill holes have penetrated the coal in the north part of the quadrangle. The first, located in 1-17S-14E, located 13 feet of coal presumably in the Sunnyside bed. In 7-17S-15E, 7 feet were uncovered in the same zone. The coal is thought to thin easterly but no absolute data confirm this. At the south end of the field the Blackhawk coal completely disappears in an easterly direction. About 1½ to 2 miles behind the outcrop is the 1,000-foot coverline. In the north third of the quadrangle the coal horizon dips under 2,000 feet of cover 2½ miles behind the outcrop.

Coal lands amount to 42.1 percent of the quadrangle. Of this land 54.1 percent is under less than 1,000 feet of cover, 35.2 percent has between 1,000 and 2,000 feet of overburden and 10.7 percent has 2,000 to 3,000 feet of overburden. The coverlines were determined by use of extending contour lines according to the average dip.

Quality of Coal

The one available analysis (table 4) for the Woodside SE quadrangle was collected from the Peterson prospect located in the NW-18S-15E on the north side of the Price River Canyon. The source is the Beckwith zone in a bed about 20 feet below the Castlegate Sandstone. The ash content is somewhat high (11.4 percent) as is the sulfur content (1.15 percent). No calorific value is available for the coal. The coal bed was physically examined at this location and followed for a short distance laterally; the high ash content will probably carry with the bed. Evidence is insufficient with this one sample to prove a high sulfur content in the Beckwith zone.

Mines and Development

The only known effort to mine coal on this quadrangle was at Peterson's prospect high on the cliff in the Price River Canyon. There are two adits both on the same Beckwith bed, one 200 yards east of the other. The prospect was active before 1905 and is located on NW. 19-18S-15E, 4,345,500mN 562,000mE. The adits are old and little coal was produced. The only other development for coal was the drilling of two exploratory holes in the north part of the quadrangle.

Reserves

Reserves calculated by Fisher (1936, p. 56) are here modified to fit the quadrangle (table 76). He did not consider beds less than 14 inches thick and beds having partings or splits were assumed to have an effective coal thickness equal to the total thickness of coal less the thickness of all partings. He only calculated reserves extending along the cliffs and did not consider the area more than 2 miles behind the outcrop.

These reserves involve the first three classes (measured, estimated and inferred) of reserve as any projection toward the east would be hazardous in this area because the Blackhawk and its coal thin in that direction. Nothing is known about recoverability rates in this area, but they will undoubtedly range between 33-1/3 percent and 50 percent with 24 to 36 million tons recoverable from this quadrangle, mostly from the north part; small tonnages could be developed locally to the south.

Table 76. Original coal reserves in the Woodside SE quadrangle (14 inches or more thick; in short tons).

Location	Bed or zone	Average thickness (feet)	Acres est.	Tonnage
T.17S. R.14, 15E.	Beckwith	2	1,862	7,000,000
N.1/3 of Twp.	Upper Sunnyside	4	3,277	24,000,000
S.2/3 of Twp.	Upper Sunnyside	2.5	723	3,000,000
	Lower Sunnyside	5.0	5,293	48,000,000
T.18S. R.14, 15E.	Beckwith	3.0	640	3,000,000
	Sunnyside	3.5	3,994	25,000,000
			Total coal	110,000,000
		Coal averaging 4 feet or more		72,000,000

PRINCIPAL WORK

Most of the data represented in this quadrangle were reworked from Fisher (1936).

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Figure 1. Relief map of central Utah showing the approximate location of the Emery coal field.

EMERY COAL FIELD

by

H. H. Doelling[1]

INTRODUCTION

Location and Extent

The Emery coal field straddles the Sevier-Emery County line, 35 miles east of Salina, 70 miles south of Price (Preface, figure 1a and figure 1), or 175 road miles south of Salt Lake City. The effective width of from 4 to 8 miles and length of about 35 miles produces an area of 210 square miles. The length trends northeasterly and parallels the Wasatch Plateau escarpment. The south Wasatch Plateau cliff approximates the west field boundary; the north limits are along the township line between 20 and 21 south, SLBM. The Coal Cliffs escarpment forms the east boundary; seams crop out along them and in their canyons. The south field boundary occurs where the Coal Cliffs disappear under the volcanics of the Fish Lake Plateau which is the south extension of the Wasatch Plateau. The west boundary cliffs contain the coal outcrops of the Wasatch Plateau coal field. The Ferron Sandstone, which contains the Emery field coal beds, extends much farther north, but in outcrop is barren of coal. The coal-bearing formations thicken westerly and additional coal occurs in the subsurface north of the field limits.

Topography and Drainage (figure 2)

The grain of the land parallels the long axis of the coal field. Three general large-scale landforms dominate: to the east, the Coal Cliffs with westward-sloping upper surfaces; in the center, Castle Valley, and to the west, hills and cliffy buttes and knolls which finally terminate at the foot of the Wasatch Plateau cliff. This three-part division shrinks to two in the south third of the field (south of Willow Springs Wash) as Castle Valley thins and finally disappears; a small valley appears in the position of Castle Valley, Paradise Valley.

With an average relief of 800 feet in most places, the Coal Cliffs are difficult to scale. From Willow Springs Wash northward the elevation of the top of the cliff varies between 6,500 and 7,000 feet. Farther south the cliff-top gradually rises to 8,500 feet. The rocky cuesta slope of the cliffs varies in width from 1 to 4 miles in the north two-thirds of the field. To the south, hilly, knobby and often mountainous land of the west side of the field lies immediately above the cliff edge.

Castle Valley is first recognized near the head of Willow Springs Wash; it widens to 6 miles along the north field boundary and continues to widen northward for 30 miles until it is 14 miles wide near Hiawatha. Part of the valley contains low rounded hills that are often gravel capped; other parts are deeply gullied by drainages. Flatter areas are used agriculturally.

The hilly, knobby belt varies from 2 to 5 miles wide. The elevation gradually increases within the rough land to the foot of the Wasatch Plateau. Principal drainages which head in the Wasatch Plateau flow at right angles to the land grain and main topographic features and usually have cut canyons through both cliffs. These include from south to north, Last Chance Creek, Willow Springs Wash, Ivie Creek, Quitchupah Creek and Muddy Creek.

Population, Industries and Transportation

The Emery coal field is a sparsely populated area; three communities in and around the field have a combined population of less than 1,000. All are in Emery County.

	Population	
	1960	1970
Emery County	3,577	3,157
Ferron	386	663
Moore	35	?
Emery	326	216

Two important highways connect the area with the more populated areas of Utah (figure 2). Interstate Highway 70, a major link between Denver, Colorado, and Los Angeles, California, cuts east-west across the center of the field. No services are available within the field or along the 110-mile length from Green River to Salina. The second highway (Utah 10) joins Price with Interstate 70 and parallels Castle Valley connecting the three towns. Graded and dirt roads provide access to other parts of the area. The nearest railroad is at Salina (Denver and Rio Grande Western Railroad-Marysvale spur), 35 miles to the west. The nearest terminals for bus and air services are at Salina and Price.

Climate

The major part of the area has a semiarid climate with rainfall varying between 8 and 16 inches annually (figure 3). In the higher areas, especially to the south, the rainfall increases to as much as 30 inches. As in all mid-latitude steppe climatic areas, the precipitation is spasmodic, some years are dry and others wet. Cyclonic precipitation peaks in winter and usually comes as snow; convectional precipitation in the summer is often torrential. Summer flash floods do much destruction to roads.

Summer high temperatures in the 90's contrast with winter lows in the low teens in Castle Valley. Above 8,000 feet, temperatures average about 10 degrees less in summer and winter. Like precipitation the temperature is unreliable with a wide range. Maximum and minimum temperatures recorded in Castle Valley are 104° and -34° F respectively.

HISTORICAL OUTLINE

Lupton (1916, p. 9-10) describes the early history of the Emery coal field:

> From 50 to 60 miles of the old Spanish Trail, which extended fromSanta Fe, New Mexico, to Monterey, California, at the time these places were centers of Spanish civilization on this continent, lie in Castle Valley. The coal in this field may or may not have been known at the time this trail was used extensively.
>
> Capt. J. W. Gunnison, of the Corps of Topographic Engineers, traversed Castle Valley from north to south in the early part of October, 1853, on the way to Sevier Valley...Lieut. E. G. Beckwith, who wrote the report of this expedition, states, in his journal for October 11, 1853: 'Specimens of coal were brought in from the hills near the camp, Capt. Gunnison and Dr. Schiel differing in opinion as to its quality.' The party was camped at this date near the north end of the Emery coal field about 3 miles east of Emery, approximately in sec. 12, T. 22 S., R. 6 E. So far as known this is the first published reference to the coal in this field.
>
> During the summer of 1873 Lieut. R. L. Hoxie, Corps of Engineers, and his party mapped the topography and geology of east-central and south-central Utah. Their route of travel led southward through Castle Valley and across this coal-bearing area. E. E. Howell, who was with this party as geologist, referred to the coal in Castle Valley and along Muddy Creek. Robert Forrester described briefly the coal in Quitchuppah and Ivie creeks and gave proximate analyses of both the 'top vein' [bed I?] and the 'bottom vein' [bed C?]. He considered these coals to be in a downfaulted portion of the Montana group, which is represented in part by the Mesaverde Formation in the Wasatch Plateau, a few miles to the west. This classification has been the topic of considerable debate by those familiar with the coals of this part of Utah. J. A. Taff in 1905 examined the coal-bearing rocks along the east face of the Wasatch Plateau and also noted the coal at the south end of Castle Valley described in the present report.

[1] Economic geologist, Utah Geological and Mineralogical Survey.

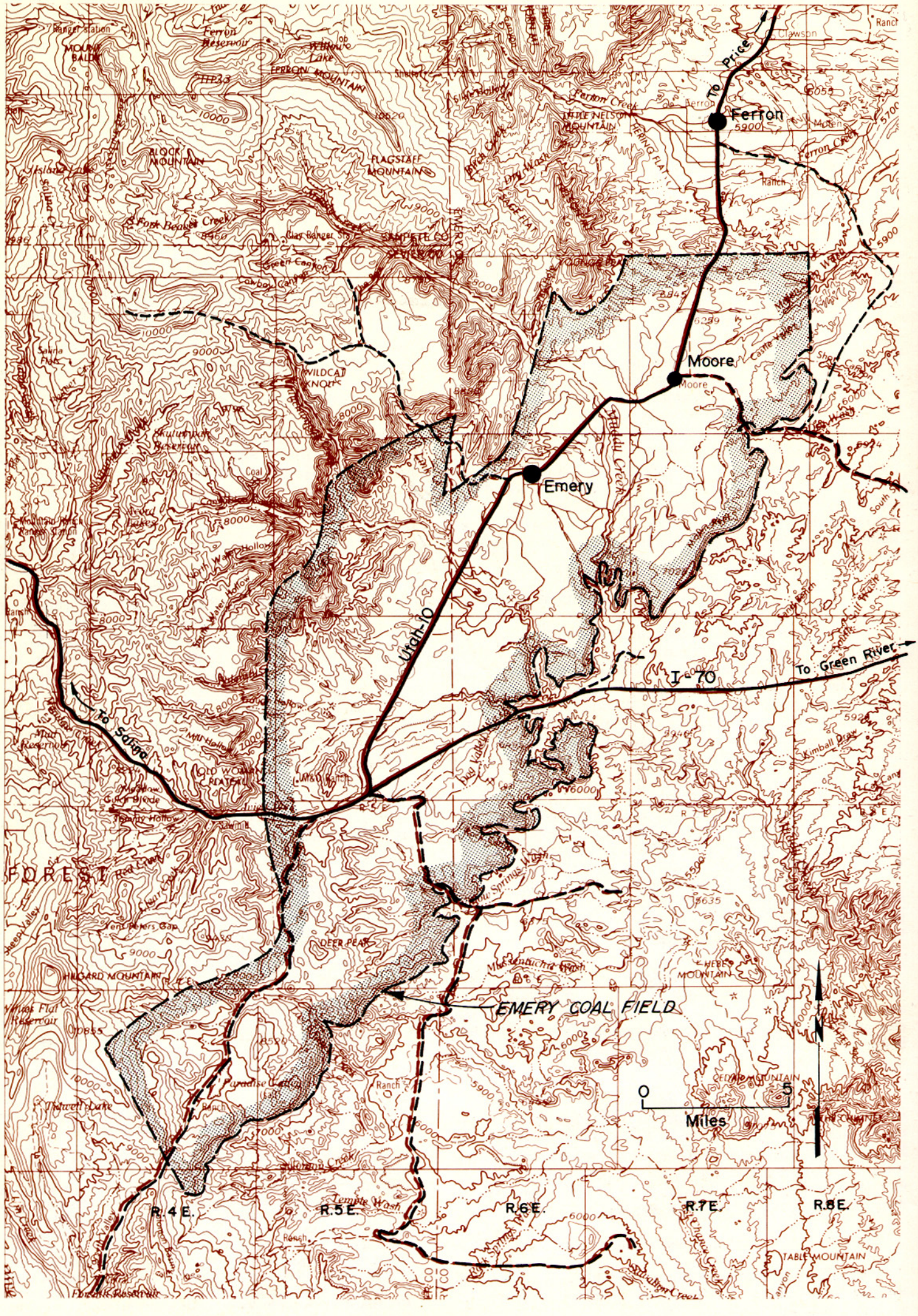


Figure 2. Topography and roads map, Emery coal field.

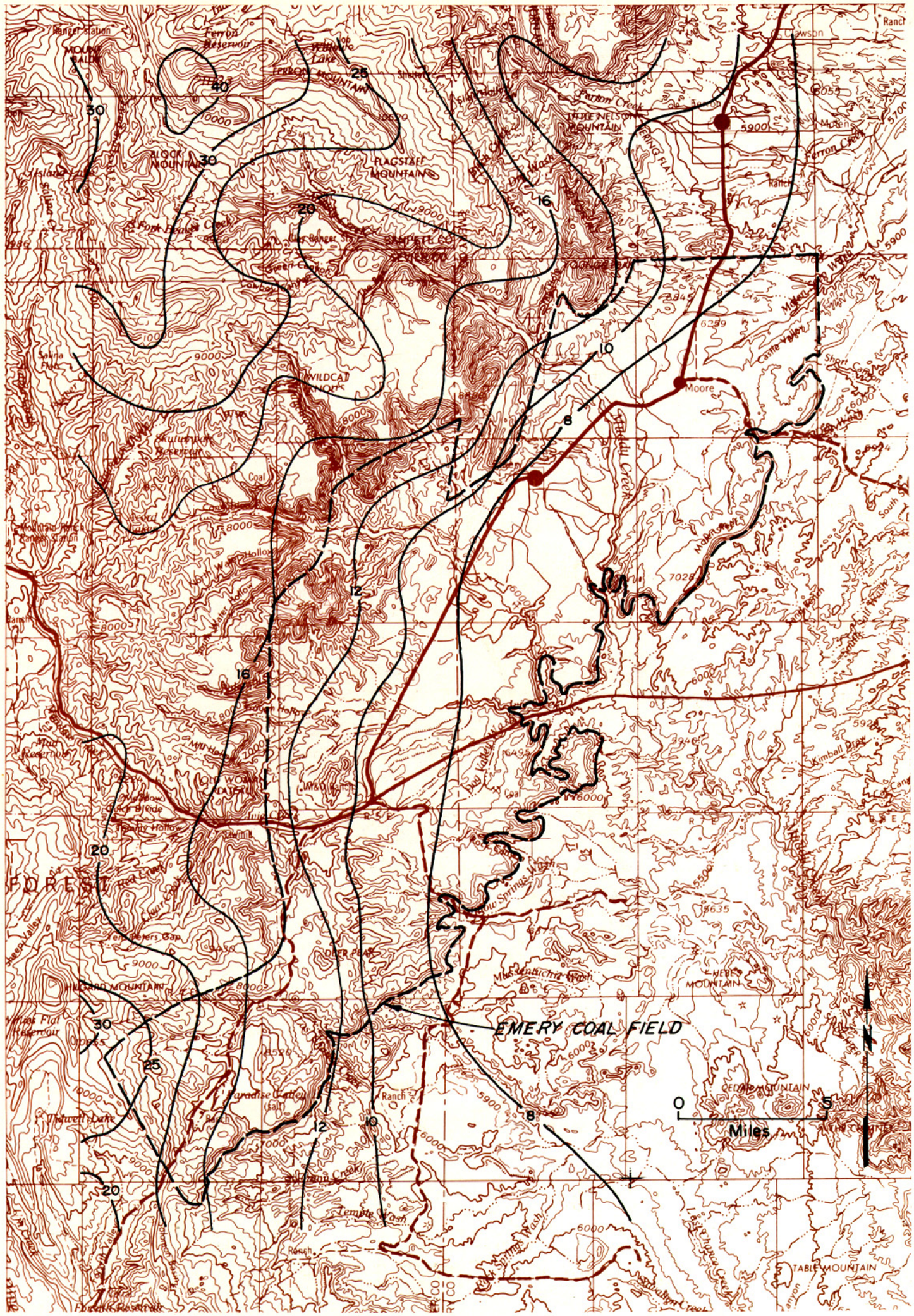


Figure 3. Rainfall map of the Emery coal field.

Lupton made the first and only comprehensive study of the Emery coal field between 1911 and 1912. His work was published by the U. S. Geological Survey in 1916. He did a creditable job in mapping the area in spite of not having a topographic base to plot his information and having to work by triangulation from known section corners. Fortunately the area had been surveyed, at least in part, by A. D. Ferron, A. Jessen, H. W. Miller, A. P. Hanson and A. Nelson.

Lupton notes that in 1881 Philip Pugsley opened a prospect at the site of the present Browning mine, which probably makes it the oldest in the field. It is suspected that other areas were prospected at the same time with intermittent activity; Lupton lists six active mines or prospects and several abandoned ones. Details of these are given in the quadrangle reports. Lupton (p. 85) lists the total production from the field as 6,000 short tons.

After Lupton's survey, two or three mines operated intermittently until the present time (1972). The Dog Valley mine opened in 1930; it is presently active as is the Browning mine. R. E. Maurer (1966a and b) made a review of the Sevier County portion of the field in 1964 and 1965. Total coal production from the field is estimated about 1.6 million tons through January 1, 1970. The 1970 production was 138,000 tons.

GEOLOGIC SETTING (figure 4)

Stratigraphy

The important coal seams of the Emery field occur in the Ferron Sandstone Member of the Mancos Shale and other coal beds in the Dakota Sandstone, perhaps in the Emery Sandstone Member of the Mancos and in the Blackhawk Formation. The coal beds in the Blackhawk Formation are important and are assigned to and discussed with the Wasatch Plateau coal field report. Maps for this report show Jurassic to Tertiary consolidated strata and some Quaternary unconsolidated deposits. Figure 5 presents a general description of each of the units. The beds crop out in parallel bands trending northeast, becoming progressively older toward the southeast.

Navajo Sandstone

The oldest Jurassic unit is recognized easily and makes a good starting point for a stratigraphic discussion. The formation is best known from its scenic exposures at Zion National Park in south Utah, but its picturesque outcrops are known in many other parts of Utah, including the San Rafael Swell. It is essentially composed of tan, yellow and orange, rounded and frosted sand grains; it is medium-grained and characteristically cross-bedded in a manner indicative of a former sand dune area. The outcrops often have been called frozen sand dunes. It weathers into semirounded buttes and knolls and into deep gorge-like canyons and is about 500 feet thick.

Carmel Formation

The Carmel is differentiated from the underlying Navajo by a sharp line of unconformity. The Carmel exposes varied lithologies of varied colors. The beds usually are clearly defined and indicate shallow sea deposition. Fossils are plentiful in the lower half and gypsum in the upper part of the unit. A section measured along Interstate 70 is given below:

Section of Carmel Formation, T. 23 S., R. 8 and 9 E. along Interstate Highway 70, Emery County, Utah.

Entrada Sandstone: sandstone, reddish brown, very fine-grained and silty, thin-bedded to massive.

Carmel Formation	Feet
1. Reddish and light tan siltstone and fine-grained sandstone, earthy weathering	.60
2. Gypsiferous siltstone alternating with light gray calcareous shale	.37
3. Gypsum, silty	.11
4. Siltstone and sandstone, shaley	.20
5. Alternating red- and tan-bedded gypsiferous siltstone, contains some very thin-bedded calcareous siltstone and sandstones near the top	.86
6. Gypsum bed	.8
7. Gray gypsiferous shale	8
8. Gypsum bed	5
9. Gray and red gypsiferous and limy siltstone	.52
10. White sandstone, fine-grained and platy weathering, contains occasional gypsum beds	.25
11. Orange and red siltstone and sandstone, gypsum in blebs, stringers and veins	.53
12. Limestone, fine-grained and sandy, platy weathering	.95
13. Alternating reddish sandstone and gypsum beds	.146
14. Limestone, thick-bedded and blocky, some oolitic	.65
15. Reddish and tan siltstone	4
16. Tan-gray limestone, finely laminated, thin-bedded to massive, cliff former	.29
17. Yellowish green and reddish sandstone and siltstone, mostly shaley and nonresistant, upper part becomes tan	.18
18. Gypsum, upper 8 feet pure	.11
19. Purple siltstone, massive	5
20. Tan and pink sandstone, fine-grained, thick-bedded to massive, and slightly cross-laminated gypsum veinlets in upper 10 feet	.25
21. Gray limestone, thin-bedded alternating with limy shale, fossiliferous, some layers are maroon in color	.15
22. Tan sandstone, medium-grained and medium-bedded alternating with calcareous shale, some sand is green (glauconitic?), thin-bedded in lower 4 feet	.17
Total Carmel Formation	.795
Navajo Sandstone	

The Carmel Formation outcrops in a band averaging 3 miles wide, 6 to 7 miles east of the Coal Cliffs. The initial limy units of the Carmel are resistant and form a cliff, but the remainder is soft and forms a wide dip slope.

Entrada Sandstone

Overlying the Carmel and to the west are the reddish brown silty sandstones of the Entrada. Part of the unit is siltstone with fine-grained sands. In a few places it is cross-bedded but mostly it is in even beds, thin to massive. According to Stokes and Cohenour (1956, p. 27) "...it tends to erode into a type of badland topography with 'stone babies,' intricate 'castles' and other fantastic shapes."

A tripartite division was noted in the Entrada. The lower part has beds a few inches to a few feet thick which weather alternately earthy and smooth. The earthy weathering beds are slightly darker in color. The middle part is mostly massive and smooth weathering and the upper unit is much like the lower. Stokes and Cohenour (1956) indicate the unit to be 250 to 840 feet thick in Emery County and estimate it to be 600 to 800 feet thick east of the coal field. The outcrop band averages 2 miles in width. Although cliffy in part, the outcrops usually form a valley in which sandy colluvium forms. The cliffy portions are supported by more resistant beds above.

Curtis Formation

The Curtis forms a light colored band between two reddish brown formations. It is a cliffy sandstone for the most part but has thin lower and upper parts composed of softer units. The lower 15 to 30 feet consist of gray shale or gray shaley sandstone that is coarse-grained. This slope-forming unit often contains veinlets of gypsum. The middle 100 to 130 feet are light gray to gray-green, fine- to coarse-grained sandstone that is medium-bedded to massive, friable, but resistant; it forms a cliff. The remaining 60 to 80 feet are shaley and slope forming, mostly light tan-gray, consisting of sandy shale and thin- to medium-bedded, medium-grained sandstone beds. These upper sands are often a darker green and glauconitic. Occasionally a reddish silty sandstone appears near the top as the unit grades into the Summerville above.

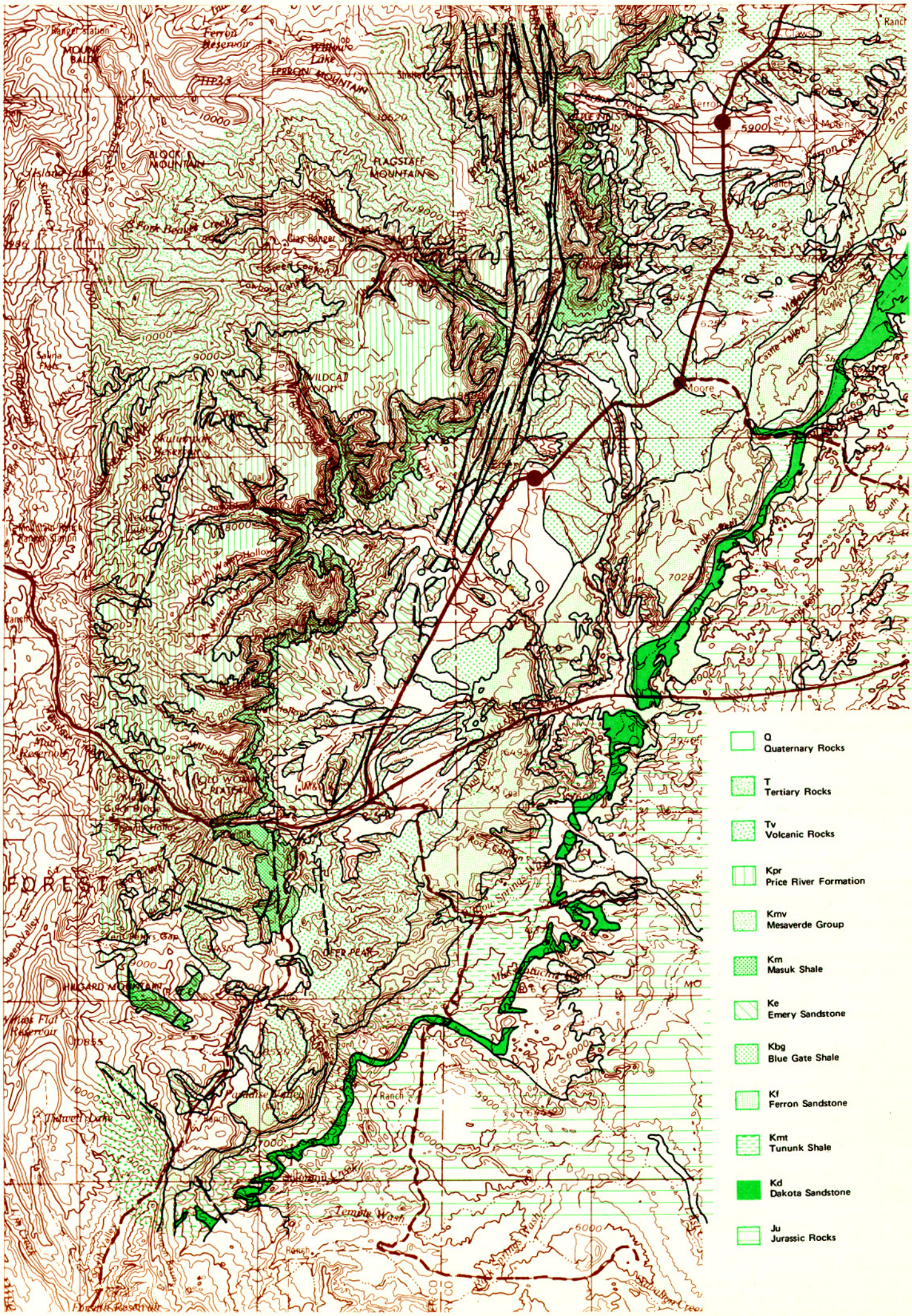


Figure 4. Generalized geology map, Emery coal field.

System	Series	Stratigraphic Unit		Thickness (feet)	Description
TERTIARY	Eocene	Green River Formation		–	Chiefly greenish lacustrine shale and siltstone.
			Colton Formation	300-1,500	Varicolored shale with sandstone and limestone lenses, thickest to the north.
	Paleocene	Wasatch Group	Flagstaff Limestone	200-1,500	Dark yellow gray to cream limestone, evenly bedded with minor amounts of sandstone, shale and volcanic ash, ledge former.
			North Horn Formation (Lower Wasatch)	500-2,500	Variegated shales with subordinate sandstone, conglomerate and freshwater limestone, thickens to north, slope former.
CRETACEOUS	?				
	Maestrichtian	Mesaverde Group	Price River Formation	600-1,000	Gray to white gritty sandstone interbedded with subordinate shale and conglomerate, ledge and slope former.
	Campanian		Castlegate Sandstone	150- 500	White to gray, coarse-grained often conglomeratic sandstone, cliff former, weathers to shades of brown.
			Blackhawk Formation *MAJOR COAL SEAMS*	700-1,000	Yellow to gray, fine- to medium-grained sandstone, interbedded with subordinate gray and carbonaceous shale, several thick *coal* seams.
			Star Point Sandstone	90- 500	Yellow-gray, massive cliff-forming sandstone, often in several tongues separated by Masuk Shale, thickens westward.
	Santonian	Mancos Shale	Masuk Shale	300-1,000	Yellow to blue-gray sandy shale, slope former, thick in north and central plateau area, thins southward.
			Emery Sandstone *COAL (?)*	500-1,000?	Yellow-gray friable sandstone tongue or tongues, cliff former, may contain *coal* (?) in south part of plateau if mapping is correct, thickens to west and south. *Coal* may be present in subsurface to west.
	Coniacian		Blue Gate Member	1,500-2,000	Pale blue-gray, nodular and irregularly bedded marine mudstone and siltstone with several arenaceous beds, weathers into low rolling hills and badlands, thickens northerly.
	Turonian		Ferron Sandstone Member *MAJOR COAL SEAMS*	300- 800	Alternating yellow-gray sandstone, sandy shale and gray shale with important *coal* beds of Emery coal field, resistant cliff former, thickens to the south.
	Cenomanian		Tununk Shale Member	500- 800	Blue-gray to black sandy marine slope forming mudstone.
	Albian	Dakota Sandstone *MINOR COAL*		185- 300	Variable assemblages of yellow-gray sandstone, conglomerate shale and *coal*. Beds lenticular and discontinuous.
	Aptian	Cedar Mountain Formation		230- 300	Light lavender and gray shales with subordinate conglomerate and shale.
JURASSIC	Upper	Morrison Formation		150- 425	Varicolored mudstone, sandstone and conglomerate, forms slopes and conglomerate portions contain large amounts of agate and jasper.
		Summerville Formation		260- 275	Brown to reddish brown siltstone and sandstone, thin-bedded, semiresistant.
		Curtis Formation		175- 240	Tan-gray to greenish gray sandstone, siltstone and occasional conglomerate, cliffy, and softer units, occasionally glauconitic.
		Entrada Sandstone		600- 800	Reddish brown sandstone, fine-grained and silty, partly earthy weathering and partly smooth weathering, thin-bedded to massive, weathers into cliffs and monuments.
		Carmel Formation		800±	Varicolored shale, sandstone, siltstone, limestone and gypsum, limestone more prevalent in lower half and more resistant than other beds.
	Lower	Navajo Sandstone		500±	Orange and yellow sandstone, medium-grained cross-bedded and massive, resistant, but weathers into picturesque buttes, knolls and deep gorges.

Figure 5. Generalized section of rock formations, Emery coal field.

Summerville Formation

The Summerville is a brown to reddish brown siltstone and sandstone noted for its even thin beds. The color of the unit is similar to that of the Entrada of this area except that it may be a little darker. The Summerville reportedly contains gypsum in the upper part of the formation in a bed up to 10 feet thick. The Summerville ranges from 260 to 275 feet thick east of the Coal Cliffs.

Morrison Formation

The Morrison is usually divided into two members, a lower Salt Wash Sandstone and an upper Brushy Basin Shale Along the west flank of the San Rafael Swell the former is not well developed. Usually one or more conglomeratic brown beds lie at the base, top or in the middle. They are lenticular mixtures of pebble conglomerate and coarse-grained sandstone which disappear and reappear. Most of the unit consists of soft varicolored shales. A typical section was measured along Dry Wash in the south part of T. 21 S., R. 8 E.

Section of Morrison Formation, T. 21 S., R. 8 E. along Dry Wash, Emery County, Utah.

Cedar Mountain Formation: light lavender shale

Morrison Formation	Feet
1. Conglomeratic alternating with coarse-grained sandstone, brown, forms massive ledge	.20
2. Shale, very light green, massive, slope former, toward top contains rounded cobbles and pebbles of friable sandstone	.26
3. Shale, purple, massive, with occasional light tan to cream-white sandstone lenses up to 1 foot thick	.6
4. Sandstone, light brown, platy	.2
5. Shale, like unit 3	.21
6. Conglomerate, varicolored pebbles, poorly sorted, semiresistant	.7
7. Shale, like unit 3	.31
8. Sandstone, light tan, medium-grained with minor maroon blotches	.2
9. Mudstone, siltstone and sandstone, red-brown and white, banded, forms a slope	.60
10. Mudstone, alternating red and brown, light lavender and white, massive and occasionally bentonitic	.37
11. Sandstone, white ledge, thin- to medium-bedded, fine- to medium-grained	.3
12. Mudstone, red-brown, massive	.8
13. Sandstone, like unit 11	.1
14. Mudstone, like unit 12	.6
15. Shale, like unit 2	.30
16. Siltstone and sandstone, red, medium resistant	.12
17. Shale, light lavender and white	.25
18. Conglomerate, ledge former, lenticular with poorly sorted pebbles	.10
19. Shale, light-gray, bentonitic in part	.80
20. Conglomeratic sandstone, massive cliff former	.25
Total Morrison	.412

Summerville Formation

In the area of the Last Chance anticline in the south end of the field (T. 25 S., R. 5 and 6 E.) the Morrison changes somewhat in character. The unit is much thinner and composed of red fine-grained sandstone or siltstone alternating with ledges of conglomeratic sandstone. The conglomeratic sandstones are identical with those of the normal Morrison of the area. The unit is only 150 feet thick. Contact with the underlying Summerville was placed where the red-brown color changed to red. No gypsum occurs in the Summerville near the Last Chance anticline. The upper contact was placed at the base of the first light lavender shale of the Cedar Mountain Formation. North of the area the Morrison contains important dinosaur remains.

Cedar Mountain Formation

Stokes and Cohenour (1956, p. 30-31) report establishment of the formation by Stokes with a type section on the west slopes of Cedar Mountain near the Buckhorn Reservoir. These rocks previously had been assigned to the Morrison. The Cedar Mountain is the first Cretaceous unit of the area and is much like the Morrison in character except that the shales and mudstones generally have a light lavender color.

Section of Cedar Mountain Formation along Dry Wash, sec. 31, T. 21 S., R. 8 E.

Dakota Sandstone: sandstone, light brown to yellow-gray,. massive cliff former.

Cedar Mountain Formation	Feet
1. Shale, light gray	.15
2. Sandstone, tan brown, coarse-grained, ledge former, thick-bedded, platy weathering	.4
3. Mudstone, light lavender, bentonitic, has occasional gypsum veinlets, slope former	.47
4. Sandstone, yellow-gray, coarse-grained, platy weathering	.3
5. Conglomerate, pebble and cobble, overall brown color, semirounded, poorly sorted, massive ledge former with some interstratified coarse sandstone, lenticular	.22
6. Mudstone, like unit 3	.95
7. Sandstone, yellow-gray, fine-grained, friable, nonresistant	.2
Total Cedar Mountain	.188

Near Last Chance Creek the Cedar Mountain thickens to 296 feet. It may be argued that part belongs to the Morrison, but the light lavender mudstones are present from the base to the top of the unit and are interrupted only by minor amounts of sandstone and conglomerate.

Dakota Sandstone

The Dakota is a relatively thin unit consisting mostly of orange to yellow-gray, medium- to coarse-grained sandstone that is mostly massive with occasional sandy shale and conglomerate. The sands are cross-bedded and friable. Lupton (1916, p. 28-30) measured several sections of the Dakota:

The formation is thicker toward the southwest, as shown by the following section measured near Horn Silver Gulch in sec. 9, T. 21 S., R. 8 E., about 8 miles southeast of Ferron.

	Feet
Sandstone, yellow, saccharoidal, contains small iron concretions; lower part slightly conglomeratic	11.5
Sandstone, massive, yellow and brown, conglomeratic near base	24.0
	35.5

The formation at this locality contains many spherical iron concretions. The upper part of the sandstone seems to be distinct from the underlying and more massive part, which weathers into large cubic blocks. A fine-grained thin yellow "clay ball" conglomerate separates the two parts . . .

About 5 miles southeast of Rochester, on the north side of Dry Wash, in the E. ½ sec. 36, T. 21 S., R. 7 E., the Dakota Sandstone is much thicker and contains more conglomerate than is shown by any other section measured in the part of Castle Valley.

	Feet
Conglomerate, consisting mainly of quartz and black chert pebbles, 2 or 3 inches in diameter	1
Sandstone, yellowish gray, soft, thin-bedded	6
Sandstone, yellowish gray, soft, mainly thin-bedded; cross-bedded in places; contains a few iron concretions stained yellow and brown	18
Clay shale, gray, yellow and red	3
Sandstone, grayish yellow, indurated, massive, coarse-grained, conglomeratic in places	26
Clay shale, yellowish gray gypsiferous	2
Total	56

About 5 miles southwest of the point where this section was measured, thin lenses of coal occur in the top of the Dakota Sandstone.

Another section was measured about 12 miles southeast of Emery and is given below (3 miles south of Ivie Creek, near the west side of sec. 36, T. 23 S., R. 6 E.).

	Feet
Sandstone, gray, brown wherever weathered, massive, and thin-bedded; iron stained in places; contains a thin lens of shaley coal at base	36
Sandstone, yellowish brown, small clay galls form a thin bed of conglomerate at base	3.5
Total	39.5

A section of the Dakota Sandstone measured near the south end of the field shows the formation to be somewhat thicker than in the vicinity of Ivie Creek, where the preceding section was measured. The character and thickness of the rocks in the Dakota Sandstone at the south end of the coal field (SE¼ sec. 25, T. 25 S., R. 4 E.) are given below.

	Feet
Sandstone and bluish sandy shale alternating	30
Shale, brown, carbonaceous	1
Coal, impure	0.7
Shale, brown, carbonaceous	0.7
Sandstone (?) poorly exposed	12
Sandstone, white	2.5
Coal, rusty, probably impure	0.2
Sandstone and sandy shale, poorly exposed	12
Shale, coaley, very carbonaceous	0.7
Total	59.8

The Dakota Sandstone is exceedingly variable in thickness and character, as is shown by the sections given above; weathering undoubtedly accounts for some of this variation in color . . .

The Dakota contains lenticular coal beds in the Henry Mountain and Kaiparowits Plateau areas. In the Emery field, coal is present, but rare.

Tununk Shale

The formation succeeding the Dakota is the Mancos Shale represented by five members—three shale units at the base, middle and top of the Mancos and two sandstone members which separate the shale members. The lowest, the Tununk, represents the first deposit of the Cretaceous marine invasion that covered much of the North American continent. It is 500 to 800 feet thick and consists of drab bluish gray shale that is sandy toward the top and bottom. It occasionally contains thin veinlets of gypsum and is locally fossiliferous. Not a true shale in the sense of the finely divided bedding, it is in reality a silty mudstone. Locally the Tununk is heavily charged with carbonaceous material. In outcrop it forms the riser to the Coal Cliffs and the immediate floor below. Along the cliffs it weathers into vertically fluted surfaces whereas the floor appears as a flat valley with low rounded mounds and hills. The shales are soft and streams cut deep gullies into it. Close to the top some thin sandstone beds appear and gradually thicken upward. The first thick bed of sandstone on the cliffs marks the beginning of the overlying Ferron Sandstone.

Ferron Sandstone

The most important stratigraphic unit in the Emery coal field is the early Upper Cretaceous Ferron Sandstone Member of the Mancos Shale. It lies conformably on the Tununk with 50 to 60 feet of interbedded thin sandstones and shale making up the transition. These beds are usually assigned with the Tununk and the first massive cliff former assigned to the Ferron. Davis (1954, p. 57) divided the formation into two parts on the basis of lithology.

The lower Ferron is a gray, fine-grained, carbonaceous, calcareous marine sandstone and siltstone containing two very persistent calcareous concretion zones. Unlike the upper Ferron, this sandstone is very consistent in thickness along a northeast-southwest outcrop. At Emery, Utah, it is 60 feet thick and at Farnham dome on the northern end of the San Rafael Swell, it is 70 feet thick . . .

. . . A decided change in sedimentation took place in the passage from the lower Ferron to upper Ferron time. Deposition from the northwest and western sources became practically insignificant as compared with a new strong supply that began to come from the southwest. The influx of flood plain and swamp type sediments ranging from 0-500 feet thick is best displayed along surface outcrops in the vicinity of Emery, Utah.

Along the Emery coal field outcrops, the lower part of the Ferron is usually a cliff former. Before disappearing under the volcanics at the south end there appears to be a thickening of the unit. The upper beds consist mainly of alternating thick to massive beds of tan, yellow-gray, mostly medium-grained sandstone, shaley sandstone of the same color and shale. The shales are clayey, silty and carbonaceous. It is in the shaley divisions that the coal beds are usually found. The beds are highly lenticular; at one point along Interstate Highway 70 a lens of sandstone splits a coal bed and within 100 yards attains a thickness of 25 feet. The upper beds thin gradually from south to north. From Moore northward the coal disappears in outcrop and the unit thins to a few interbedded successions of thin sandstone and shale beds. The thinning is the consequence of intertonguing with the overlying Blue Gate and of lagoonal to littoral facies change.

The Ferron Sandstone in outcrop thickens from Mounds at the north end of the San Rafael Swell, where it is 70 feet thick, to Last Chance Creek, 70 miles southwest, where it is 800 feet thick. In the subsurface it thickens westward and southwestward. Along I-70 on the east side of the San Rafael Swell it is thin, almost indiscernible in the Mancos Shale.

Lupton (1916, p. 31) indicates that coal is of little value north of an east-west line through the town of Emery; Katich (1954, p. 46) indicates no coal in outcrop north of an east-west line through Moore village. Katich notes that coal beds in the Ferron were encountered in the drilling of the Clear Creek gas field near Scofield and near Price in the NE. SE. 28-14S-10E. The well near Price penetrated a coal bed 7½ feet thick.

Coal in the Ferron is distributed from the lower third of the member upward to the top. Lupton (1916, p. 43) grouped the coal into 13 beds lettered A to M with the former being the lowest in the stratigraphic column. These beds are not everywhere present. The lower Ferron as described by Davis is generally barren. The lower group of coal beds A to E follows generally within a 75-foot interval. This is then followed by a mostly barren interval 75 to 150 feet, containing, when present, the F and G beds. The upper zone of about 75 to 125 feet contains beds H to L. The M bed, when present, occurs along the contact with the overlying Blue Gate Shale.

Figure 6 shows the stratigraphic nature of the Ferron within the coal field. The position of the Ferron in the area with respect to the overlying and underlying beds is shown in cross section (figure 7).

Blue Gate Shale

The Blue Gate is a soft drab blue-gray shale like that of the Tununk. It crops out along Castle Valley and has contributed to the formation of the landform. The monotonous nodular and irregularly bedded mudstone and siltstone is occasionally interrupted by a thin bed of sandstone. The lower part of the unit generally has been stripped back off the more resistant sandstones of the Ferron leaving a bare rock Ferron dip slope. An exception to this is to the south of Willow Springs Wash where hills of Blue Gate occur right above the Ferron at the cliff's edge. The Blue Gate ranges from 1,500 to 2,000 feet and continues to thicken to the north. In Castle Valley the Blue Gate has a soil surface suitable for agriculture. Pure outcrops of the Blue Gate, as those of the other two shale members of the Mancos, support little vegetation because of its poor moisture-holding qualities. In Castle Valley the major streams have gullied the Blue Gate badly. Along much of Castle Valley the Joes Valley-Paradise fault zone has truncated the top of the Blue Gate. On the opposite (west) side of the faults, the Emery Sandstone Member of the Mancos usually occurs. The same fault zone passes through the Paradise area in the south part of the field; west of the fault the geology is not completely worked out. The sandstones there are also assumed to be Emery Sandstone. In general, west exposures of the Blue Gate are in low rounded hills.

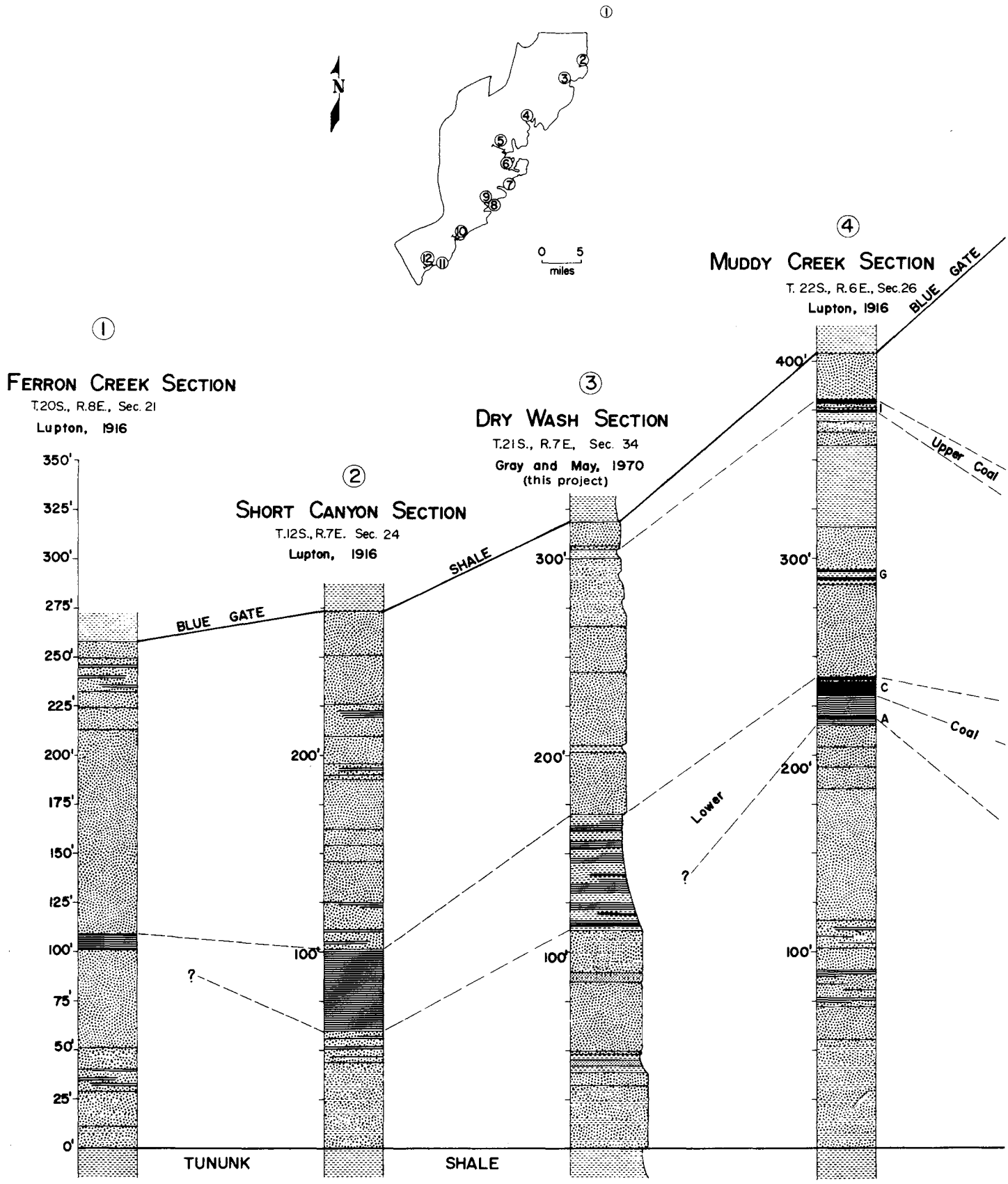
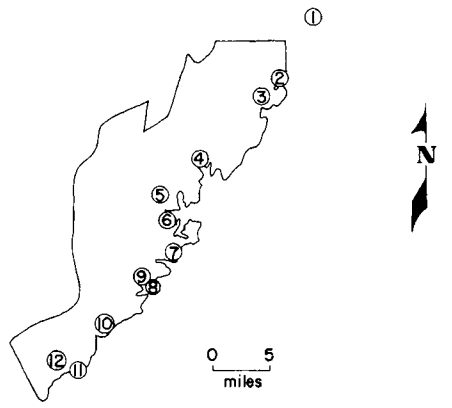


Figure 6. Sections of the Ferron Sandstone Member of the Mancos Shale, Emery coal field.



⑤

IVIE CREEK SECTION

T.23S., R.5E., Sec. 7, 17, 18

Lupton, 1916

⑥

I-70 SECTION

T.23S., R.6E., Sec. 20, 21

Doelling, 1971

(this project)

⑦

N. OF ROCK CANYON SECTION

T.24S., R.6E., Sec. 14

Lupton, 1916

⑧

WILLOW CREEK (A) SECTION

T.24S., R.5E., Sec. 13

Doelling, Gray and May, 1970

(this project)

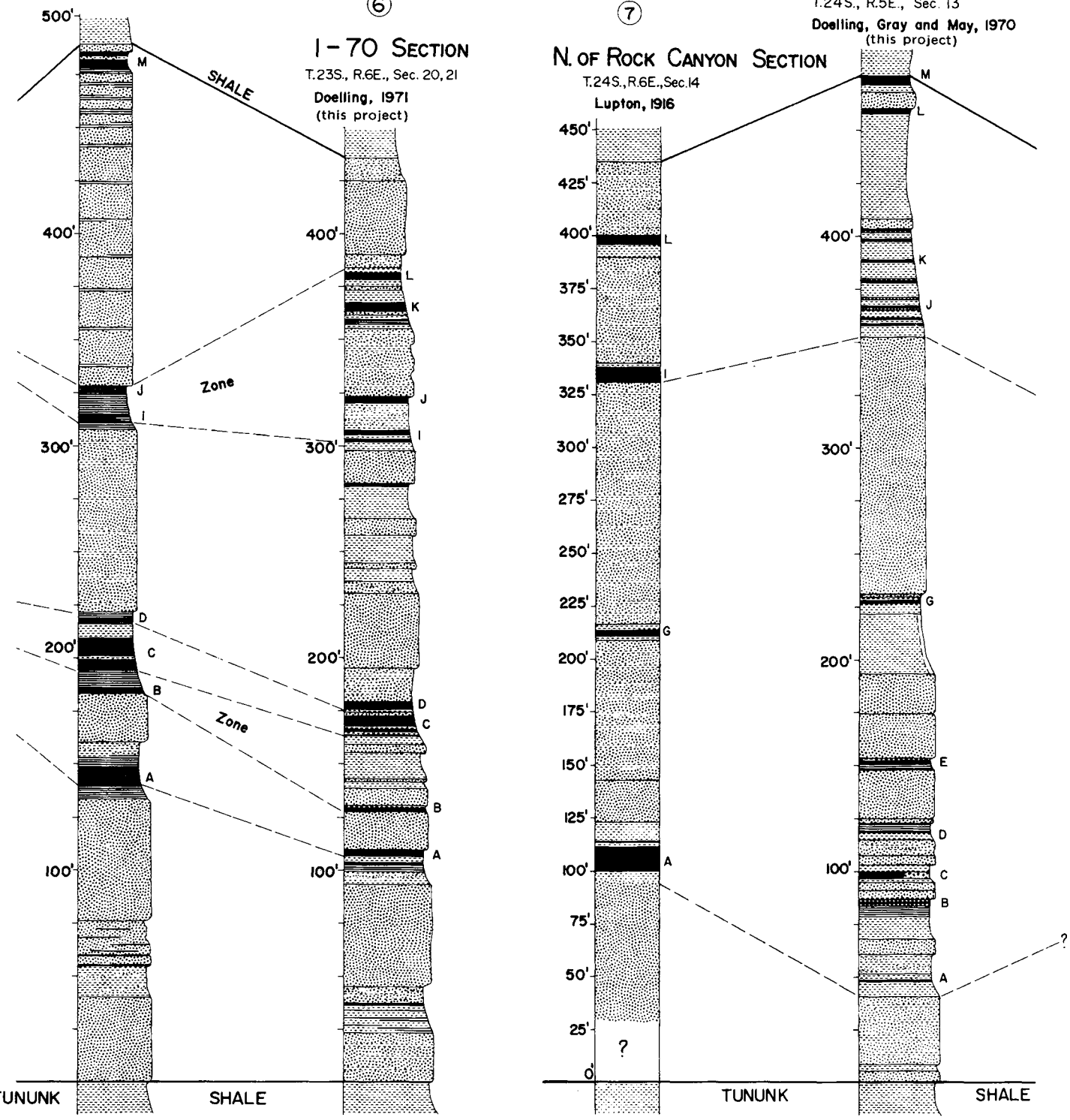
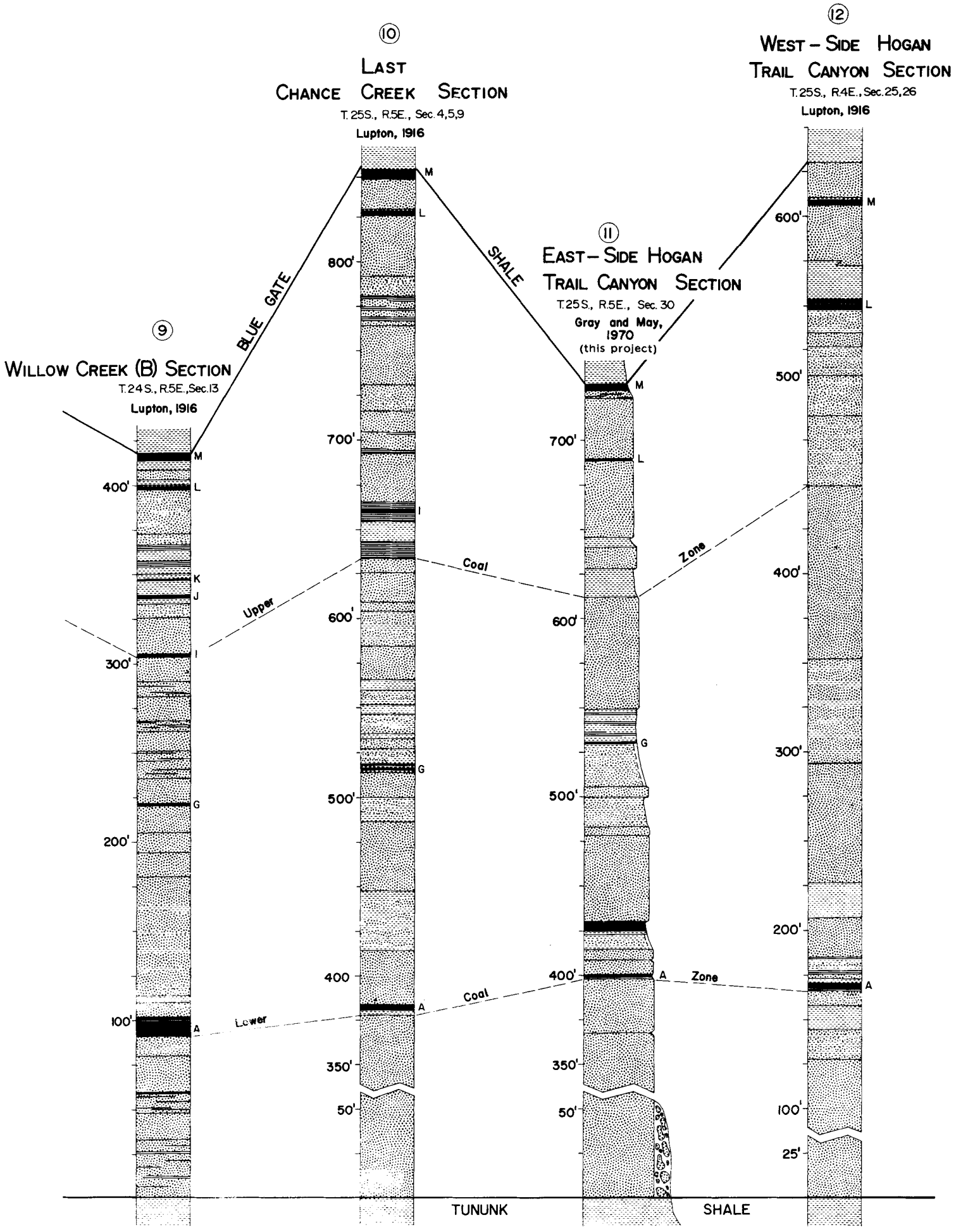


Figure 6. (continued)



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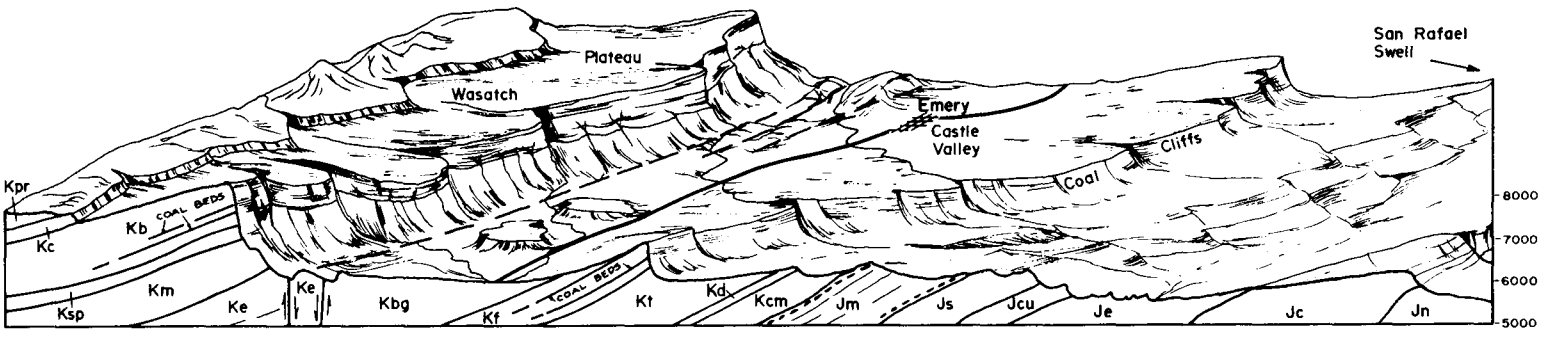


Figure 7. East-west cross section and physiographic diagram of the Emery coal field and surrounding area.

Emery Sandstone

The Emery succeeds the Blue Gate as a member of the Mancos Shale. Greater study of the Emery is required to determine its coal-bearing potential. It forms a series of step-like cliffs at the foot of the Wasatch Plateau and north of Emery it splits into two tongues separated by marine shale. To the south of Emery it is a single unit (an estimated 500 to 1,000 feet). Both the Ferron and Emery thicken westward which may explain the thickening to the south. Farther west the sandstones are expected to merge with the exclusion of the marine shale units. It has been alluded that the Emery should, like the Ferron, contain lagoonal deposits in its west exposures and perhaps contain coal. According to Hale and Van de Graaff (1964, p. 129) the Emery is dominantly a marine sandstone facies along the east front of the Wasatch Plateau, but thickens westward and changes rapidly to a coal-bearing facies beneath the plateau area.

The Emery consists of yellow-gray to brown thick-bedded to massive sandstone beds, shaley sandstone beds of similar color and gray shale; carbonaceous shales increase to the south. In the Paradise area a thick coal outcrop west of the fault zone is questionably assigned to the Emery. The coal seam is caught in a fault sliver and may be Ferron or even Blackhawk coal. The Emery is known to contain coal beds in the Henry Mountains, 50 miles to the southeast.

Masuk Shale

The description of this uppermost member of the Mancos Shale in the Emery coal field area is almost the same as the Tununk's, but the Masuk ranges from 300 to 1,000 feet thick with the thinnest sections to the south and west. It represents the last marine invasion into the area. Toward the upper part of the unit it becomes progressively sandier, finally giving way to the Star Point Sandstone which overlies it.

Star Point Sandstone

The character of the Star Point is well illustrated by Spieker (1931, p. 23) in a section measured on the south side of Mill Hollow in sec. 25, T. 23 S., R. 4 E.

	Feet
Sandstone and shale of coal-bearing Blackhawk Formation	
1. Sandstone, white at top, very massive, forming vertical cliff	100
2. Sandstone, largely in thin massive beds separated by thinner partings of shales	128
3. Shale, very sandy, harder than main body of Mancos Shale, containing increasing number of thin sandstone beds toward top	160
Total	388
Mancos Shale (main body)	

The Star Point is the initial cliffy sandstone on the Wasatch Plateau cliffs. It supports the Masuk Shale below in the cliff. The thickness in the Wasatch Plateau ranges from 90 to 1,000 feet. Adjacent to the Emery field it is generally less than 500 feet thick.

Blackhawk Formation

The Blackhawk is an important coal-bearing unit and is the basis for the Wasatch Plateau coal field. The formation varies between 700 and 1,000 feet and consists of alternating slope and cliff-forming units with cliff-forming units dominant. All the important coal beds occur in the lower half of the formation. In a section measured by Spieker (1931, p. 30-33) the unit consists of one-third shale and two-thirds sandstone. The Blackhawk makes up the upper part of the Wasatch Plateau cliffs. The better coal beds developed in the unit adjacent to the Emery field are the Muddy, Ivie and the upper Hiawatha. The Blackhawk is discussed in more detail in the Wasatch Plateau coal field report.

Castlegate Sandstone

The Castlegate caps the Wasatch Plateau cliffs and varies from 150 to 500 feet thick, but in this area is generally less than 300 feet thick. The Castlegate is a white to gray, coarse-grained often conglomeratic sandstone that weathers to shades of brown.

Formations Above the Castlegate Sandstone

On top of the Wasatch Plateau younger units continue to build on the older. They successively add overburden to the Ferron beds, removing them from mining consideration under present technologies. These units include the Price River, North Horn, Flagstaff, Colton and Green River formations. They are briefly described in the Generalized Section of Rock Formations (figure 5) for the Emery coal field and in more detail in the Wasatch Plateau coal field presentation.

Lava Flows and Volcanic Debris

Andesitic, latitic and basaltic flows lie atop the Fish Lake Plateau to the southwest of the coal field. Basalt boulders and other volcanic debris are scattered over much of the south part of the region. The coal-bearing Ferron disappears under these volcanics terminating the field to the south. In the Paradise area the volcanic debris covers large areas of bedrock, especially in the vicinity of the fault zone effectively confusing stratigraphic relationships.

Unconsolidated Deposits

Unconsolidated deposits are mapped in three groups. (1) Alluvium, usually along the major creeks and streams, consists of partly stratified gravel, sand, silt and clay. Below the Mancos the alluvium, heavily charged with Mancos mud, changes color to drab gray. (2) Gravel generally has developed on benches atop the Mancos shaley units below the Wasatch Plateau cliffs to thicknesses up to at least 75 feet. (3) Landslides are common along the cliffs and occasionally form continuous aprons below them.

Structure

The Emery coal field area has a simple structure, representing gently northwest-sloping beds on the flank of the San

Rafael Swell (figure 7). According to Stokes and Cohenour (1956, p. 42):

> . . . the San Rafael Swell is a huge upfold or elongate anticline. The total length of the structure is almost 80 miles, but the northern limits are difficult to place since the flattening out of the dip toward the north is very gradual. The east edge of the Swell is marked by an abrupt topographic and structural feature, the so-called Reef, where the beds become nearly vertical. The western side is not so abrupt and the dips from the center of the Swell merge westward with the regional inclination toward the Wasatch Plateau . . .

The Emery field is located on this regional inclination toward the Wasatch Plateau. The strike of the beds is mainly northeast, but as they disappear under the volcanics at the south end of the field they are aligned nearly east and west. Occasionally the regional trend varies. Faults are inconsequential over most of the area except along the Joes Valley-Paradise fault zone. The zone parallels the strike of the field and occurs near the west margin.

Folds

Between Price and Geyser Peak along Castle Valley, several small domes or anticlines from north to south include: Farnham anticline, Castledale dome, Paradise dome, Rochester anticline and Last Chance Creek dome. The last two are in the Emery coal field, as now constituted, but if the Ferron Sandstone contains thick coal seams in the subsurface west of the outcrops, then all of them would be of interest.

The Farnham anticline is located at the north end of the San Rafael Swell near the town of Wellington, Carbon County. It is 3 miles long and ¾ mile wide; the flanking dip of the rocks does not exceed 10° except locally along faults. The axis trends north-south through secs. 12, 13 and 24, T. 15 S., R 11 E. The anticline is badly faulted with the major trend paralleling the fold axis. Adjacent to these faults the dips range from 25° to 85°. The core of the structure exposes Cedar Mountain Formation. The Ferron Sandstone, here barren of coal, surrounds it in the form of cuestas to the west, north and east.

Lupton (1916, p. 40) describes the Castledale dome as nearly circular and about 3 miles in diameter. Horizontal beds prevail in the center and dips develop up to 11° at the west side. The dome is somewhat eroded by Cottonwood Creek 3 miles east of Castle Dale. Where the creek cuts across the dome the Tununk occurs in the core. As in the Farnham structure the outcrops of the Ferron display no thick beds of coal.

Paradise dome is smaller than the Castledale structure and also nearly circular. Because of the westward regional dip the steeper flank is on that side; the maximum observed dip on the west flank is 6° and on the east flank, 2°. The dome is located in the northeast part of T. 20 S., R. 8 E. The center exposes the Cedar Mountain Formation. Ferron beds to the west are steepened only slightly.

The Rochester anticline is located 2 to 3 miles east of Moore in the southeast quarter of T. 21 S., R. 7 E., or just north of the Moore Dry Wash gap through the Coal Cliffs. Only the Ferron Sandstone is involved at the surface in the parallel-to-strike structure. Dips on the west flank range to 15° and the largest east flank dip is 6°. A paralleling syncline lies a mile to the east.

The Last Chance anticline, for the most part, strikes at right angles to the regional trend. The raised anticline has caused the coal-bearing formations in the vicinity of Last Chance Creek, T. 25 S., R. 5 E. to erode, pushing the Coal Cliffs westward 6 to 7 miles. Where the axis collides with the Coal Cliffs only a slight warping remains as it plunges to the west. Paralleling Last Chance Creek a synclinal axis reverses the dips again. The distance between the two axes near the spot where Last Chance Creek plunges over the cliff is about 1 mile. The dip between the two axes is 2° to 3° southwest. The influence of the Last Chance flexures disappears less than a mile behind the cliff where a set of folds (the Deer Creek anticline and syncline) trending at right angles cuts them off. On the east side is the syncline and its axis plunges toward Last Chance Creek from both directions. The strata dip toward the axis to 10° from the east and to 14° from the west. The anticlinal axis also plunges toward the creek. Beds on its west side dip 3° to 6°.

Faults

The major fault system partially marks the west boundary of the coal field–the Joes Valley-Paradise fault zone. The zone trends N. 20° E. and in most places consists of two large displacement faults. These mark the east and west limits of the zone; the rocks between have collapsed graben fashion and are broken by paralleling minor faults.

Just east of Emery town as many as six faults with the boundary faults displacing the rock at least 1,000 feet occur. The width of the zone is about 2 miles. The displacement across the zone near Emery is probably a few hundred feet. The faults are less well exposed farther south, but are evident in the Paradise area to the south. According to Graham (1970, p. 5), the throw of the fault zone may be as much as 2,000 feet. He notes that many minor faults occur parallel to the Paradise fault or at right angles to the zone. In addition several faults, both perpendicular and parallel to the zone on the west side of Paradise Valley, occur.

Few faults of small displacement cut the strata east of the zone. One notable east-west fault cuts the Ferron just before it disappears under the volcanics at the south end of the field in Willow Basin.

Unconformities

Unconformities along the west flank of the San Rafael Swell occur between the Navajo and Carmel, Entrada and Curtis, Summerville and Morrison, Morrison and Cedar Mountain and Cedar Mountain and Dakota Sandstone; in the Wasatch Plateau formations one exists between the Blackhawk and Castlegate and, according to Picard (1954), above the Castlegate. None of these has any affect on the coal of the Ferron Sandstone.

Probable numerous local unconformities within the Ferron undoubtedly affect the coal from place to place. However, nothing in this area has been investigated. Both Davis (1954, p. 57) and Katich (1954, p. 48) delineated a lower Ferron tongue which contains abundant spherical concretions to 8 feet in diameter. Lupton (1916, p. 31) noted these concretions southward to Ivie Creek.

Davis notes a decided change between this tongue and the overlying coal-bearing beds; the change may represent a depositional hiatus.

GEOLOGIC AND TECTONIC HISTORY

The geographical positions of former shorelines and tectonic events aid in predicting what happened to subsurface coal beds.

During Jurassic time the area fluctuated between continental and marine conditions. As attested by the numerous unconformities, deposition was not always continuous and erosion took place on a limited scale. The Navajo originated on a huge desert area of shifting sand. The Carmel was deposited in an area of shallow seas that underwent evaporation at intervals. The sea first planed off the sand dunes of the Navajo and deposited the limestones, siltstones and gypsum. The Carmel thickens westward and the sea undoubtedly encroached eastward across the swell area.

The Entrada shows even bedding and aeolian type crossbedding. The latter is not as prevalent in the west San Rafael Swell. Nevertheless, it originated through water and wind action. The environment is thought to be continental. The upper Entrada was again planed off by a Jurassic sea which extended southward. The area represents the southernmost extension of this sea. The presence of glauconite generally attests to marine conditions that

prevailed during Curtis deposition. To the east and south the unit passes into nonmarine redbed equivalents.

The Summerville redbeds are even in nature indicating sedimentation in water. The environment may have been lacustrine and deposition was in shallow water. The thin alternating beds may indicate a varve-like depositional control. The Morrison was deposited in mainly fluvial and partly lacustrine environments. Bentonite of volcanic origin is found in the shales suggesting volcanic activity, perhaps to the west. Dinosaurs roamed on the mudflats. If the Morrison was properly measured in the vicinity of Last Chance anticline it may show that the anticline was active in Late Jurassic time. Nevertheless, after Jurassic time thicknesses of beds returned to normal. No demonstrable change in dip between the Summerville and Cedar Mountain beds exists.

An unconformity separates the Jurassic from the Lower Cretaceous beds. The beds that follow are similar to those of the Morrison and show resumption of Morrison environments. After the Cedar Mountain shales were deposited, a period of erosion followed. The Dakota formed as a pediment on the surface. To the west and south the Dakota spread as a sheet of fluvial deposits, which in some areas formed considerable coal. Major coal-forming environments did not extend into the Emery area, however.

According to Katich (1954, p. 46) much of the lower part of the Tununk Shale was deposited during late Lower Cretaceous and early Upper Cretaceous time from waters of a westward-transgressing Mancos sea. In central Utah this sea probably reached as far west as Sanpete Valley. To the west the orogenic pulsations had begun to elevate the land. One of these pulses shed a significant amount of clastics eastward, pushing the shoreline back across the present-day San Rafael Swell to Green River. Lagoons formed behind the shorelines gave rise to the coal deposits of the Ferron Sandstone. Although the major structural features, such as the San Rafael Swell, are believed to have developed in Tertiary time, some evidence indicates that initial activity began in the Cretaceous. If this activity were more fully understood, the configuration of paleoshorelines might be worked out and local axes of lagoonal deposits defined.

As time progressed orogenic activity to the west waned for a time; as the subsidence continued the Mancos sea pushed westward again and the Blue Gate marine shales covered the area. Another period of mountain building began thereafter, not as great as that during Ferron time, but which pushed the sea back to a line somewhere within the Wasatch Plateau. The nearshore sand deposits of the Emery were deposited ahead of the beach and presumably lagoonal deposits were formed behind it. The Emery, according to Hale and Van de Graaff (1964, p. 129), thickens westward and changes rapidly to a coal-bearing facies beneath the plateau area. It may contain coal in the south part of the Emery field if stratigraphic correlations have been made properly, but no proof exists. Coal is known in the Emery of the Henry Mountains Basin 50 miles to the south and 20 miles east. Location of the Emery paleoshorelines would help solve the problem.

Again orogenic activity waned or subsidence increased and the shoreline proceeded westward and the Masuk shales were deposited. This was followed by the major orogenic pulses that produced the mountain chains in west Utah with which we are familiar today. The Mancos sea retreated to the east and disappeared from the scene. During this regression the Mesaverde (Blackhawk) coals were deposited and the environment changed to dominantly continental. Subsidence continued into early Tertiary time so that fluvial and lacustrine sediments were received. Sometime in the mid-Tertiary, presumably beginning in the Eocene, the region began to be uplifted and the San Rafael Swell pushed up in earnest. A long period of nondeposition and erosion followed to produce the present-day landscape.

Basically the axes of the lagoonal deposits of the Cretaceous in which the major coal deposits of Utah lie are north-south. Enough evidence, however, exists to show that the San Rafael Swell, Last Chance anticline and perhaps other structural features began activity as early as the Cretaceous to modify the axes; further insight into these changes would help define the area's coal resources.

Correlation with Surrounding Areas

Correlations of importance to the Emery coal field are associated with the Ferron and Emery coal-bearing beds. Relationships with the overlying Blackhawk beds are discussed in the Wasatch Plateau report. The only other coal field based on Ferron and Emery coal is the Henry Mountains coal field. At least part of the Ferron can be correlated with the Straight Cliffs Formation of the Kaiparowits Plateau coal field. The Emery has no facies counterpart in the Kaiparowits. Long-range correlations also have been made between the Frontier coal-bearing beds of the Vernal and Tabby Mountain fields. The Frontier is slightly older than the Ferron. These units may be continuous in the subsurface since the Cretaceous beds notoriously cross time lines. This is understandable in light of irregularities in the transgression and regressions of the Mancos sea.

West Utah

No counterparts to the Ferron exist in west Utah inasmuch as this was the source area for clastics of the unit. The Ferron undoubtedly changes to continental facies westward, the clastics becoming coarser and the entire interval eventually disappearing adjacent to the source.

South Utah

Cross section A-A' (figure 8) is a pictorial representation of a possible correlation between the Straight Cliffs Formation of the Kaiparowits and the Ferron. Fossils place the entire Ferron in the Turonian series and work by Peterson (1969) in the Straight Cliffs extends that unit from the Turonian to early Campanian. The Straight Cliffs consists of four members, the lower two separated from the upper two by an unconformity of significant duration. The main coal-bearing beds lie immediately above this unconformity and fossils indicate a Coniacian to Campanian age. Some coal beds, although uncommercial, occur below the unconformity in the Turonian rocks.

Below these rocks is a cliff-forming littoral sandstone. The Ferron has a counterpart to this sandstone in its lower member and the coal beds may be a direct correlation with the Straight Cliffs coal beds below the unconformity. However, these coal beds are present in the south Kaiparowits and disappear northward in the direction of the Emery coal field. The coal beds of the Ferron are grouped, as discussed under Coal Seams, into a lower zone and an upper zone. The situation is similar in the Kaiparowits in the beds above the unconformity. The stratigraphic distance between upper and lower coals in the south part of the Emery field is 200 to 250 feet. In the north Kaiparowits, the upper and lower zones are 250 to 350 feet apart. Thus the Straight Cliffs Formation might correlate with the Ferron and be continuous under the volcanics and cross time lines from younger to older as one proceeds northward. This is similar to the Ferron which crosses time lines northward from younger to older but believed to be continuous with the Frontier. Such a correlation may be speculative, but at least part of the Straight Cliffs can be matched in age with the Ferron. In the Kaiparowits, following deposition of the Straight Cliffs, no reincursion of the Mancos sea occurred and continental deposition ensued.

Southeast Utah

Cross-section B-B' (figure 9) illustrates relationships as they may exist between the Emery field and the Henry Mountains field. The stratigraphic units in the Henry Mountains area are the same and directly correlated with those in the Emery field. Only thickness and slight facies changes can be detected.

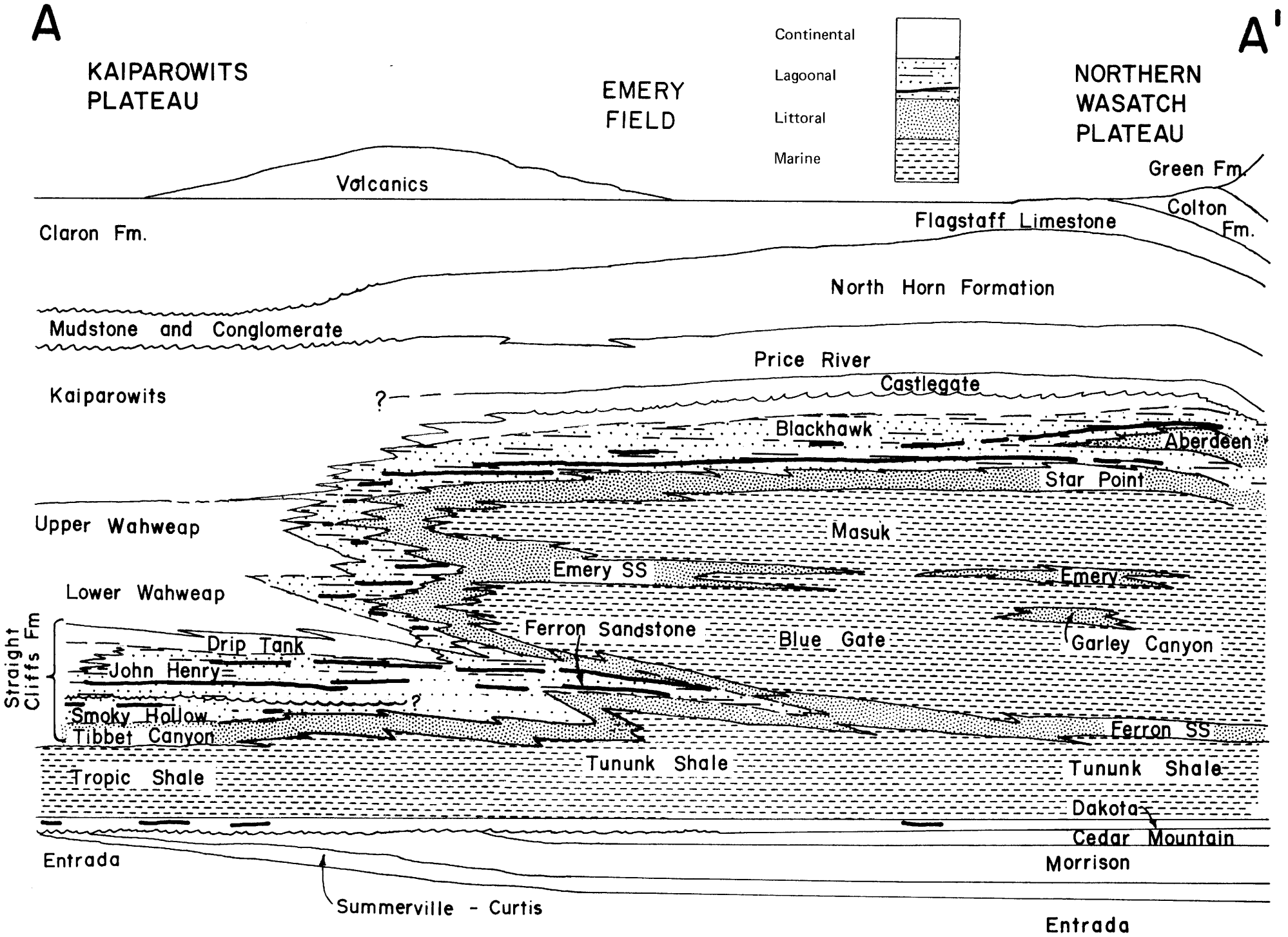


Figure 8. Stratigraphic correlation diagram, Kaiparowits Plateau to north Wasatch Plateau.

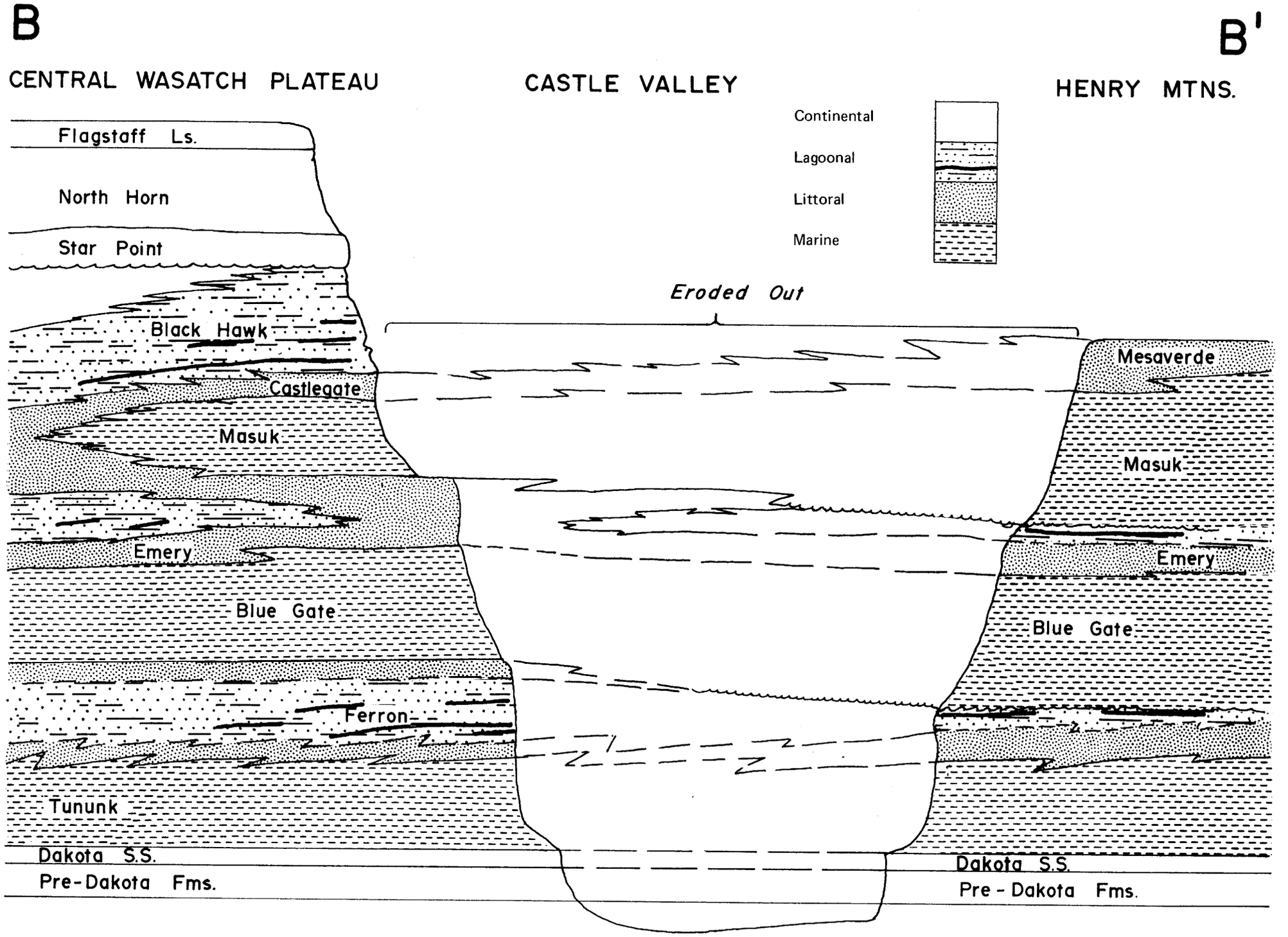


Figure 9. Stratigraphic correlation diagram, central Wasatch Plateau to the Henry Mountains.

COAL DEPOSITS

Status of Information

The only comprehensive work published on the Emery coal field is that by Lupton in U. S. Geological Survey Bull. 628. A small amount of additional data is available from brief accounts of the field or from published geologic work not directly pertinent to the field. A limited amount of analyses of coal samples is also published, mostly by the U. S. Bureau of Mines.

Lupton's work is reasonably adequate for surface data and all of it is repeated here. Other surface data have been added and an attempt has been made to match the geologic contacts and coal seams with the topography. A few additional samples of coal have been collected and analyzed.

The References section lists all principal and supporting work thought pertinent to the geology and coal resources.

Mines, Prospects and Production

Coal was discovered early in the Emery coal field; the first recorded mine was the Browning in 1881 (figure 10). Activity was irregular until 1930; production has been steady since. At present two mines are active and these have been the most important. The closed mines all have been abandoned for at least 20 years (table 1).

In 1969 production at the Browning mine was 36,978 tons, at the Dog Valley mine, 20,685 for a total of 57,663 tons. In 1970, the Browning yielded 115,239 tons and Dog Valley 23,334 for a total production of 138,573 tons.

Total production from the field has been about 1,640,000 tons and 90 percent are attributable to the above two mines.

Land Ownership

The land in and around the Emery coal field is predominantly owned by governmental agencies. The largest blocks of private land are in Castle Valley. The distribution of ownership is approximately as follows: Bureau of Land Management 50.5 percent, private property 21.8 percent, National Forest Service 21.8 percent and state of Utah 5.9 percent.

Coal lands under the jurisdiction of the National Forest Service are mainly in the south part of the field. Locations of these properties are shown on figure 11.

Claims for mining the coal were held by the following companies and individuals on January 1, 1970:

	Name	Type of Claim
1.	T. Addley	Private property
2.	R. Albrechtsen	Federal prospecting permit application
3.	I. Browning	Private property
4.	Consolidation Coal Co.	Federal leases, state leases, private property
5.	R. J. Hollberg	Private property, state leases
6.	D. Hunter	Federal permits and prospecting permit applications
7.	L. T. and C. G. Hunter	Private property
8.	Ivie Creek Coal Co.	Private property
9.	H. E. Jensen	State leases
10.	J. H. Knight	Federal lease
11.	Mountain State Resources Corp.	Federal permits and prospecting permit applications
12.	K. E. Peterson	State leases
13.	Southern Utah Fuel Co.	Federal lease
14.	Sun Valley Coal Co.	Private property
15.	Unassigned	Private property
16.	H. Wilson	Private property

Table 1. Mines and prospects, Emery coal field.

Quadrangle	Location	Remarks
Acord Lakes SE		
Browning mine (San Raphael) Upper coal zone-I bed	SE.NW.33-22S-6E 4,301,215m.N. 477,440m.E.	Active intermittently 1881-1936 and fully active 1937-1970
Dog Valley mine (Sun Valley) Upper coal zone	NE.SW.32-23S-6E 4,291,215m.N. 476,500m.E.	Active 1930-1970
Emery East		
Casper mine Lower coal zone	SE.NW.26-22S-6E 4,302,290m.N. 482,070m.E.	Activity unknown
Cox prospect Upper coal zone	NE.SE.7-22S-7E 4,306,780m.N. 486,460m.E.	Activity unknown
Moore prospect Upper coal zone	NW.NE.13-22S-6E 4,306,000m.N. 484,270m.E.	1905 active
Williams mine Upper coal zone	NE.SW.12-22S-6E 4,306,540m.N. 483,860m.E.	Activity unknown
Prospect Lower coal zone	NW.NW.19-22S-7E 4,304,180m.N. 485,180m.E.	Activity unknown
Emery 3 NE		
Willow Spring mine Lower zone-A bed	SE.NW.13-24S-5E 4,286,890m.N. 472,090m.E.	Active 1940?-1946
Emery 3 SW		
Willow Basin mine Lower coal zone	NE.NW.3-26S-4E 4,270,200m.N. 459,410m.E.	Period of activity unknown
Mesa Butte		
Bear Gulch mine Lower coal zone	NE.NW.2-23S-6E 4,299,920m.N. 481,280m.E.	Active 1897-1916?
Emery mine (Cowboy mine) Upper coal zone	SW.NW.2-23S-6E 4,299,300m.N. 480,890m.E.	Active 1906-1920's

These holdings change from time to time and are presented to indicate the type of activity at a point in time. The locations are shown on figure 12.

Approximately 123 square miles are held for the purpose of coal extraction–about 59 percent of the available ground. All the open land is where coal is expected to be deep, away from the outcrop or where surface indications show that the coal seams are thin.

Quality of Coal

The quality of coal of the Emery coal field is tested by forty-seven analyses (table 2). Except for the samples collected in the Acord Lakes SE quadrangle, most were from outcrops or abandoned prospects and show a wide range of characteristics. The qualities demonstrated at the Browning or Dog Valley mine are probably characteristic for the field. The split condition and impurities of many seams probably create the fluctuations noted in ash, sulfur and Btu/lb values.

Table 2. Average proximate analyses of coal, Emery coal field.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	47	7.4	2.3 -23.6
Volatile matter	46	37.7	32.3 -43.9
Fixed carbon	46	44.8	32.9 -52.2
Ash	47	8.5	4.0 -23.6
Sulfur	46	0.95	0.31- 4.66
Btu/lb	44	11,450	7,823-12,970

Abernethy, Peterson and Gibson (1969a, p. 7) analyzed the major ash constituents in two samples from the Emery coal field (table 3, p. 437).

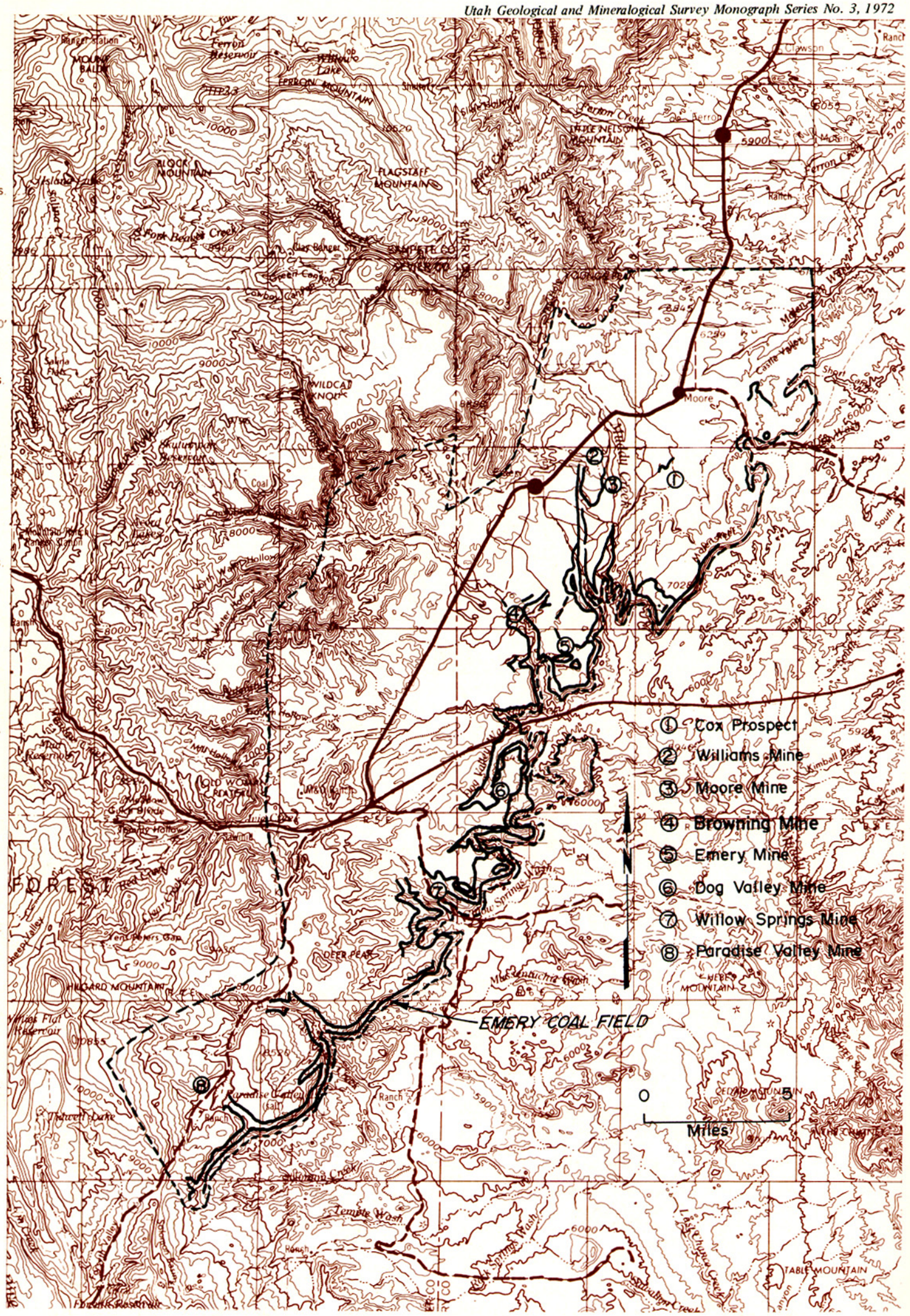


Figure 10. Coal seams and mines map, Emery coal field.

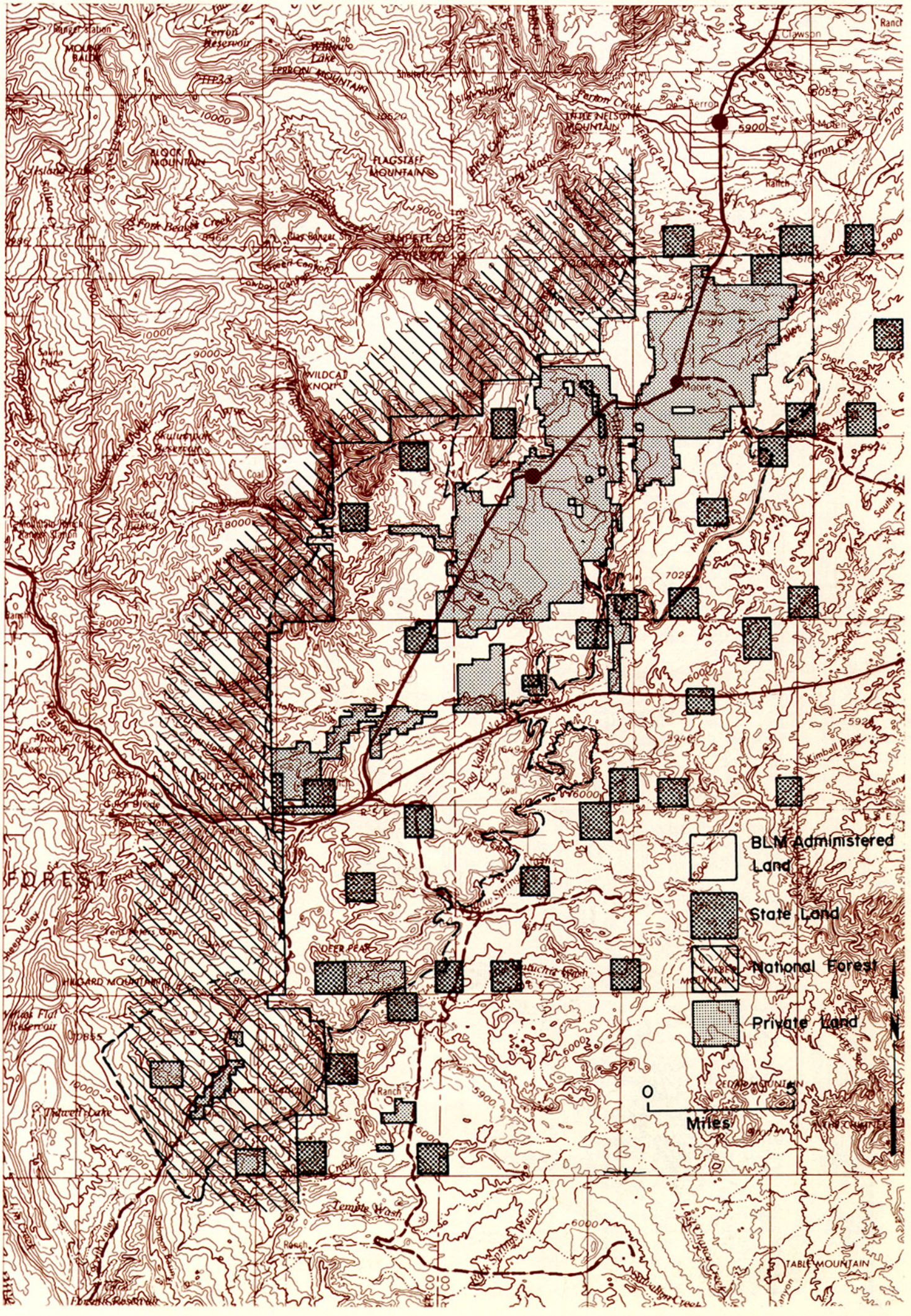


Figure 11. Land ownership map, Emery coal field.

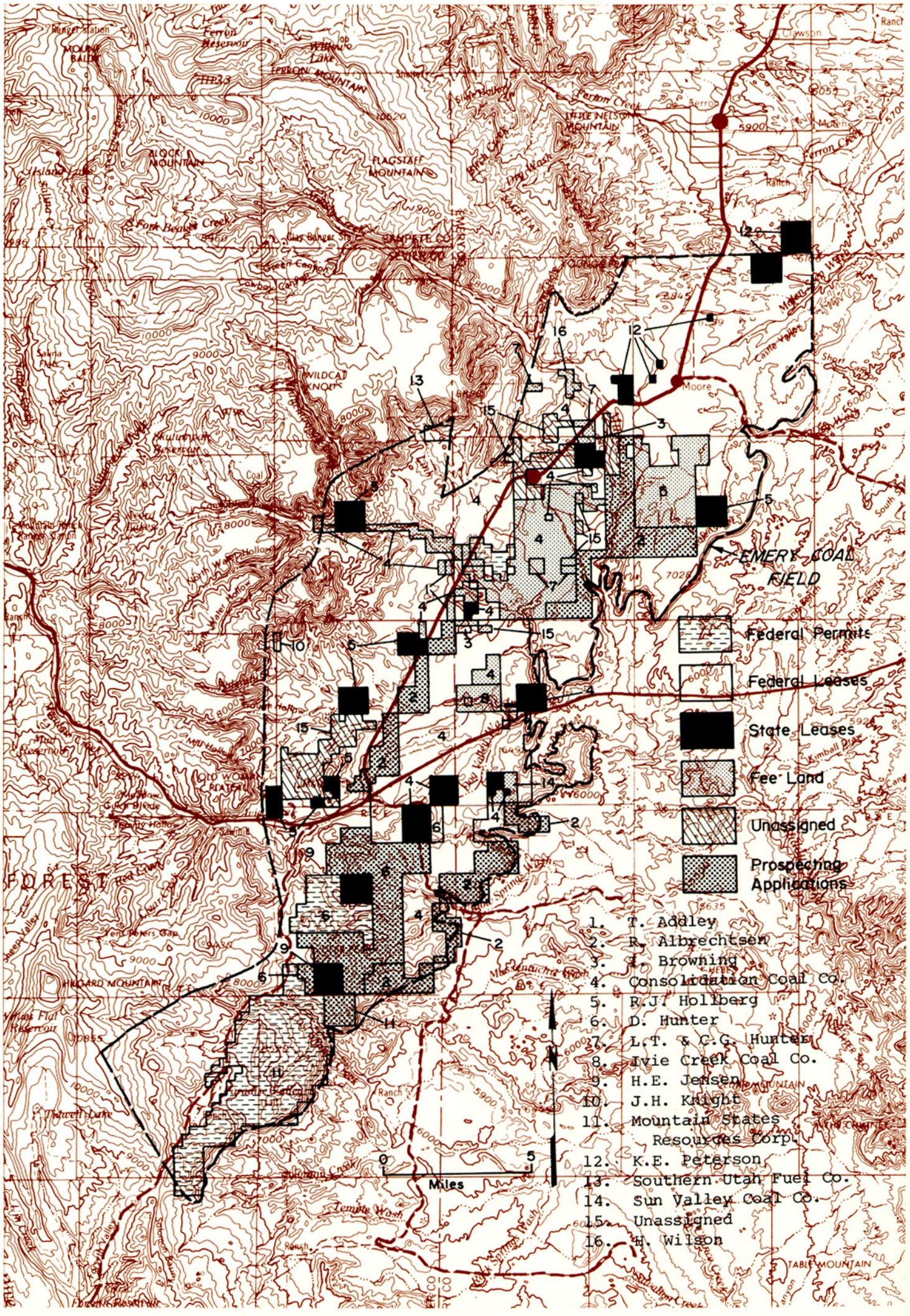


Figure 12. Leases and permits map, Emery coal field.

Table 3. Analyses of ash constituents of two samples, Emery coal field.

	Ferron A Bed	Ferron J[1] Bed
Ash	6.3 percent maf coal	8.2 percent maf coal
Sulfur	0.5	1.4
S_1O_2	46.7 percent ash	39.4 percent ash
Al_2O_3	19.2	15.5
Fe_2O_3	8.0	9.6
T_1O_2	1.3	1.2
P_2O_5	0.8	0.2
CaO	10.9	17.0
MgO	4.5	4.5
Na_2O	1.5	3.1
K_2O	0.2	0.1
SO_3	6.8	8.1
AST	2,220	2,120

[1]Probably represents I bed.

The same authors ran spectrochemical analyses of the ash (1969b, p. 22) and came up with the following trace elements in percent of ash (table 4):

Table 4. Trace-element composition of coal samples, Emery coal field.

	Ash Percent	
	Ferron A Bed	Ferron J[1] Bed
Arsenic	0.0	0.0
Boron	0.08	0.08
Barium	0.08	0.08
Beryllium	0.0002	0.0002
Cobalt	0.005	0.005
Chromium	0.01	0.005
Copper	0.001	0.002
Gallium	0.005	0.002
Germanium	0.0005	0.0008
Lanthanum	0.01	0.01
Lithium	0.01	0.008
Manganese	0.005	0.01
Molybdenum	0.001	0.001
Niobium	0.005	0.005
Neodymium	0.0	0.0
Nickel	0.005	0.008
Lead	0.004	0.003
Rubidium	0.0	0.0
Scandium	0.005	0.002
Tin	0.001	0.001
Strontium	0.1	0.1
Vanadium	0.01	0.01
Yttrium	0.01	0.005
Zinc	0.01	0.01
Zirconium	0.1	0.08

[1]Probably represents I bed.

Reserves

By definition the Emery coal field includes those coal beds not confined in the Mesaverde Group or younger beds. Essentially, however, all the coal is contained in the Ferron Sandstone Member of the Mancos Shale. A few thin seams have been discovered in the Dakota Formation and some doubt exists as to the presence of coal in the Emery Sandstone Member. In the Ferron at least 14 coal beds are defined and grouped into four coal zones. The reserves are calculated from beds averaging 4 feet or more thick. About six of the fourteen beds are included.

Previous calculations made by Lupton (1916, p. 86) are repeated along with his comments:

A careful estimate was made of the coal in the Emery coal field. It is assumed in calculating the tonnage that each acre of land underlain by a coal bed 1 foot thick (1 acre-foot) contains 1,800 tons. In the table given below two columns of figures are shown. The one on the left gives the estimated tonnage; the one on the right shows approximately the amount of coal that can be recovered, on the assumption that only 1,000 tons of coal can be mined from each acre-foot. By careful mining, however, much more than this amount may be recovered.

Township	Total Coal	Recoverable
T.21S. R.6E.	21,463,000	11,923,000
T.21S. R.7E.	311,000	173,000
T.22S. R.6E.	427,176,000	237,320,000
T.22S. R.7E.	21,736,000	12,075,000
T.23S. R.5E.	214,310,000	119,061,000
T.23S. R.6E.	355,877,000	197,710,000
T.24S. R.5E.	268,389,000	149,106,000
T.24S. R.6E.	33,171,000	18,027,000
T.25S. R.4E.	30,093,000	16,741,000
T.25S. R.5E.	54,734,000	30,408,000
T.26S. R.4E.	1,805,000	1,002,000
	1,429,065,000	793,546,000

It is assumed that Lupton terminated his calculation along the east flank fault of the Joes Valley-Paradise fault zone. The lower coal thickness limit is also unknown but thought to be 1 or more feet. Averitt (1964, p. 50) indicates Lupton's estimate may be high.

Including new data, a re-evaluation of reserves was made by quadrangle. A lower limit of 4 feet and a 1,742 ton acre-foot was set (table 5).

Table 5. Original coal reserves, Emery coal field.

Quadrangle	Class I and II (measured and estimated)	Class III (inferred)
Acord Lakes SE	209,200,000	289,200,000
Emery East	150,702,000	181,931,000
Emery 1 NE	–	–
Emery 3 NE	131,813,000	49,950,000
Emery 3 NW	72,000,000	98,200,000
Emery 3 SW	34,840,000	–
Mesa Butte area	78,000,000	–
east of quadrangle	–	134,550,000
	676,555,000	753,831,000
	Total Coal	1,430,386,000

The east flank fault of the fault zone also was used to limit these reserves; surprisingly, Lupton's figure is duplicated which may have been low instead of high. Because of the lenticular nature of the coal and the small area of good development in seams, the figure should, nevertheless, be accepted as optimistic.

The Ferron extends westward to the foot of the Wasatch Plateau before its coal seams are buried beneath more than 3,000 feet of overburden. This involves the area between the Joes Valley-Paradise fault zone and the Wasatch Plateau cliff. Coal seams are expected to extend into this area with a reasonable amount of assurance. A Class IV (potential) reserve classification is therefore extended to it.

The reserves calculated for the Emery coal field are classed and summarized as follows:

Class I (measured)	Based on adequate exploration and development data, properly correlated.	757.6×10^6 short tons
Class II (indicated)	Based on geologic measurement supplemented by limited drill-hole information or limited to 1½ miles from control point.	
Class III (inferred)	Based on geologic inference and projection of the habit of the coal beyond 1½ miles from control point.	672.8×10^6 short tons
Class IV (potential)	Based on geographic and geologic position with little supporting data and includes coal up to 3,000 feet of cover.	634.5×10^6 short tons
	Total	2,064,900,000 short tons

Total field production has been 1,640,000 tons yet the reserves have barely been tapped. Lupton assumed a 55.6 percent

recovery, but this seems high. No figures are available from the mines to calculate actual recovery. In the Book Cliffs and Wasatch Plateau coal fields the recovery rate per single seam averages between 40 and 50 percent. Roof and floor conditions are expected to be worse in the Emery field and no more than 40 percent should be expected. Calculators of reserves in the Book Cliffs and Wasatch Plateau fields have worked out figures that were at least 3 times higher than what was removable in the mines. This is explained at least in part by closely spaced multiple coal seams which also may be a problem here.

Coal Seams

The Emery coal field has seen little development in its 90-year history. Well known area names have not developed and the following are proposed: (1) Muddy Creek area—includes everything north of Ivie Creek, (2) Dog Valley area—includes the area between Ivie Creek and the south side of Willow Spring Wash and (3) Paradise area—involving the south end of the field. In addition coal has been discovered in the Ferron Sandstone in the subsurface near Price, 45 miles to the north, and is designated the Price area.

Lupton (1916), in his comprehensive work of the area, listed 14 coal beds. Thirteen, associated with the Ferron, are lettered A to M from oldest to youngest. The other bed is in the Dakota and is actually a zone. It is useful in the field to group 12 of the beds into 3 zones inasmuch as it is difficult to trace the individual beds along the outcrop. Thus beds A to E fall into a Lower coal zone, beds F and G make up the Middle coal zone and beds H to L are in the Upper coal zone. The M bed always lies within a few feet of the Upper Ferron contact. The zones usually can be recognized easily along the cliffs and canyon walls.

Generalized divisions of the Ferron Sandstone		Feet
M bed zone	Lagoonal facies, slope forming	0 to 25
Upper sandstone	Littoral facies, cliff forming	10 to 150
Upper coal zone	Lagoonal facies, slope forming	15 to 150
Middle coal zone	Lagoonal and littoral, cliff forming	75 to 200
Lower coal zone	Lagoonal facies, slope forming	25 to 115
Lower sandstone	Littoral facies, cliff forming	34 to 400

Muddy Creek Area

The two most important beds of the Muddy Creek area are the C and I beds. The known extent of these beds is shown on figures 13 to 15. Four named mines have opened on the I bed, Upper coal zone: the Browning, Williams, Moore and Cox. The I bed averages 4 to 6 feet in most of the surface exposures except along Quitchupah Creek where it thickens to 20 feet. Although not verified, this thickness is supposed to continue northward for at least 3 miles.

The C bed, Lower coal zone, is thick in all surface exposures except to the northeast along the Molen Reef section of the Coal Cliffs. Drill holes 2 to 3 miles west of the reef intersect thick coal 1 mile west and 2 miles south of Moore. The bed achieves a maximum thickness of 20 feet on the east side of Quitchupah Creek Canyon and thins out south of Ivie Creek. Its extent to the west is unknown. The Casper and Bear Gulch mines, both abandoned, are opened on the C bed.

The F bed, Middle coal zone, is found 4 and 5 feet thick in secs. 30 and 31, T. 22 S., R. 7 E. in small erosional remnants atop the Molen Reef.

Dog Valley Area

The Dog Valley area is characterized by many lenticular coal beds, many of which achieve minable thickness over local areas. The highest noteworthy seam is the M bed. It is thick in one small area on the north wall of Willow Springs Wash. It is here present in an isolated erosional remnant atop the cliff and averages 4 feet thick. The M bed is split by thin partings of shale and bone.

The L bed averages 4 feet thick in a 3-mile, north-south-trending area west of Dog Valley Wash. It is not known how far west the bed continues thick. The I bed is important from Dog Valley Wash eastward to the cliffs. On the west side of the wash the bed ranges to 5.6 feet and is usually split. Along Interstate Highway 70 the bed totals 3 feet thick near the intersection with Dog Valley Wash. About 1,000 feet to the west along I-70, the bed is split by 30 feet of sandstone and each bench is less than 1 foot thick. The I bed averages 8.8 feet between Ivie Creek and Rock canyons. The maximum thickness is 13 feet at the Dog Valley mine.

The F bed of the Middle coal zone is thick near the mouths of Ivie Creek and Dog Valley Wash where it averages 5½ feet. It thins westward and is uninteresting west of the place where I-70 joins Dog Valley Wash.

In the Lower coal zone the C bed is thick only along the north margin of the area. In Ivie Creek the bed has 13.3 feet of coal, but at Dog Valley Wash and I-70 it thins to 4 feet. The A bed is thick throughout most of the area. Only in some of the east-extending promontories along the Coal Cliffs is the bed thin. It thins north of Ivie Creek in the Muddy Creek area. Between Ivie Creek and Willow Spring Wash it averages between 4 and 6 feet thick. From Willow Springs Wash to the south boundary of the area it thickens to a maximum of 14 feet and then thins farther southward. How far this thick coal extends westward is not known.

Paradise Area

Like the Dog Valley area the Paradise area consists of many highly lenticular coal beds which achieve commercial thickness in localized areas. The uppermost M bed is usually present everywhere, but achieves the 4-foot thickness at scattered localities. The bed is usually under shallow cover around Paradise Lake and can be strip-mined easily. The thickness in this local area averages 5.4 feet with a maximum thickness of 10 feet.

In the Upper zone the L bed achieves minable thicknesses. One localized area is in Last Chance Creek Canyon and another surrounds the Hogan Ranch Trail Canyon. The average coal thickness is about 5 feet in these two areas with a maximum thickness of about 9 feet. The drill, in isolated cases, has picked up a thick bed between the L and the A beds. Such beds were ignored in reserve determinations because their areal extent is undefined.

The Lower coal zone is represented by the A bed, which is thick except in an embayment south of Last Chance Creek. To the north it averages 6 feet thick and to the south 7.2 feet. The thickest section is from a drill hole in which 13 feet may have been encountered. The extent of the A bed to the west is not known. A coal bed 12 feet thick is exposed west of the fault zone and the Pacific Natural Gas Well, 8-25S-4E, apparently has encountered 22 feet of coal in two beds. The continuity of these beds will have to be ascertained by future drilling.

Price Area

Katich (1954, p. 46) notes that coal beds were encountered in the Ferron in the drilling of the Clear Creek gas field in the Wasatch Plateau and that a coal bed 7½ feet thick was encountered in the Ferron in a well drilled in NE SE 28-14S-10E near Price. This is about 10 miles east of the nearest outcrops of the Ferron where the formation is barren of coal. The top of the Ferron is about 1,100 feet below the surface at this locality.

Gray, Patalski and Schapiro (1966, p. 81) note an area of coal in the Ferron Sandstone believed a duplicate of the one noted by Katich near Price.

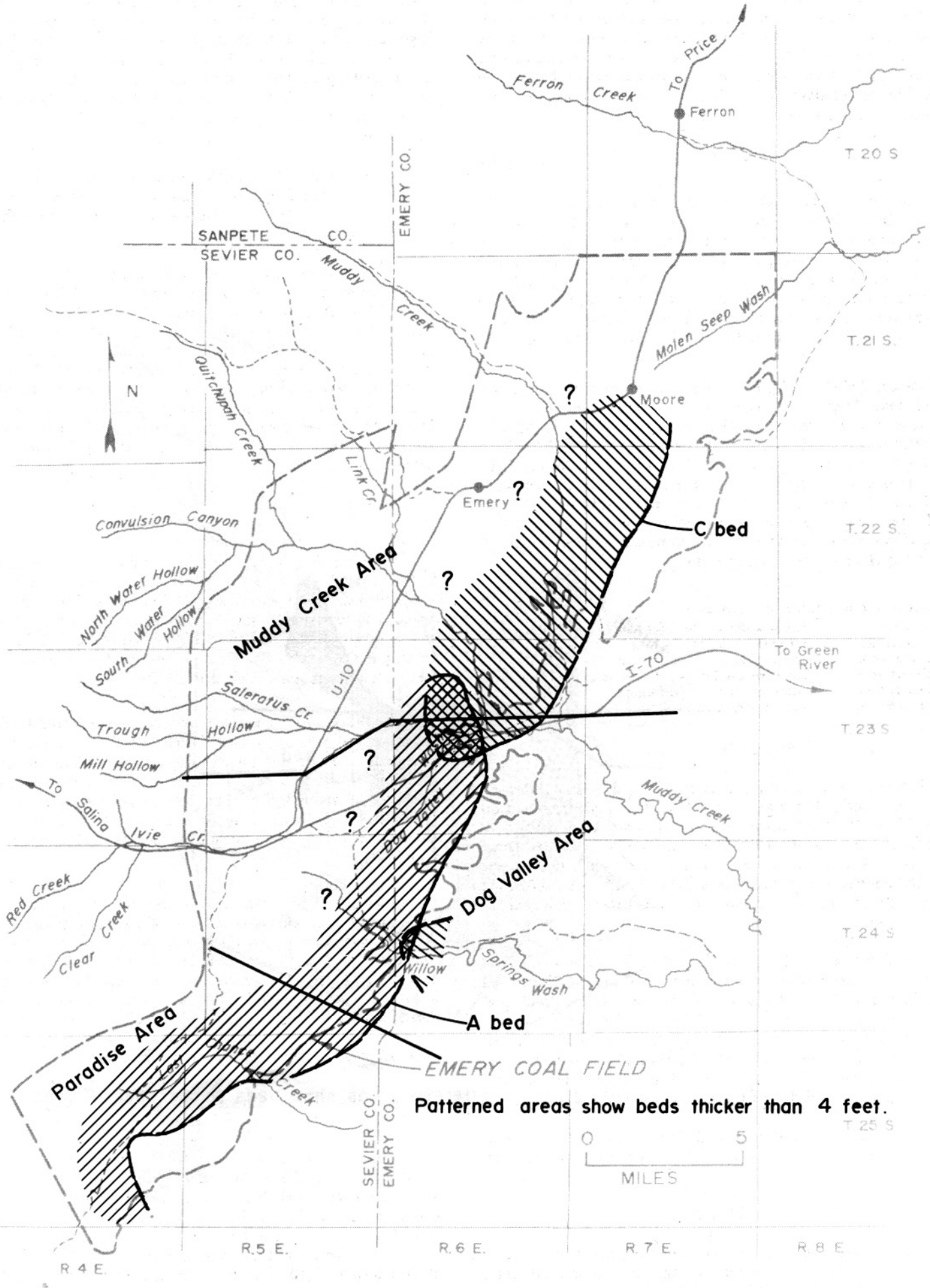


Figure 13. Approximate areas of Lower coal zone development, Emery coal field.

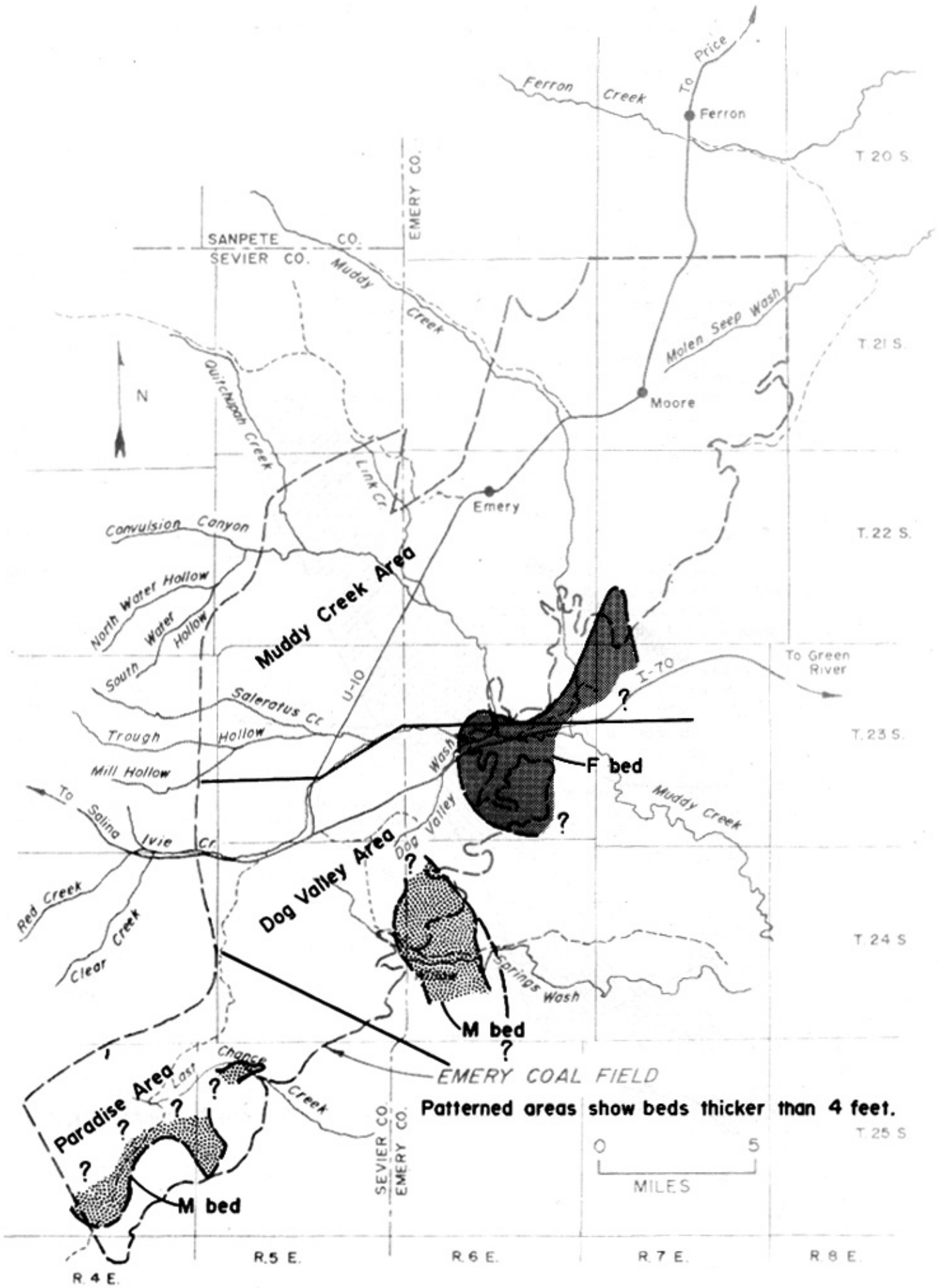


Figure 14. Approximate areas of M bed and Middle coal zone development, Emery coal field.

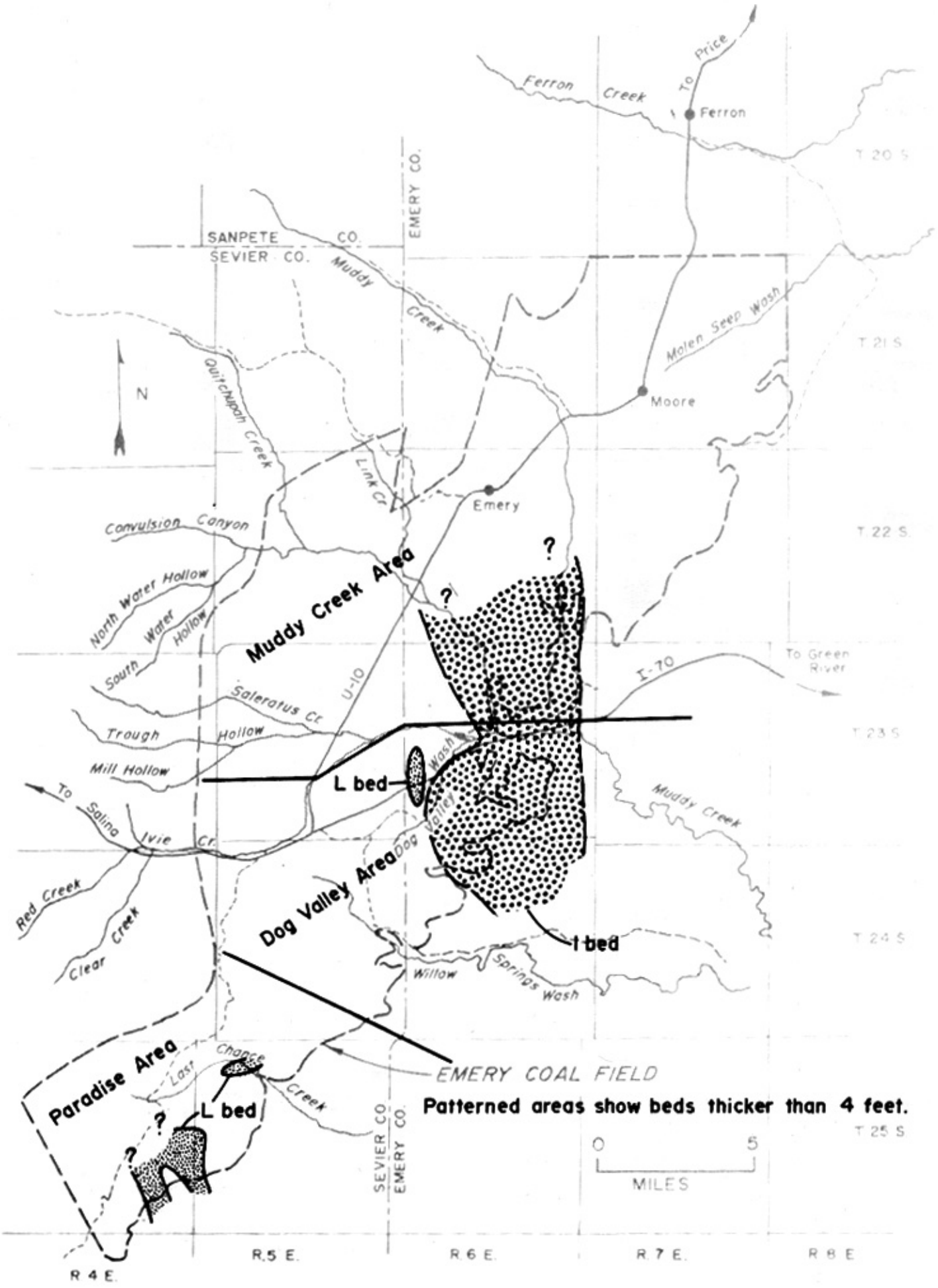


Figure 15. Approximate areas of Upper coal zone development, Emery coal field.

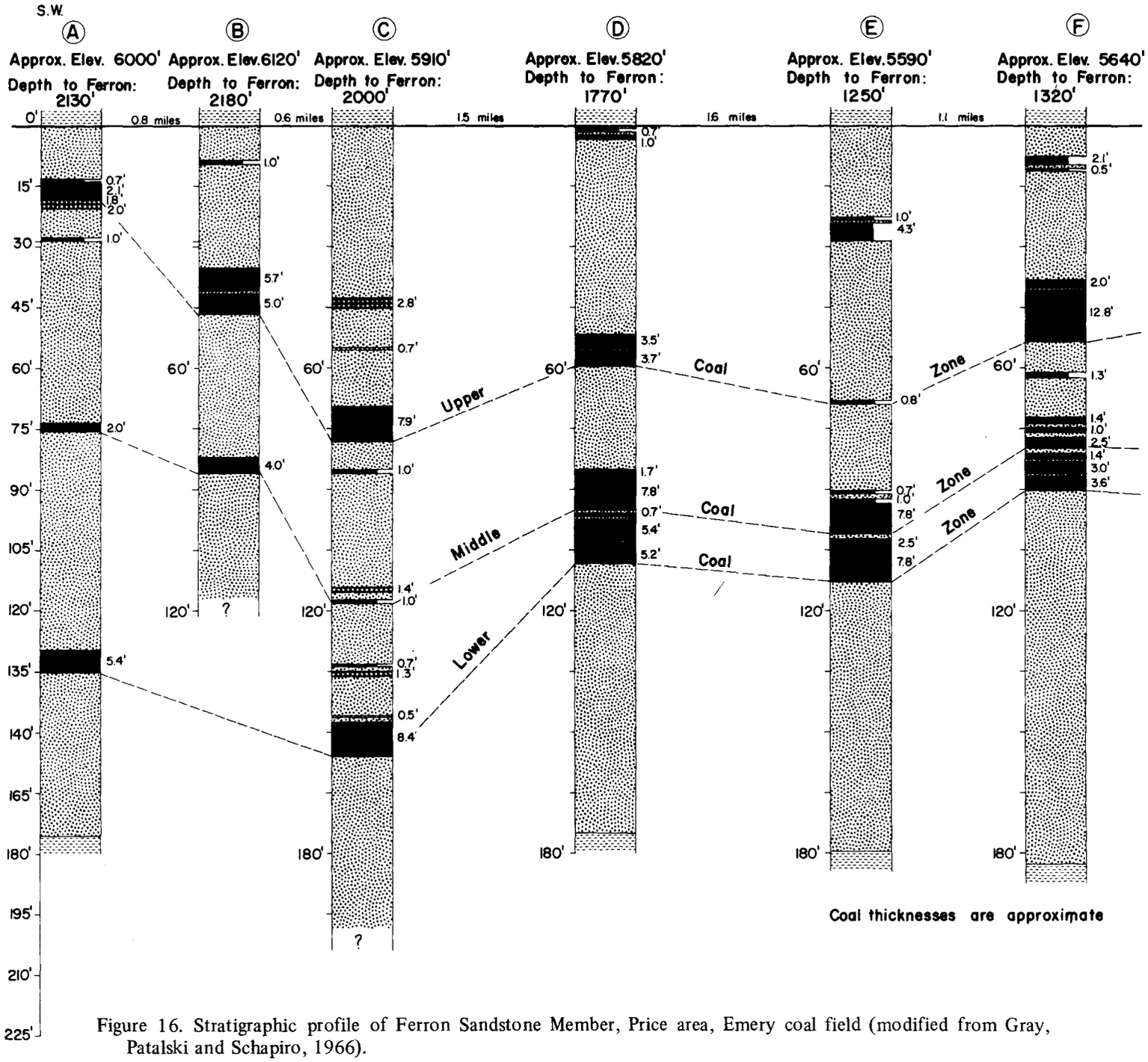


Figure 16. Stratigraphic profile of Ferron Sandstone Member, Price area, Emery coal field (modified from Gray, Patalski and Schapiro, 1966).

The coal deposits in this area are high-volatile A or B in rank and, in general, are of slightly better or equivalent coking quality than the Sunnyside seam high-volatile coal. These coals occur in the Cretaceous system in the Ferron Sandstone Member of the Mancos Shale, and lie in three distinguishable zones, each of which is composed of one or more beds. Most of these beds are inclined or dip from the horizontal in a northerly direction. An exploratory drilling program revealed the thickness and areal extent of coal deposits in this area. However, examination of the drill cores showed that the thickness of the zones and the distance between zones were extremely variable from one hole to another. The variability made it difficult to identify the zones and estimate the potential of the coal deposits in the area.

Depth to the coal, its thickness and some characteristics are indicated in the stratigraphic profile of the Ferron Sandstone Member, Price area diagram (figure 16). The exact locations of the holes are confidential. The area southwest of Price is leased and held for coal by R. A. Lutz and R. J. Hollberg. The question is raised whether other areas under Castle Valley contain thick coal beds even though the surface outcrops 5 to 10 miles west are barren.

WATER RESOURCES

The source of the water is meteoric precipitation that falls on the high areas of the Fish Lake and Wasatch plateaus. That which falls below is meager and quickly consumed by evapotranspiration. In the winter the most effective moisture is snow which slowly melts and percolates into soil and rock. This subsurface water feeds the springs and permanent streams. By far most of the drainage for the plateau area is westward; the source area for drainages to the east gets narrower from north to south. The largest stream in the area, Muddy Creek, has an average flow of about 41 cfs and draws on 89 square miles near Emery. Quitchupah and Ivie creeks are the remaining two permanent streams. No flow figures are available for them, but they drain about 200 square miles collectively. The water carried by these creeks fluctuates greatly from year to year being highly influenced by periods of drought or heavy rainfall. Willow Springs Wash and Last Chance Creek carry copious amounts of water following a summer cloudburst, otherwise the flow is small and in dry years intermittent.

Paradise Lake in the south part of the field is brackish and dries out during years of drought. Small reservoirs have been constructed in the plateau areas for recreational and storage purposes. The headwater basins of the Fremont River, a large south-flowing tributary of the Colorado River, are located 6 to 12 miles east of the south end of the field. The headwaters of Salina Creek, a large west-flowing tributary of the Sevier River, are located 6 to 12 miles east of the central part of the coal field. Certainly adequate water for industrial purposes could be developed in these areas. All surface water rights are appropriated and the right-to-use requires negotiation.

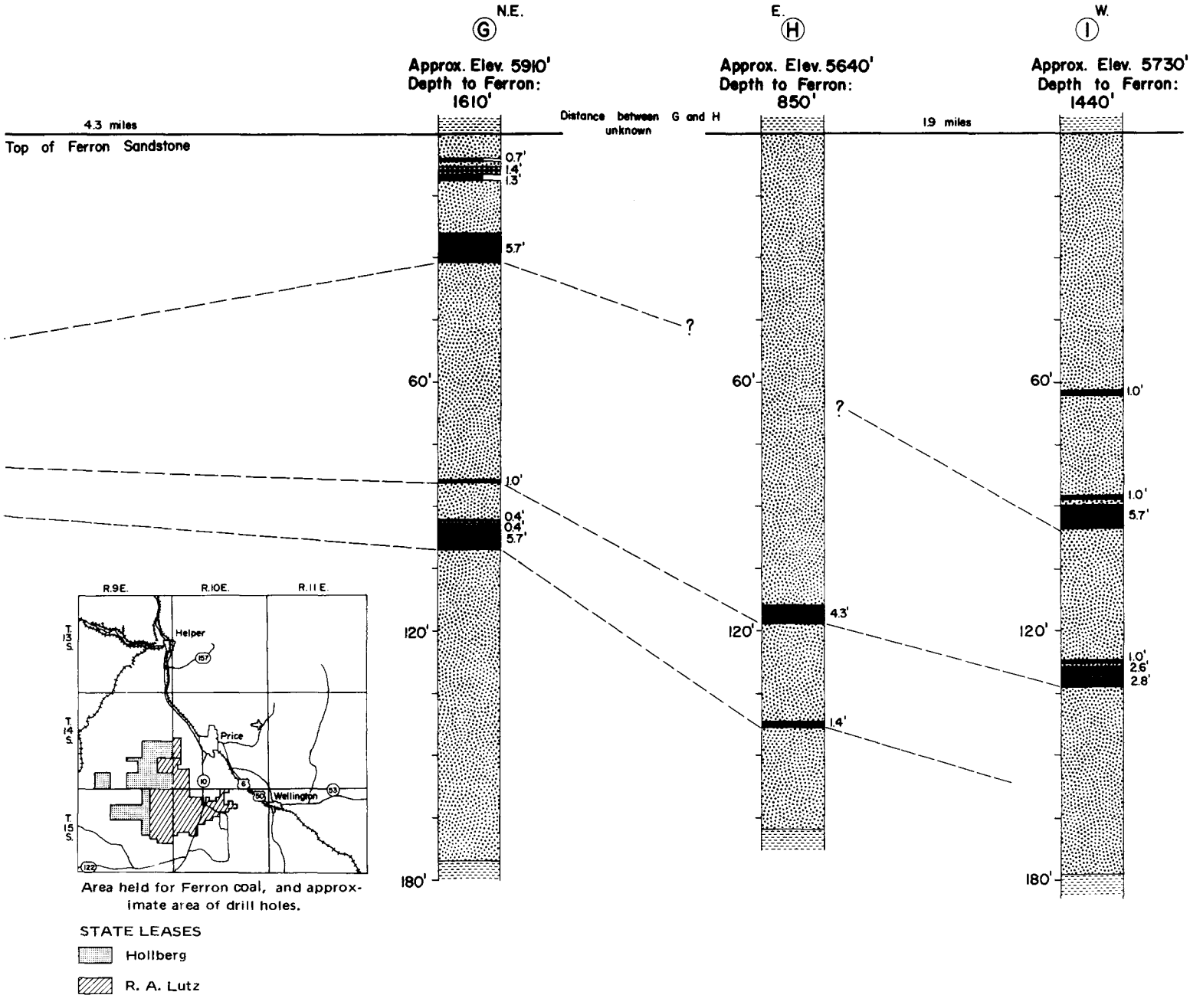


Figure 16. (continued)

ECONOMIC CONSIDERATIONS AND FORECAST

Only two mines have produced a significant amount of coal in the Emery coal field; geologic problems that might be encountered have not been previously discussed. Judging from the surface condition of the coal beds, it appears that multiple coal seams, undulating nature of the coal seam, floors and roofs and splitting will create the greatest problems. In the Browning mine the coal bed is extremely thick and most of the problems are alleviated by leaving a coal floor and roof.

All mining in the past has been underground and most of the future mining must be carried out in this fashion. A small number of limited areas exist where surface mining procedures might be carried out and the coal produced more cheaply. Hileman, Collins and Wilson (1970) worked out a cost analysis for an underground mine in the Wasatch Plateau not far from the Emery coal field producing 2 million tons of coal annually. All the modern safety laws are considered. Their analysis considers coal heights 6 to 12 feet and mines on the plateau that are practically level, nongassy and just wet enough for ideal mining conditions. The estimate includes good tops requiring little timber with roof bolts installed on 4-foot centers. The cost-per-ton in such a mine is calculated to be $3.90 if 2 million tons are produced annually for 15 years. Since 1968 when Hileman, Collins and Wilson made their observations, costs have increased substantially, notably in labor and through new safety regulations.

Under ideal conditions and disregarding inflationary tendencies as the years progress, cost for mining a ton of underground coal in the Emery field will be $5 to $6 per ton.

At present most of the coal is trucked to Price or Salina, a distance of about 50 miles. The two towns are on the railroad and Price lies in the heart of the Wasatch Plateau and Book Cliffs coal fields. Production more than doubled between 1969 and 1970 as the need for good coal increased in other parts of the United States and abroad. Development of the coal is presently consistent with market demands. The traditional markets were central and south Utah which in the last year were supplemented by exports to Japan. Present markets will probably be retained over the next 10 years and only modest increases in production can be expected.

A large increase in production and development of other areas of the field depend on the construction of new coal-fired power plants. If one were built, depending on negotiations between power company officials and prospective coal producers, production might increase tenfold.

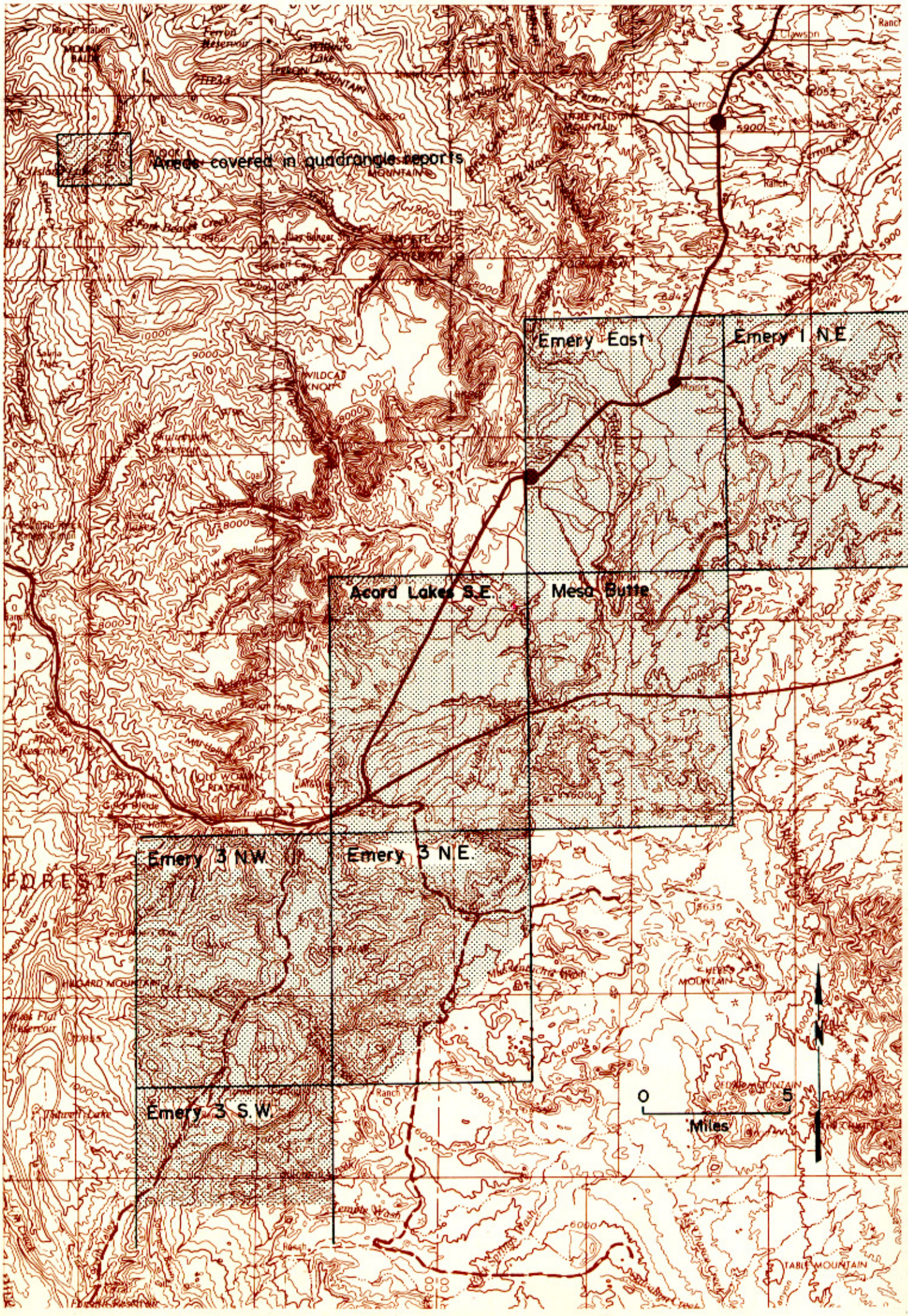


Figure 17. Quadrangle index map, Emery coal field.

QUADRANGLE REPORTS

ACORD LAKES SE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

This quadrangle is central and represents the most productive part of the Emery coal field (figures 17 and 18). The coal seams and the Coal Cliffs are located along the east map margin; the major part of the map area represents Castle Valley. The foothills up to and part of the Wasatch Plateau cliff are in the northwest map corner.

Elevations below the Coal Cliffs range between 5,800 and 6,000 feet; Castle Valley is between 6,000 and 6,900 feet and the top of the Wasatch Plateau is about 8,800 feet. The coal outcrops of the Emery field are found between 6,000 and 6,400 feet.

Two important highways join in the southwest. Interstate Highway 70, constructed partly along Ivie Creek and partly along Dog Valley Wash, joins Green River with Salina. It is basically an east-west route. Utah Highway 10 joins Price with the area and from its intersection with I-70 is principally a north-south route. Graded jeep roads provide access to other parts of the quadrangle from Utah 10. I-70 is a limited access highway and is not useful in the study of coal seams except where road cuts have been made across the beds. The town of Emery is located 3 to 4 miles north of the quadrangle.

STRATIGRAPHY

Consolidated Upper Cretaceous strata and mostly unconsolidated Quaternary deposits make up the surface exposures of the Acord Lakes SE quadrangle. The oldest unit (to the southwest), the Tununk Shale, consists of drab gray marine mudstone and occasional thin sandy layers. It is nonresistant except where protected by an overlying cliffy layer. At Coal Cliffs the Tununk is supported by the Ferron Sandstone and the mudstones stand with near vertical slopes in the lower part of the cliff. The Tununk is an estimated 600 to 700 feet thick.

The Ferron Sandstone contains the important coal seams of the area. Its character is illustrated by the following section measured along I-70 in sec. 20, T. 23 S., R. 6 E.

Blue Gate Shale

Ferron Sandstone	Feet
1. Alternating thin shaley sandstone, gray shale, carbonaceous shale and thin coal seams	15.0
2. Sandstone, yellow-gray to tan, medium-grained, thick-bedded to massive, resistant	35.0
3. Alternating thin shaley sandstone, gray shale, carbonaceous shale, burned red by oxidation of coal seam	30.0
4. Coal	0.5
5. Carbonaceous shale	1.8
6. Gray shale	2.0
7. Alternating shaley sandstone and gray shale	32.0
8. Coal, poorly exposed, may have thin split	3.0
9. Like unit 7	13.0
10. Coal	2.2
11. Gray shale	2.0
12. Coal	1.2
13. Gray shale	4.0
14. Sandstone, like unit 2	30.0
15. Coal	2.5
16. Shale with interbeds of sandstone	15.0
17. Sandstone, yellow-gray, thick-bedded	8.0
18. Gray shale	13.0
19. Sandstone, yellow-gray, medium-bedded	2.5
20. Gray shale	6.0
21. Sandstone, yellow-gray, shaley	6.0
22. Sandstone, like unit 2	35.0
23. Shale and sandstone, nodular weathering	16.0
24. Coal	5.0
25. Gray shale	1.4
26. Coal	1.2
27. Gray shale and carbonaceous shale	1.5
28. Coal	0.5
29. Gray shale and carbonaceous shale	4.0
30. Sandstone, like unit 17	4.0
31. Like unit 29	12.0
32. Sandstone, like unit 19	1.5
33. Gray shale	3.0
34. Sandstone, like unit 17	8.0
35. Carbonaceous shale	1.3
36. Coal	1.5
37. Sandstone, like unit 2	18.0
38. Coal	3.0
39. Gray shale	3.0
40. Bone coal	1.0
41. Gray shale with thin interbeds of carbonaceous shale and sandstone	9.0
42. Sandstone, yellow-gray, massive, forms cliff	48.0
43. Sandstone, yellow-gray, thin- to medium-bedded	8.0
44. Coal	0.8
45. Gray shale alternating with carbonaceous shale and thin coal beds	13.0
46. Sandstone, yellow-gray, medium- to thick-bedded, medium-grained, with minor interbedded gray shale	23.0
Total Ferron Sandstone	447.4

Tununk Shale

The Ferron is 60 percent sandstone and 40 percent gray shale, carbonaceous shale, shaley sandstone and coal. All the beds are lenticular so that correlations within the unit are difficult. The massive sandstones are very resistant and form cliffs and ledges. Behind the Coal Cliffs is a barren rock slope from which the softer shales of the overlying Blue Gate have been eroded.

The Blue Gate appears much like the Tununk Shale except it is not as dark and does not participate in a cliff. The nodular and earthy weathering gray shales often have a yellowish cast as a result of increased sand content. Occasional thin brown beds of sandstone occur as well. Surface deposits of gravel or alluvium often form on it. These surfaces are nearly planar in places or have very gentle slopes. Pure outcrops of the Blue Gate usually occur as rounded hills, the surfaces of which are fluted with closely spaced, finely textured drainages. The Blue Gate, along with the Quaternary unconsolidated deposits that have formed on it, creates the largest outcrop area of the Acord Lakes SE quadrangle. The Blue Gate is cut off by the major fault of the Joes Valley-Paradise fault zone. Within the graben are exposures of Emery Sandstone. On the far side of the zone the upper part of the Blue Gate reappears followed by the Emery. The Blue Gate is estimated to be about 1,600 feet thick.

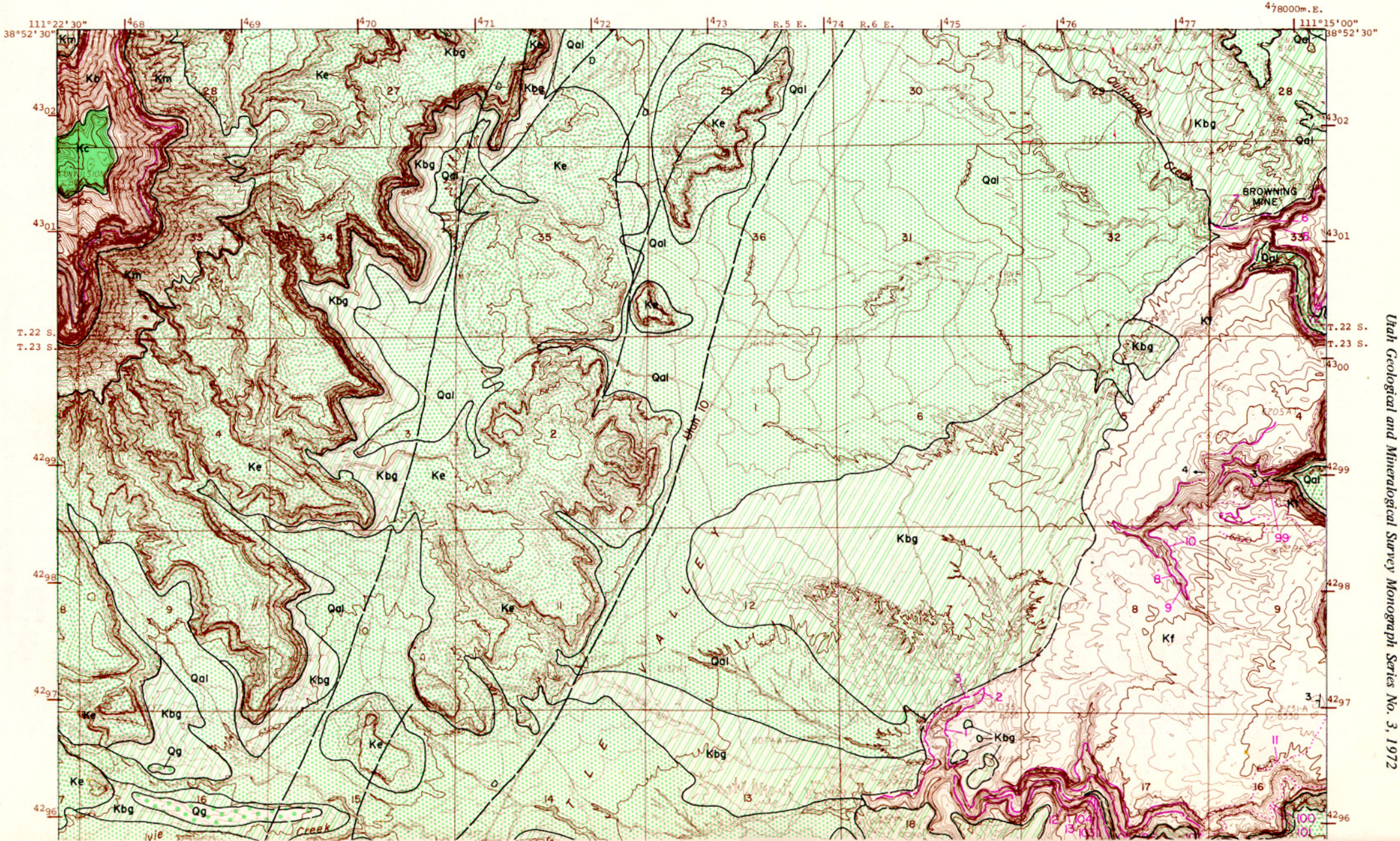
The Emery consists mainly of thick-bedded to massive, cliffy sandstones alternating with much thinner beds of gray shale and shaley sandstone. The outcrops form step-like cliffs and hills below the main Wasatch Plateau cliff. The unit is estimated to be 800 feet thick. The final member of the Mancos Shale is the Masuk Shale. In its outcrop habit it duplicates the Tununk; its upper part also is supported in a cliff by overlying sandstone beds. The Masuk, approximately 700 feet thick, is a little sandier than the Tununk and is not as dark.

Formations of the Mesaverde Group complete the stratigraphic sequence.

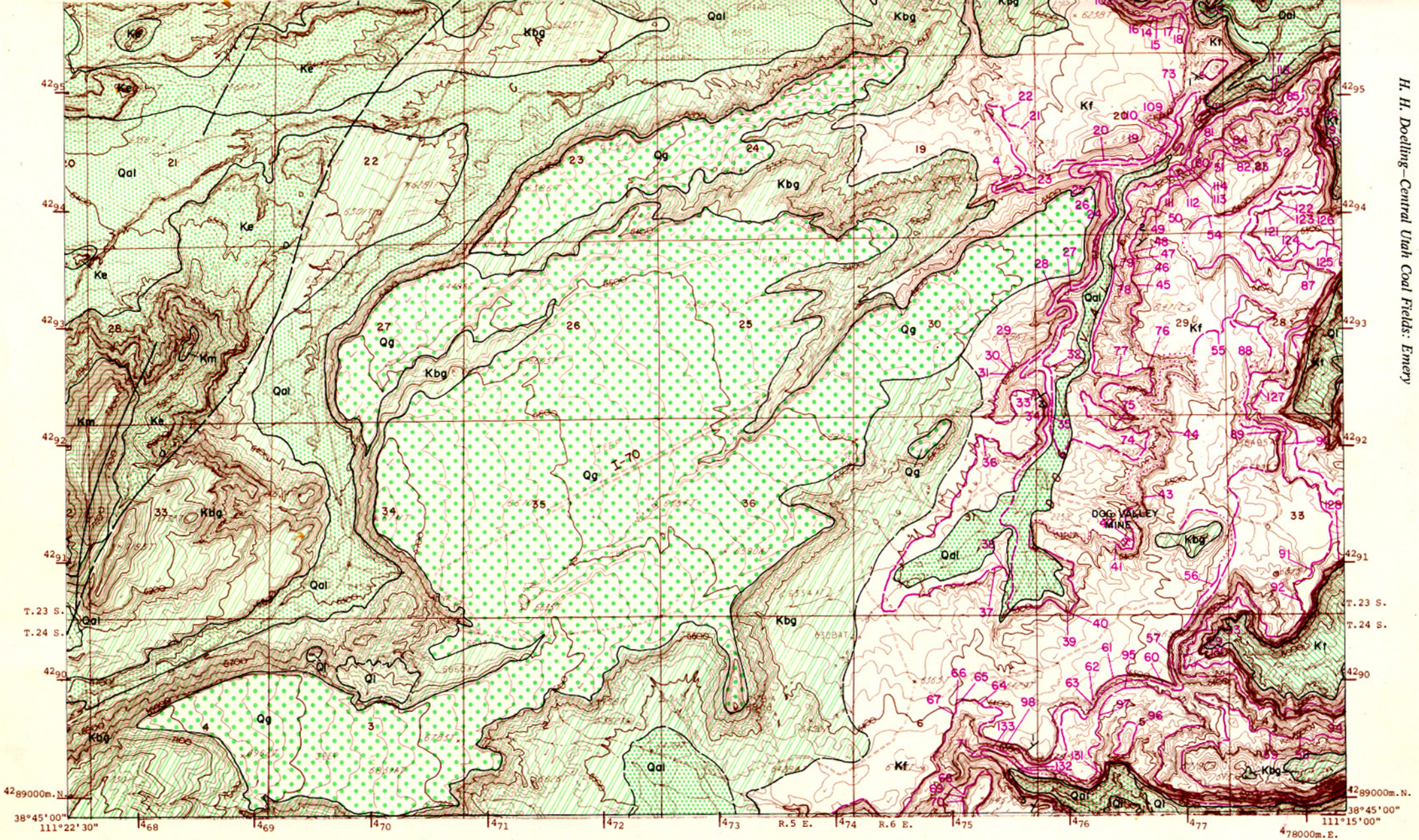
	Approximate thickness (feet)
Castlegate Sandstone	Incomplete
Blackhawk Formation	850
Star Point Sandstone	300

The Star Point and Castlegate sandstones are both cliff formers and the Blackhawk is a heterogeneous unit dominated by cliff formers. The Blackhawk in the lower third contains coal and forms the basis of the Wasatch Plateau coal field.

ACORD LAKES, S.E., UTAH



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972



Topography by U.S. Geological Survey

SCALE: 1:42240

1 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

Contour interval 20 feet

Geology by E. M. Spieker, 1931, USGS, and C. T. Lupton, 1916; coal data by C. T. Lupton, 1916, USGS, and H. H. Doelling, 1970, UGMS.

Figure 18. Coal and geology map, Acord Lakes SE quadrangle (explanation pages 448-449).

EXPLANATION (figures 18, 20, 22, 24, 27, 29 and 31)

Coal bed
Dashed where inferred or poorly exposed, dotted where burned. Thickness of coal in feet measured at triangles. Larger numbers refer to location of measured section shown on accompanying sheets.

32 1.0 Purple

Prospect

Coal mine

Burned zone
Area covered with natural clinker or red-burned sandstone.

Purple

Coal drill hole

Strike and dip of beds

Apparent dip of beds

Syncline
Axis, dashed where approximately located or where ill defined.

Anticline
Axis, dashed where approximately located or where ill defined.

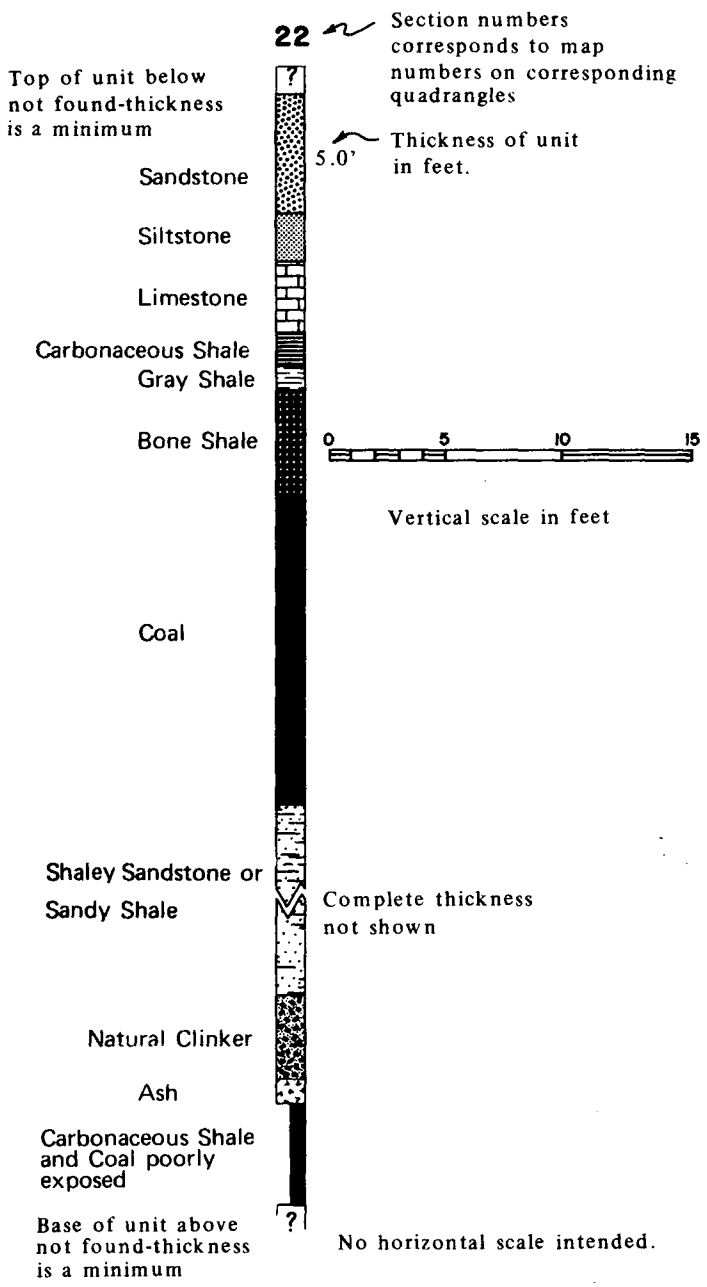
Monocline
Arrow points in direction of dip, dashed where approximately located or where ill defined.

Geologic unit contact
Dashed where location is approximate.

Horizontal strata

Fault
Dashed where inferred or ill defined.

Explanation For Measured Sections



EXPLANATION (continued)

QUATERNARY

Qal — **Alluvium**
Stratified clay, silt, sand, gravel and some unsorted flood deposits.

Ql — **Landslide Deposits**
Mixed rubble and blocks of material slumped from formations at higher elevations.

Qg — **Gravel Deposits**
Partly consolidated poorly sorted and stratified deposits of rock fragments of local origin, pediments or terrace, up to 75 feet thick.

TERTIARY

Tv — **Volcanic Flows**
Bullion Canyon Series, volcanic flows.

TERTIARY
CRETACEOUS

Tw — **North Horn Formation**
Variegated shales with subordinate sandstone, conglomerate and freshwater limestone, thickens to north, slope former. 500-2,500 feet.

Kp — **Price River Formation**
Gray to white gritty sandstone interbedded with subordinate shale and conglomerate, ledge and slope former. 200-1,000 feet.

Kc — **Castlegate Sandstone**
White to gray, coarse-grained often conglomeratic sandstone, cliff former, weathers to shades of brown. 150-500 feet.

Unconformity

Kb — **Blackhawk Formation**
Yellow to gray, fine- to medium-grained sandstone, interbedded with subordinate gray and carbonaceous shale, several thick coal seams basis of Wasatch Plateau coal field. 700-1,000 feet.

Ks — **Star Point Sandstone**
Yellow-gray massive cliff-forming sandstone, often in several tongues separated by Masuk Shale, thickens westward. 90-1,000 feet.

Km — **Masuk Shale**
Yellow to blue-gray sandy shale, slope former, thick in north and central plateau area, thins southward. 300-1,300 feet.

Ke — **Emery Sandstone**
Yellow-gray friable sandstone tongue or tongues, cliff former, may contain coal (?) in south part of plateau if mapping is correct, thickens to west and south. Coal may be present in subsurface to west. 50-800 feet.

Kbg — **Blue Gate Shale**
Pale blue-gray, nodular and irregularly bedded marine mudstone and siltstone with several arenaceous beds, weathers into low rolling hills and badlands, thickens northerly. 1,500-2,400 feet.

Kf — **Ferron Sandstone**
Alternating yellow-gray sandstone, sandy shale, gray shale and carbonaceous shale, several thick coal seams, cliff former. 50-900 feet.

Kt — **Tununk Shale**
Blue-gray to black sandy marine slope forming mudstone. 400-750 feet.

Kd — **Dakota Sandstone**
Variable assemblages of yellow-gray sandstone, conglomerate shale and coal. Beds lenticular and discontinuous. 15-75 feet.

Unconformity

Kcm — **Cedar Mountain Formation**
Light lavender and gray shales with subordinate conglomerate and shale. 230-300 feet.

Unconformity

JURASSIC

Jm — **Morrison Formation**
Varicolored mudstone, sandstone and conglomerate, forms slopes and conglomerate portions contain large amounts of agate and jasper. 150-415 feet.

Unconformity

Js — **Summerville Formation**
Brown to reddish brown siltstone and sandstone, thin-bedded, semiresistant. 260-275 feet.

Jcu — **Curtis Formation**
Tan-gray to greenish gray sandstone, siltstone and occasional conglomerate, cliffy and softer units, occasionally glauconitic. 180-240 feet.

Unconformity

Je — **Entrada Sandstone**
Reddish brown sandstone, fine-grained and silty, partly earth weathering and partly smooth weathering, thin-bedded to massive, weathers into cliffs and monuments. 800± feet.

Jc — **Carmel Formation**
Varicolored shale, sandstone, siltstone, limestone and gypsum, limestone more prevalent in lower half and more resistant than other beds. 800± feet.

Unconformity

Jn — **Navajo Sandstone**
Orange and yellow sandstone, medium-grained cross-bedded and massive, resistant, but weathers into picturesque buttes, knolls, and deep gorges. 500± feet.

Ju — **Jurassic Undifferentiated**
Dakota, Cedar Mountain, Morrison, Summerville and Curtis formations undifferentiated.

The gravel-capped terraces that have formed atop the Blue Gate merit additional attention because of their economic value. Lupton (1916, p. 38) describes these:

> The most conspicuous gravel-capped terraces in the entire field occur directly south of Ivie Creek in T. 23 S., R. 5 and 6 E., and T. 24 S., R. 5 E...The material composing the greater part of the gravels which cap the terraces consists principally of subangular to rounded fragments of basalt, the largest of which are 4 or 5 feet in diameter. They are derived from the extensive masses of this rock in the vicinity of Mount Hilgard and Mount Alice and to the southwest. In places as much as 20 feet of this material rests unconformably on the Mancos Shale.

Lupton leaves the impression that the clastics are dominantly volcanic in origin. Sedimentary clastics such as quartzites, chert and limestone also are present in large quantities. This gravel was used in the construction of Interstate Highway 70.

STRUCTURE

The strike of the Ferron coal-bearing beds is north to northeasterly and the dip is 2 to 4 degrees to the west. No faults of consequence exist except along the Joes Valley-Paradise fault zone. Between the bounding faults of the zone the strata have dropped graben fashion. The width of the zone varies between ½ and 1½ miles. On the west side of the zone the sequence continues as if the fault were not there; there seems to be little displacement across the zone. The actual displacement of the faults is difficult to determine, but some have moved at least several hundred feet.

PROPERTY CONTROL

The only lands not underlain with coal in the Acord Lakes SE quadrangle are at the base of the Coal Cliffs along the east map margin. The coal of the Emery field lies at depths less than 3,000 feet over most of the quadrangle and only in the northwest corner is it buried at greater depth. About 95.5 percent of the map area can be considered part of the Emery coal field. A small acreage of Wasatch Plateau coal occurs in the northwest map corner.

Ownership of land is as follows: Bureau of Land Management 75.2 percent, private property 17.3 percent, state of Utah 7.2 percent and National Forest 0.3 percent.

The land below the Coal Cliffs is controlled by the BLM and the land in the northwest map corner is controlled by the National Forest Service.

More than 75 percent of the available coal land of the quadrangle are held for coal; almost all the area between the Coal Cliffs and Utah Highway 10 is held, as are several scattered parcels west of the highway. Consolidation Coal Co. dominates the area. Locations of lands by holders are shown on figure 12. The names of companies and persons who hold the land are listed below (January 1, 1970).

Name	Type of Claim
T. Addley	Private land
I. Browning	Private land
R. Albrechtsen	Permit applications
Consolidation Coal Co.	Federal leases, state leases and private land
R. J. Hollberg	State leases
D. Hunter	Permit applications
Ivie Creek Coal Co.	Private land
Sun Valley Coal Co.	Private land
Unassigned	Private land

COAL

Surface Information

All the coal beds of Lupton (1916, p. 43) are represented and sections measured by him and others are shown as divided in this report (M, Upper, Middle and Lower coal zones) and also by his designations (beds A to M; figure 19). Although the coal outcrop of the Wasatch Plateau coal field is shown, no representative sections exist (northwest map corner).

The M bed, the uppermost in the Ferron Sandstone, is usually in the upper 10 feet of the unit. Four sections were measured, all located in the central part of the map along Ivie Creek. Location 2 shows 5 feet of coal split in two places. At the other locations it thins and the bed is not considered important.

The Upper zone consists of locations 5 to 71 and H, I, J, K and L beds. Bed L is thin at all locations except in secs. 19, 30 and 31, T. 23 S., R. 6 E. It thickens westerly along Interstate Highway 70 before it V's out. The thickest beds are 4 feet and the area probably represents a local thickening. Beds K and J, when present, are thin. Bed I is the important seam of the Upper zone. It is thick in all sections east and south of Dog Valley Wash, noticeably thin along Ivie Creek and thick in sections north of Ivie Creek. The thickest location is 20 feet of clear coal at the Browning mine; immediately south of the Browning mine the bed averages 5.4 feet. In the Dog Valley area it averages 8.8 feet, but the coal is usually split. An exception is the Dog Valley mine where 13 feet of clean coal occur. Locations east of the mine are few, but there is an indication that it thins. The H bed is less than 4 feet thick at all locations.

The F and G beds comprise the Middle zone; the G bed is thin wherever sections have been located. The F bed thickens along the south side of Dog Valley Wash. To the immediate north it is burned and it thins rapidly to the south. The thickest location shows 12 feet of coal with the average 5½ feet.

The Lower coal zone consists of beds A to E. No locations were determined with D and E coal. Locations 99 to 133 are on beds A, B and C. Bed C seems to be thick everywhere in the northeast map area. Only four locations were measured but the outcrop is usually burned. Bed B is undeveloped and total coal up to 7 feet thick has been found in Bed A. All of the thicker A sections are south of Ivie Creek where the average thickness is 5 feet.

Subsurface Information

Consolidation Coal Co. drilled several holes to determine the condition of coal beds behind the outcrop. The results of these drillings are currently confidential. Surface data indicate that all seams are very lenticular so that any projection westward is hazardous.

Average depth and estimated thickness of the Blue Gate place the 1,000-foot coverline somewhat east of the east-flanking fault of the Joes Valley-Paradise fault zone. The 2,000-foot coverline occurs along the Emery Sandstone outcrops and the 3,000-foot limit is in the Masuk Shale.

Quality of Coal

Of the thirty analyses available for Ferron coal in the Acord Lakes SE quadrangle (table 6), most are from the Browning and Sun Valley (Dog Valley) mines. The average proximate analyses are given in table 7 (page 456).

This group of analyses is the only diagnostic set in the Emery field for the area. As it appears, sulfur and ash vary locally dependent upon the degree of splitting of the seam. Walker and Hartner (1966, p. 37) analyzed sulfur content from the Browning mine, I bed, with total sulfur of 0.56 percent: 0.01 percent sulfate, 0.12 percent pyritic and 0.43 percent organic sulfur.

Gomez, Landers and Boyd (1967, p. 12) calculated carbonization product yields for the Browning and Sun Valley (Dog Valley) mines coal (table 8, page 456).

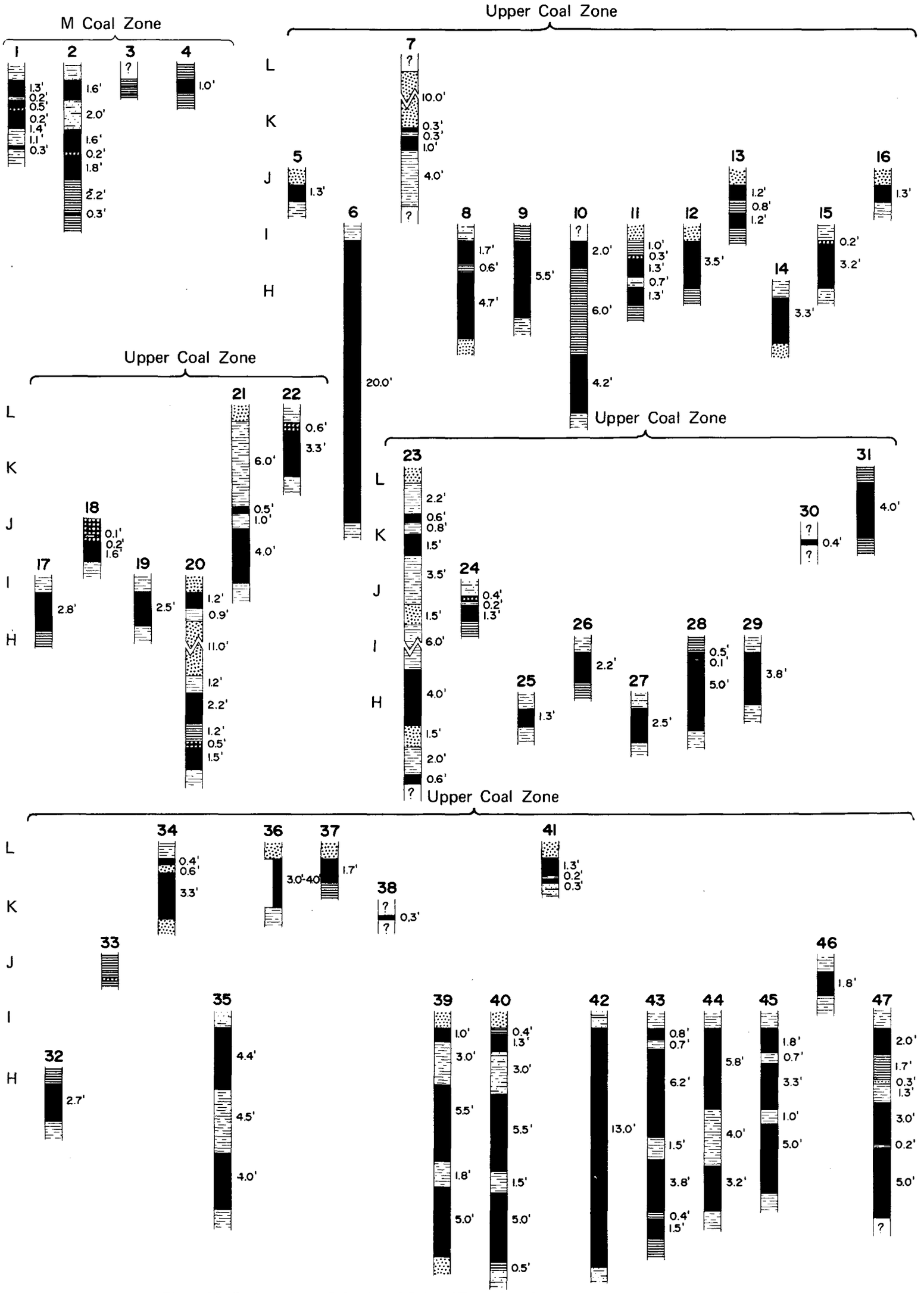


Figure 19. Coal sections of the Acord Lakes SE quadrangle (vertical scale: 1 inch = 8 feet).

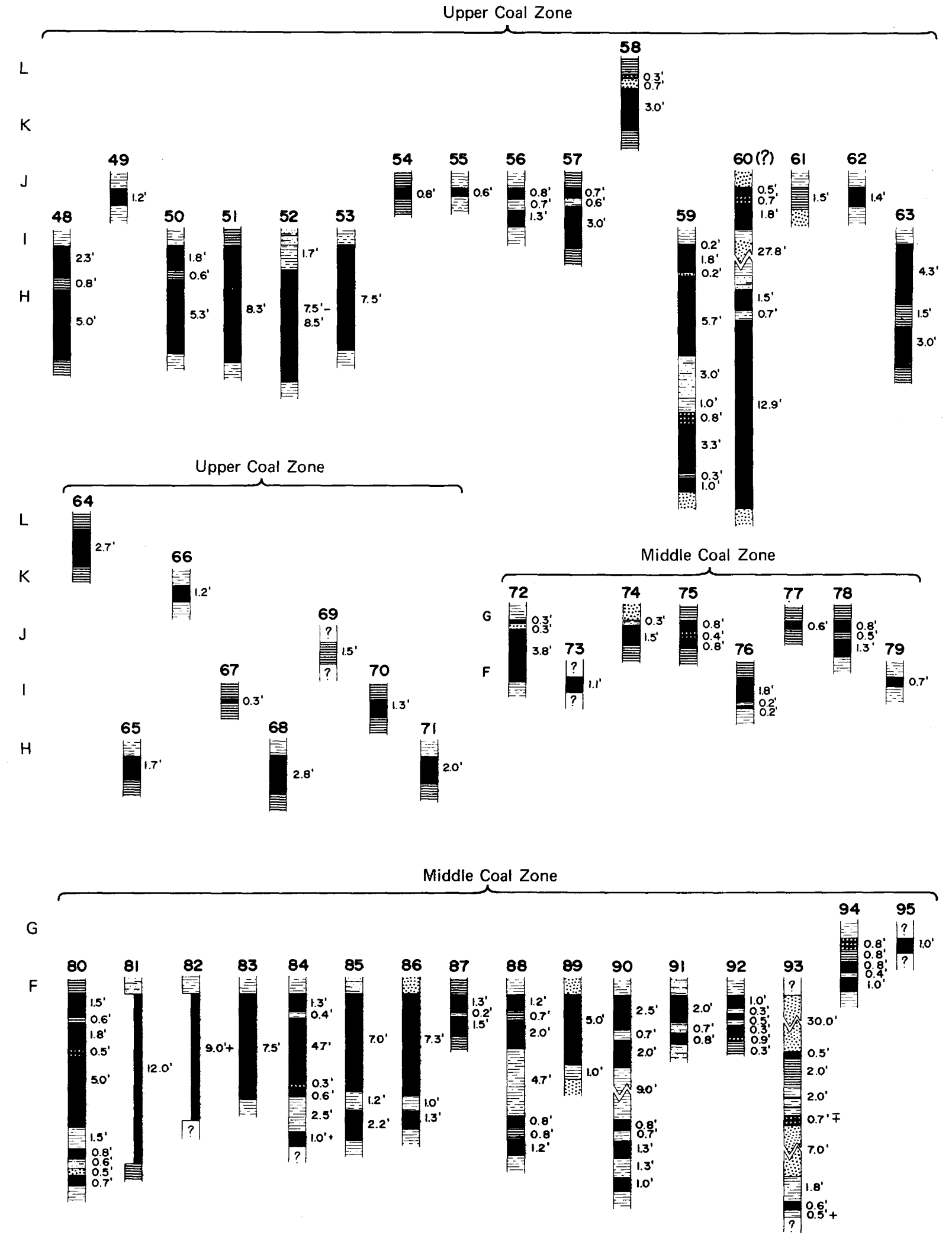


Figure 19. (continued)

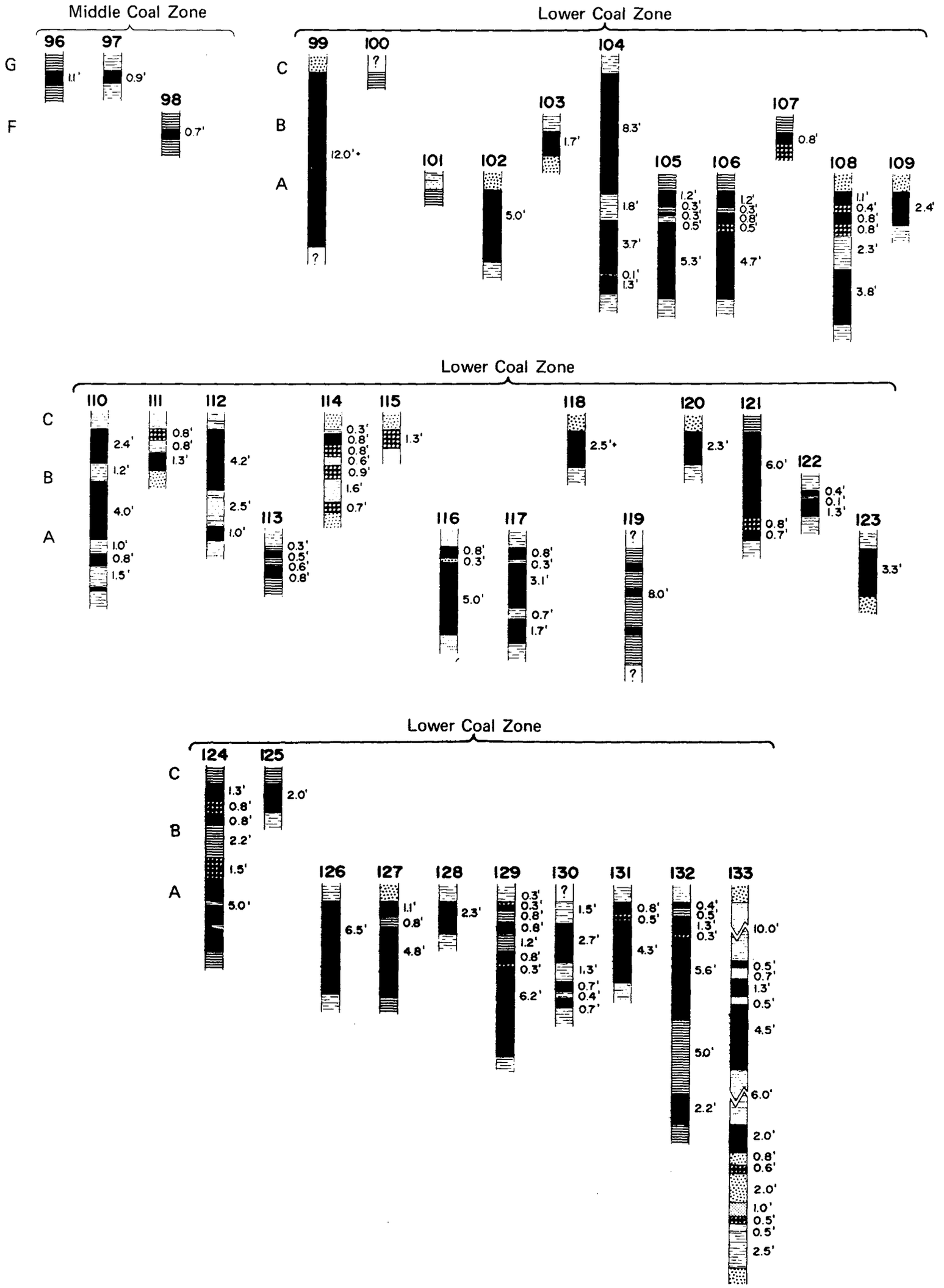


Figure 19. (continued)

Table 6. Quality coal data, Emery coal field.

No.	Mine or Prospect-Coal bed	Township & Range UTM grid		PROXIMATE ANALYSES					ULTIMATE ANALYSES						OTHER TESTS			Kind of Samples	Ref. Source
				AN	M	VM	FC	Ash	S	H	C	N	O	Btu/lb	AST	ADL	HGI		
			ACORD LAKES SE QUADRANGLE																
1	Browning mine Upper coal zone I bed	SE.NW.33-22S-6E 4301215mN 477440mE	A B C D	3.9 3.6 – –	40.9 41.0 42.6 45.4	49.3 49.4 51.2 54.6	5.9 5.95 6.2 –	.4 .39 .4 .4	5.5 5.51 5.3 5.6	73.0 73.24 76.0 81.0	1.3 1.26 1.3 1.4	13.9 13.66 10.8 11.6	12,970 13,000 13,500 14,380	2,100 – – –	.3 – – –	– – – –		20
2	Browning mine Upper coal zone I bed		A	4.8	–	–	6.2	.56	–	–	–	–	–	–	–	–		49
3	Browning mine Upper coal zone I bed		A C	4.1 –	39.0 40.7	48.5 50.6	8.3 8.7	0.96 1.0	–	–	–	–	12,590 13,130	–	–	–	T	4
4	Browning mine Upper coal zone I bed		A C	4.1 –	38.8 40.5	49.1 51.2	8.0 8.3	0.77 0.8	–	–	–	–	12,730 13,280	–	–	–	T	4
5	Browning mine Upper coal zone I bed		A C	6.4 –	39.7 42.4	46.9 50.1	7.0 7.5	0.75 0.8	–	–	–	–	12,470 13,310	–	–	–	T	4
6	Browning mine Upper coal zone I bed		A C	3.9 –	39.6 41.2	48.8 50.8	7.7 8.0	0.58 0.6	–	–	–	–	12,820 13,340	–	–	–	T	5
7	Browning mine Upper coal zone I bed		A C	3.7 –	40.0 41.5	48.7 50.6	7.6 7.9	0.48 0.5	–	–	–	–	12,800 13,300	–	–	–	T	5
8	Browning mine Upper coal zone I bed		A C	6.1 –	39.8 42.4	46.6 49.6	7.5 8.0	0.56 0.6	–	–	–	–	12,520 13,330	–	–	40 –	T	5
9	Browning mine Upper coal zone I bed		A C	4.5 –	39.8 41.7	49.3 51.6	6.4 6.7	0.76 0.8	4.9 5.1	70.9 74.2	1.2 1.3	11.4 11.9	12,880 13,480	–	–	–	T	6
10	Browning mine Upper coal zone I bed		A C	4.0 –	38.9 40.5	49.2 51.3	7.9 8.2	0.77 0.8	–	–	–	–	12,730 13,270	–	–	–	T	6
11	Browning mine Upper coal zone I bed		A C	4.4 –	38.9 40.7	49.9 52.2	6.8 7.1	0.48 0.50	–	–	–	–	12,960 13,550	–	–	–	T	6
12	Browning mine Upper coal zone I bed		A C	6.1 –	39.5 42.1	47.6 50.7	6.8 7.2	0.47 0.5	–	–	–	–	12,540 13,360	–	–	–	T	6
13	Browning mine Upper coal zone I bed		A C	3.8 –	39.6 41.2	49.4 51.4	7.1 7.4	0.77 0.8	–	–	–	–	12,860 13,370	–	–	–	T	6
14	Browning mine Upper coal zone I bed		A C	3.8 –	38.4 39.9	48.6 50.5	9.2 9.6	2.31 2.40	–	–	–	–	12,500 13,000	–	–	–	T	8
15	Browning mine Upper coal zone I bed		A C	3.9 –	39.9 41.5	48.0 49.9	8.3 8.6	1.35 1.4	–	–	–	–	12,730 13,240	–	–	–	T	8
16	Browning mine Upper coal zone I bed		A C	4.0 –	39.3 40.9	49.3 51.4	7.4 7.7	1.06 1.10	–	–	–	–	12,780 13,320	–	–	–	T	8
17	Browning mine Upper coal zone I bed		A C	3.8 –	40.1 41.7	49.1 51.0	7.0 7.3	0.96 1.00	–	–	–	–	12,850 13,370	–	–	–	T	8
18	Browning mine Upper coal zone I bed		A C	5.0 –	39.4 41.5	48.3 50.8	7.3 7.7	0.86 0.9	–	–	–	–	12,560 13,210	–	–	–	T	8
19	Browning mine Upper coal zone I bed		A C	4.2 –	39.4 41.1	48.6 50.7	7.9 8.2	1.34 1.4	–	–	–	–	12,820 13,380	–	–	–		9
20	Browning mine Upper coal zone I bed		A B C	4.53 1.1 –	38.6 40.0 40.5	45.98 47.6 48.2	10.87 11.3 11.4	– – –	– – –	– – –	– – –	– – –	11,929 12,360 12,495	– – –	– – –	– – –		50
21	Outcrop Upper coal zone I bed	NE.SW.32-23S-6E 4291075mN 476175mE	A B C D	16.7 8.9 – –	34.3 37.5 41.2 45.0	41.9 45.8 50.3 55.0	7.1 7.8 8.5 –	1.12 1.22 1.34 1.46	– – – –	– – – –	– – – –	– – – –	9,500 10,380 11,400 12,460	– – – –	8.5 – – –	– – – –		3
22	Prospect Upper coal zone I bed	SW.SW.32-23S-6E 4290570mN 475950mE	A C	4.5 –	36.4 38.1	51.9 54.4	7.2 7.5	1.10 1.15	–	–	–	–	11,575 12,120	–	–	–		3
23	Sun Valley mine Upper coal zone I bed	NE.SW.32-23S-6E 4291215mN 476500mE	A C	6.6 –	40.0 42.8	46.5 49.4	7.3 7.8	1.68 1.8	4.8 5.1	68.2 73.0	1.3 1.4	10.2 10.9	12,150 13,010	–	–	45 –		5

Table 6. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES AN	M	VM	FC	Ash	ULTIMATE ANALYSES S	H	C	N	O	Btu/lb	OTHER TESTS AST	ADL	HGI	Kind of Samples	Ref. Source
24	Sun Valley mine Upper coal zone I bed		A C	7.4 –	38.1 41.1	47.3 51.2	7.1 7.7	0.56 0.6	– –	– –	– –	– –	12,110 13,080	– –	– –	– –	T	6
25	Sun Valley mine Upper coal zone I bed		A C	7.7 –	37.7 40.8	46.7 50.6	7.9 8.6	0.55 0.6	– –	– –	– –	– –	11,940 12,930	– –	– –	45 –	T	6
26	Sun Valley mine Upper coal zone I bed		A C	8.4 –	36.8 40.2	43.9 47.9	10.9 11.9	0.64 0.7	– –	– –	– –	– –	11,250 12,280	– –	– –	– –	T	6
27	Sun Valley mine Upper coal zone I bed		A C	7.6 –	36.0 39.0	46.6 50.4	9.8 10.6	0.55 0.6	– –	– –	– –	– –	11,600 12,560	– –	– –	– –		7
28	Sun Valley mine Upper coal zone I bed		A C	8.3 –	39.2 42.8	46.7 50.9	5.8 6.3	0.46 0.5	– –	– –	– –	– –	12,180 13,290	– –	– –	– –		8
29	Sun Valley mine Upper coal zone I bed		A C	7.5 –	38.2 41.3	44.2 47.8	10.1 10.9	0.83 0.9	– –	– –	– –	– –	11,650 12,590	– –	– –	– –		9
30	Sun Valley mine Upper coal zone I bed		A C	4.4 –	41.1 43.0	37.3 39.0	17.2 18.0	0.36 0.38	– –	– –	– –	– –	12,342 12,910	– –	– –	– –		3
	EMERY EAST QUADRANGLE																	
1	Casper mine Lower coal zone C bed	SE.NW.26-22S-6E 4302290mN 482707mE	A C	2.3 –	33.4 34.2	40.7 41.6	23.6 24.2	0.66 0.68	– –	– –	– –	– –	9,965 10,200	– –	– –	– –		3
2	Casper mine Lower coal zone C bed		A B C D	5.2 3.4 – –	39.1 39.8 41.2 48.4	41.6 42.4 43.9 51.6	14.1 14.4 14.9 –	.81 .82 .85 1.00	– – – –	– – – –	– – – –	– – – –	11,270 11,480 11,800 13,980	– – – –	1.8 – – –	– – – –		44
3	Casper mine Lower coal zone C bed		A B C D	16.7 8.9 – –	34.3 37.5 41.2 45.0	41.9 45.8 50.3 55.0	7.1 7.8 8.5 –	1.1 1.2 1.3 1.5	– – – –	– – – –	– – – –	– – – –	9,500 10,380 11,400 12,460	– – – –	– – – –	– – – –		34
4	Williams mine Upper coal zone I bed	NE.SW.12-22S-6E 4306540mN 483860mE	A B C D	4.0 3.1 – –	41.8 42.2 43.5 49.5	42.6 43.0 44.4 50.5	11.6 11.7 12.1 –	4.66 4.70 4.85 5.52	– – – –	– – – –	– – – –	– – – –	11,990 12,100 12,480 14,200	– – – –	.9 – – –	– – – –		44
	EMERY 3 NE QUADRANGLE																	
1	Outcrop Lower coal zone-A	NW.26-24S-5E 4284000mN 470390mE	A C	10.1 –	33.4 37.2	40.5 45.0	16.0 17.8	.33 .37	– –	– –	– –	– –	8,612 9,580	– –	– –	– –		3
2	Outcrop Lower coal zone-A	SE.7-24S-6E 4287950mN 474390mE	A C	10.6 –	32.9 36.8	41.6 46.5	14.9 16.7	.37 .41	– –	– –	– –	– –	8,305 9,290	– –	– –	– –		3
3	Prospect Lower coal zone-A	SE.NE.26-24S-5E 4283910mN 471390mE	A C D	18.41 – –	33.86 41.50 44.54	42.16 51.67 55.46	5.57 6.83 –	.41 .50 .54	– – –	– – –	– – –	– – –	9,486 11,626 12,478	– – –	11.6 – –	– – –		20
	EMERY 3 NW QUADRANGLE																	
1	Outcrop	NW.9-25S-5E 4278500mN 467290mE	A C	11.9 –	36.4 41.3	42.7 48.5	9.0 10.2	0.53 0.60	– –	– –	– –	– –	– 9,830	– –	– –	– –		3
2	Emery prospect Ivie bed	10-24S-4E 4287720mN 469759mE	A C	12.9 –	37.2 42.7	43.9 50.4	6.0 6.9	.6 .7	– –	– –	– –	– –	10,600 12,170	2,240 –	5.6 –	– –		21
3	Emery prospect Ivie bed	3-24S-4E?	A B C D	13.9 7.63 – –	35.2 37.72 40.8 44.62	43.6 46.82 50.7 55.38	7.3 7.83 8.5 –	.6 .66 .7 .79	– – – –	– – – –	– – – –	– – – –	10,540 11,300 12,240 13,367	2,340 – – –	6.7 – – –	– – – –		21
	EMERY 3 SW QUADRANGLE																	
1	Willow Basin mine Ferron bed	SW.NW.3-26S-4E 4270200mN 459410mE	A C D	23.57 – –	32.61 42.67 49.52	33.25 43.50 50.48	10.57 13.83 –	2.88 3.77 4.38	– – –	– – –	– – –	– – –	7,823 10,235 11,878	– – –	17.0 – –	– – –		20
2	Drill hole "M" bed	19-25S-5E 4274290mN 464150mE	A C	10.2 –	36.2 40.3	37.6 41.9	16.0 17.8	0.85 0.95	– –	– –	– –	– –	9,526 10,608	– –	– –	– –		24
3	Drill hole upper zone	24-25S-4E 4274400mN 463080mE	A C	12.3 –	37.9 43.2	42.8 48.8	7.0 8.0	1.51 1.72	– –	– –	– –	– –	10,650 12,138	– –	– –	– –		24
4	Drill hole Upper zone	24-25S-4E 4274490mN 463040mE	A C	12.5 –	35.1 40.1	40.2 46.0	12.2 13.9	1.90 2.17	– –	– –	– –	– –	9,813 11,216	– –	– –	– –		24

Table 6. (continued)

No.	Mine or Prospect-Coal bed	Township & Range UTM grid	PROXIMATE ANALYSES					ULTIMATE ANALYSES					Btu/lb	OTHER TESTS			Kind of Samples	Ref. Source
			AN	M	VM	FC	Ash	S	H	C	N	O		AST	ADL	HGI		
								MESA BUTTE QUADRANGLE										
1	Emery mine "I" bed Upper zone	SW.NW.2-23S-6E 4299300mN 480890mE	A	5.19	43.89	46.91	4.01	.31	–	–	–	–	–	–	2.3	–		47
			C	–	46.29	49.48	4.23	.33	–	–	–	–	–	–	–	–		
			D	–	48.34	51.66	–	.34	–	–	–	–	–	–	–	–		
2	Emery mine		A	5.11	36.71	50.42	7.76	2.06	–	–	–	–	–	–	.8	–		35
			C	–	38.69	53.13	8.18	2.17	–	–	–	–	–	–	–	–		
			D	–	42.14	57.86	–	2.36	–	–	–	–	–	–	–	–		
3	Outcrop "I" bed Upper zone	SE.SW.2-23S-6E 4298315mN 481380mE	A	7.0	36.6	51.0	5.4	.66	–	–	–	–	11,532	–	–	–		3
			C	–	39.4	54.8	5.8	.71	–	–	–	–	12,400	–	–	–		
4	Outcrop "I" bed Upper zone	NE.NW.11-23S-6E 4298565mN 481325mE	A	11.8	37.7	45.2	5.3	.99	–	–	–	–	8,467	–	–	–		3
			C	–	42.7	51.3	6.0	1.12	–	–	–	–	9,600	–	–	–		
5	Outcrop Lower zone	NW.SE.3-23S-6E 4298975mN 479815mE	A	10.7	35.6	46.2	7.5	.40	–	–	–	–	9,707	–	–	–		3
			C	–	39.9	51.7	8.4	.45	–	–	–	–	10,870	–	–	–		

Table 7. Average proximate analyses of coal, Acord Lakes SE quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	30	5.6	3.7 -16.7
Volatile matter	29	38.9	34.3 -41.1
Fixed carbon	29	46.1	37.3 -51.9
Ash	30	7.5	5.8 -17.2
Sulfur	29	0.82	0.36- 2.31
Btu/lb	29	12,322	9,500-12,970

Table 8. Carbonization product yields for the Browning and Sun Valley coal mines.

Mine	Char	Water of Decomposition	Tar plus light oil	Gas	Gas Scf/lb	Btu/scf
Browning	72.4	5.5	16.4	4.8	0.972	803
Sun Valley	70.8	5.7	16.3	5.9	1.044	746
Sun Valley	71.2	5.4	16.1	5.9	1.048	747

Mines and Development

The only active mines in the Emery coal field, the Browning and Dog Valley mines, are located on this quadrangle. Recent production from these two mines is given below:

	1969	1970
Browning mine	36,978	115,239
Dog Valley mine	20,633	23,334

Other than these two mines, only abandoned prospects, mostly located in the Dog Valley area, occur (table 9).

Table 9. Mines in the Acord Lakes SE quadrangle.

Mine	Location	Remarks
Browning mine (San Raphael) Upper coal zone-I bed	SE.NW.33-22S-6E 4,301,215m.N.	Active intermittently 1881-1936 and fully active 1937-1970
Dog Valley mine (Sun Valley) Upper coal zone-I bed	NE.SW.32-23S-6E 4,291,215m.N. 476,500m.E.	Active 1930-1970

Lupton (1916, p. 84) gives this account of the Browning mine:

In 1881 Philip Pugsley opened a prospect on the outcrop of coal bed I in the NE½ SW¼ sec. 33, T. 22 S., R. 6 E., on the east side of Quitchuppah Creek and directly south of the mouth of Dipping Vat Creek [the present mine mouth is not at the location shown by Lupton's map]. This mine, which supplies the greater part of the fuel for the town of Emery and the ranchers living near by, is known locally as the Browning mine. . .The local bed at this place is 20 feet thick. . .The entry bears N 85° E for a distance of 165 feet. One room, about 40 feet in length, has been turned to the north at a point about 90 feet from the mine mouth. In mining, only the lower 12 feet of coal is removed, the upper part of the bed serving as a roof that requires no support. The coal is brought to the surface by means of a small car on a steel track. The surface equipment consists of wagon scales, a substantial coal bin, and a dwelling house for the use of the miners. During the winter of 1910-11 about 450 tons of coal was sold at the mine at $1.50 a ton. The total amount of coal removed is probably not less than 2,000 short tons. . .

The Browning mine operated intermittently between 1881 and 1936. Thereafter the operation has been steady. A minimum estimate of production prior to 1937 is 8,000 tons. Total production from the mine or mines from 1881 to 1970 is an estimated 1,318,000 tons.

The Dog Valley mine opened in 1930 and has operated almost steady since; it did not produce in 1939, 1949, 1950, 1951 and 1952. The mine is opened on the I bed which at this locality is 13 feet thick. Total production, 1930 to 1970, was approximately 313,000 tons.

Lupton (1916, p. 85) mentions other prospects on the quadrangle:

In the NW½ NE¼ sec. 33, T. 22 S., R. 6 E., on the north side of Dipping Vat Creek, a tributary of Quitchuppah Creek, there is an abandoned drift on coal bed I. The total thickness of the coal could not be measured on account of caving and the presence of water. The drift is 20 to 30 feet long and the coal apparently equals in quality and thickness that exposed in the Browning mine. The strata dip more steeply at this place than at the Browning mine. It is estimated that at least 200 tons of coal has been removed.

A prospect drift on coal bed A, in the SW¼ SE¼ sec. 33, T. 22 S., R. 6 E., on the north side of Quitchuppah Creek, bears nearly north and is about 50 feet long. Probably not more than 30 or 40 tons of coal has been taken from this prospect.

At least two prospects occur in the Dog Valley area, one at locations 39 and 40 and another at location 32. They are small and appear not to have exceeded the prospect stage. Little if any coal was produced for the commercial market. A total of 1,631,400 tons is estimated to have been removed from the quadrangle.

Reserves

Lupton (1916, p. 86) calculated coal reserves by lumping by township all the coal in beds presumably 1 foot or more thick. His reserves modified to fit into the confines of this quadrangle are as follows:

	Tons
T.22S. R.6E.	50,000,000
T.23S. R.5E.	214,310,000
T.23S. R.6E.	315,877,000
T.24S. R.6E.	40,250,000
T.24S. R.6E.	10,500,000
	630,937,000

The reserves, re-evaluated into estimated (Class II) reserves, including areas within 1½ miles of a control point and areas where coal beds are more than 4 feet thick, are shown in table 10.

Table 10. Original coal reserves (Classes I and II) in the Acord Lakes SE quadrangle (in short tons).

Location	Acres	Average thickness (feet)	Tons x 10^6	Bed or zone
T.22S. R.6E.	993	20.0	34.6	I, upper zone
	521	9.2	8.3	C, lower zone
T.23S. R.5E.	188	5.0	1.6	A, lower zone
T.23S. R.6E.	1,252	4.0	8.7	L, upper zone
	2,239	5.4	21.1	I, upper zone
	1,001	8.8	15.3	I, upper zone
	686	5.5	6.6	F, middle zone
	2,978	9.2	47.7	C, lower zone
	5,513	5.0	48.0	A, lower zone
T.24S. R.5E.	435	5.0	3.8	A, lower zone
T.24S. R.6E.	265	8.8	4.1	I, upper zone
	1,078	5.0	9.4	A, lower zone
		Total Coal	209.2	

Coal is reasonably assured to be present under Castle Valley beyond the 1½-mile limit set under Class II reserves. Table 11 is deduced by projecting the coal habit westward to the Joes Valley-Paradise fault zone, a distance ranging between 2 and 3 miles. Coal beds are lenticular, however, and coal may or may not be continuous with that at the outcrop.

Table 11. Inferred coal reserves (Class III, all beds) in the Acord Lakes SE quadrangle (in short tons).

Location	Acres	Average thickness (feet)	Tons x 10^6
T.22S. R.5E.	350	19.5	11.9
T.22S. R.6E.	1,798	19.5	61.1
T.23S. R.5E.	8,322	12.9	187.0
T.23S. R.6E.	500	12.9	11.2
T.24S. R.5E.	1,500	6.9	18.0
		Total Coal	289.2

Coal between the Joes Valley-Paradise fault zone and the 3,000-foot limit of overburden is placed in the Class IV or potential reserve category. The condition, thickness and quality of the coal are uncertain. Only the presence of the resource can be accepted with some degree of assurance. The habit projected into this area has a reserve of 381.6 million tons (Class IV).

PRINCIPAL WORK

The geology was modified from the work of Spieker (1931). The coal data of Lupton (1916) were augmented by field work conducted by the Utah Geological and Mineralogical Survey for this study. Analyses of coal samples came from several sources, especially the U. S. Bureau of Mines.

"I" coal bed being split by a sandstone bed along Interstate 70, Acord Lakes SE quadrangle. The bed is 9 to 12 feet thick about 300 yards to the left. Note the lenticularity of sedimentary beds in the Ferron Sandstone.

Ferron coal beds along Interstate 70, Acord Lakes SE quadrangle.

Dog Valley mine dumps and loading docks, Acord Lakes SE quadrangle.

EMERY EAST QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The town of Emery is located on the west map edge, 55 miles south of Price in the north part of the defined coal field (figures 17 and 20). The Coal Cliffs are located in the southeast map corner and most of the surface is a part of Castle Valley. Foothills leading to the Wasatch Plateau cliff lie to the northwest. Castle Valley lies at 6,000- to 6,400-foot elevations; the rim of the Coal Cliffs rises to almost 7,200 feet and the foothills to the west rise to 7,500 feet. Muddy Creek flows across the quadrangle from north to south.

The principal road, Utah Highway 10, connects Emery with Price. It continues southward joining Interstate Highway 70 within 10 miles. Eventually the road reaches Salina in Sevier County. A few graded roads and several jeep roads provide access to the Coal Cliffs from Emery and Utah 10.

STRATIGRAPHY

All the consolidated units exposed on the quadrangle are Cretaceous in age and all but one are Upper Cretaceous. The single Lower Cretaceous formation is the Cedar Mountain which has its outcrops below the Coal Cliffs. This unit consists mainly of light lavender shales. An occasional brown conglomeratic sandstone interrupts the otherwise monotonous 200-foot thick sequence.

The Dakota consists mainly of tan-gray to yellow sandstone, but in many places it is interbedded sandstone, shaley sandstone, conglomerate and even coal. The unit, thin but resistant, forms a ledge; its thickness has not been determined on the quadrangle but varies between 20 and 80 feet throughout the field.

The Tununk Shale, the first member of the Mancos, is an estimated 600 feet thick. It makes up the lower part of the Coal Cliffs and is a dark gray shale. Toward the top thin sandstone beds occur; the boundary with the overlying Ferron is drawn under the first thick bed of sandstone.

The Ferron Sandstone Member is the coal-bearing unit and consists of cliff-forming sandstone interbedded with shaley or softer units. The softer beds are composed of shaley sandstone, gray shale, carbonaceous shale and coal. Near the top is a resistant bed of sandstone from which the overlying beds have been stripped. This dip slope stripped area is about 2½ miles wide. The thickness of the Ferron varies, thinning to the northeast. Near the northeast map corner the Ferron is assumed to be about 300 feet thick, in the southwest corner about 450 feet thick. Several thick coal beds occur in the Ferron which thin northeastwardly and finally disappear.

The Blue Gate Shale is the foundation for most of Castle Valley. Its upper surface largely has been covered by alluvium and is farmed. Rounded hills of drab shale break through the alluvium at regular intervals and the tops of many of these are supported by a thick layer of gravel. The Blue Gate is about 1,600 feet thick.

The Emery Sandstone Member crops out in the foothills of the Wasatch Plateau. It forms a step-like series of smaller cliffs and is about 800 feet thick. To the north it splits into two tongues and thins, to the south it appears to thicken. On the quadrangle the Emery is cut off by the Joes Valley-Paradise fault zone. Within the zone are segments of the Mesaverde Group formations: the Star Point, Blackhawk and Castlegate formations.

STRUCTURE

The strike of the land is northeasterly and units dip up to 7 degrees to the northwest. There are no faults of consequence except those of the Joes Valley fault zone in the extreme northwest map corner.

PROPERTY CONTROL

Almost 95 percent of the land may be regarded as underlain with coal. The ownership of the quadrangle is as follows: private property 54.4 percent, Bureau of Land Management 37.2 percent, National Forest Service 5.7 percent and state of Utah 2.7 percent.

The locations of these lands are shown on figure 11. In essence the forest lands are to the northwest, the private lands cover most of Castle Valley and the BLM lands cover the Ferron outcrop.

Most of the south half of the quadrangle is held by companies or individuals for the coal (1970). Claims to the coal cover 40.4 percent of the total land area and 42.6 percent of the available coal lands. Holders of such claims are listed below and the location of these holdings is shown on figure 12.

Name	Type of Claim
R. Albrechtsen	Prospecting application
I. Browning	Fee lands
Consolidation Coal	Fee land, state lease, federal permit
R. J. Hollberg	Fee land, state lease
L. T. & C. G. Hunter	Fee land
K. E. Peterson	Fee land
Unassigned	Fee land
H. Wilson	Fee land

In addition some holdings extend beyond the boundaries of the map into other quadrangles not covered in the field report. These areas are underlain by the Ferron host rocks, but the coal is extended there on the basis of inference only; no surface exposures occur. Holders of coal lands in these areas not previously mentioned include T. Addley and Southern Utah Fuel Co. The former has fee lands and the latter has a federal lease.

COAL

Surface Information

Sixty-eight sections of coal were measured on the quadrangle (figure 21). Locations 1 to 32 give an indication of the condition of the Upper coal zone. The I and H beds are ubiquitous but only the I bed is 4 feet or more thick. All the thick sections are located along Muddy Creek. In many cases the bed is split in two with each bench less than 4 feet thick. The average thickness of the coal around Muddy Creek is 5.8 feet. The bed is known to thin eastward and continues thick southward. The Middle zone is poorly represented with measured sections and beds are thin. The thickest bed is 2 feet and located near the south end of the quadrangle on the west side of Muddy Creek Canyon.

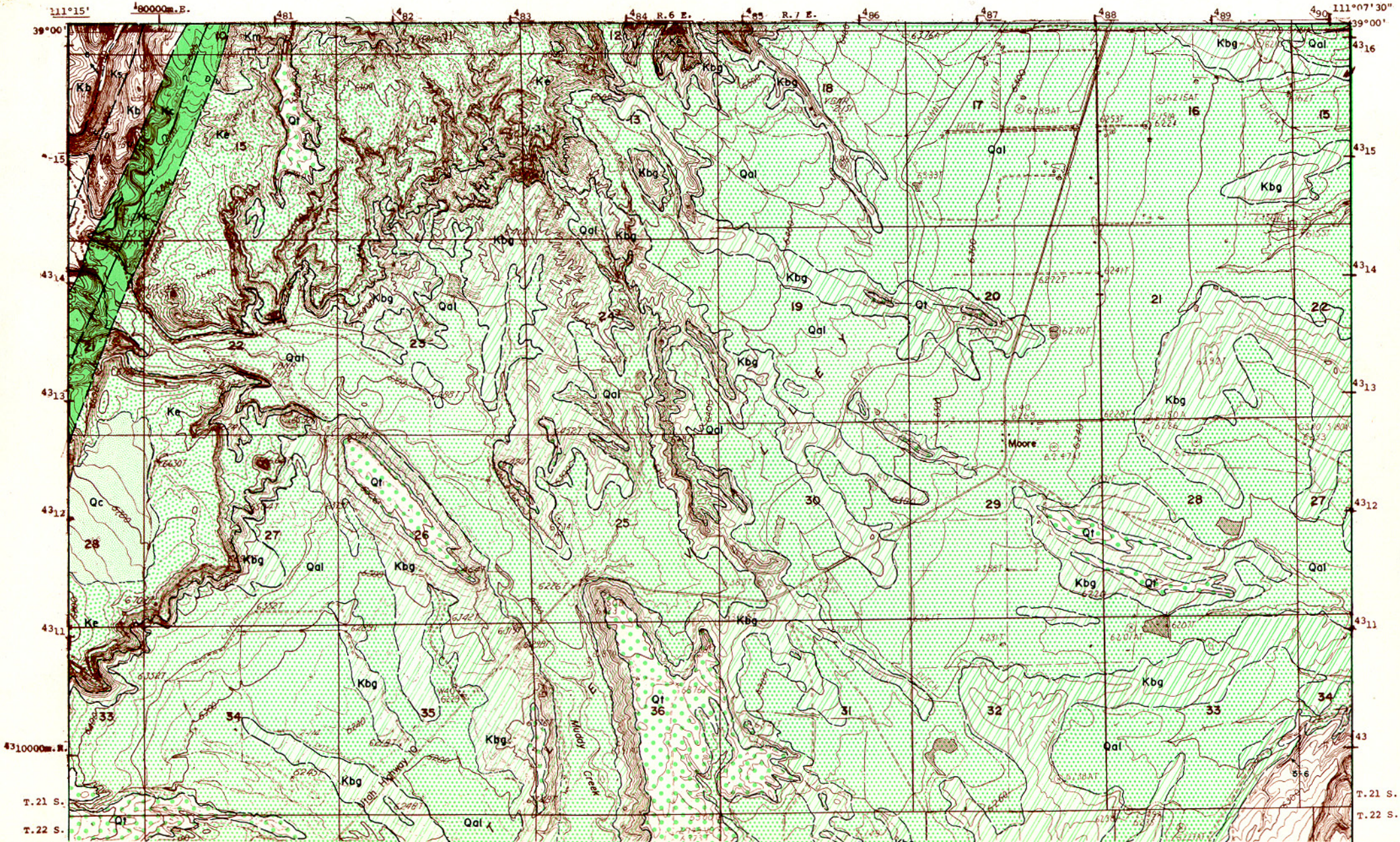
The Lower zone is the most important and widespread zone but only the C bed is thick. Most surface sections (40 to 58) are split by gray or carbonaceous shale. The thickest seam of clean coal is 7.2 feet; an average of 6.2 feet of coal occur in the C horizon. If mined an average of 0.8 feet of waste will have to be removed as well. The bed of coal is expected to thin to noncommercial thicknesses in the southeast part of the quadrangle. The coal bed is known to thicken to the southwest.

Subsurface Information

Available coal data from six drill holes located in T. 22 S., R. 7 E. are given as locations 63 to 68. These holes indicate a thickening behind the outcrop. Up to 13½ feet are recorded in a single seam. No correlation was attempted but it is thought that the seams are from the Lower coal zone.

It is estimated that the 1,000-foot coverline trends northeasterly through the town of Emery and that the 2,000-foot line is within the Emery outcrops. The Ferron coal is expected to be

EMERY EAST, UTAH



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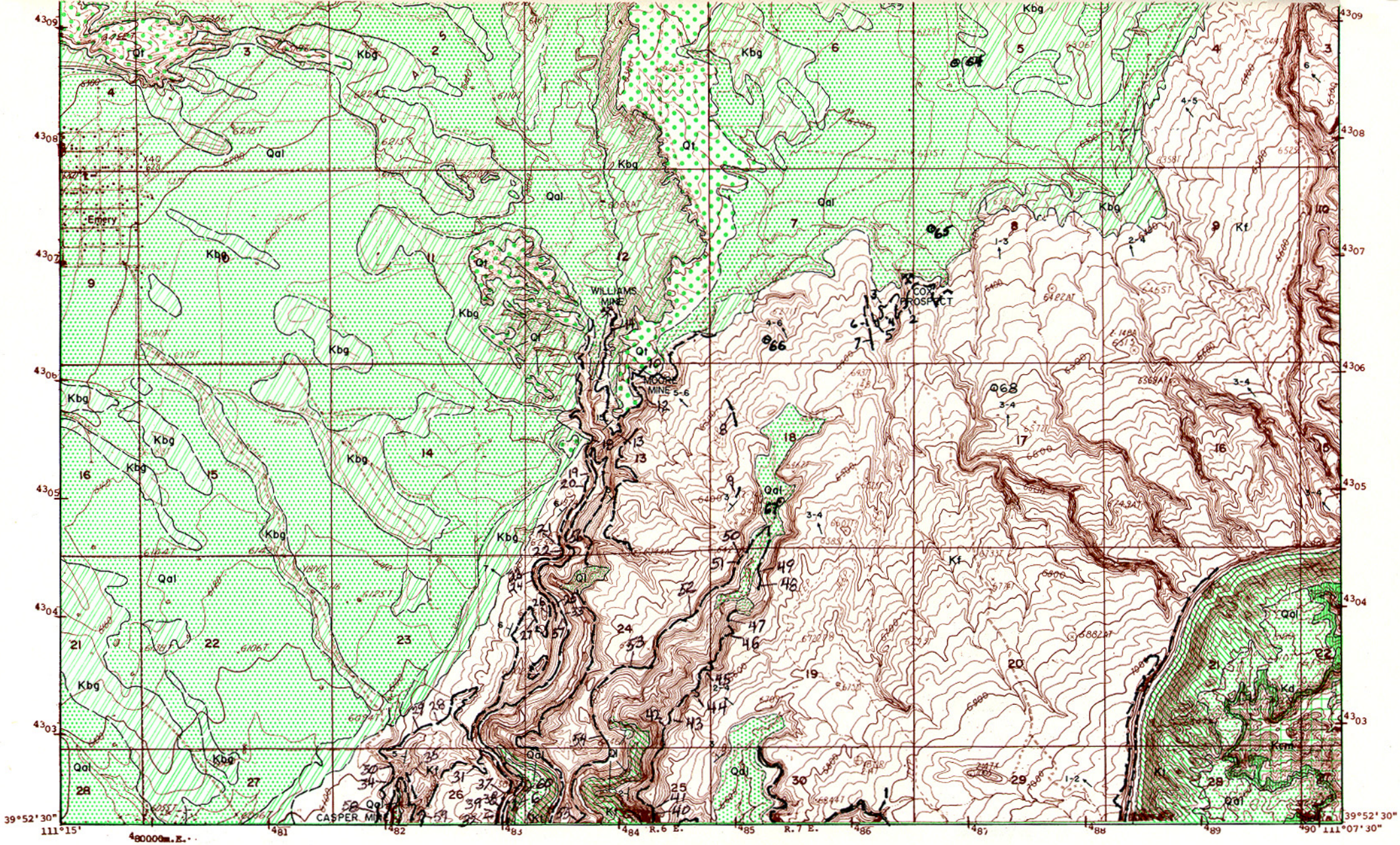


Figure 20. Coal and geology map, Emery East quadrangle (explanation pages 448-449).

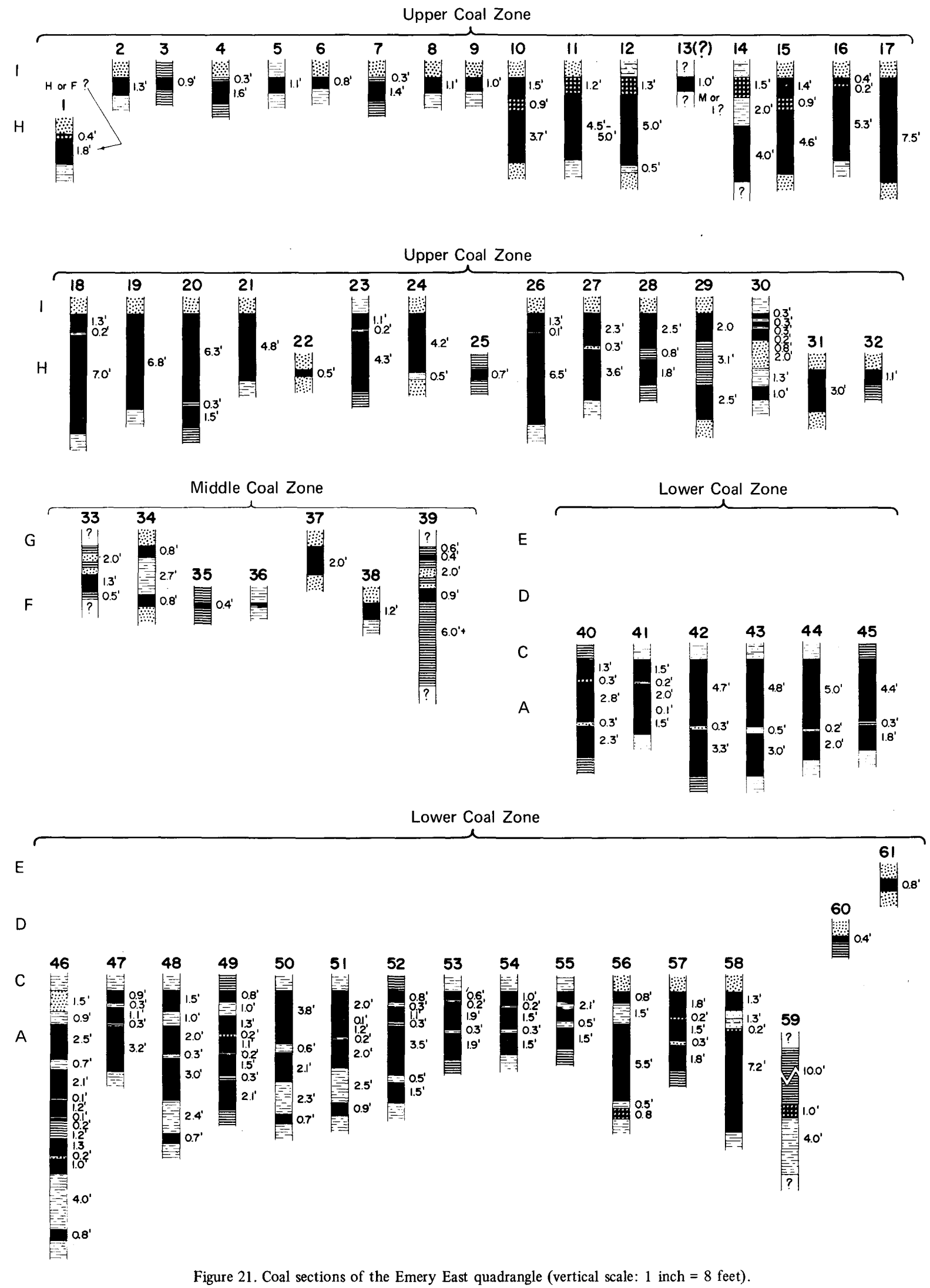


Figure 21. Coal sections of the Emery East quadrangle (vertical scale: 1 inch = 8 feet).

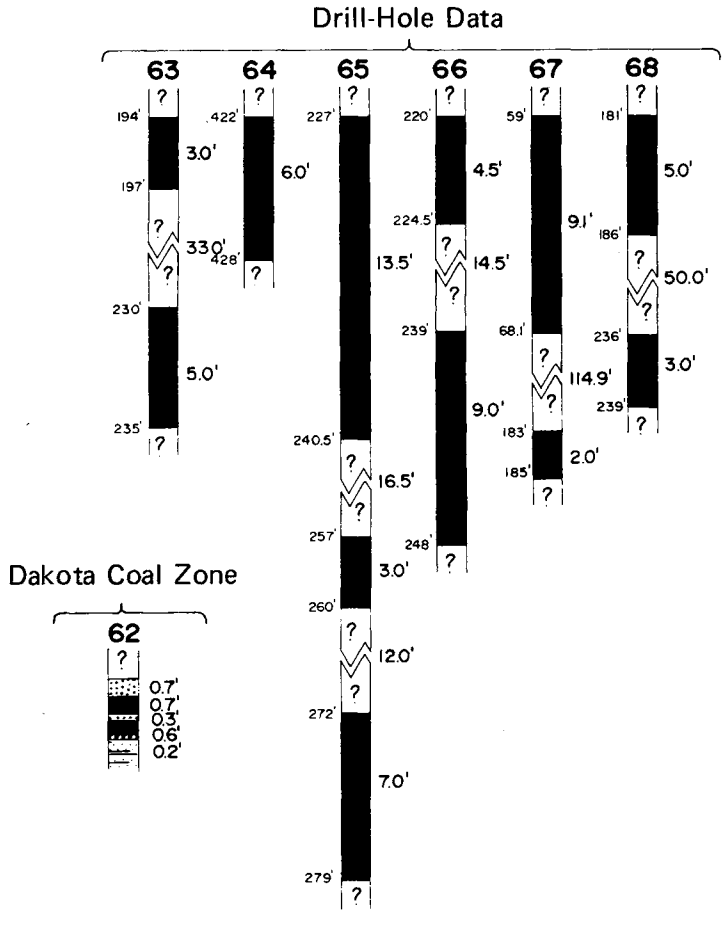


Figure 21. (continued)

found at greater than 3,000-foot depths within the Joes Valley-Paradise fault zone.

Quality of Coal

Only four analyses of coal are available for the Emery East quadrangle (table 6), one from the Upper zone at the Williams mine and the other three in the Lower zone from the Casper mine. The Upper zone coal sulfur analysis is very high (4.7 percent) but not believed to be characteristic for all of the Upper zone in the quadrangle. The three lower zone analyses vary considerably which probably reflects the manner in which the samples were taken. More analyses need to be run to properly evaluate the coal of each zone. Table 12 gives the average proximate analyses of the coal.

Table 12. Average proximate analyses of coal, Emery East quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	4	7.1	2.3 -16.7
Volatile matter	4	37.2	33.4 -41.8
Fixed carbon	4	41.7	40.7 -42.6
Ash	4	14.1	7.1 -23.6
Sulfur	4	1.81	0.66- 4.66
Btu/lb	4	10,681	9,500-11,990

Mines and Development

At least five mines or prospects have been opened on the quadrangle, three on the Upper zone and two on the Lower (table 13).

Lupton (1916, p. 83) describes some of the mines and prospects present when he made his investigations. Essentially little development has occurred since.

The Cox prospect . . . is on a lens of coal believed to be at the horizon of coal bed I, which, 300 feet east of the prospect is replaced by massive sandstone. The prospect consists of a single drift about 20 feet long which extends slightly east along the strike of the rocks. Probably not more than 10 or 15 tons of coal has been removed. Owing to the well-preserved sandstone roof, propping is unnecessary.

Table 13. Mines and prospects, Emery East quadrangle.

Mine	Location	Remarks
Casper mine Lower coal zone, C bed	SE.NW.26-22S-6E 4,302,290m.N. 482,070m.E.	Activity unknown
Cox prospect Upper coal zone I bed	NE.SE.7-22S-7E 4,306,780m.N. 486,460m.E.	Activity unknown
Moore prospect Upper coal zone I bed	NW.NE.13-22S-6E 4,306,000m.N. 484,270m.E.	1905 active
Williams mine Upper coal zone I bed	NE.SW.12-22S-6E 4,306,540m.N. 483,860m.E.	Activity unknown
Prospect Lower coal zone C bed	NW.NW.19-22S-7E 4,304,180m.N. 485,180m.E.	Activity unknown

A drift about 100 feet in length extends N 15° E on coal bed I . . . and is locally known as the Moore mine. It is reported to have been opened in 1905 by Thomas Thompson, of Ferron, Utah. The roof, which is sandstone, is much broken by joints and requires considerable support. At least 150 tons of coal has been mined from this place.

The Williams mine, also on bed I, is on the east side of Muddy Creek. . .Its entry, from which no rooms have been turned, is about 200 feet long and 12 feet wide and bears 5.60° E. As the coal bed has a fairly good sandstone roof very little propping is necessary. . .Probably 600 or 700 short tons of coal has been removed from this mine.

One of the oldest mines in this field, known locally as the Casper mine, is on coal bed C on a tributary of Muddy Creek. . .about 4 miles southeast of Emery. The coal bed at this place strikes N 5° or 6° E, and dips about 2° W. Those mining coal here have left pillars here and there between great irregular cavelike rooms, some of which are large enough for a team and a wagon to turn in them. It has been the custom to load the wagons in the mine at the faces of the entry and rooms, thus avoiding any mine haul and the construction of a loading tipple. Owing to the irregular shape of the mine cavity, it is difficult to estimate the amount of coal removed, but it is believed that 1000 to 2000 tons has been taken from the Casper mine. . .The coal bed has a good sandstone roof and requires very little support. . .

All these mines and prospects have long been closed. From the manner of Lupton's description, the mines already were abandoned in 1916. Total coal removed from the quadrangle is thought to be less than 3,000 tons.

Reserves

Lupton (1916, p. 86) calculated the reserves for the field which are here modified to fit the quadrangle.

	Tons
T.21S. R.6E.	21,463,000
T.22S. R.6E.	188,376,000
T.22S. R.7E.	16,036,000
Total Coal	225,875,000

It is not believed that Lupton assigned any reserve to T. 21 S., R. 7 E. in this quadrangle. He did assign 311,000 tons to the township but for an area closer to the surface exposures to the east (Emery 1 NE quadrangle).

In reassessing and including new subsurface and surface data, the reserves in table 14 were deduced.

That coal exists in the north third of the quadrangle in thick beds is speculative; it is thought that the Class III and Class IV estimates are optimistic. Additional inferred reserve (Class III) should be extended to the area immediately west of the quadrangle in T. 22 S., R. 6 E. Lupton assigned approximately 134,550,000 tons to this area in all beds. No subsurface data are

Table 14. Original coal reserves in short tons (Classes I and II; beds average 4 feet or more thick), Emery East quadrangle.

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.21S. R.7E.	1,300	5.5	12,455,000	Lower zone
T.22S. R.6E.	4,622	5.8	46,699,000	Upper zone
	3,808	6.2	41,128,000	Lower zone
T.22S. R.7E.	4,320	6.7	50,420,000	Lower zone
		Total Coal	150,702,000	
	Class III (Inferred)		181,931,000	All beds
	Class IV (Potential)		133,128,000	All beds
		Grand Total	465,761,000	

available and one can only assume or extend known data. The property is owned by Consolidation Coal Co. who have drilled these lands. Miners at the Browning mine unofficially indicated that the coal in the mine maintains a 20-foot thickness northward to the town of Emery; Lupton's figure is therefore considered a conservative reserve for all beds.

PRINCIPAL WORK

The major part of the data collected for this area was from Lupton (1916). Surface data and some analytical data by the author supplement his work. Drill-hole information was donated by the owner.

Coal Cliffs east of Moore, Emery 1 NE quadrangle. The upper cliff, the Ferron Sandstone, is coal bearing; immediately below is the Tununk Shale and the first hogback beneath it is the Dakota-Burro Canyon. The variegated shales are Morrison Formation.

EMERY 1 NE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Emery 1 NE quadrangle is located in the north part of the coal field 2 miles east of Moore and Utah Highway 10 (figures 17 and 22). The area is 46 miles south of Price with the Coal Cliffs cropping out across the northwest map corner. The lands below the cliffs are uninhabited and buttes, cliffs and badlands define the landscape. Elevations in this area range from 5,700 to 6,100 feet above sea level. The Coal Cliffs rise 500 feet to the north and 700 feet to the south above this surface but the Ferron dip slope lowers to 6,200 feet within 2 miles. Castle Valley, west of the rocky dip slope, is reasonably flat but often deeply gullied by washes.

A major dirt road passes east-west across the quadrangle joining Moore and Utah Highway 10 with Interstate 70 in the San Rafael Swell. The road employs Dry Wash Canyon to cut through the Coal Cliffs. I-70 is about 7 miles southeast of the east map edge. Few trails traverse the dip slope to provide access to the coal seams; the cliff face is unscalable.

STRATIGRAPHY

Stratigraphic units exposed on the map area include the interval between the Jurassic Carmel Formation to the Cretaceous Blue Gate Shale Member of the Mancos Shale. The Carmel, exposed in the extreme southeast map corner, consists of brownish red gypsiferous shales. The reddish brown siltstones and fine-grained sandstones of the Entrada follow. These beds are soft but create a low badland, butte-covered surface. The overlying beds are quite resistant and a cliff usually marks the upper contact. A northeast-trending strike valley 2¼ miles wide has formed on the Entrada outcrops and is drained by South Salt Wash. The formation is estimated to be about 620 feet thick.

The Curtis is a yellow-gray band between two red-colored formations. The unit has an outcrop width of about ¾ mile, most of which is a westward-dipping slope. The formation is resistant in its middle part and forms a cliff immediately over the lower contact. The thickness of the Curtis is about 200 to 225 feet.

The Summerville is much like the Entrada in color, but its beds are thinner and a little more resistant. In some places the outcrops are cliffy, in others they are worn down and covered with soil to form smoothly sloping areas. It is reported that the Summerville has a thick bed of gypsum near the top but it may be missing in this quadrangle. The Summerville was measured in sec. 8, T. 22 S., R. 8 E., as 263 feet thick.

The Morrison outcrops cut diagonally across the map area from the southwest to the northeast corner in an outcrop band, 1¾ miles wide. The dominant lithology is varicolored mudstone, which is occasionally interrupted by very resistant brown conglomerate and sandstone beds. Alluvium has developed on much of the surface but areas of rounded hills and cuestas of mudstone capped by resistant layers of conglomerate are common. The unit was roughly measured in secs. 5 and 6, T. 22 S., R. 8 E., to be 410 feet thick.

The Lower Cretaceous Cedar Mountain Formation is much like the Morrison but the mudstones are a light lavender and the formation is not as thick. Measured in sec. 3, T. 21 S., R. 8 E., the unit is 188 feet thick. The Dakota caps the Cedar Mountain possibly as a former pediment surface. The Dakota is orange and yellow-gray sandstone, resistant–forming a cuesta–and massive. Along the north map edge the Dakota is 35.5 feet thick and in sec. 36, T. 21 S., R. 7 E. is estimated to be 25 feet thick. It is usually barren of coal but two thin coal beds were measured in sec. 22, T. 22 S., R. 7 E.

The Dakota is covered by the drab gray shales of the Tununk which first forms a low, nearly smooth surface and then makes up the lower and major part of the Coal Cliffs. The surfaces are marked by closely spaced gullies which give them a vertically fluted, castellated appearance. Near the top, the Tununk becomes sandier and a few thin beds of sandstone work the transition with the Ferron beds above. The Tununk is estimated to be about 600 feet thick.

The Ferron Sandstone is the coal-bearing unit which caps the Coal Cliffs. It is exposed in a 1- to 2-mile wide dip slope behind the cliffs. The unit was measured in two places on the quadrangle, the first by Lupton (1916) in sec. 24, T. 21 S., R. 7 E. The lower Ferron is about 60 feet thick above which 50 feet of carbonaceous beds lie. The remaining 170 feet consist of alternating bedded sandstone, sandy clay, massive sandstone and thin clay beds. The section is without coal. The next measurement is in Dry Wash Canyon, sec. 34, T. 21 S., R. 7 E., 2 to 3 miles from the first. The lower Ferron is 110 feet thick followed by 60 feet of carbonaceous beds including some thin coal beds. The entire unit is 320 feet thick. The Ferron continues to thicken southward and probably westward, increasing in carbonaceous beds in these directions.

The youngest consolidated unit–the Blue Gate Shale–occurs in Castle Valley. Only the lower part of the gray shale unit is exposed. Occasional landslides occur along the Coal Cliffs and alluvium has collected in Castle Valley, Dry Wash and in other washes in the badlands area east of the cliffs.

STRUCTURE

The beds strike northwest over most of the quadrangle with a variation north of Dry Wash on the Ferron dip slope. Here the northward-trending axis of the Rochester anticline is paralleled to the east by a small syncline. Beds dip into the syncline at the normal inclination then rise to the crest of the anticline at 3° to 4°. On the west side of the anticline the beds steepen to 10°. No significant faults were mapped.

PROPERTY CONTROL

The lands of the Emery 1 NE quadrangle are owned by the Bureau of Land Management (86.4 percent), the state of Utah (8.3 percent) and individuals (5.3 percent).

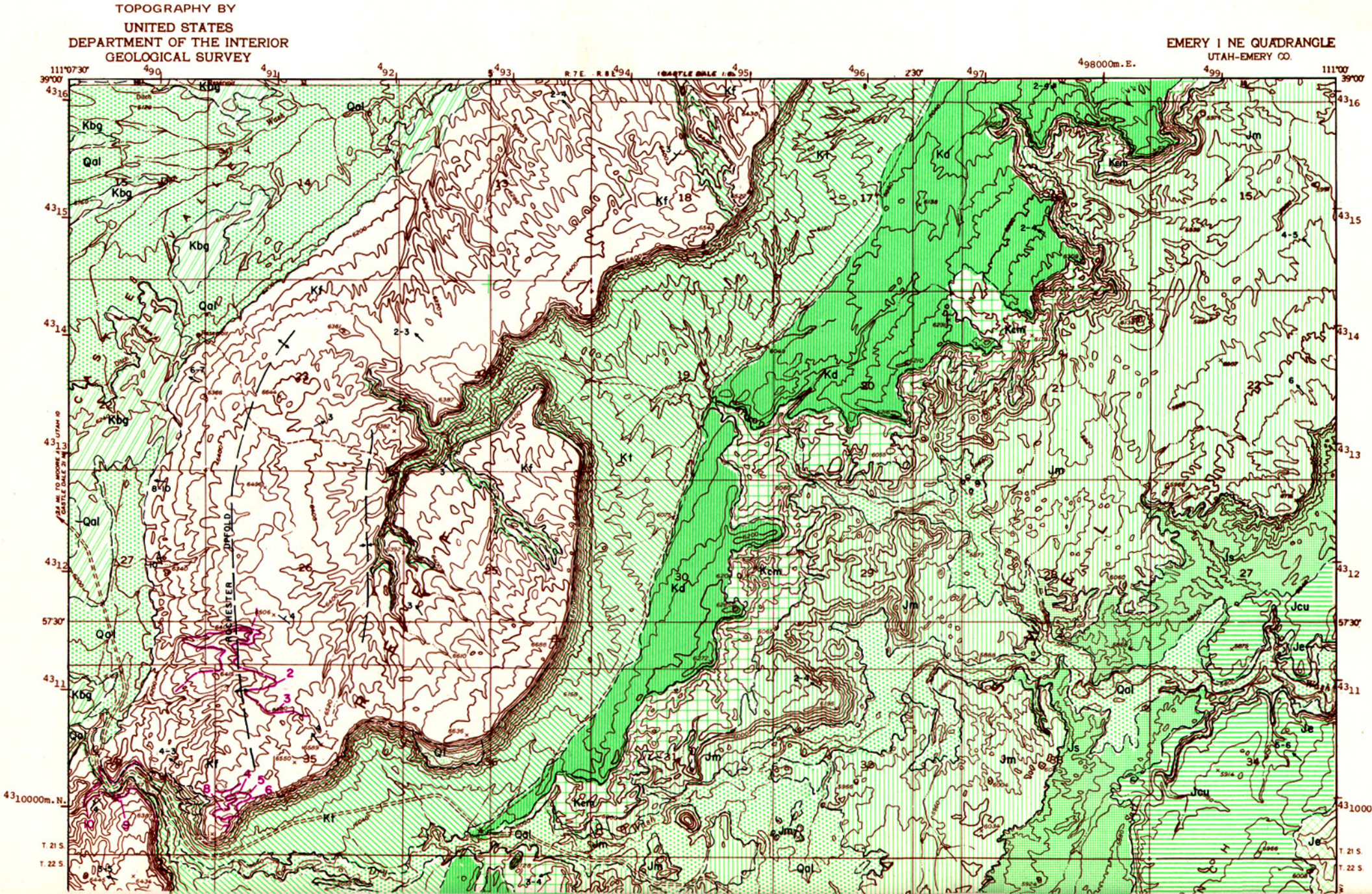
Coal lands amount to 21.1 percent of the quadrangle. Of the state lands 8.8 percent are on coal-bearing areas, all of the private lands are underlain with potential coal and 17.4 percent of the BLM lands fall in this category.

None of the lands, as of January 1, 1970, was leased or permitted for coal. North of the quadrangle in sec. 2, T. 21 S., R. 7 E. and sec. 36, T. 20 S., R. 7 E. two sections were held as state coal leases by K. E. Peterson.

COAL

Surface Information

Twenty-one sections of coal were measured on the quadrangle: 19 from the Lower coal zone (beds B and C), two from the Dakota Sandstone (figure 23). All the sections are thin according to the standards set in this report. The thickest bed is at location 5 with a 2.3-foot thickness. The coal appears to be lenticular and perhaps even discontinuous. The Dakota seam reaches a maximum thickness of 1½ feet but the bed is local in extent.



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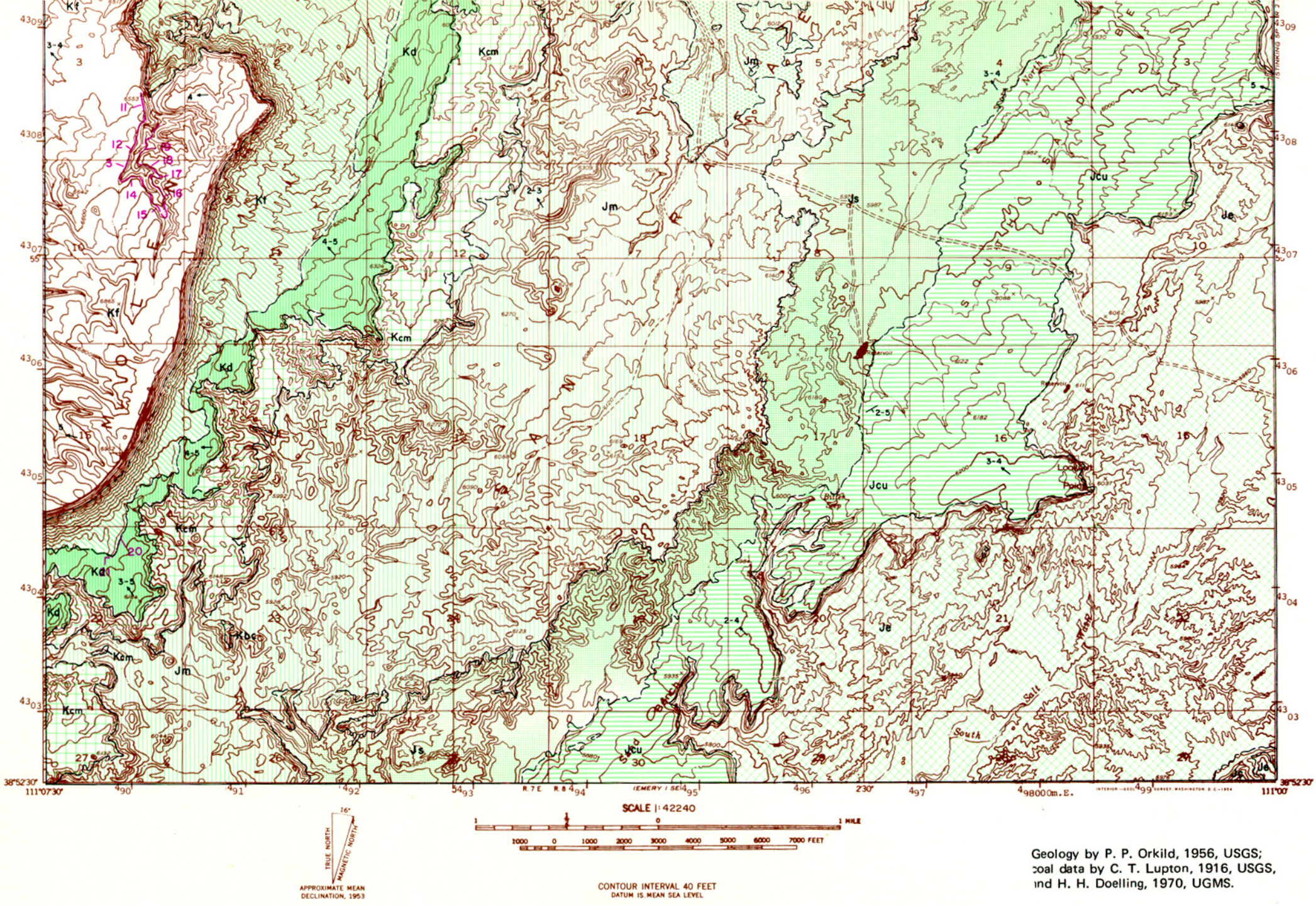


Figure 22. Coal and geology map, Emery 1 NE quadrangle (explanation pages 448-449).

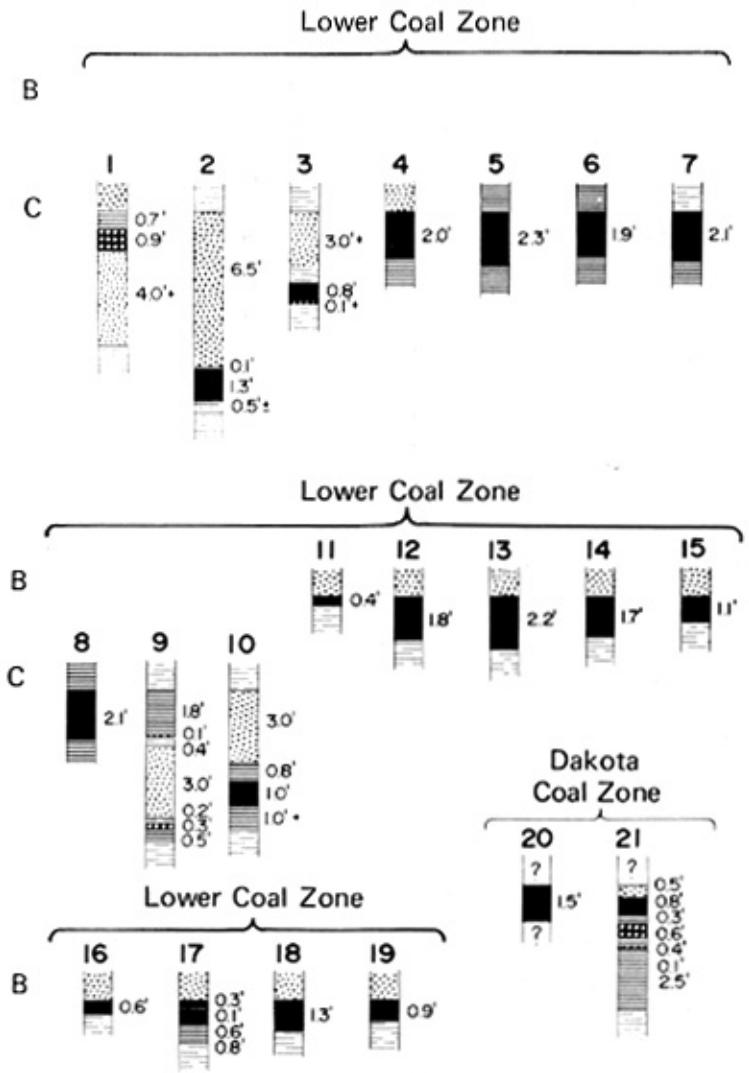


Figure 23. Coal sections of the Emery 1 NE quadrangle (vertical scale: 1 inch = 8 feet).

Subsurface Information

No drill-hole data are available for the Emery 1 NE quadrangle. The coal should not occur deeper than 1,000 feet anywhere on the map area.

Quality of Coal

No analyses are available of the coal of this quadrangle.

Mines and Development

The only development indicated on the quadrangle is located in SW. 34-21S-7E, on the south side of Dry Wash Canyon (UTM location, 4,310,085m.N. and 489,620m.E.). The prospect is a small hole in the canyon wall; the period of activity is unknown and production was not achieved. The thickness of the seam at location 9 is less than 1 foot.

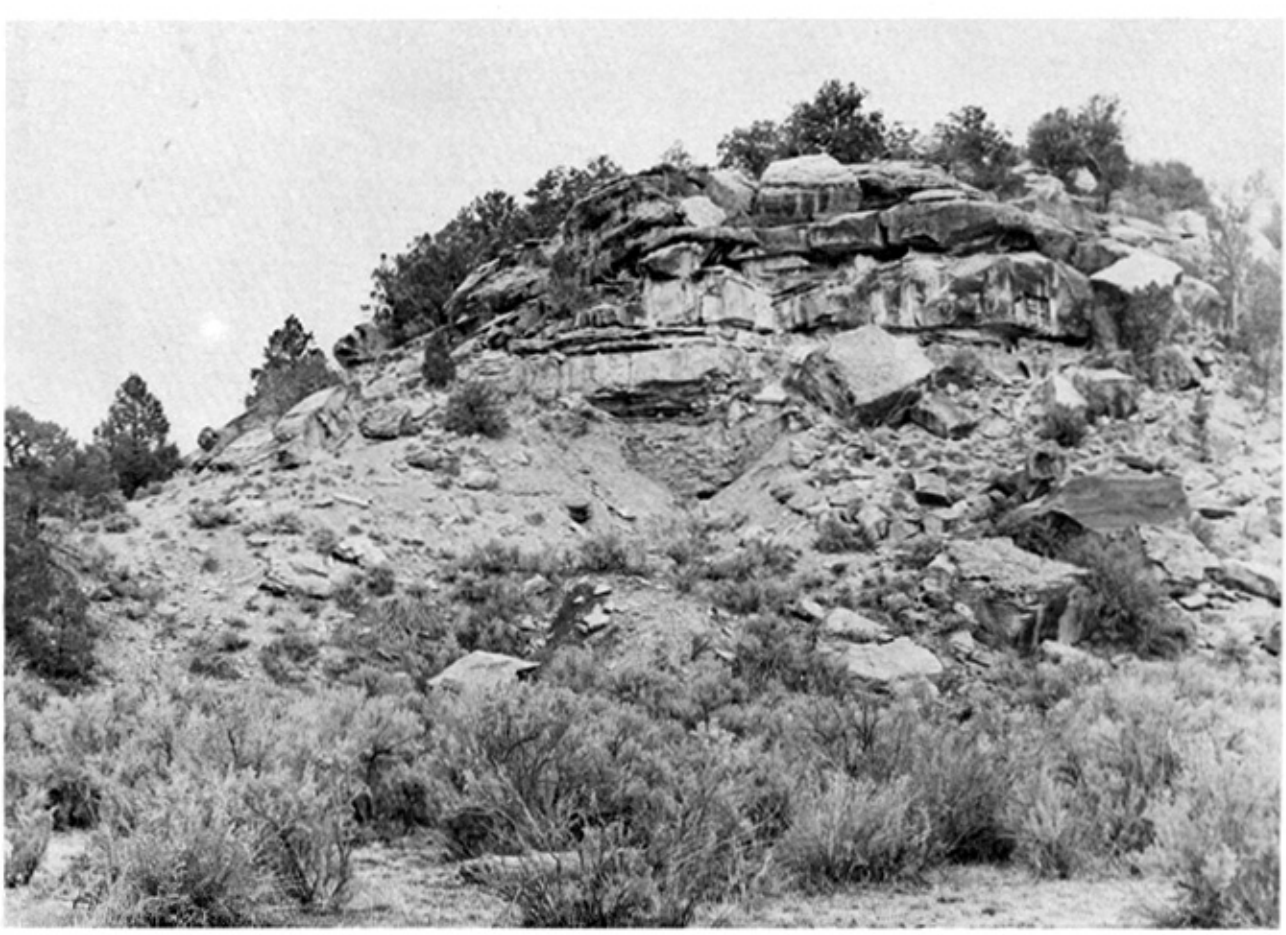
Reserves

No reserves of coal in beds 4 feet or more thick can be assigned to the quadrangle. Lupton (1916, p. 86) assigned 311,000 tons to T. 21 S., R. 7 E. for beds over 1 foot thick. How much he calculated for the portion of T. 22 S., R. 7 E. in the Emery 1 NE quadrangle is unknown, but it is presumed a similar amount.

PRINCIPAL WORK

The geology presented on this quadrangle is mainly the work of Orkild (1956) and the coal data are mainly the work of Lupton (1916). Some additional stratigraphic and coal sections were measured for this report.

Below: An abandoned mine west of the Paradise fault zone, south Emery coal field near Paradise Lake, may be in the Ferron, Emery or Blackhawk formations. The bed is 11 to 13 feet thick and is terminated by a fault to the right; it dips under alluvium to the left.



EMERY 3 NE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Emery 3 NE quadrangle located in the south part of the field straddles the Emery-Sevier County line (figures 17 and 24). The Coal Cliffs trend northeasterly across the map area; the principal drainage that cuts through them is Willow Springs Wash. A gradual rise in elevation along the cliffs from northeast to southwest, 6,500 to 7,600 feet, is the result of an irregularity in the regional geologic structure. The rocks behind and below the cliffs also participate in this rise. The lands below the cliffs are composed of varied types of bedrock appearing as badlands, low cliffs, buttes and mesas. Bedrock areas are often interrupted by large areas of nearly flat alluvial or colluvial material. Above and behind the cliffs are hilly to mountainous areas and only along the north map margin are any appreciable flat areas. The relief along the Coal Cliffs ranges from 500 to 800 feet. The coal crops out along the cliffs and on the canyon walls of Willow Springs Wash and its tributaries.

No towns or paved roads occur on the quadrangle. A graded road leads from Interstate Highway 70 and Utah Highway 10, from 3 miles to the northwest to Willow Springs Wash. The road branches below the Coal Cliffs, one arm continuing eastward into the San Rafael Swell and another extending south toward Wayne County. Short four-wheel drive roads extend from the graded road in the vicinity of Willow Springs Wash. No road provides access to coal outcrops outside that local area.

STRATIGRAPHY

Bedrock units exposed on the quadrangle range from the Jurassic Entrada Sandstone to the Cretaceous Blue Gate Shale. Only the upper 300 feet of the Entrada are exposed in Last Chance Valley along the south map margin. The orange-red-brown sandstone rims the anticlinal valley as a cliff; it is fine-grained, silty and thick-bedded to massive.

The succeeding Jurassic and Lower Cretaceous beds are partially differentiated and partially grouped on the map. The grouping ends with the Dakota Sandstone at its upper boundary. The description of each of these units is exemplified by the following measured sections:

Section of Dakota, Cedar Mountain, Morrison, Summerville and Curtis formations, sec. 6, T. 25 S., R. 6 E. and sec. 1, T. 25 S., R. 5 E.

	Feet
Tununk Shale	
Dakota Sandstone	
1. Sandstone, orange, medium-grained, but occasionally conglomeratic, cross-bedded, thick-bedded to massive, some thin interbeds of gray shale	50-75
Unconformity	
Cedar Mountain Formation	
1. Mudstone, light lavender, bentonitic	77
2. Sandstone and conglomerate, tan and dark gray, well cemented	8
3. Mudstone, like unit 1	65
4. Mudstone, like unit 1, interbedded with occasional beds of light purplish gray coarse-grained sandstone	48
5. Sandstone, brown-gray, medium-grained, blocky	4
6. Mudstone, like unit 1	94
Total Cedar Mountain	296
Unconformity	
Morrison Formation	
1. Conglomerate, dark brown, contains lumps and nodules of chalcedonic material	10
2. Sandstone and siltstone, red, fine-grained, slope forming, no discernible bedding	17
3. Sandstone, light brown, medium-grained, cross-bedded	4
4. Sandstone and siltstone, like unit 2	24
5. Sandstone, like unit 3	2
6. Sandstone and siltstone, like unit 2	10
7. Sandstone, like unit 3	6
8. Sandstone and siltstone, like unit 2	46
9. Sandstone, light tan, medium-grained, ledge former	2
10. Sandstone and siltstone, like unit 2	30
Total Morrison	151
Unconformity	
Summerville Formation	
1. Sandstone and siltstone, light chocolate to reddish brown, fine-grained, thin-bedded	250
2. Sandstone and siltstone, light tan, fine-grained, some thin beds of greenish sandstone reminiscent of the Curtis	25
Total Summerville	275
Curtis Formation	
1. Shale, light tan gray, sandy occasional subordinate thin sandstone in medium beds, medium-grained, nonresistant	80
2. Sandstone, yellow-tan, coarse-grained, cliff former, friable	114
3. Shale, sandy	6
4. Sandstone, like unit 2	9
5. Sandstone, shaley, coarse-grained	18
Total Curtis	227
Unconformity	
Entrada Sandstone	

The Mancos Shale with its five members lies atop the Dakota. Only the lower three, in ascending order, the Tununk Shale, Ferron Sandstone and the Blue Gate Shale, are exposed on the quadrangle. The lower Tununk consists of dark, often carbonaceous, marine mudstone, nodularly bedded and uniform. The lower part of the 600- to 700-foot unit usually occurs in a rolling, low hilly outcrop habit badly gullied by the drainage. The upper part unites with the Ferron Sandstone to form the Coal Cliffs. The fringe of the cliffs is lined with an apron of landslides because the softer Tununk is eroded under the massive sandstone units of the Ferron. Large blocks of the Ferron collapse to the slope below.

The Ferron, which consists of alternating littoral and lagoonal deposits, contains the coal beds. The littoral sandstones are massive, cliff forming, yellow-gray to tan in color and fine- to medium-grained. The lagoonal deposits consist of alternating shaley sandstone, medium-bedded blocky sandstone, gray shale, carbonaceous shale and coal.

Figure 25 illustrates the nature of the Ferron along the south side of Willow Springs Wash.

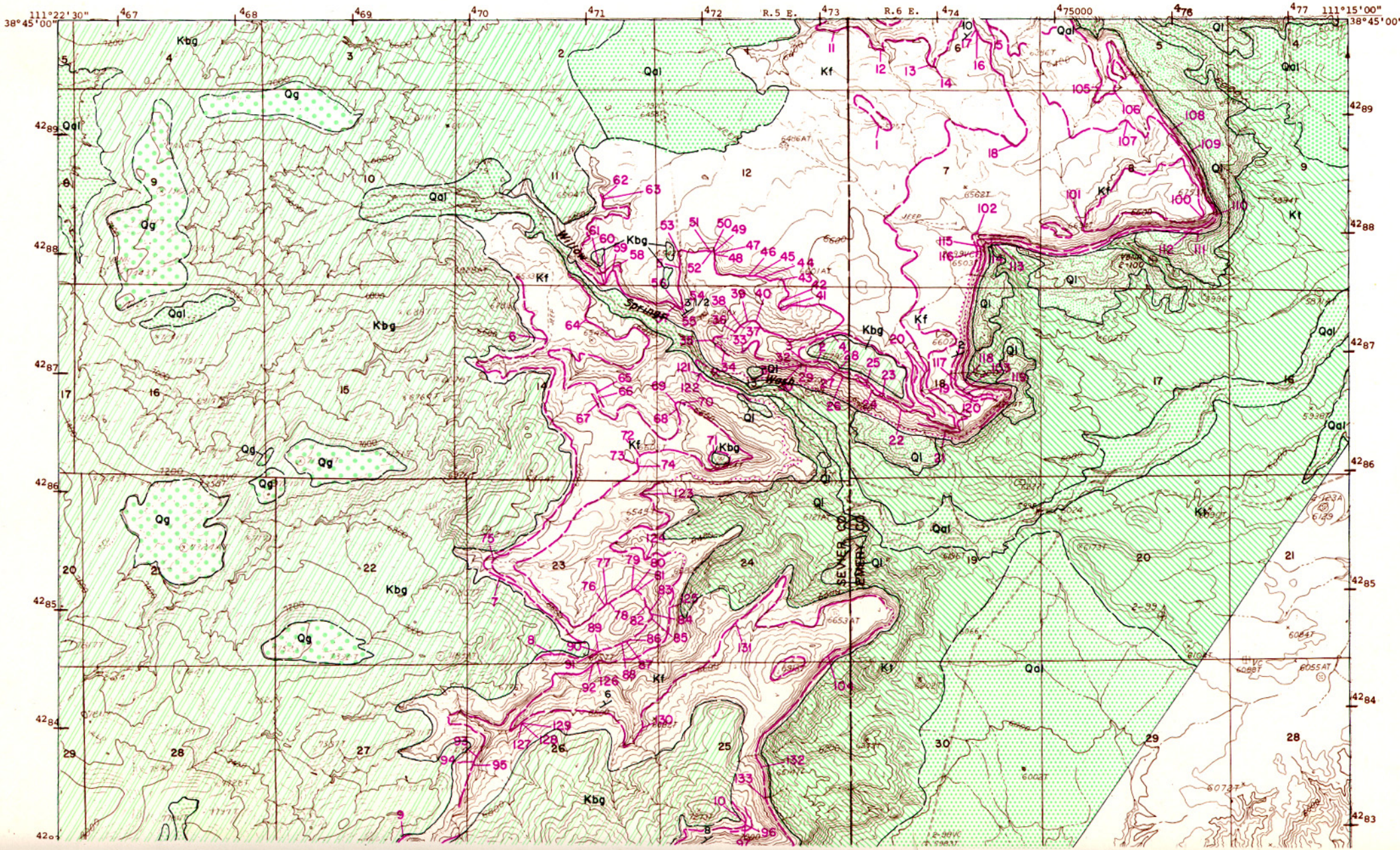
All the A to M coal beds can be recognized as well as the division between Upper, Middle and Lower coal zones. Some of the coal beds are badly burned which has the effect of reddening the outcrops. The Ferron was measured about 475 feet thick along Willow Springs Wash, but thickens southwestward to about 600 feet.

In the north map area the bare dip slope of the Ferron is about 1½ miles wide but narrows quickly southward to where the dip slope is scarcely wide enough to walk on. The hilly upland region exposes the rounded hills of the Blue Gate Shale. The shale is similar in structure to the Tununk, but the color is not as dark. Occasional thin beds of brown medium-grained sandstone form ledges. The tops of the Blue Gate hills are often flattened, the surface covered with volcanic gravel. The unit is estimated to be 1,600 feet thick, the lower part of which remains in the map area.

STRUCTURE

Two structures influence the attitude of beds on the Emery 3 NE quadrangle. The first, the San Rafael Swell, parallels the cliffs and imposes the regional dip. The second, the Last Chance anticline, trends east-west in the south map area. The Jurassic beds near the county line reflect this trend. The coal beds are controlled in strike and dip by the San Rafael Swell, but the higher

EMERY 3NE, UTAH



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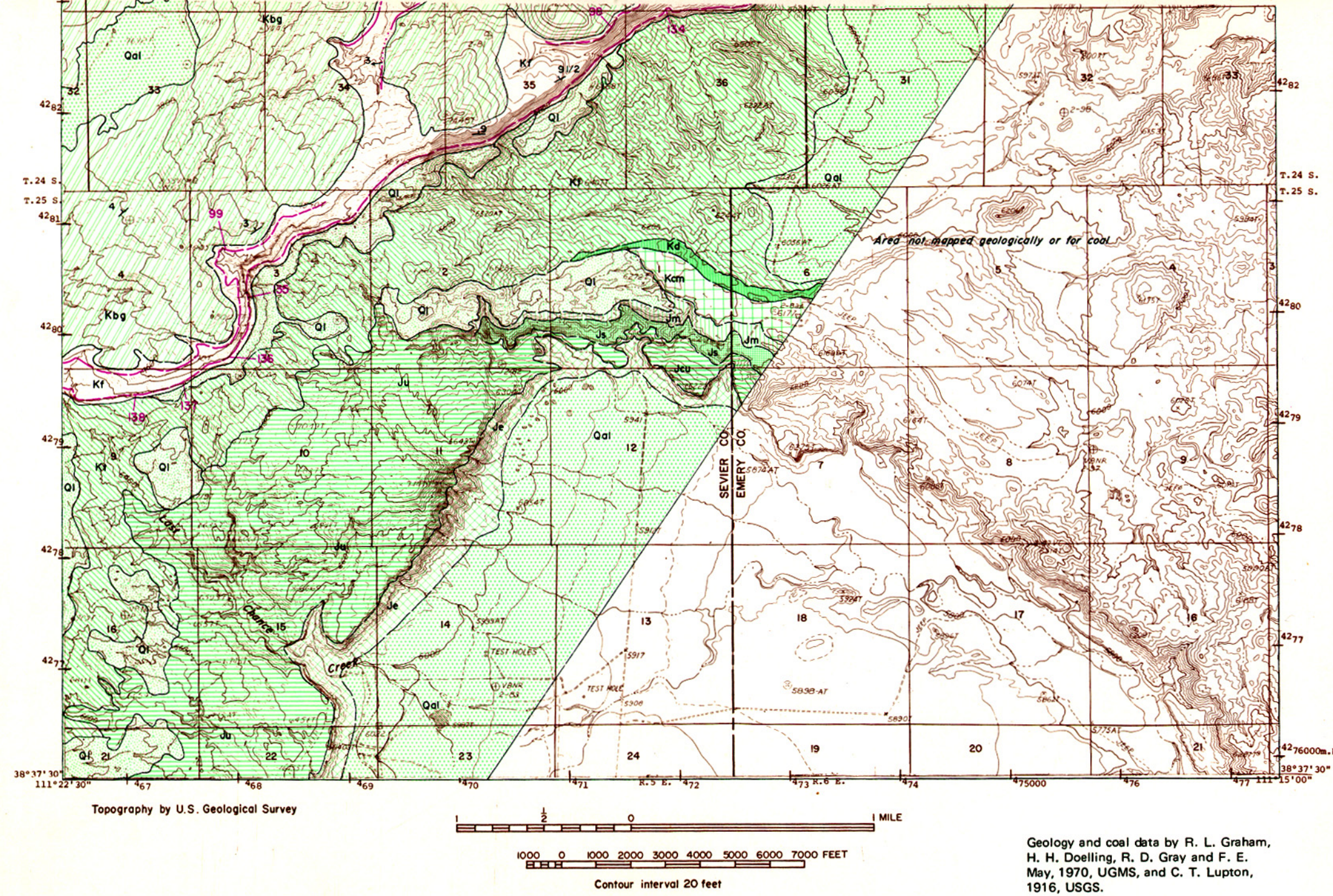


Figure 24. Coal and geology map, Emery 3 NE quadrangle (explanation pages 448-449)

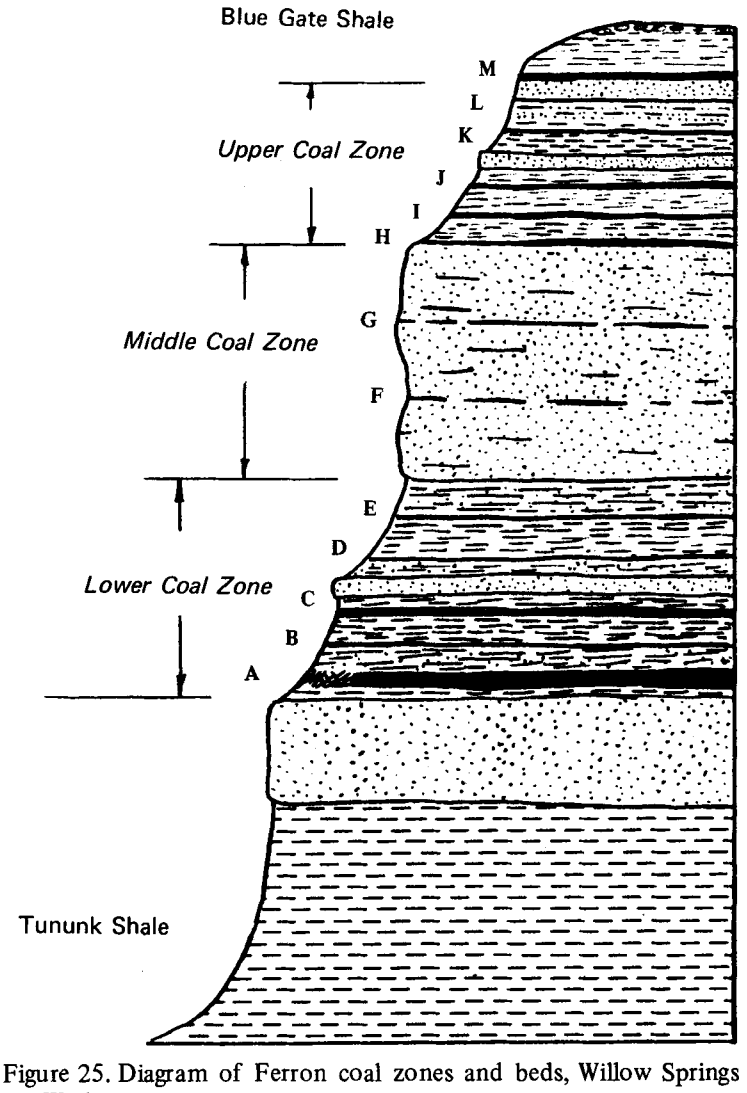


Figure 25. Diagram of Ferron coal zones and beds, Willow Springs Wash.

elevation of the cliff to the south is the influence of the Last Chance anticline. The regional dip is 3 to 5 degrees northwestward, but in the south exposures, the dip increases to 10 degrees because of the Last Chance structure.

No faults of consequence were discovered on the quadrangle; if any are located, they should have small displacements.

PROPERTY CONTROL

Ownership of the Emery 3 NE lands is as follows: Bureau of Land Management 84.8 percent, state of Utah 11.8 percent and private property 3.4 percent.

The private lands apparently have coal reserved to the United States and only 22 percent of the state lands are underlain with coal. Of the area of the quadrangle 38.6 percent can be classified as coal land. Practically all of the coal land is held by companies or persons in the form of leases, permits or other type of claim (January 1, 1970):

Name	Type of Claim
R. Albrechtsen	Permit application
Consolidation Coal Co.	Federal leases, state leases
D. Hunter	Federal permits and permit application
H. E. Jensen	State leases
Mountain States Resources	Permit application

COAL

Surface Information

One hundred and thirty-eight sections of coal were measured on the quadrangle (figure 26). All of Lupton's coal beds from the lowest A bed to the highest M bed are present in the area of Willow Springs Wash. The uppermost M bed is located practically at the Blue Gate-Ferron contact; it is highly lenticular, mostly split and usually represented by thin carbonaceous beds. On the north side of Willow Springs Wash it is present in a bed which averages 4 feet. The area involved is small and the coal is split by thin seams of bone or shale.

The Upper coal zone includes beds H to L. All are thin; the thickest bed measured is 2.6 feet. Locations 100 to 104 represent beds F and G or the Middle coal zone, which is also subcommercial. The Lower coal zone involves beds A to E, but only beds A and C are represented with measured sections. Bed C develops into 4 feet of coal in sec. 18, T. 24 S., R. 6 E. but elsewhere it is thin or missing. Bed A is the most valuable with coal seams up to 14 feet. It is thick everywhere except on the eastward-projecting salients north of Willow Springs Wash. It thins westward in T. 25 S. and achieves its maximum thickness in the canyon to the south of and tributary to Willow Springs Wash.

Subsurface Information

The coal of the Lower coal zone may be buried under more than 1,000 feet of cover under a few of the Blue Gate hills, but for the most part it occurs with less overburden.

At present no drill-hole data are available and the trend of the coal cannot be verified to the northwest.

Quality of Coal

Three analyses attest to the quality of the Ferron coal of this quadrangle (table 6). All are samples from the Lower coal zone A bed at weathered outcrops and prospects. The first two were channelled and some of the shaley and boney material of the splits is included. The analyses are not thought to be representative and further sampling is necessary. Sulfur is low on these samples, but moisture and ash are high (table 15).

Table 15. Average proximate analyses of coal, Emery 3 NE quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	3	13.0	10.1 -18.4
Volatile matter	3	33.4	32.9 -33.9
Fixed carbon	3	41.4	40.5 -42.2
Ash	3	12.2	5.6 -16.0
Sulfur	3	0.37	0.33- 0.41
Btu/lb	3	8,801	8,305-9,486

Mines and Development

The only known mine on the quadrangle is the Willow Spring mine along Willow Springs Wash (table 16). A prospect and possibly another were noted in the canyon tributary to and south of Willow Springs Wash.

Table 16. Mine in the Emery 3 NE quadrangle.

Mine	Location	Remarks
Willow Spring mine Lower zone-A bed	SE.NW.13-24S-5E 4,286,890m.N. 472,090m.E.	Active 1940?-1964

At present the site is abandoned, the adit is caved and no data are available on the production achieved. It is suspected the operation was small and that total production did not exceed 1,000 tons.

Reserves

Lupton (1916, p. 86) calculated the original reserve for the Emery field by township. Shown below, they are modified to fit the Emery 3 NE quadrangle.

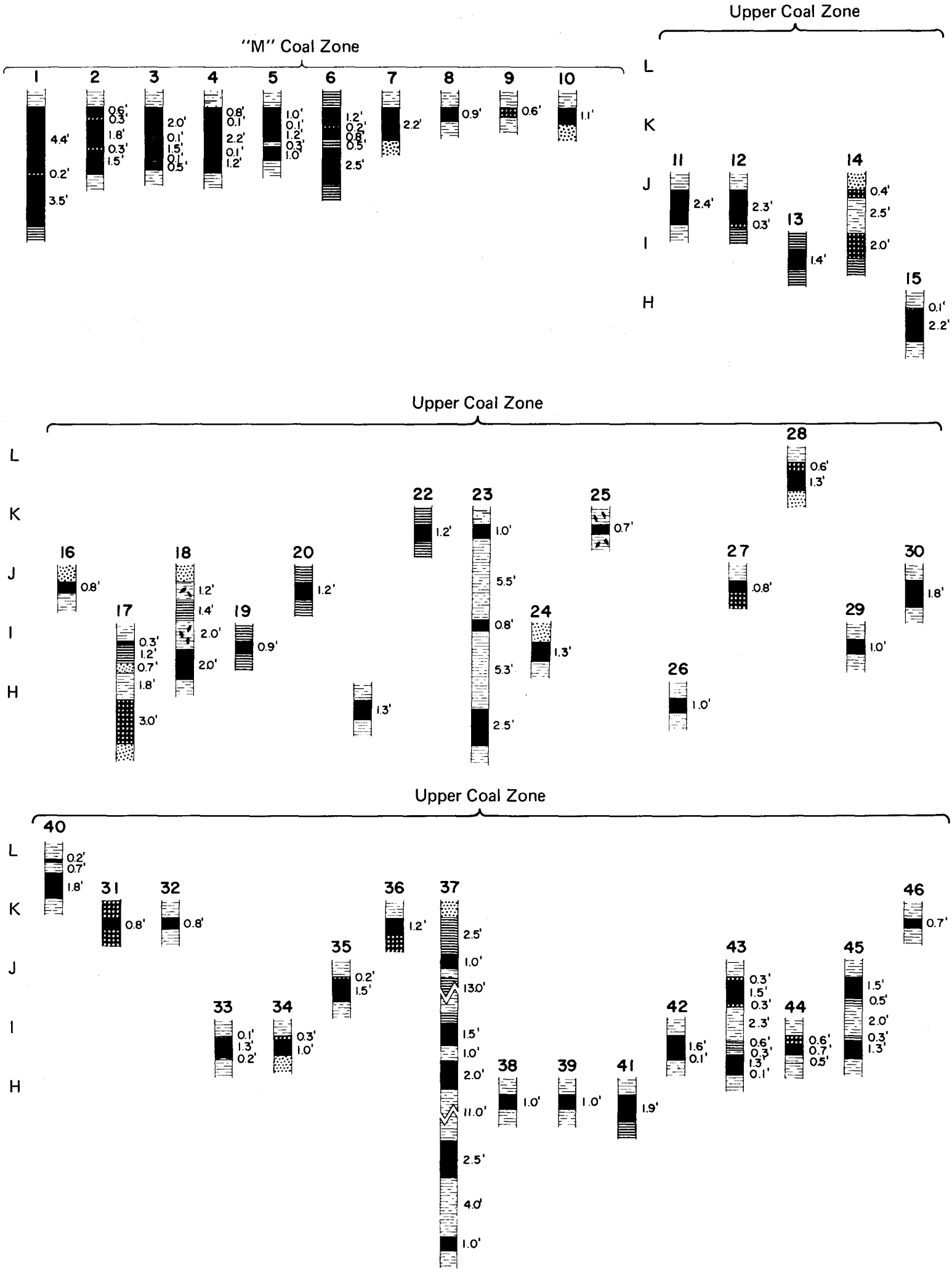


Figure 26. Coal sections of the Emery 3 NE quadrangle (vertical scale: 1 inch = 8 feet).

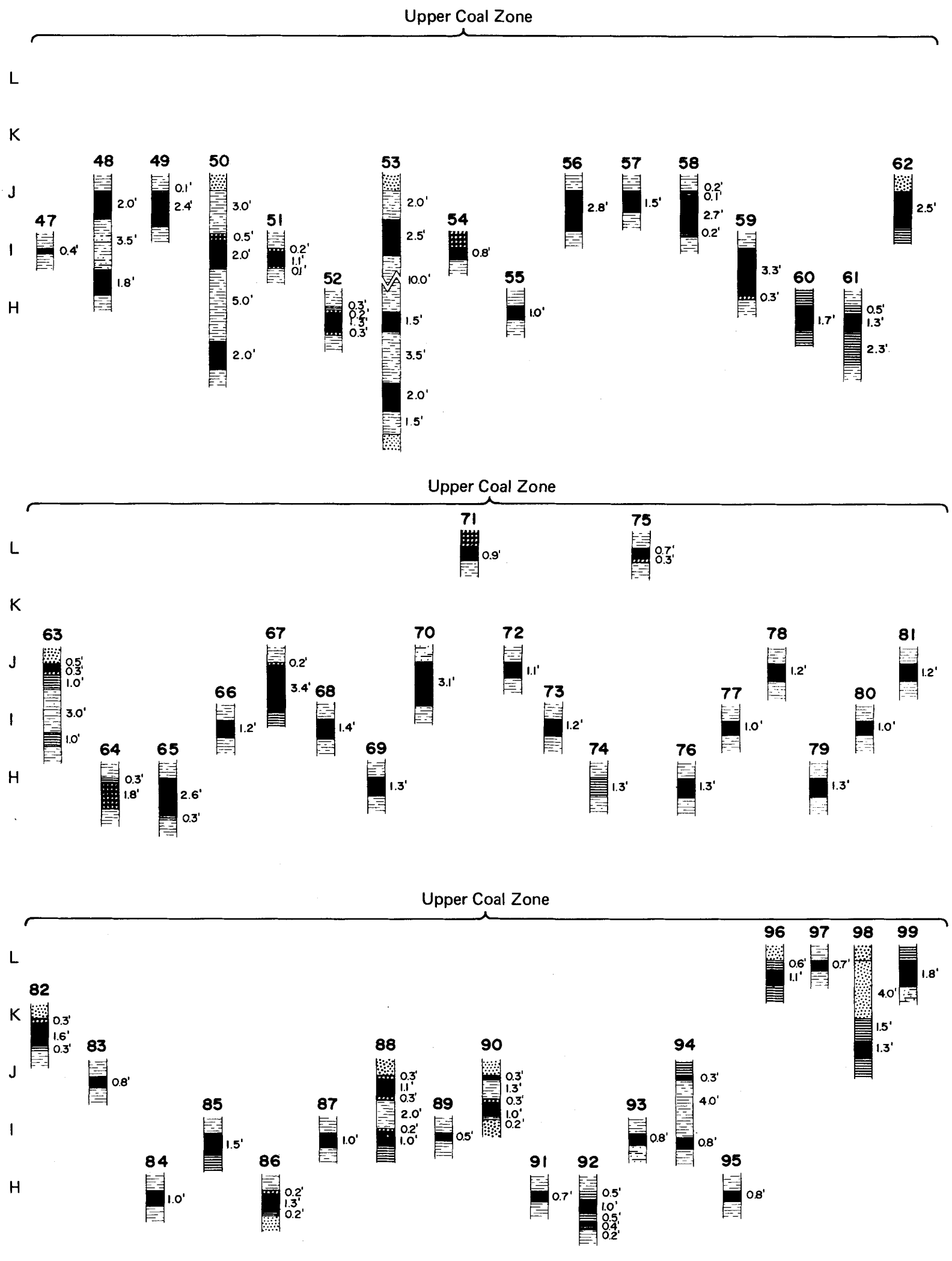


Figure 26. (continued)

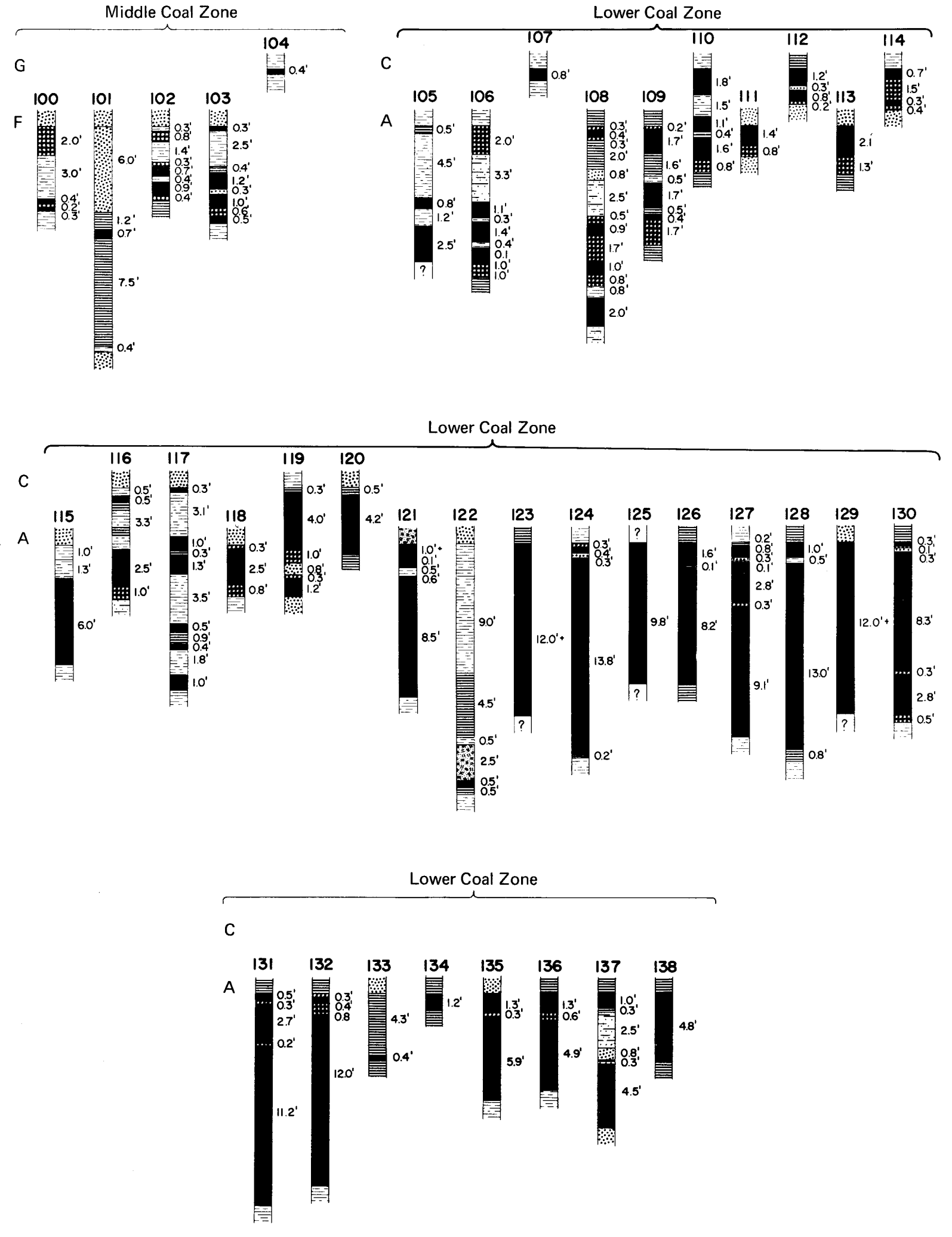


Figure 26. (continued)

	Tons	
T.24S. R.5E.	176,884,000	All beds
T.24S. R.6E.	22,671,000	All beds
T.25S. R.5E.	2,000,000	All beds
Total coal	201,555,000	

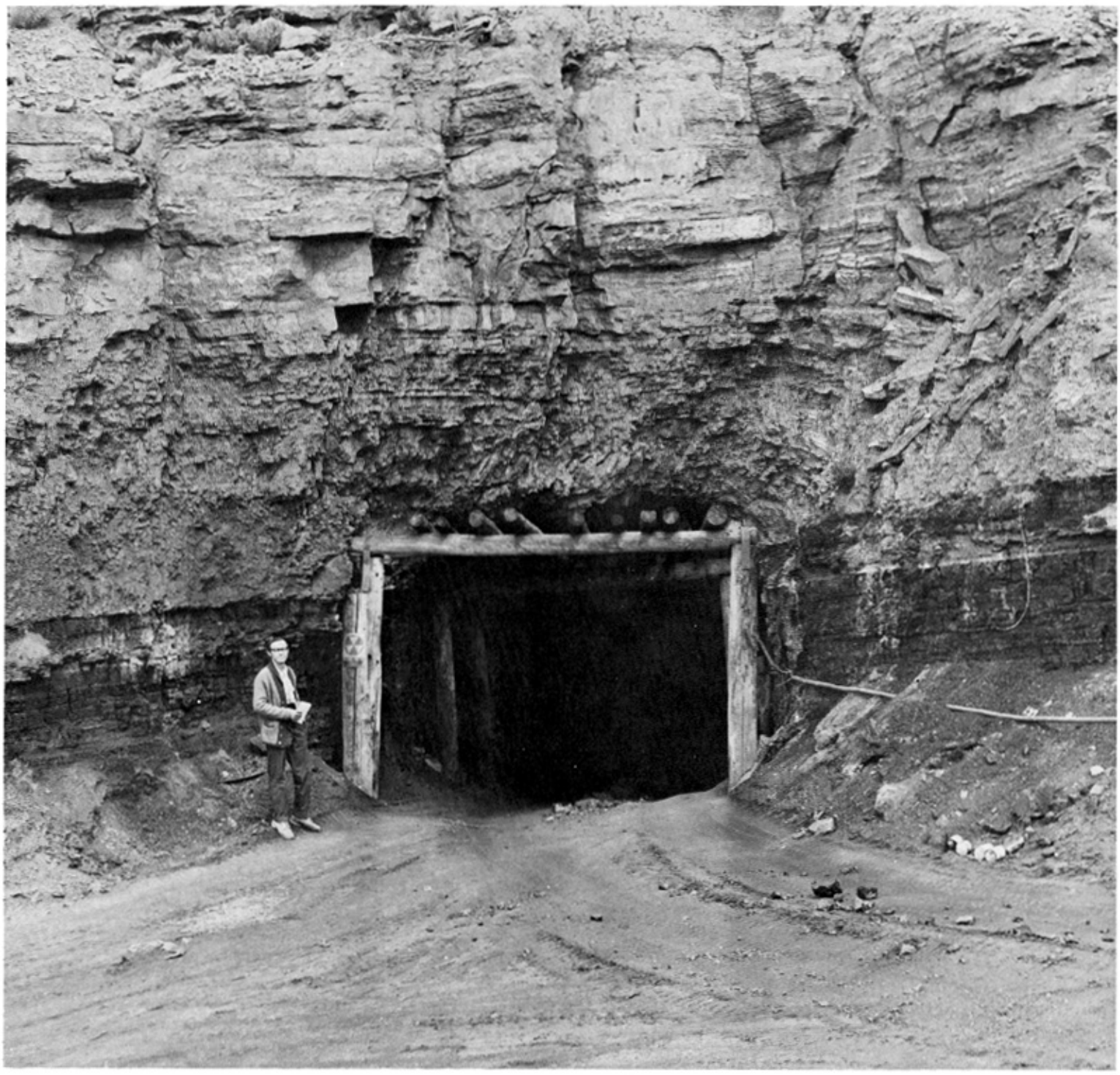
A recalculation based on coal beds 4 feet or more thick is given in table 17.

PRINCIPAL WORK

The geology was remapped in reconnaissance fashion by Utah Geological and Mineralogical Survey geologists and new coal data were collected. Lupton's (1916) coal data were incorporated into the study.

Table 17. Original coal reserves in short tons (Classes I and II; beds average 4 feet or more thick), Emery 3 NE quadrangle.

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.24S. R.5E.	28	4.0	195,000	"M" bed
central	4,309	11.3	84,821,000	A bed, lower zone
north	1,095	5.7	10,874,000	A bed, lower zone
south	1,781	6.5	20,166,000	A bed, lower zone
T.24S. R.6E.	51	4.0	355,000	"M" bed
	46	4.0	321,000	C bed, lower zone
	896	5.5	8,585,000	A bed, lower zone
T.25S. R.5E.	654	5.7	6,496,000	A bed, lower zone
		Total	131,813,000	
Class III				
T.24S. R.5E.	4,779	6.0	49,950,000	A bed, lower zone
		Total Coal	181,763,000	



Portal to Dog Valley mine cut in the "I" seam, Acord Lakes SE quadrangle; coal bed is 11 to 13 feet thick.

EMERY 3 NW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The quadrangle is located at the south end of the Wasatch Plateau coal field and nearly at the south end of the Emery coal field where both abut against the Fish Lake Plateau (figures 17 and 27). The Paradise area lies south of Utah Highway 10 (Interstate 70). The land is difficult of access, mountainous and rugged. Altitudes range from 6,800 feet near the mouth of Last Chance Creek to more than 10,000 feet in the southwest map corner. The coal beds lie at elevations between 6,800 and 9,200 feet.

The principal road is Utah Highway 72, a graded road which joins Utah 10 with Fremont and other towns in Wayne County. It roughly parallels the Paradise fault in the east third of the quadrangle; other roads are rough mountain trails. Snow is a problem in the wintertime and unplowed roads seal off the area for the season.

Parts of two coal fields are represented in the quadrangle: the Emery field east of the Paradise fault and the Wasatch Plateau field west of the fault. An exception to this division is made in the southwest map corner to include the Paradise Valley prospect in the Emery field.

STRATIGRAPHY

Both unconsolidated and consolidated beds have significant outcrop areas on the Emery 3 NW quadrangle. East of the Paradise fault the outcrops consist of the lower members of the Mancos Shale. West of the fault the consolidated units are typically Wasatch Plateau commencing with the Emery Sandstone and extending up section to the North Horn (Tw). The uniformity of outcrop is unlike that of the north quadrangles because of the presence of many faults and covering gravel deposits.

The Tununk Shale Member of the Mancos is the oldest unit; it is exposed in the southeast map corner. It forms badland topography in the desert east of the Coal Cliffs. It is a dark brown-black clay and siltstone shale about 800 feet thick. The Tununk is capped by a resistant sandstone unit, the Ferron, which supports the Coal Cliffs. It consists of alternating sandstone and shale beds with as many as ten coal beds above a basal 180-foot sandstone unit. Drainages have not cut deeply into this unit and during flash floods waterfalls develop over it. The Ferron, which is about 800 feet thick, forms the basis of the Emery coal field. Only the upper 400 to 450 feet contain coal beds. The lower interval consists mainly of littoral cliff-forming sandstones. Only three to four beds achieve thicknesses of commercial interest: one, a lower bed near the top of the lower sandstone and the upper two, within 150 feet of the top. Occasionally a fourth bed occurs intermediate. The uppermost bed is usually located along the Blue Gate-Ferron contact.

The Blue Gate Shale Member of the Mancos is the uppermost unit east of the fault. At least 1,000 feet of the member are exposed in rounded hills, mountains and knolls atop the Ferron. The Blue Gate is a blue-gray shaley and silty unit much like the Tununk with intermittent thin beds of sandstone. Alluvium derived mainly from the clay of the Blue Gate occurs in numerous patches on its surface. The complete Blue Gate is an estimated 1,600 feet thick.

The next unit, the Emery Sandstone, is here confined to the west side of the fault. The mapping presented is preliminary and all exposures noted as the Emery may in reality be a similar cousin. If one were to remove the Cretaceous sandstones from their normal sequence, they would be difficult to separate and identify. The Emery forms a series of step-like cliffs, each sandstone bed separated from the next by intervening shale. Normally the unit is barren of coal, but a 12- to 13-foot seam lies in the south end of the quadrangle just west of the fault in a slice. Another coal bed about 3 feet thick occurs topographically higher on the opposite side of a fault. It is certainly possible that these are fault slivers of the Ferron or even the Blackhawk, but for the present they are assigned to the Emery. Because no base of the unit can be determined and the lower part is against the fault, no complete thickness can be determined. At least 800 feet are exposed in outcrop. In a well drilled NE.SE. 8-25S-4E the initial unit was reported to be Blue Gate Shale and an orderly sequence of beds followed below through the Dakota. Faults or improper mapping may explain this phenomenon. In the well, the top of the Ferron was penetrated 2,245 feet below the surface–more than the estimated Blue Gate total thickness. The local area is badly in need of detailed mapping.

The blue-gray drab shales of the Masuk Shale Member of the Mancos are exposed above the Emery. It is much like the Blue Gate but sandier and often exhibits a yellow-gray color. In the north part of the quadrangle the outcrop is continuous; to the south it is broken up into islands separated by seas of gravel. The Masuk is the youngest member of the Mancos and is about 600 feet thick in Emery 3 NW.

The Star Point Sandstone, as usual, forms a cliff above the Masuk. Thick-bedded to massive sandstone beds yellow-gray in color dominate, each bed separated by shale or sandy shale. The Star Point is about 200 feet thick and seems to thicken slightly northward. The upper contact is more difficult to discern on this quadrangle because the lower part of the Blackhawk is cliffy and the Hiawatha coal bed is not developed.

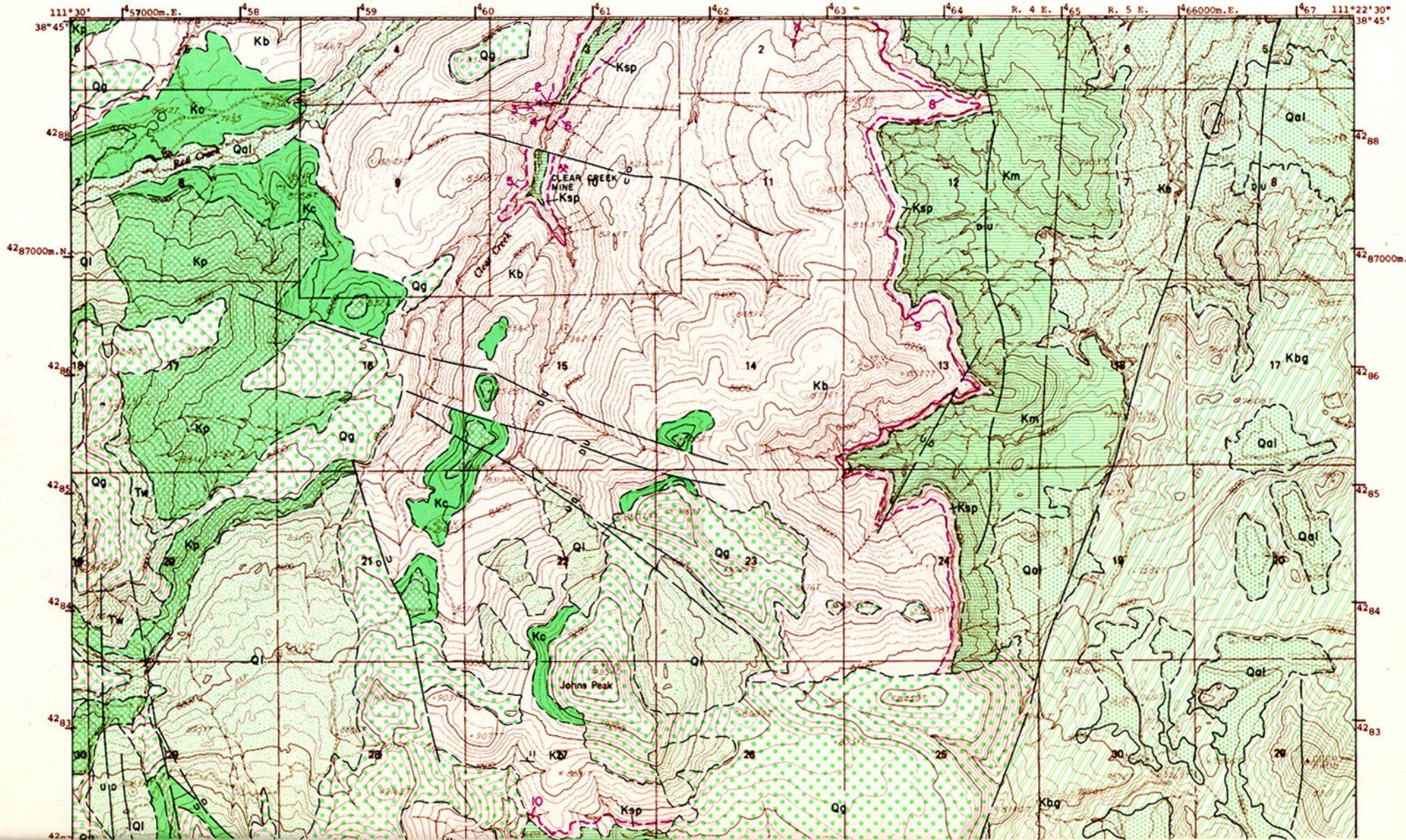
The north central map area consists dominantly of exposures of the Blackhawk Formation, which forms the basis of the Wasatch Plateau coal field. All the coal beds are believed in the lower part of the unit. The lithology of the 750-foot formation is alternating sandstone and shale. Spieker (1931, p. 35) provided a rough generalization of its lithology:

	Feet
Upper massive sandstones, little or no coal	280
Blocky sandstone, shale and thin coal beds	350
Lower massive sandstone and thick coal beds	120
	750

The next younger unit is the Castlegate Sandstone, a massive coarse-grained and cliff-building unit. The Price River Formation is similar except that the bedding is not as massive and intervening shaley units occur. Consequently the formation is less resistant. In places the initial coarse-grained unit above the Blackhawk is not a massive cliff former and the entire sequence is assigned to the Price River Formation. The combined Castlegate-Price River may be 800 feet thick. The exposures are located in the northwest part of the map.

Wedged between faults to the northwest are small patches of the North Horn Formation (Tw). Thickness of the variegated shale unit is impossible to determine because of faulting. In the southwest map corner Bullion Canyon volcanics of Tertiary age, which cap a large part of the Fish Lake Plateau, outcrop. The volcanics which effectively end the coal field continue southward in one plateau block after another for 50 miles where Cretaceous rocks again reappear in the Kaiparowits Plateau. In the Kaiparowits the rocks are coal bearing as well. The area surrounding the volcanics is covered with an apron of high-level gravel composed of volcanics, quartzites, chert and limestone. The latter constituents appear to have a Precambrian or Paleozoic primary age which probably indicates a major uplift beneath the volcanics. In addition large patches of landslide developed on some of the incompetent units.

EMERY 3N.W., UTAH



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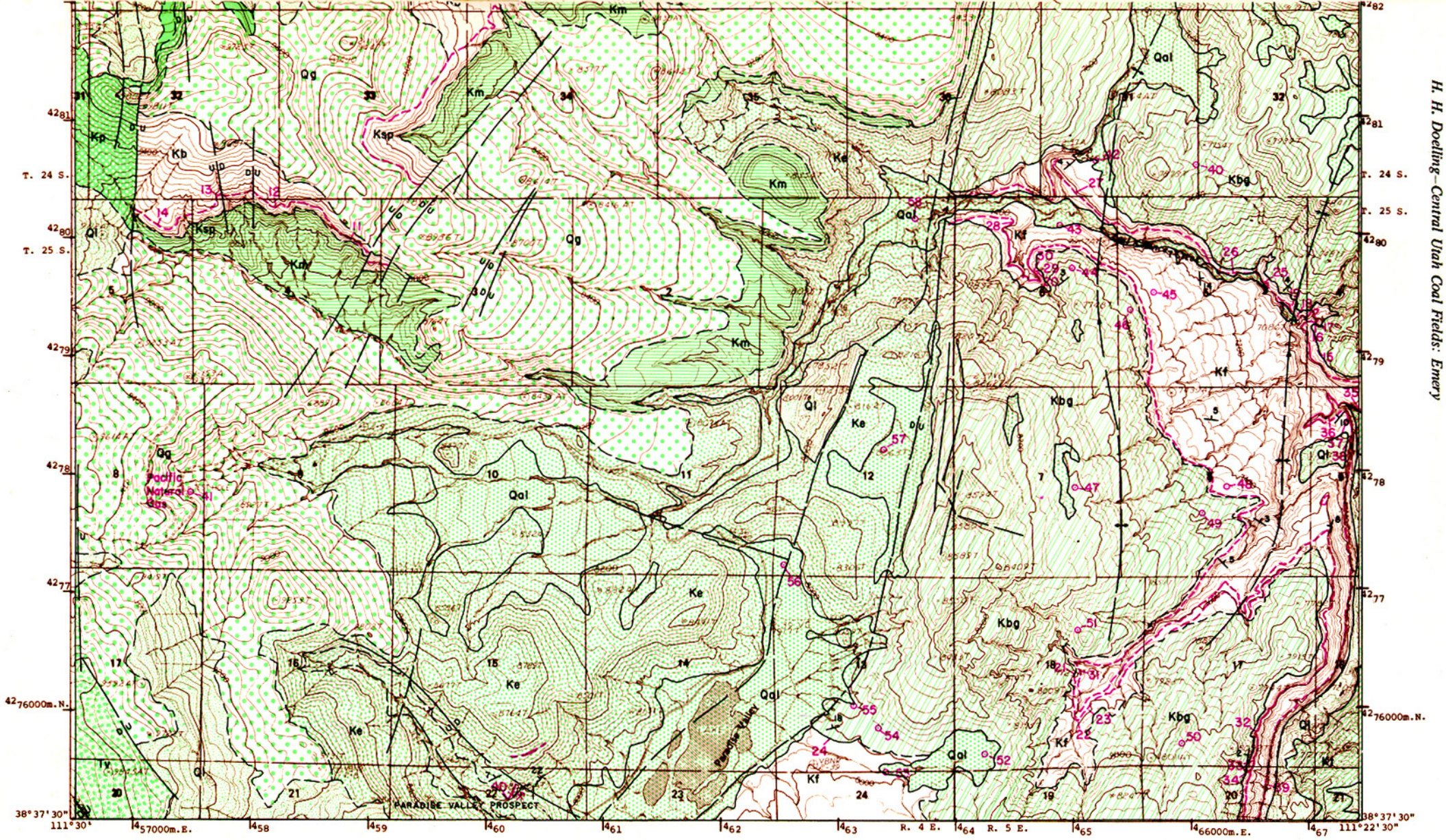

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TOPOGRAPHY BY
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

Contour interval 20 feet

Geology and coal data by E. M. Spieker
1931, USGS.

Figure 27. Coal and geology map, Emery 3 NW quadrangle (explanation pages 448-449).

STRUCTURE

Numerous faults on Emery 3 NW probably represent a clash between the Joes Valley-Paradise fault zone and those involved with the apparent uplift centered to the south. The Joes Valley faults trend mainly north-south and have the larger displacements. The Ferron is exposed just east of the major fault and a little to the south. The other faults appear to have an irregular direction although in clusters they have similar trends. They are probably radial and concentric to the high centered to the south. With a few exceptions most of these faults have less than 100 feet of displacement. One north-south fault along the west map edge has at least a 1,500-foot displacement with Price River against the Masuk. This fault may be a southward extension of the Musinia fault zone. Other faults may be detected by future mapping and those presented may have to be realigned. East of the Paradise fault the rocks are little faulted but moderately folded. At least a pair of structural axes can be determined with dips between them up to 15 degrees. Less is known about the attitude of beds to the west. Regionally they dip gently westward or northwestward as is the case in the north part of the quadrangle. Farther south the beds are inclined more to the north at steeper angles.

PROPERTY CONTROL

On January 1, 1970, lands of the Emery 3 NW quadrangle were divided as follows: National Forest Service 78.5 percent, Bureau of Land Management 16.7 percent, private property 2.9 percent and state of Utah 1.9 percent.

BLM lands and state lands are located along the east edge of the map and the private land is mostly in the Paradise Valley area. The coal lands are divided between the Blackhawk, bearing Wasatch Plateau coal, and the Emery coal field (Ferron coal). It is estimated that a little more than 70 percent of the land may be classed for coal. Actually only a few hundred acres are not underlain with coal. A band of land between the Blackhawk and Emery outcrops, however, is considered to exceed the 3,000-foot overburden limit for the Ferron. Of the coal lands 51.3 percent are assigned to the Wasatch Plateau and 48.7 percent to the Emery field.

Over 77 percent of the Emery portion of the coal lands are leased or permitted, all by Mountain States Resources Company; this includes 32-24S-5E as a state lease. No land is held in the Wasatch Plateau area.

COAL

Surface Information

Thirty sections are available for the Emery 3 NW quadrangle (figure 28); fourteen represent the Wasatch Plateau and the remainder the Emery field. The coal data for the Wasatch Plateau are supplied in the Emery 3 NW quadrangle report for that field (p. 163).

The coal in the Emery field is in the Ferron Sandstone Member of the Mancos Shale. Originally studied by Lupton (1916) the coal seams were given letter designations A to M. In this area only three beds or perhaps zones are prominent: an upper, lower and a zone located at the top of the Ferron. This uppermost coal, the M bed, is represented by ten sections indicating coal up to 10 feet thick. It is lenticular and best developed in a gulch on the south side of Last Chance Canyon. The next coal zone, probably Bed L designated as the Upper coal zone, lies about 35 to 60 feet below the upper contact. The bed is mostly thin in outcrop except in an axis paralleling the anticline in secs. 6 and 7, T. 25 S., R. 5 E. Here the bed is 4 to 5 feet thick but is usually split by ½ foot of shale.

The Lower coal zone, probably the A bed, lies atop a 160-foot lower massive sandstone of the Ferron. The sandstone and shaley beds above the sandstone are lenticular and it is possible that some measurements include everything to the D bed. In outcrop the exposures are mostly thin except at the mouth of Last Chance Creek where the bed thickens from 2½ feet at the cliff edge to 5 feet in an interval of 1,000 feet. This may indicate that the bed thickens to the northwest in the subsurface.

Just west of the Paradise Valley is a 12-foot thick coal outcrop presently assigned to the Emery. If this is a sliver of Ferron Sandstone it lends importance to the theory that the coal thickens westward behind the outcrops. Palynological data do not support this assumption.

Subsurface Information

In the Emery field at least sixteen available drill holes yield some general information: eleven are located east of the main Paradise fault, three just to the west of the fault and one, originally drilled for natural gas, is 4 miles west of the fault. Coal beds ranging to 13 feet thick are believed to have been encountered. The greatest thickness is in the Lower coal zone in hole 5. Other holes penetrated the zone as thin as 4.5 feet in places with a 6-inch split in the middle. The Upper zone beds range to 9 feet thick. The best area appears to be in the vicinity of holes 54 and 55. Normally two beds occur in the upper zone with a separation of 35 to 45 feet in drill hole. The combined coal thickness is usually more than 10 feet. The uppermost bed may correspond to the M bed.

Drill holes 56, 57 and 58 just west of the fault did not penetrate coal. All the coal east of the fault has less than 1,000 feet of overburden, except perhaps at isolated knolls to the northeast. In 1963 Pacific Natural Gas No. 48-3 was drilled in NE.SE. 8-25S-4E. The Ferron was encountered at 2,245 feet, the Dakota at 3,835 feet and the Cedar Mountain Formation at 3,970 feet depth. Subsequent examination of drill-hole cuttings revealed two coal beds near the top of the Ferron. The first and uppermost bed is thought to be 9 feet thick and the second, 13 feet thick. Separation is 75 to 80 feet. This appears to be in agreement with the two Upper zone beds discovered by the drill holes east of Paradise fault. The coal bed west of the fault at the Paradise Valley prospect dips 7 degrees westward and a projection toward the gas well nearly intersects the hole at the proper elevation. However, recent palynological data from the prospect's coal favor a Blackhawk horizon. Twelve feet of coal are exposed at the prospect. In the gas well, at the position of the Lower coal zone, only an indication of the presence of coal was detected.

The 3,000-foot overburden limit atop the Ferron is impossible to place accurately in light of correlation problems. If the gas well data are correct, the line will fall somewhere parallel and within the Masuk Shale outcrops. Other assumptions are highly speculative. The upper coal beds east of the fault are shallow enough over a considerable acreage to be surface-mined.

Quality of Coal

Three analyses are available for coal in the quadrangle: two from the Ivie bed in the Blackhawk Formation and one from the Lower zone of the Ferron at map location 36 (table 6). On all three, sulfur content is low, between 0.5 and 0.6 percent. The moisture content is high but this may be the result of samples collected from weathered outcrops or prospects. The ash content of the Ferron coal is higher than that of the Ivie bed (6.5 percent to 9.0 percent) and the calorific value for the Ferron is lower.

Mines and Development

A few small mines and several prospects have been opened on the Emery 3 NW quadrangle. Adits have been driven in Clear Creek Canyon, Red Creek Canyon, Last Chance Canyon and on the west side of Paradise Valley. Those in Red Creek and Clear Creek canyons are in the Ivie bed. Those in Last Chance Canyon are in the Upper zone of the Ferron and the one on the west side

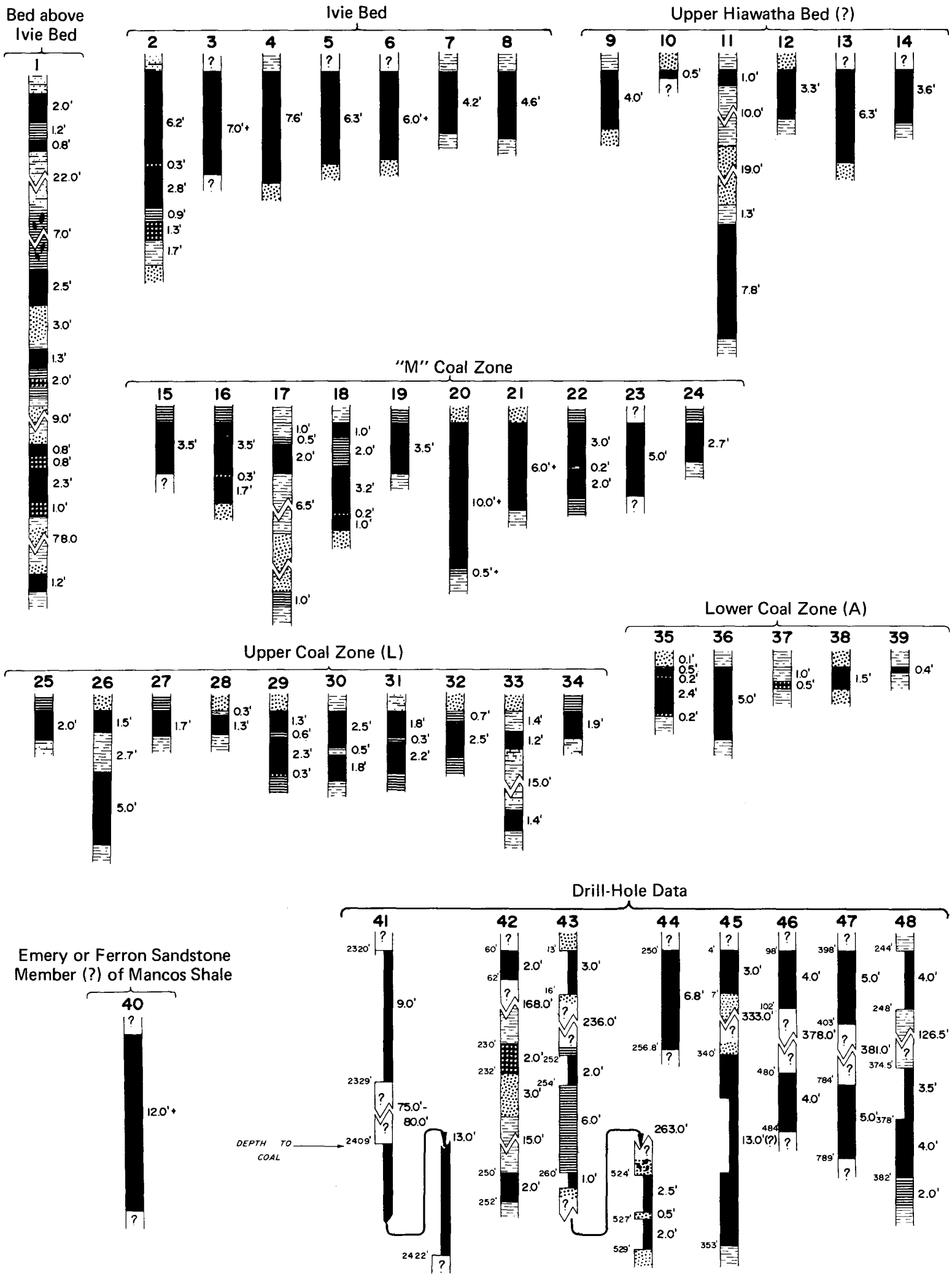


Figure 28. Coal sections of the Emery 3 NW quadrangle (vertical scale: 1 inch = 8 feet).

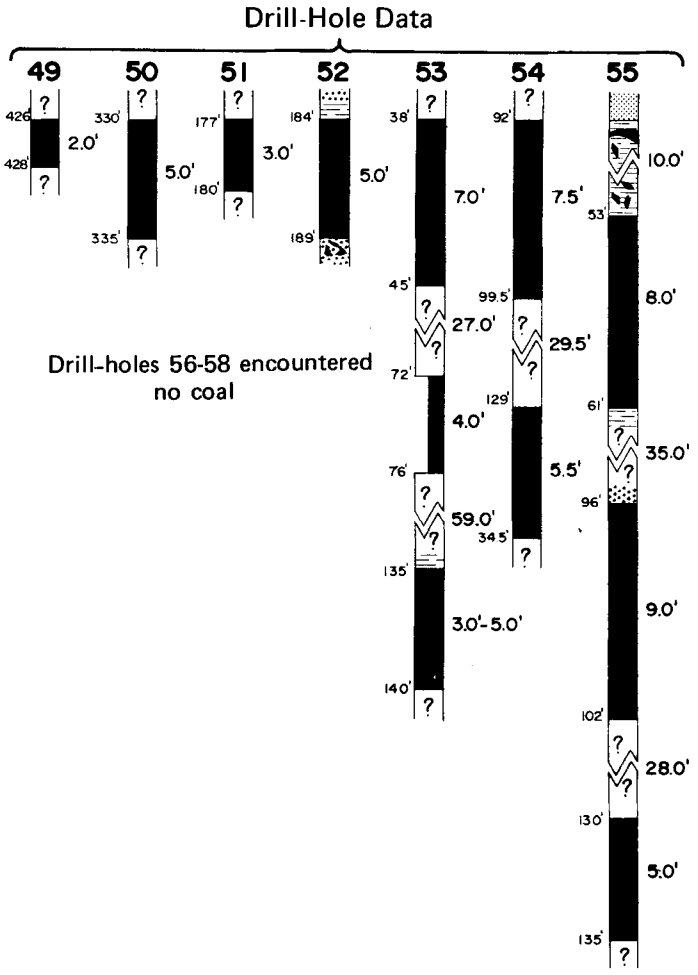


Figure 28. (continued)

of Paradise Valley is not yet definitely correlated. Lupton (1916, p. 76) makes no mention of the prospect at this locality and it is believed that the digging was later than 1916. The other prospects were noted by Spieker from his 1922 field work. Nothing is known about these mines or their production. Some of the tunnels were visited by the present author; all seem old and as if little coal was removed.

Reserves

Spieker (1931, p. 206) calculated the reserves for the Wasatch Plateau part of the field (table 18).

Lupton (1916, p. 86) worked out reserves for the Emery field. His reserves adjusted to the quadrangle are shown in table 19.

Table 18. Original coal reserves in short tons (beds 30 or more inches thick), Emery 3 NW quadrangle, Wasatch Plateau coal field.

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.24S. R.4E.	8,852	6.0	95,601,600	Ivie bed secs. 1-18, 21-24
	5,400	4.0	38,880,000	other beds
		Total coal	134,481,600	

Table 19. Original coal reserves in short tons, Emery 3 NW quadrangle, Emery coal field.

Location	Total	Recoverable	Bed or zone
T.24S. R.5E.	92,259,000	51,255,000	All beds
T.25S. R.4E.	10,031,000	5,580,000	All beds
T.25S. R.5E.	36,630,000	20,350,000	All beds
Total coal	138,920,000	77,185,000	

No consideration is made for Emery (Ferron) coal west of the fault zone. With the new drill-hole data into account a re-evaluation is made of the reserve (table 20).

Table 20. Reevaluated coal reserves in short tons (beds 4 feet or more thick and east of Paradise fault only), Emery 3 NW quadrangle.

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.24S. R.4E.	296	10.0	5,200,000	All beds
T.24S. R.5E.	4,349	10.0	75,800,000	All beds
T.25S. R.4E.	612	5.4	5,700,000	M bed
	632	6.4	7,000,000	Upper zone
	225	6.0	2,400,000	Lower zone
	819	5.7	8,100,000	All inferred beds
T.25S. R.5E.	2,404	5.4	22,600,000	M bed
	333	4.0	2,300,000	Upper zone
	630	6.4	7,000,000	Upper zone
	2,392	6.0	25,000,000	Lower zone
	950	5.5	9,100,000	All inferred beds
		Total coal	170,200,000	

Potential Emery coal field reserves on the west side of the fault include areas in T. 24 S., R. 5 E. and T. 25 S., R. 4 E: 19,800,000 short tons.

Total coal on the quadrangle, including beds from both fields and all classes, is 424,500,000 tons. This tonnage divided into classes of reserve is as follows.

Classes I & II	82,500,000	(Measured, indicated)
Class III	222,200,000	(Inferred)
Class IV	119,800,000	(Potential)

PRINCIPAL WORK

Data for the Emery 3 NW quadrangle came from Spieker (1913), Lupton (1916), Graham (1970) and a small amount of additional work was done in the field specifically for this report. Considerable unpublished data were also supplied by Mountain States Resources Co.

EMERY 3 SW QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Emery 3 SW quadrangle is the southernmost of the Emery coal field (figure 17 and 29). The north edge is located 10 miles south of Utah Highway 10 and Interstate 70, 70 miles south of Price and 40 miles southeast of Salina. Only the northwest part of the map area can be considered coal land. The land is rugged, mountainous and cliffy. In the badlands and rough lands below the Coal Cliffs, elevations range from 6,500 to 8,000 feet. The cliffs have a relief of 600 to 700 feet; the land above continues to rise although not as steeply. The highest areas are above 10,000 feet and Geyser Peak is 10,597 feet above sea level. Most of the coal beds are exposed along the cliffs between 7,400 and 8,600 feet above sea level.

Access to the cliffs from below is poor. The main road above, Utah Highway 72, is graded. Jeep trails connecting with Utah 72 and leading to the outcrops are few. The highway is closed in winter because of snow.

STRATIGRAPHY

Consolidated stratigraphic units that crop out on this quadrangle are Jurassic, Cretaceous and Tertiary in age. The Jurassic units have not been mapped and the area is shown as a single undifferentiated unit. Units that are undoubtedly exposed in this grouping include the Entrada, Curtis, Summerville and Morrison formations. Two Cretaceous units are also included, Cedar Mountain and Dakota formations. The Dakota is thin, about 60 feet, and its outcrop nearly follows the line marking the base of the overlying Tununk Shale. A description of the Dakota is given by Lupton (1916, p. 29) in a section measured in SE ¼ sec. 25, T. 25 S., R. 4 E.

	Feet
Sandstone and bluish sandy shale alternating	.30
Shale, brown, carbonaceous	.1
Coal, impure	0.7
Shale, brown, carbonaceous	0.7
Sandstone (?), poorly exposed	.12
Sandstone, white	2.5
Coal, rusty, probably impure	0.3
Sandstone and sandy shale, poorly exposed	.12
Shale, coaley, very carbonaceous	0.7
Total	.59.9

The Dakota is overlain by the Tununk Shale which represents the first Cretaceous marine invasion of the area. Lupton (1916, p. 39) notes that the unit is about 600 feet thick and consists of bluish drab shale that is sandy in its lower and upper parts. The unit is remarkably uniform and its exposures in this quadrangle do not differ. Examination of the map indicates that the Tununk is at least 700 feet thick. The Tununk is usually covered with landslide debris as it becomes very plastic when wet. Large blocks, boulders and even large sections of the overlying Ferron Sandstone have collapsed into it.

The coal-bearing Ferron is exposed along the cliffs which roughly trend northeasterly. The southwest exposures end abruptly at the Joes Valley-Paradise fault zone. West of the fault the surface rocks consist of Tertiary volcanics or Emery Sandstone. What is mapped as Emery may be Ferron Sandstone or Blackhawk Formation. A measurement of the Ferron made in NE.30-25S-5E describes the unit:

Mancos Shale: Blue Gate Member

Ferron Sandstone	Feet
1. Carbonaceous shale	1.5
2. Coal, poorly exposed	1.2
3. Gray shale, sandy	4.0
4. Sandstone, yellow-gray, massive, cliff forming	.35.0
5. Coal	1.0
6. Sandstone, like unit 4	.43.0
7. Gray shale	5.4
8. Sandstone, light tan, medium-grained, thick-bedded, resistant	.11.9
9. Gray shale	.15.9
10. Sandstone, like unit 4	.63.0
11. Gray and carbonaceous shale	.18.5
12. Coal and gray shale	0.5
13. Covered slope–shale?	.24.3
14. Sandstone, brown and tan, medium-grained, medium-bedded, weathers into loose thin plates and blocks	5.8
15. Gray shale, poorly exposed	.16.7
16. Sandstone, like unit 14	4.6
17. Sandstone, light tan, fine-grained, massive, resistant ledge former	.47.9
18. Coal, poorly exposed	5.2
19. Gray shale	1.9
20. Sandstone, like unit 14	.22.6
21. Carbonaceous shale and thin coal	1.9
22. Sandstone, tan to brown, medium-grained, thick-bedded, resistant ledge former	.30.5
23. Sandstone, white to light tan, coarse-grained, massive ledge former	.60.0
24. Sandstone, like unit 23, but poorly exposed, covered with landslide debris, accuracy of measurement insured only because the true contact between the Tununk and Ferron was located under rubble	.307.8
Total Ferron	.730.1
Tununk Shale	

All the sedimentary beds of the Ferron are lenticular, including the coal. Essentially three zones of coal exist: a Lower characterized by unit 18 of the preceding section, an Upper characterized by unit 5 and the M bed characterized by unit 2.

Atop the Ferron is the Blue Gate Shale, mostly gray, occasionally interrupted by a thin bed of brown or tan sandstone. The unit is incompletely exposed and only the lower 500 to 600 feet are present.

Cretaceous beds crop out west of the Joes Valley-Paradise fault zone; these were mapped as Emery, but may well be another fault block of the Ferron or Blackhawk. The Emery Sandstone Member of the Mancos overlies the Blue Gate and in the vicinity of Emery town is 800 feet thick. It normally forms a step-like series of cliffs with the risers taller than the width of the planars. The lithology is the same as that of the Ferron except that in outcrop usually no coal occurs and the amount of shale is less. Just north of the quadrangle a 12-foot coal bed is exposed in a fault sliver which may refute the previous sentence.

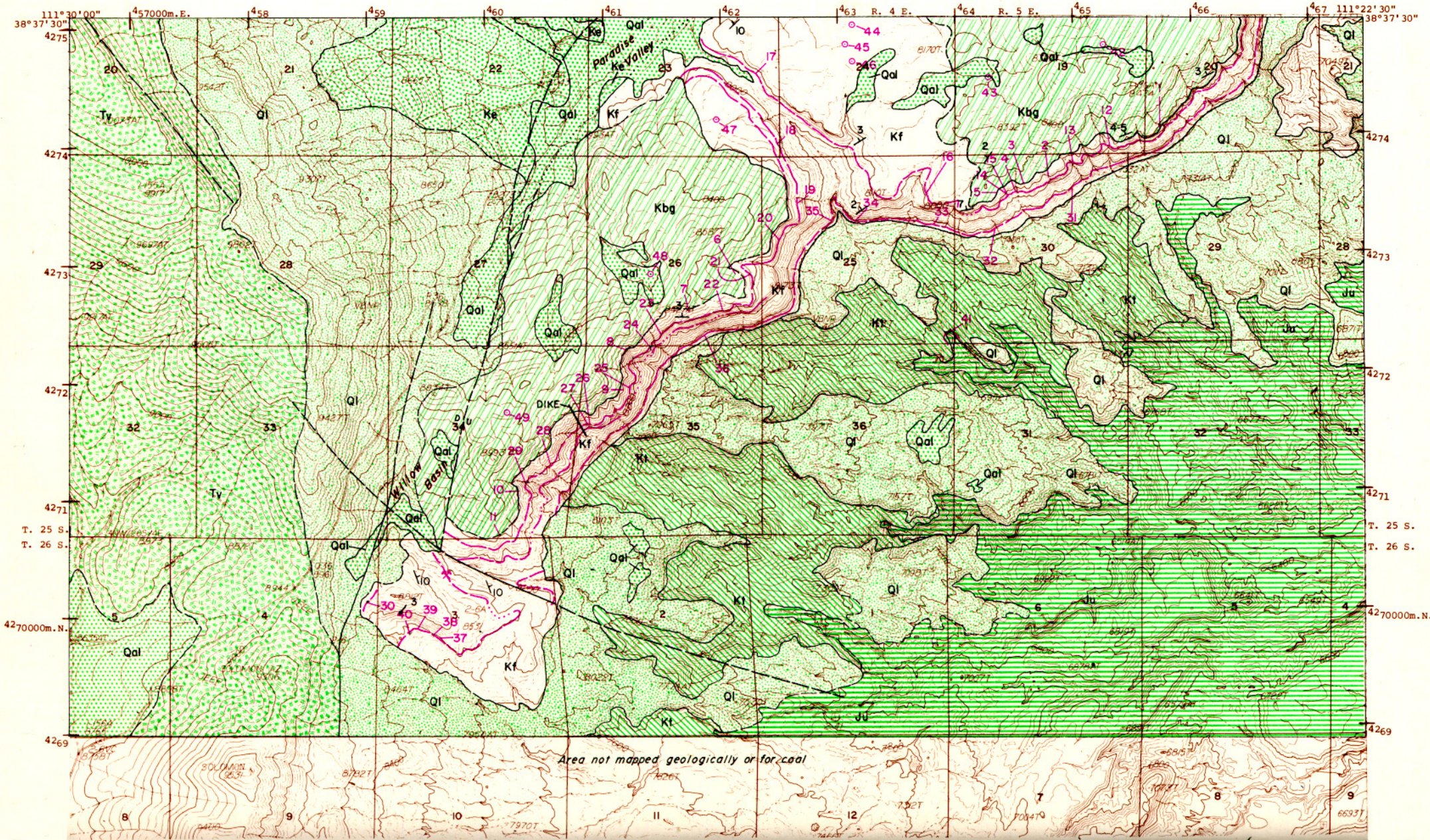
In the west part of the quadrangle are exposures of volcanic rocks. They have not been adequately studied and belong to the Bullion Canyon series of volcanic flows: andesites, latites and basalt. They effectively cover the Cretaceous beds in that part of the area. Volcanic boulders also lie over much of the surface, the vesicular basalt scattered atop the Blue Gate, Ferron, Tununk and Jurassic units below the cliffs.

A large surface area of landslide debris also is present above and below the cliffs. A large patch of alluvium is located at the south end of Paradise Valley and smaller patches have collected at other favorable areas.

STRUCTURE

The strike of the Ferron is very nearly northeast and northwesterly dips are up to 10 degrees. Most dips measured between 2 and 5 degrees. The Joes Valley-Paradise fault zone is by far the most significant structural feature of the area and trends N. 25° E. There are several faults in the zone and most likely not all have been properly mapped. Paradise Valley, in the north part of the map, is a graben block caught between two major faults. If the Emery is exposed west of the fault, the total displacement is about 2,000 feet, but if the Ferron Sandstone is exposed, then displacement is much less. The Willow Basin fault appears to cut across the fault zone at right angles. Its presence causes the

EMERY 3 S.W., UTAH



Utah Geological and Mineralogical Survey Monograph Series No. 3, 1972

Topography by U.S. Geological Survey

SCALE: 1:42240

½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

Contour interval 20 feet

Geology by R. L. Graham, 1969, UGMS; coal data by C. T. Lupton, 1916, USGS, and H. H. Doelling, F. E. May and R. D. Gray, 1970, UGMS.

southernmost mile of the Ferron outcrops to change dip. The regional strike is N. 50° E. with dips a few degrees to the northwest. South of the Willow Basin fault the beds strike N. 29° W. with dips 10° northeast. The displacement is not great; the fault is rotational and acted as a hinge.

PROPERTY CONTROL

All but 4.4 percent of the land is owned by governmental agencies. The state of Utah controls 2.1 percent, National Park Service 3.1 percent, Bureau of Land Management 9.7 percent and the National Forest Service 80.7 percent. Only about 12 percent of the land is considered favorable for coal, all located in the north third of the quadrangle. Practically all this land is in the Fishlake National Forest.

All the coal lands east of the Joes Valley-Paradise fault system are held by Mountain States Resources Co. in the form of prospecting permits. This amounts to three-fourths of what is considered potential coal land (January 1, 1970).

COAL

Surface Information

The Ferron has three zones of coal developed in the Emery 3 SW quadrangle (figure 30). Their position in the stratigraphic column is approximately as shown below:

Blue Gate Shale Member of Mancos	Thickness (feet)
"M" bed	0-5
Interval	35-45
Upper coal zone beds	0-7.5
Interval	250-340
Lower coal zone beds	0-6.5
Sub-coal strata	

The Lower coal zone crops out only along the cliffs. Most measurements are thin and the average is 2.2 feet with total coal up to 6.4 feet. Location 37 indicates a single seam of 5.1 feet, but 1.4 feet appear to be boney. The coal appears to thicken slightly westward.

The Upper coal zone occurs in the upper part of the Ferron cliff and V's into the canyon (Hogan Ranch Trail Canyon) that finally connects with Paradise Valley. The coal outcrops are mostly thin and the zone carries an average of 4.0 feet of coal. The coal is usually split by shale and/or bone. The M bed is located at or near the contact of the Ferron with the overlying Mancos. The thickest surface section is 5½ feet thick, but it has a ½-foot shale split near the top. Total coal in the bed averages 2.7 feet.

Subsurface Information

Eight drill holes have penetrated the Ferron, all drilled by Mountain States Resources Co. in 1969 and 1970. Thicknesses of individual seams range to 11 feet. The Lower zone was reached by drill holes 47, 48 and 49 which indicate coal 5, 7 and 11 feet respectively supporting the surface data which show the coal thickening westward. Holes 44 to 49 intersected the Upper zone with coal ranging from 2 to 10 feet. The thickest seams were intersected in sec. 24, T. 25 S., R. 4 E. The coal in holes 7 and 8 was thin. Holes 44 to 47 missed the M bed because the strata have been removed by erosion. Holes 42, 43 and 49 hit thick coal.

None of the coal beds east of the fault zone occur with more than 1,000 feet of cover. Depth to the coal west of the faults is undeterminable without new drilling.

Quality of Coal

Four available analyses of coal representing all beds or zones show little difference between them. Three were tested from drill-hole cores or cuttings and the other was collected at a weathered ruin of an old prospect (Willow Basin mine). Average proximate analyses are given in table 21:

Table 21. Average proximate analyses of coal, Emery 3 SW quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	4	14.6	10.2 -23.6
Volatile matter	4	33.5	32.6 -37.9
Fixed carbon	4	38.5	33.3 -42.8
Ash	4	11.4	7.0 -16.0
Sulfur	4	1.78	0.85- 2.88
Btu/lb	4	9,453	7,823-10,650

Sampling technique at the drill-hole sites may have produced some contamination and the four tests are inconclusive. As it stands the coal is a subbituminous A to a high-volatile C bituminous coal of medium sulfur content.

Mines and Development

Other than the recent drilling performed by Mountain States Resources Co., the only development for coal is a small prospect located in Willow Basin (table 22). Nothing is known about the prospect; the adit is caved and from appearances old.

Table 22. Mine in the Emery 3 SW quadrangle.

Mine	Location	Remarks
Willow Basin mine Lower coal zone A bed	NE.NW.3-26S-4E 4,270,200m.N. 459,410m.E.	Period of activity unknown

Reserves

Lupton (1916, p. 86), with surface evidence only, calculated the following reserve considering all beds over 1 foot thick east of the fault zone. His figures are adjusted to fit the quadrangle (table 23).

Table 23. Coal reserves 1 foot or more thick east of the fault zone, Emery 3 SW quadrangle.

Location	Tons	Bed or zone
T.25S. R.4E.	20,062,000	All beds
T.25S. R.5E.	16,104,000	All beds
T.26S. R.4E.	1,805,000	All beds
Total Coal	37,971,000	

In a reevaluation based on 4 feet or thicker seams the following reserves are deduced (table 24).

Table 24. Original coal reserves in short tons (Classes I and II), Emery 3 SW quadrangle.

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.25S. R.4E.	350	4.0	2,400,000	"M" bed
	1,000	4.8	8,300,000	Upper zone
	1,600	7.2	20,000,000	Lower zone
T.25S. R.5E.	330	5.2	3,000,000	"M" bed
	108	5.5	1,000,000	Upper zone
T.26S. R.4E.	20	4.0	140,000	all beds
		Total Coal	34,840,000	

Not enough is known about the area west of the fault zone to determine a potential (Class IV) reserve. No Class III reserves exist.

PRINCIPAL WORK

Lupton (1916) contributed much outcrop data and mapping was by R. L. Graham (1970) for Mountain States Resources. The drill-hole data were donated by MSR and additional surface data were collected by H. H. Doelling, F. E. May and R. D. Gray of the Utah Geological and Mineralogical Survey for this study during the summer of 1970.

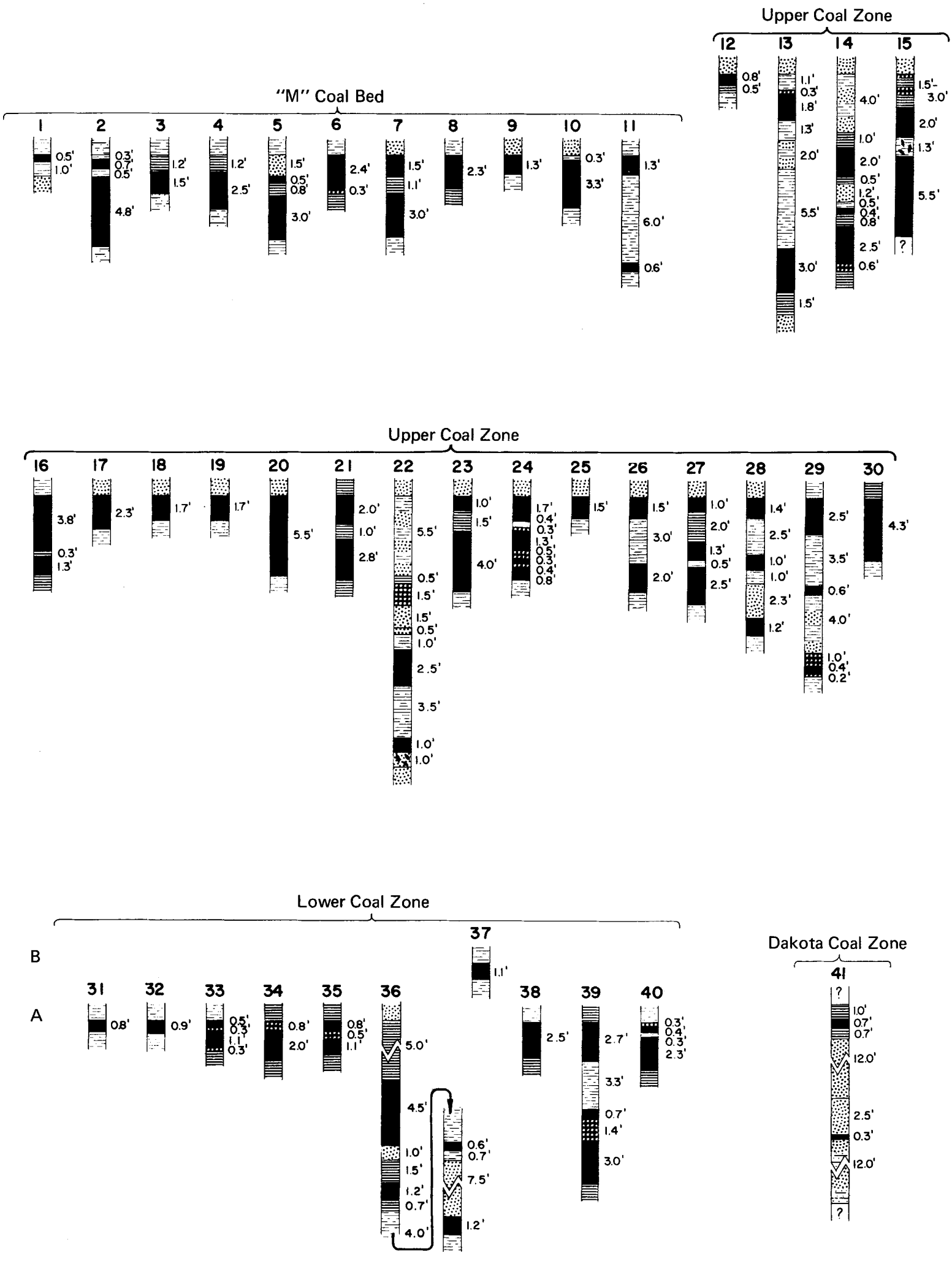


Figure 30. Coal sections of the Emery 3 SW quadrangle (vertical scale: 1 inch = 8 feet).

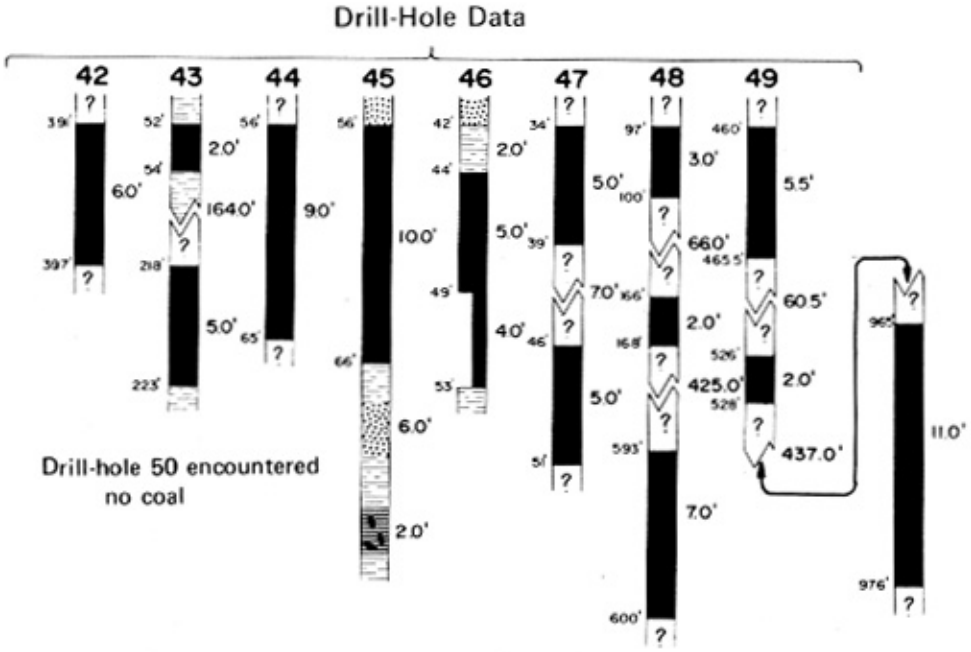
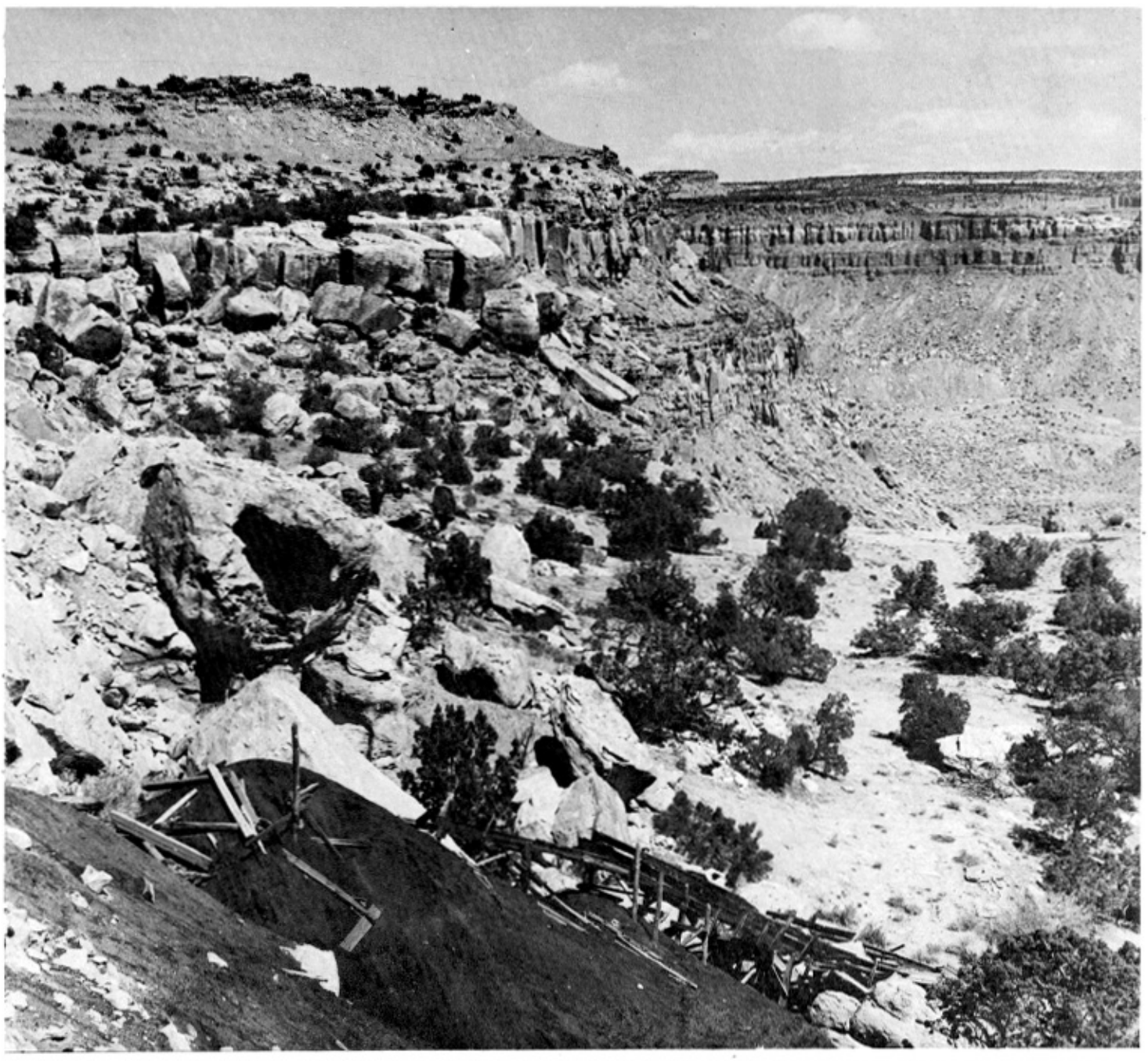


Figure 30. (continued)



Abandoned Bear Gulch mine cut in the C bed, Mesa Butte quadrangle. Slopes between sandstone beds contain shale and coal.

MESA BUTTE QUADRANGLE

LOCATION, GEOGRAPHY AND ACCESSIBILITY

The Mesa Butte quadrangle lies along the east edge of the central part of the coal field (figures 17 and 31). The Coal Cliffs are well exposed along the west and north map margins. Interstate Highway 70 traverses the quadrangle and joins Green River 55 miles to the east with Salina 47 miles to the west. I-70 is a major artery linking Denver, Colorado, with Los Angeles, California. Emery is the closest town, 3 miles north of the northwest map corner. Four deep canyons have cut into the Coal Cliffs, the four creeks uniting to form the Muddy River below. These drainages include the Muddy, Quitchupah, Ivie and Dog Valley creeks or washes.

Elevations in the badlands below the cliffs range from about 5,400 to 6,000 feet. The upper edge of the cliff is between 6,500 and 7,000 feet with the higher elevations to the northeast. The elevation of Castle Valley, which appears to the northeast, is about 6,000 feet. The coal seams are located along the cliffs and along the canyon walls. I-70 passes through the area but it cannot be used to reach other parts of the quadrangle as it is designed for limited accessway. The coal areas are reached from Emery and Castle Valley by truck and jeep roads.

STRATIGRAPHY

Jurassic and Lower Cretaceous units are exposed on the southeast half of the map and Upper Cretaceous units crop out in the northwest half. All units have a northeast-trending band of outcrop, the width of which is a function of thickness, weathering characteristics and local dip.

The oldest unit is the Entrada Sandstone, a reddish brown, fine-grained sandstone and siltstone unit, estimated to be about 620 feet thick. The beds erode easily but when supported by an overlying resistant bed such as the Curtis Formation, they form cliffs. Buttes and remnants of upper beds are scattered over the outcrop surface. The Entrada often weathers into goblins, stone babies and other weird picturesque forms. The bedding is thick to massive.

A thinner, but mostly resistant unit, is the Curtis Formation. A section measured along I-70 describes the unit:

Section of Curtis Formation measured along I-70, secs. 3 and 10, T. 23 S., R. 7 E.

	Feet
Summerville Formation	
Curtis Formation	
1. Sandstone, siltstone and shale; reddish alternating with green, sometimes glauconitic, slope former and transitional with overlying Summerville	60
2. Sandstone, light greenish gray, fine- to medium-grained, thick-bedded, to massive, cliff former	103
3. Shale, gray, silty, contains gypsum veinlets	25
Total	188
Unconformity	
Entrada Sandstone	

The Curtis forms a light colored band between two reddish brown units. The overlying Summerville appears much like the Entrada except that the strata are thin- to thick-bedded. The Summerville forms a cliff or steep slope and usually requires no resistant cap rock for support. In the south part of the quadrangle it has been eroded nearly flat. The unit is estimated to be about 275 feet thick.

The Morrison is the last Jurassic unit. It consists mostly of variegated shale that is occasionally interrupted by a thick bed of pebble conglomerate or conglomeratic sandstone. These conglomeratic units have an overall brown or brown-gray color on weathered surfaces. Except for the conglomeratic beds the unit is very soft and in outcrop forms rounded hills. The shales are often bentonitic, all impermeable and mostly devoid of vegetation unless soil has formed on it.

The Lower Cretaceous Cedar Mountain Formation succeeds the Morrison and is similar in appearance to it. It can be distinguished by the lighter and mostly lavender color of the shales. The thickness is estimated to be about 200 feet.

The Dakota Sandstone is described in a section by Lupton (1916, p. 29):

Section of Dakota Sandstone measured about 12 miles southeast of Emery, 3 miles south of Ivie Creek, near the west side of sec. 36, T. 23 S., R. 6 E.

	Feet
Sandstone, gray, brown wherever weathered, massive and thin-bedded, iron stained in places, contains a thin lens of shaley coal at base	36
Sandstone, yellowish brown, small clay balls form a thin bed of conglomerate at base	3.5
Total	39.5

The Dakota is highly lenticular but the total thickness probably does not exceed 80 feet anywhere on the quadrangle. The unit is a ledge former and, succeeded by a very soft unit, has a stripped dip slope. Because of this, an outcrop width of a mile is not unusual.

The first shaley member of the Mancos Shale, the Tununk, follows. It is a dark gray, massive mudstone or shale that is often carbonaceous. The unit is about 600 to 700 feet thick and uniform in its lithology. It is somewhat sandy near the bottom imparting a lighter shade of gray to the outcrops. Shortly beneath the top, thin fine-grained sandstone beds appear.

The basal Ferron Sandstone Member of the Mancos Shale is encountered when the first thick-bedded sandstone is reached. The upper part of the Tununk joins with the Ferron to form the Coal Cliffs. The Ferron may be divided into two subunits; the first, or lower part, of thick-bedded to massive yellow-gray cliffy littoral sandstone between 100 and 140 feet thick followed by alternating sandstone, shaley sandstone, gray shale, carbonaceous shale and coal 350 to 400 feet thick. Many coal beds are developed in this interval: a grouping in the lower third and a grouping in the upper third. Some coal beds appear in the middle, but they are usually thinner and not as many occur. The Ferron is much more resistant than the overlying Blue Gate Shale which has been eroded back leaving a wide dip slope upper surface of sandstone at the top of the Coal Cliffs. The Blue Gate is the youngest consolidated unit; it forms rounded gray shale hills in Castle Valley.

All around the Coal Cliffs, the plastic Tununk Shale has collapsed producing a series of landslides. Boulders of the Ferron Sandstone have participated; the blocks are so large on occasion that part of a coal seam can be observed in the rubble. Other unconsolidated types are alluvium and colluvium which have developed on the softer units.

STRUCTURE

The regional strike on the west flank of the San Rafael Swell is about N 35° E and the beds dip at an average of 3 degrees. A long synclinal axis just north of Mesa Butte was mapped trending nearly east-west. The synclinal bends the strike almost due north on its north flank for a distance of less than a mile. No prominent faults were noted on the quadrangle.

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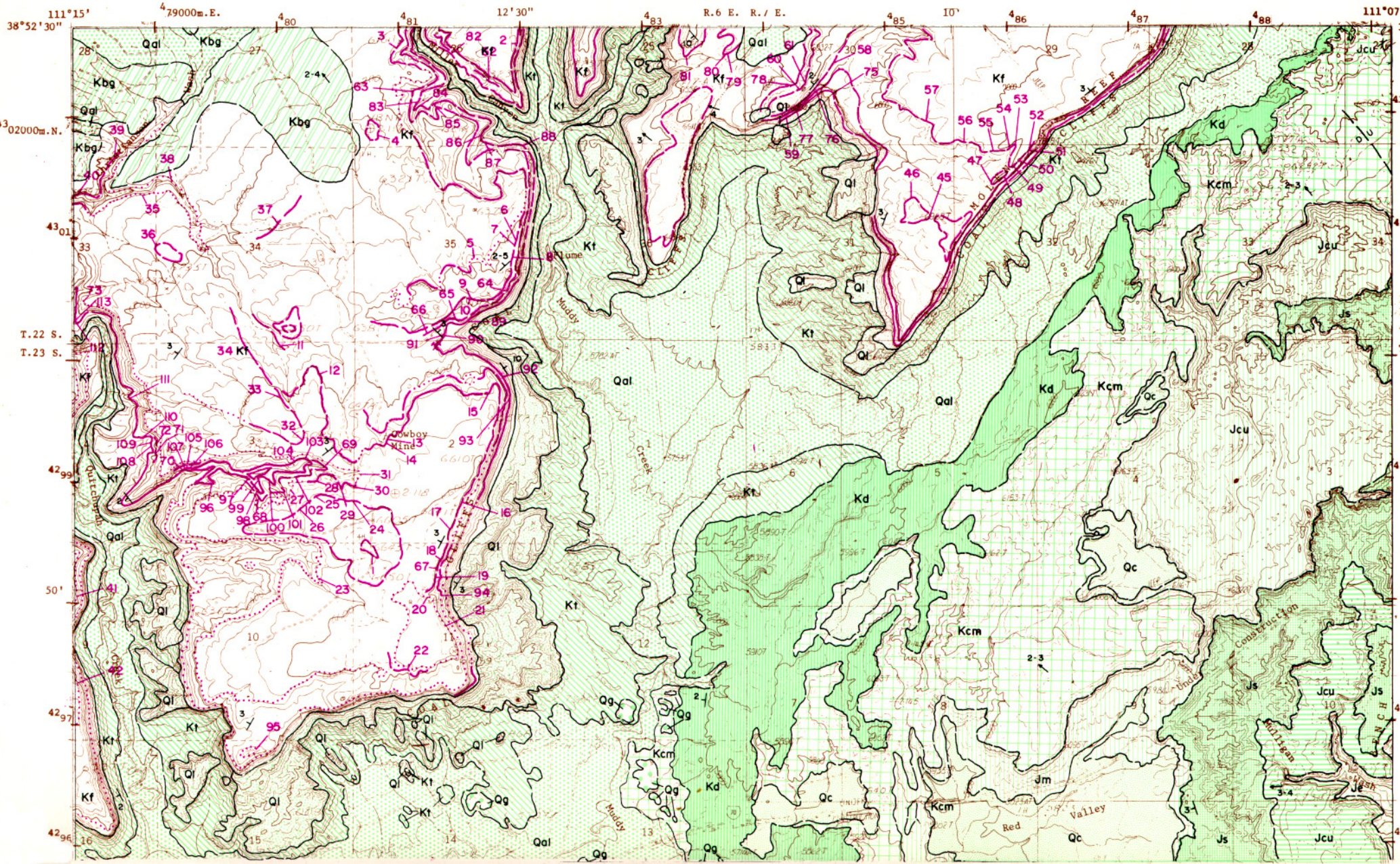
MESA BUTTE, UTAH



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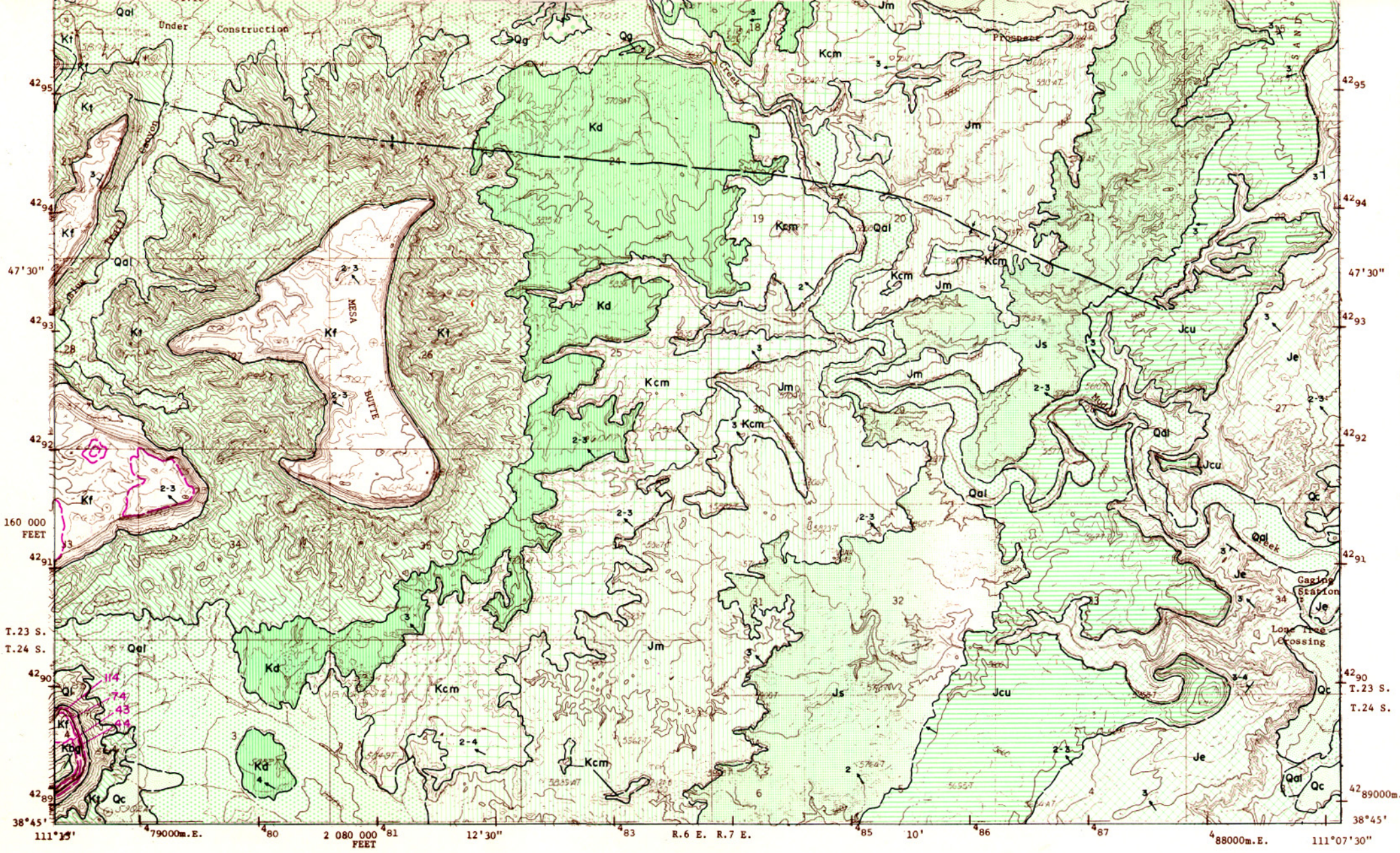

Geology by C. T. Lupton, 1916, USGS;
coal data by C. T. Lupton, 1916, USGS,
and H. H. Doelling, 1970, UGMS.

Figure 31. Coal and geology map, Mesa Butte quadrangle (explanation pages 448-449).

PROPERTY CONTROL

The lands of the Mesa Butte quadrangle are owned mostly by the federal government. The Bureau of Land Management controls 80.2 percent, the state of Utah 11.6 percent and private property 8.2 percent.

About half of the private property is superimposed on coal-bearing strata, but only 15 percent of state lands are coal bearing. Most of the coal acreage belongs to the BLM.

Fourteen percent of the area of Mesa Butte quadrangle are coal land. Of this 39 percent are held for coal. The two coal landholders are Consolidation Coal Co. (mostly held on private land) and Ray Albrechtsen (permit applications). Locations of properties are shown on figures 11 and 12. The property control is dated January 1, 1970.

COAL

Surface Information

The 114 coal sections are grouped into an upper M bed or zone, the Upper coal zone, Middle coal zone and Lower coal zone. The M bed is located near the top of the Ferron and often the coal appears to be the final unit and the upper formational boundary. The Upper coal zone is in the upper third of the Ferron and includes the L to H beds. The Middle coal zone is located in the middle third and includes the G and F beds. The Lower zone is in the lower third of the formation and includes beds A to E.

One section of bed M was measured on a remnant on the Ferron dip slope. The coal, only ½ foot thick, cannot be considered important on the quadrangle. The horizon is mostly removed by erosion. The distance between individual beds of the Upper zone varies because of their lenticular nature and is not the interval shown on the section sheets (figure 32). Locations 2 to 44 are in the Upper zone. All of the H, J and K measurements are less than 4 feet thick and considered unimportant. The thicker coal beds, I and L, which range to 7.3 feet, are confined to the area between Muddy and Quitchupah canyons and a promontory which barely projects onto the map area in the southwest corner.

Locations 45 to 74 illustrate the condition of the Middle zone. Only the F bed has a thickness of 4 feet, but it is always split. The thick sections are all located east of Muddy Canyon in small erosional remnants. Elsewhere the F bed is consistently about 2 feet thick.

Locations 75 to 114 describe the Lower coal zone. If correlations are correct the E and A beds are thin and of little consequence. The D and C beds are thick. The interval between them is 18 to 20 feet thick and some of the sections show both together. Thick coal totals more than 23 feet. Individual seams of more than 11 feet are encountered. The coal beds are closely spaced so that the intervals between them may be regarded as splits. They are lenticular with an average coal thickness of 9.9 feet, except the easternmost exposures along the Molen Reef portion of the Coal Cliffs are thin.

Subsurface Information

No drill-hole data are available for the quadrangle. None of the coal is buried under more than 1,000 feet of overburden; small areas are so shallowly buried that the coal might be strip-mined or augered.

Quality of Coal

It is not known whether the results of the five available analyses are diagnostic of the area (table 6). The higher moisture content coal was collected at outcrops. Sulfur was low except in one sample from the Emery mine. Btu/lb are inconsistent and may reflect the sampling of oxidized coal (table 25).

Table 25. Average proximate analyses of coal, Mesa Butte quadrangle.

	No. Analyses	As-received (percent)	
		Average	Range
Moisture	5	8.0	5.1 -11.8
Volatile matter	5	38.1	35.6 -43.9
Fixed carbon	5	47.9	45.2 -51.0
Ash	5	6.0	4.0 - 7.8
Sulfur	5	0.88	0.31- 2.06
Btu/lb	3	9,902	8,467-11,532

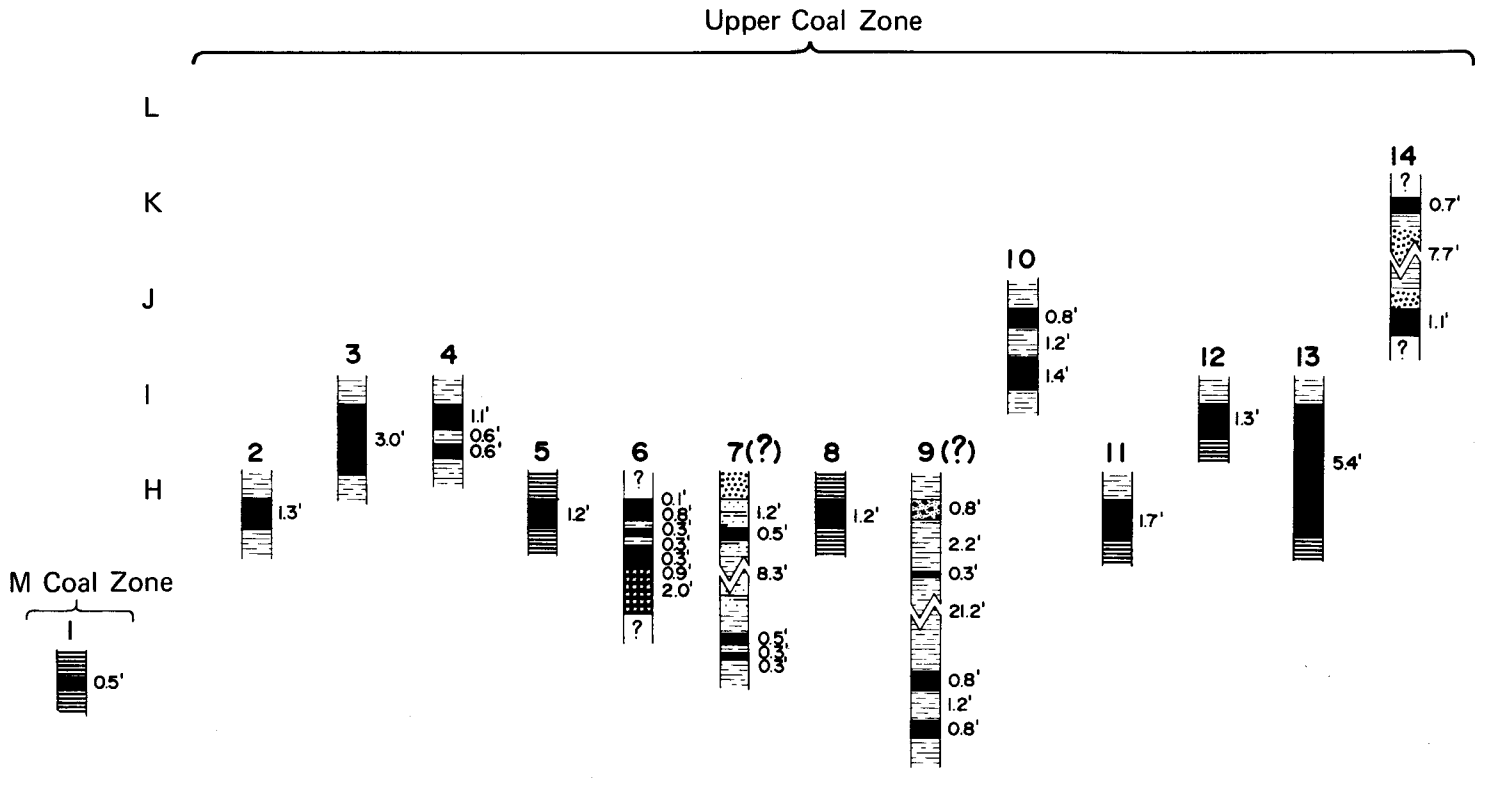

Figure 32. Coal sections of the Mesa Butte quadrangle (vertical scale: 1 inch = 8 feet).

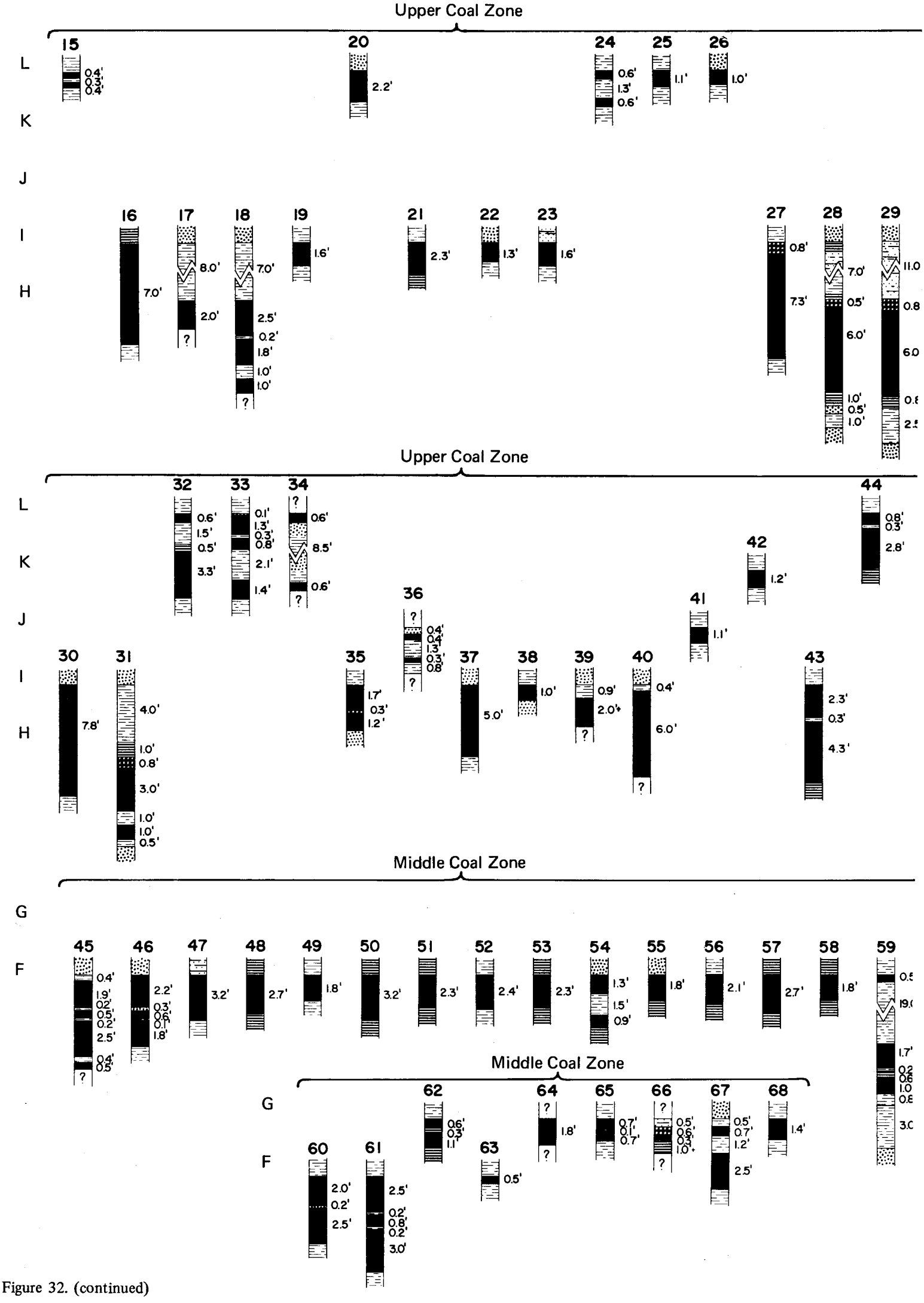

Figure 32. (continued)

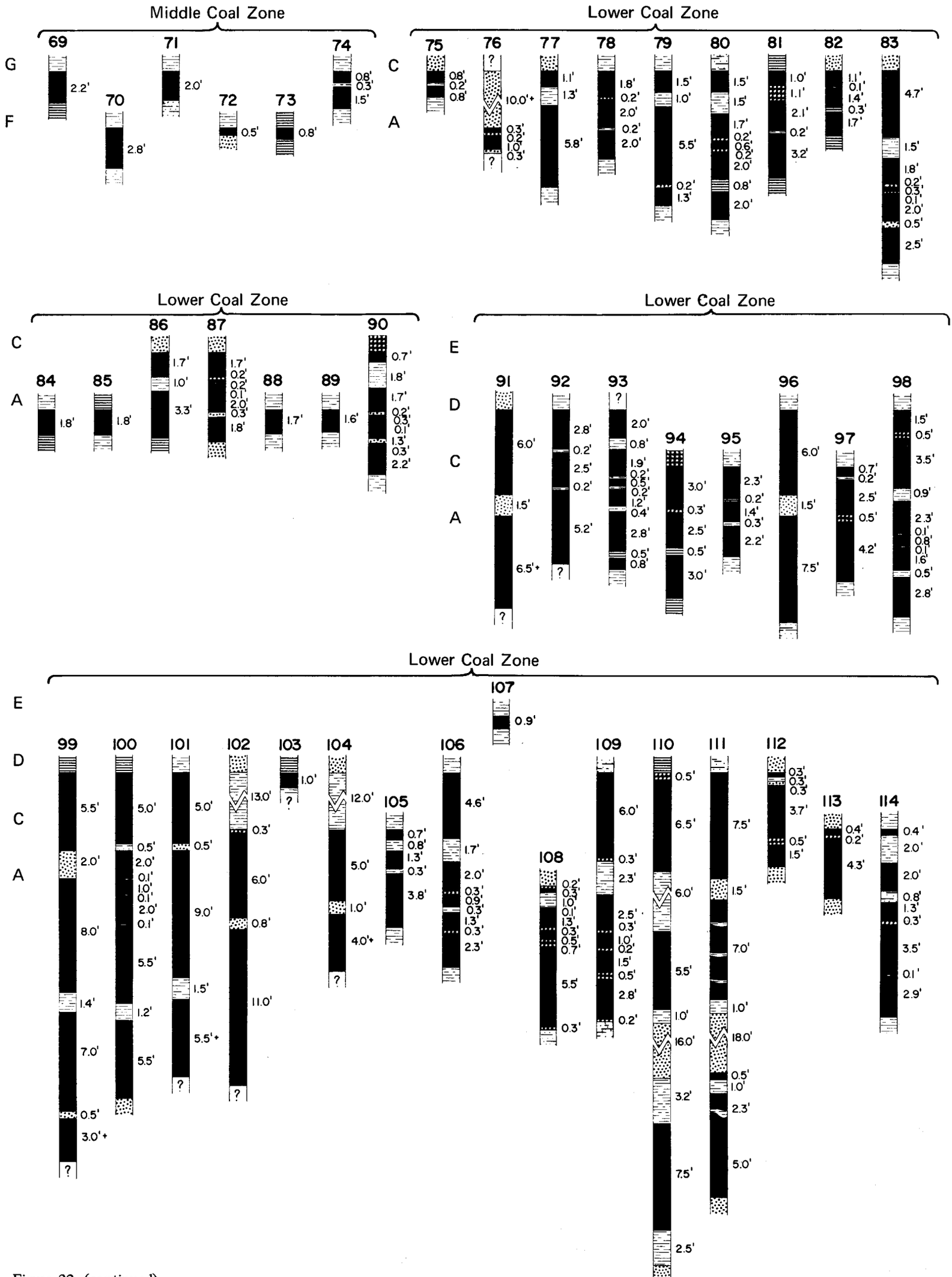

Figure 32. (continued)

Mines and Development

Two mines and a few prospects define the development for coal. There may be some drill holes but the information is unavailable. The mines are listed below (table 26):

Table 26. Mines and prospects, Mesa Butte quadrangle.

Mine	Location	Remarks
Bear Gulch mine Lower coal zone	NE.NW.2-23S-6E 4,299,920m.N. 481,280m.E.	Active 1897-1916?
Emery mine (Cowboy mine) Upper coal zone	SW.NW.2-23S-6E 4,299,300m.N. 480,890m.E.	Active 1906-1920's

Little is known about the Bear Gulch mine; the adit is presently caved and it is not known what the production was. There are several adits at the Emery mine. Workings include a 50- and a 20-foot drift, two rooms in 5 feet of coal and several adits. The floor is shale as is the roof. Total production is estimated at 1,000 tons.

Reserves

Lupton's (1916, p. 86) reserves adjusted to approximate areas on the quadrangle are as follows (all coal 1 foot or more thick are included; table 27):

Table 27. Coal reserves 1 foot or more thick, Mesa Butte quadrangle.

Location	Tonnage	Bed or zone
T.22S. R.6E.	54,250,000	All beds
T.22S. R.7E.	5,400,000	All beds
T.23S. R.6E.	40,000,000	All beds
T.24S. R.6E.	500,000	All beds
Total coal	100,150,000	

A re-evaluation considering coal 4 feet or more thick follows (table 28):

Table 28. Original coal reserves in short tons (Classes I and II; beds 4 feet or more thick), Mesa Butte quadrangle.

Location	Acres	Average thickness (feet)	Tons	Bed or zone
T.22S. R.6E.	850	5.3	7,850,000	Upper zone
	2,364	6.0	24,710,000	Lower zone
T.22S. R.7E.	20	4.7	160,000	Middle zone
	114	7.0	1,390,000	Lower zone
T.23S. R.6E.	777	5.3	7,170,000	Upper zone
	2,091	9.9	36,060,000	Lower zone
T.24S. R.6E.	23	6.6	660,000	Lower zone
		Total Coal	78,000,000	

All this reserve is Class II being within 1½ miles of a control point. Recoverability, which may be a problem inasmuch as many of the beds are closely spaced, is estimated at 33 1/3 percent.

PRINCIPAL WORK

The geology around the coal beds was mapped by Lupton (1916) and supplemented by large-scale mapping in the area below the cliffs by the Utah State Department of Highways, Materials section. The latter maps are undated and color printed. The coal data by Lupton are supplemented by new information.

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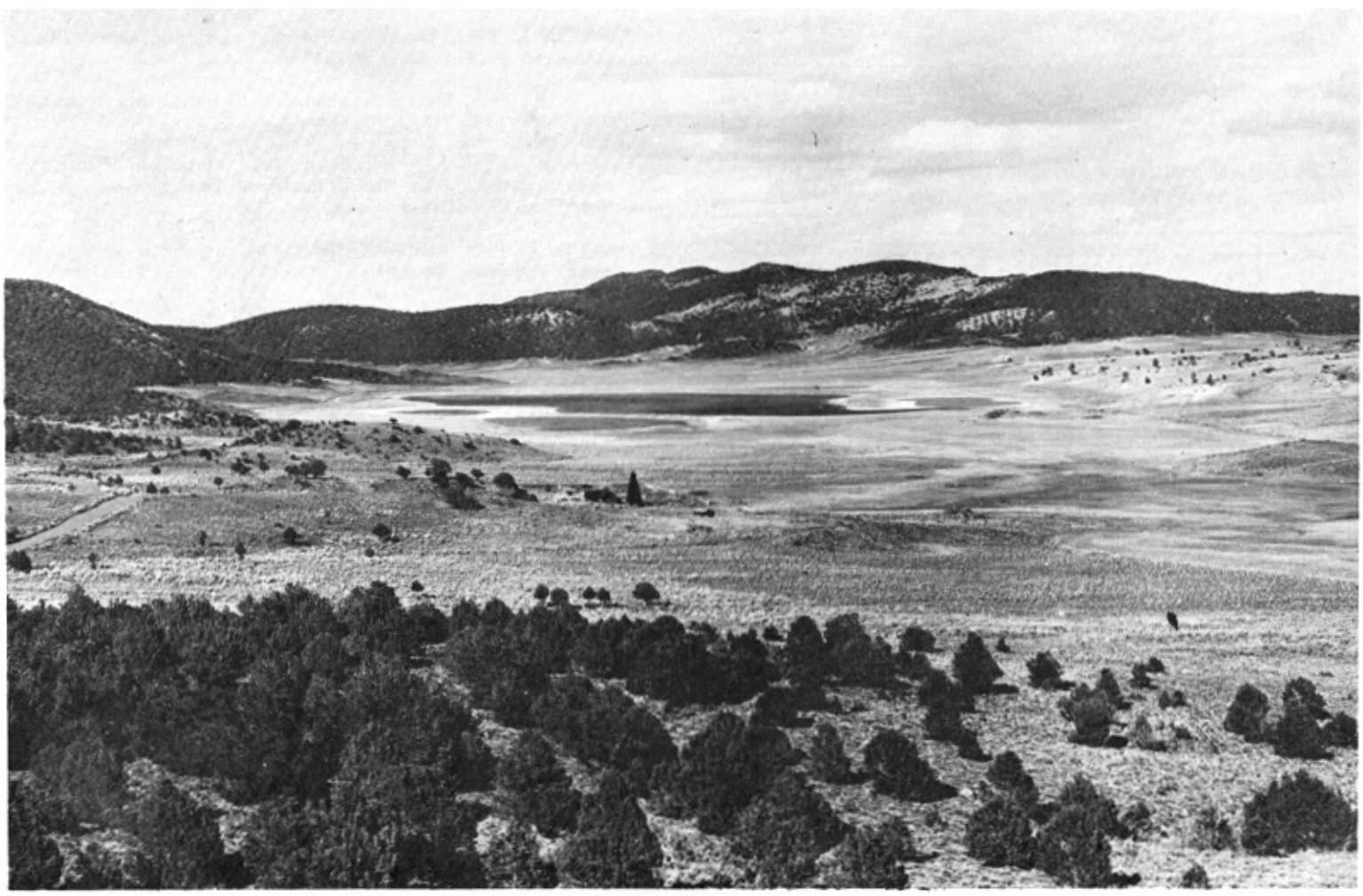

Paradise Valley in south Emery field. Slopes and hills to the right of the lake are underlain with at least three coal beds that generally exceed 4 feet thick. Part of the beds may be strip-mined.

A SURVEY OF PALYNOMORPHS FROM SEVERAL COAL-BEARING HORIZONS OF UTAH

by F. E. May[1]

ABSTRACT

Several Cretaceous coal-bearing formations of Utah ranging in age from Cenomanian (Dakota Sandstone) to Danian-Maestrictian (Price River Formation) were sampled and the sampler macerated to produce palynological preparations. The resulting fossil assemblages were photographed and studied for this paper.

Nine formations from twelve coal fields are analyzed and nearly 500 palynomorphs are illustrated in the plates. Conclusions are not detailed and eventually must be succeeded by thorough investigations of the various areas. The illustrated assemblages are evaluated as practically as possible with the amount of sampling utilized; the evolutionary advancement of angiosperm pollen from Cenomanian age through Maestrictian-Danian can be observed by following the plate sequence.

INTRODUCTION

To date palynology has been applied little to the Cretaceous formations of Utah. Paleontological observations made by former researchers of the Utah Cretaceous were based on relatively sparse megafossil assemblages and, in most cases, little was known about the fossil content of the formations. Formations, especially near coal horizons, were expected to contain excellent assemblages of fossil pollen, spores and perhaps microplankton (Orlansky, 1971, Gray and others, 1966, Lohrengel, 1969 and Wheelwright, 1958). Samples collected from several of the coal-bearing horizons of Utah were macerated and studied to see if fossil pollen and spore assemblages exist in each of the areas; if so, this information might open up new avenues for stratigraphic study.

Samples of coal and, to a lesser extent, associated shales from several coal-bearing horizons of the state, were gathered in the field. The great number of coal areas in the state and the several formations involved made an overall detailed palynological picture of Utah impractical. This study, therefore, represents only a survey of palynomorphs as they appeared in the samples gathered from each area (figure 1). Although a minimum number of samples was used from each area, they illustrate the variety one might encounter; most formations were sampled and studied from several areas. A formation, such as the Dakota Sandstone, may be studied from four or more different coal fields permitting conclusions about age and paleoecology that otherwise might not be established.

Nine Cretaceous formations from twelve Utah coal fields were studied. They represent a broad area covering much of the state, as well as a long geological period. Palynomorphs in the Utah Cretaceous system first appear in the Dakota Sandstone of the Cenomanian stage. The only known older Cretaceous formation in Utah is the Cedar Mountain Formation, a redbed sequence, which appears barren of palynomorphs. The youngest Cretaceous formation treated is the Price River Formation (Neslen Member), which would appear Maestrictian or possibly Danian in age. These and the intervening formations representing Middle Cretaceous to Uppermost Cretaceous time, approximately 30 million years, contain the angiosperm pollen fossils; they first appeared world wide at about the Aptian-Albian interval and then rapidly expanded into dominance (figures 1 and 2). Angiosperm evolution is well documented throughout these formations and can be recognized readily in plates 1 to 32 (Appendix 1 and figure 3). The assemblages on the plates can be studied to corroborate or dispute previously derived age dates for the various formations through the stage of evolution of the angiosperm pollen.

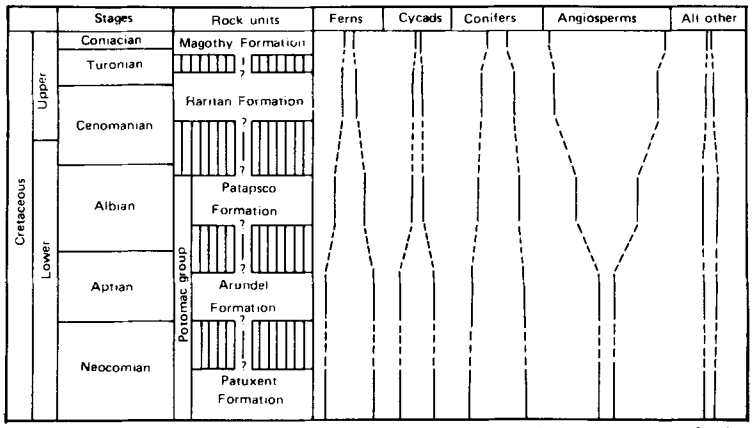

Figure 1. Relative proportions of genera in plant groups of the successive Cretaceous floras of eastern United States (from Dorf, 1955).

Pollen and spore assemblages shown on the plates yield general conclusions about paleoecology and paleogeography. Assemblages illustrate strong marine influence on the continental environment as well as fluvial influence on the continental nonmarine environment. Climates during time of deposition can be evaluated by the relative abundances of fern spores and angiosperm pollen.

Vegetation which produced the palynomorphs also formed the composition of the coal. Perhaps then the palynomorph assemblage present indicates the quality of coal. In addition, the degree of carbonization of palynomorph exines is proportionate to metamorphism placed on the coal.

PALYNOLOGY

Palynology is the study of the pollen spores and certain microplankton. For the most part these are acid-resistant bodies in a size range from about 5 microns (μ) to perhaps more than 500μ. The great majority of grains, from about 15μ to 65μ generally occurs in greatest abundance in sedimentary rocks with silt-sized particles or in coals and peats.

The outer coals (exines) of pollen grains, as well as spores and some microplankton, are composed of a resistant material

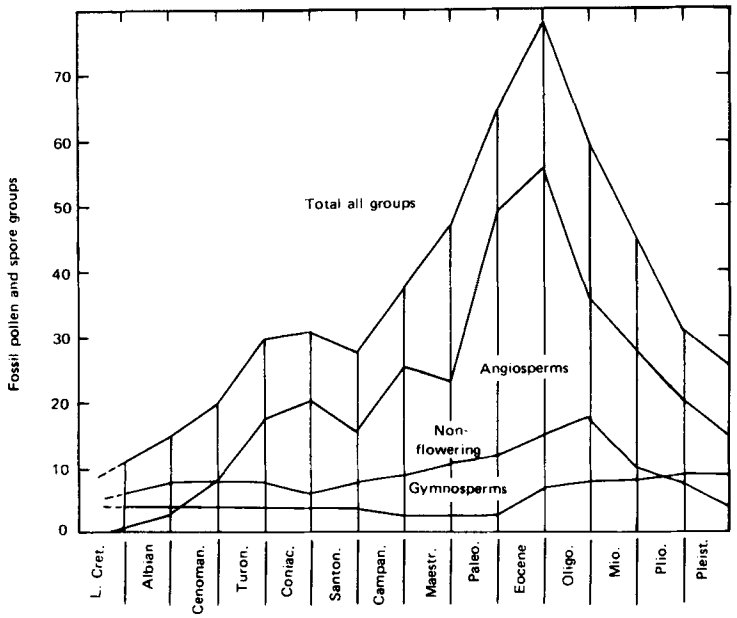

Figure 2. Total fossil pollen and spore groups Lower Cretaceous-Pleistocene (after Cousminer, 1961).

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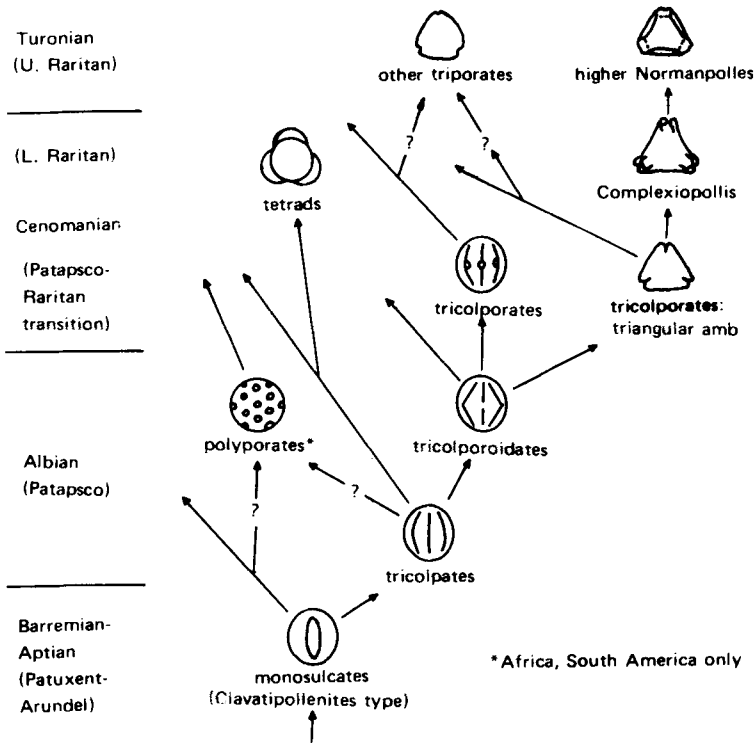


Figure 3. Suggested evolutionary interrelationships of the major angiosperm pollen types of the Potomac-Raritan interval (Barremian-Turonian, after Doyle, 1969).

called sporopollenin, which is organic and is probably either a carotenoid or a type of condensed carbohydrate. It is resistant to acid treatments wherein the enclosing rock is dissolved away from the exines during maceration and the exines are left undisturbed. Since it is so resistant to chemical breakdown, sporopollenins' molecular construction has been difficult to study. It is, however, susceptible to oxidation and therefore may become weathered in outcrops or destroyed in certain laboratory procedures. Also, metamorphism of rocks can "carbonize" (devolatilize) exines, making them less translucent and finally opaque so that palynomorphs from highly metamorphosed rocks are always worthless.

The pollen grain transports the male gametes to the egg (within the ovule) and generally is formed in a tetrad with three other grains. At the time of dispersal, the pollen grains generally separate individually from the tetrad and become windborn or are dispersed by some other mechanism. Water and wind are the greatest agents and many pollen, spores or microplankton eventually find their way, undisturbed, into the sediments, except for those which become involved in reproduction. Great numbers of pollen must be produced to maintain a species. This abundance is seen in palynological preparations of coals which show raw coal with more than 1 million pollen per gram.

Except for oxidation and metamorphism, preservation is no problem. Sporopollenin-like material has been found in Precambrian rocks and from Silurian time to present, great varieties of palynomorphs have been deposited. Figures 4 and 5 present descriptions of some palynomorph types. A glossary of palynological terms follows. The superscript number following a term refers to the figure in which the term is illustrated.

angle	corners or apices of a triangular spore.
anisopolar	having poles of different shape; synonymous with heteropolar.
annulus	a ringlike area around a pore formed by an exine thickening.
aperture[4]	a general term for germinal exitus in pollen grains and spores; it is used for colpi or pores in spermatophytes and for laesurae in pteridophytes and bryophytes; *inaperturate* grains lack apertures.
antapical	in thecate dinoflagellate (those with a resistant theca), the posterior end, frequently extended into two antapical horns.
apical areas[4]	areas adjoining corners of a triangular spore; also refers to the anterior end of elongate dinoflagellate, which is frequently extended into a single apical horn.
apiculae[4]	small conical protuberances at spore corners.
appendici	elongate projections at apices of a triangular spore.
appendiculate	spore with appendici.
archeopyle	distinctive opening in fossil dinoflagellates formed by release of a single plate or group of plates.
arcus (plural arci)	a bandlike, locally thickened exine which extends between apertures.
auriculae	earlike projections at spore corners.
baculate[5]	ornamented with rodlike, unpointed, radial projections (baculae) higher than thick, with tips not expanded; contrast *clavate*.
bisaccate[5]	pollen grain with two ektexinous protuberances or bladders on either side of the central body.
bladders (or sacci)[5]	ektexinous protuberances that stand apart from the central body; most common in some gymnospermous pollen.
canaliculate	a striate type of ornamentation in which width of ridges (lirae) exceeds width of grooves (canals or striae); contrast *cicatricose*.
central body[5]	the central part of saccate pollen or of cingulate or zonate spores.
cicatricose	a striate type of ornamentation in which width of canals exceeds width of lirae; contrast *canaliculate*.
cingulum[4]	a thickened equatorial rim attached to a central body; both are in same plane; compaction of spores sometimes produces the appearance of a cingulum in some forms.
clavate[5]	ornamented with clublike unpointed radial projections (clavae) higher than thick, with expanded tips; contrast *baculate*.
colpate[4]	angiosperm pollen with one or more colpi.
colporate[4]	dicots with a composite aperture of colpi and pores, colpi do not reach poles and pores are equatorial in position.
columella[5]	rodlike element between endexine and outer endexine.
colpus (plural colpi)[4]	a longitudinal furrow perpendicular to equator on pollen grain; length is more than two times width.
commissure[5]	the trace of slit of dehiscence on trilete or monolete spores.

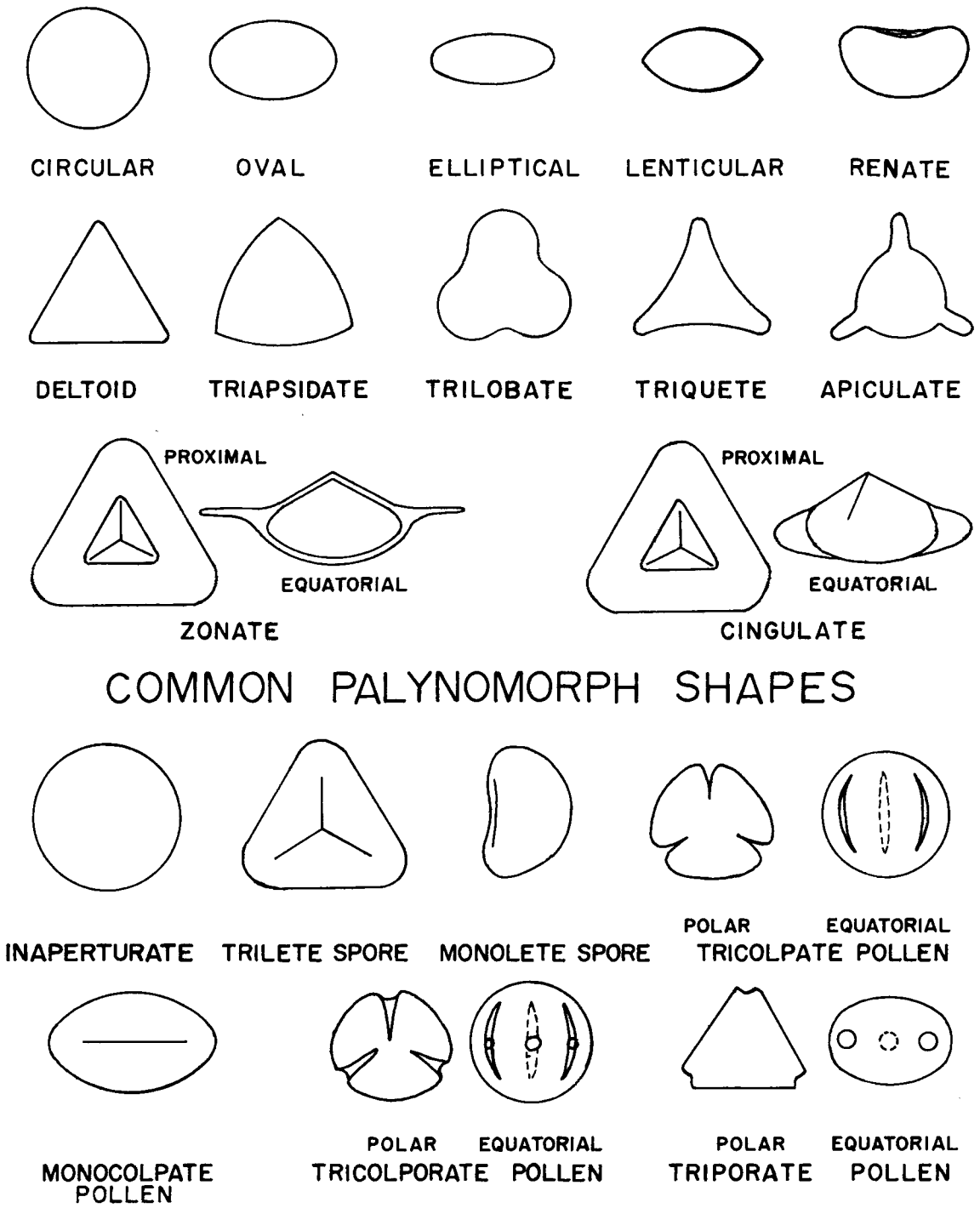


Figure 4. Schematic drawings of spores and pollen grains illustrating descriptive terminology for shapes and germinal apparatus (from Orlansky, 1970, figure 4).

cyst	layer of resistant organic material which apparently forms within the cell wall of dinoflagellates.
deltoid[4]	shape of equilateral triangle with straight sides and sharp apices.
distal[5]	the side of the spore or pollen grain which faces outward in the tetrad; monocolpate pollen grains have a distal furrow which helps distinguish them from similar monolete spores with proximal apertures.
echinate[5]	ornamented with pointed spines with broadened bases.
ektexine	outer layer of exine, composed generally of small grains or elements.
endannulus	see annulus.
endexine	distinct inner layer or exine generally of simple homogeneous structure.
equator[5]	a line separating distal from proximal hemispheres in spores; many spores have biconvex rather than spherical shapes, the polar diameter being generally shorter than the equatorial diameter and thus have a preferred orientation when compacted in enclosing sediment; the equator then becomes identical with the equatorial outline.
equatorial outline[5]	outline of spore in polar (proximal or distal) view.
exine[5]	the outermost highly resistant layer of the pollen and spore wall; it may be simple, of structureless endexine, or a more complex two-layered type (compare *ektexine* and *endexine*). This layer is one which fossilizes; inner layers and cell contents decay rapidly.
fossulate[5]	ornamented with nonparallel elongate

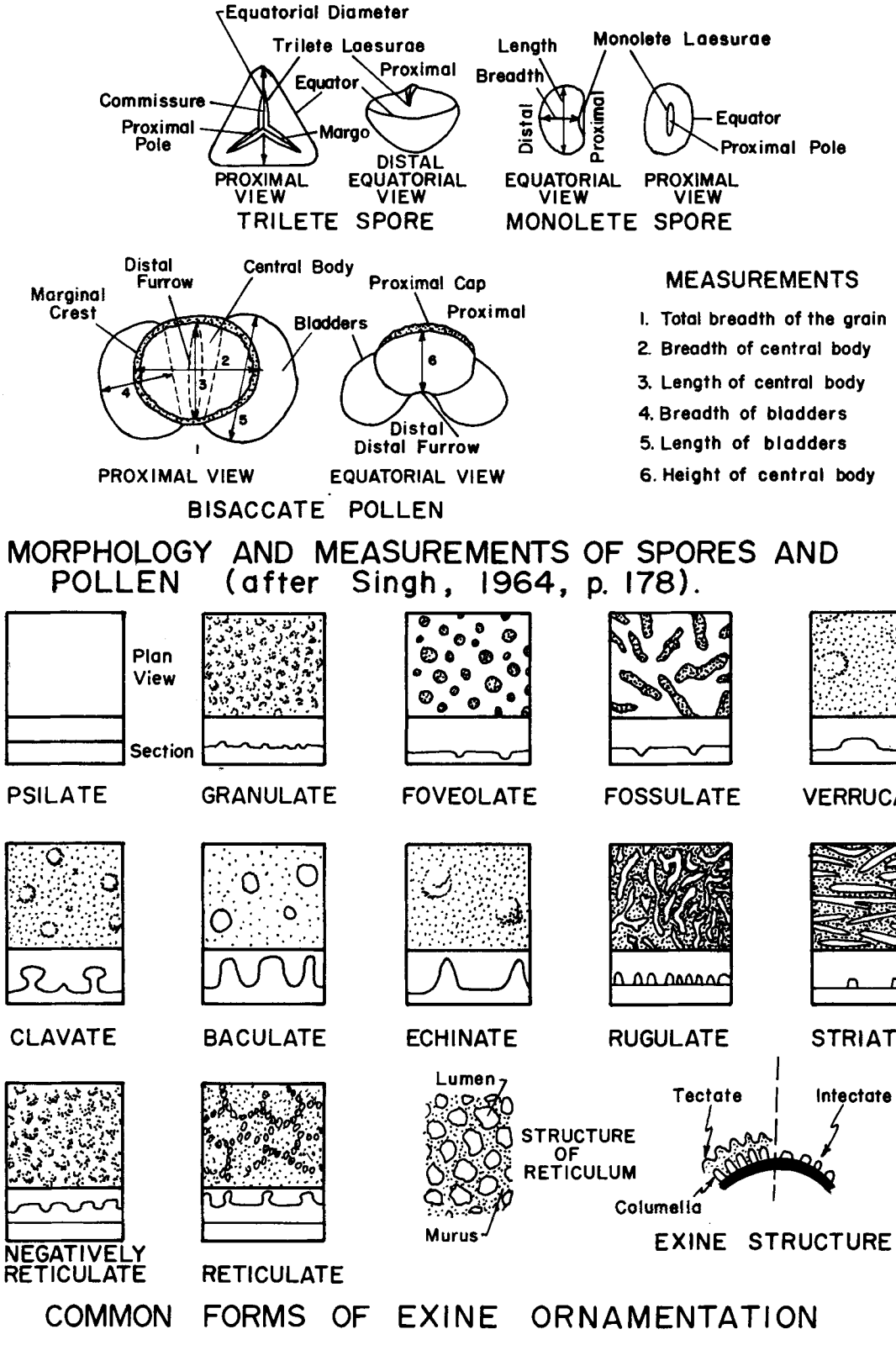


Figure 5. Schematic drawings of spores and pollen grains illustrating morphology, dimensions measured and exine ornamentation terms (from Orlansky, 1970, figure 5).

grooves (fossulae) which have nonanastomosing cavities.

foveolate[5] — ornamented with circular pits (foveolae) up to two microns in diameter, or with larger pits too widely separated to form a reticulum.

furrow — synonym of colpus.

fusiform — spindle-shaped.

gemmate — ornamented with subspherical projections (gemmae) which have constricted bases; contrast *verrucate*.

girdle — equatorial depression in dinoflagellates.

granulate[5] — ornamented with flattened isodiametric projections (granules) larger than one micron, but smaller than 1/20 the equatorial diameter of a spore that is larger than 20 microns.

intectate[5] — literally, without a tectum; that is, one in which the exine consists generally of a single complete layer; the equivalent of the endexine, although enough unfused ektexine elements may be present to form a sculpture pattern.

laesura (plural laesurae)[5] — triradiate (trilete) or single (monolete) scar, which includes adjoining exine structures such as commissures or margo where present.

lenticular[4] — the shape of a biconvex lens.

lirae — see striate.

LO analysis — (from L: lux, light; O: obscuritas, darkness) a type of analysis that helps to clarify nature of minute (smaller than one micron) ornamentation in which elevations and depressions cannot always be differentiated. Under oil-immersion objective and at different levels of focus, the sculptured exine will show changing bright and dark patterns. For example, in a pitted grain, puncta will appear as minute dark "islands" in high focus, and as bright islands in low focus; in scabrate exines, on the contrary, minute projections appear as bright islands in high focus and as dark ones in low focus.

lumen (plural lumina)[5] — the depression between the ridges (muri) of the netlike reticulum.

margo[5] — distinct area surrounding aperture, distinguished by differences in exine thickness or sculpture from areas more distant from aperture.

monocolpate[4] — pollen with a single longitudinal distal furrow.

monolete[5] — spores, usually renate or bean-shaped, having single proximal laesura.

monosaccate — pollen with a single bladder that surrounds the central body.

muris (plural muri)[5] — netlike ridge bounding lumen in reticulate sculpture.

negatively reticulate[5] — sculpture in which polygonal narrow "ditches" separate higher exine "isles"; commonly found in sculptured exines where projecting elements are closely packed; contrast *reticulate.*

ornamentation[5] — general term used for external modifications of the ektexine which are of great diagnostic value; "sculpture" is essentially synonymous.

outline — see equatorial outline.

oval[4] — the shape of an egg.

palynology — a general term applicable to the studies of acid-resistant microfossils; most commonly, these include plant microfossils: spores, pollen grains, macerated tissues and dinoflagellates, also hystrichospheres and marine microfossils of problematical and diverse origin.

palynomorph — an inclusive name for microfossils found in palynological preparations, such as spores, pollen grains, dinoflagellates and hystrichospheres.

polar island — triangular structure formed by intersecting arci; generally used in describing polar area of some syncolpate forms.

pole — center of distal or proximal surface; the polar axis is a projected line connecting the poles.

pollen — the microgametophyte of sporophytes (gymnosperms and angiosperms).

pore[4] — a more or less isodiametric aperture in sporophytes; length-width ratio is less than 2:1.

proximal[5] — the side of the spore or pollen grain which faces the center of the tetrad; spores generally have trilete or monolete marks on this side.

psilate[5] — ornamentation in which exine is smooth with no sculpturing elements, or the elements are smaller than 0.3 micron in diameter.

punctate — ornamented with minute pits (puncta) smaller than one micron, but larger than 0.3 micron in diameter.

renate — kidney- or bean-shaped.

reticulate[5] — ornamented with a network of anastomosing ridges (muri) that enclose depressions (lumina) which may be regular or irregular in outline.

reticulum — reticulate sculpture.

rugulate[5] — ornamented with elongate, narrow, irregularly distributed ridges (rugulae).

saccate[5] — general term for pollen grains with bladders.

scabrate — ornamented with minute elevations smaller than one micron.

sculpture — see ornamentation.

spore — a reproductive body of pteridophytes and lower plant groups, capable of giving rise to a new individual.

striate[5] — ornamented with elongate linear elements (lirae are raised ridges; striae are grooves between the lirae) which are more or less parallel.

sulcus — a synonym of colpus.

syntricolporate — tricolporate grain with colpi joined at poles.

tectate[5] — refers to exine structure which is at least two-layered; the outer layer (tectum) generally completely veils the inner.

tectum — exine surface formed by fusion of elements of ektexine or of their outer ends, and which is separated from the endexine by columellae.

tetrad — a union of four spores or pollen grains formed by a mother cell by two successive reduction divisions; it is frequently tetrahedral in shape, the spores occupying the corners of the tetrahedron; also see *distal, proximal,* illustrated on plate 5, figure 12.

theca (plural thecae) — resistant cellulose-like covering of dinoflagellates, usually plated, divided by a girdle into hemispheres, epitheca and hypotheca.

torus (plural tori) — a protrusion or invagination of exine which parallels the Y mark.

trilete[5]	refers to triradiate laesurae that mark germinal area on proximal side of spores.
triapsidate[4]	shape resembling that of three equidistant semicircles; synonymous with tricircular.
triquete[4]	shape subtriangular with concave sides.
triradiate ridges	raised ridges which support trilete laesurae.
verrucate[5]	ornamented with isodiametric, flat-topped, wartlike projections (verrucae) in which lower part is not constricted and which are larger than granules; contrast *gemmate*.
zona[4]	a thin equatorial flange around equator of spore.

TECHNIQUES OF MACERATION

A wide variety of techniques is used to free palynomorphs from shales, coals and peats, etc. A prerequisite to macerating samples is adequate care to insure that contamination will not occur. Samples should be stored in sealed containers and during processing should be treated within reasonable limits of cleanliness.

Coal

Two to three grams of coal are pounded in a mortar and pestle to a fine granular size. If the fine coal is soluble in 10 percent KOH, it is placed in a glass beaker and covered with 10 percent KOH and boiled for about 3 minutes. A dark colored liquid will result. The sediment is then washed repeatedly in a centrifuge with distilled water at about 3,000 rpm until the wash water remains reasonably clean. At this point a preliminary slide can be made from the residue and a little water. If palynomorphs are present, they may need staining; occasionally a natural shading allows them to be seen adequately without stain. If they are too pale, add approximately 50 cc of distilled water to the residue and a few drops of basic fuchsin stain. The stain should be washed out in the centrifuge until the wash water remains nearly clear. The palynomorphs should retain sufficient stain to be seen.

If the coal is not soluble in 10 percent KOH, an intermediate step is necessary. The coal sediment is placed in a 1:1 solution of $KClO_3$ and HNO_3 for 3 to 5 hours in a hood. It is then washed in a centrifuge and the resulting residue placed in the 10 percent KOH. Then proceed as described above.

Shale

Shales are pulverized as described for coals. If calcareous, place in 10 percent HCl until reaction ceases and wash in a centrifuge with distilled water. Put the sediment in a plastic beaker and add 52 percent HF under a hood with a fan. If the reaction becomes too violent, a quick spray with ethyl alcohol stops it. In a hot bath the reaction may take 4 to 5 hours, sometimes longer depending on the nature of the silicate. Wash out the HF in a centrifuge (ca. 3,000 rpm); 2 to 3 washings are usually adequate. Use only plastic ware (Teflon is best) with HF, i.e., stir rods, test tubes, beakers. Boil residue in 20 percent HCl for 15 minutes, then wash. KOH treatment now may be followed as described for coals.

PHOTOGRAPHIC TECHNIQUES

All photographs were taken with Panatomic X, 35-mm film and a Leica 35-mm camera attached to a Leitz Ortholux microscope. Exposure time was measured with a Gossen Microsix-L light meter attached to the upper part of the microscope. Each photograph was noted according to photograph number, slide number, type of grain photographed, magnification, size of grain and coordinate grid numbers for relocation.

EXPLANATION TO PLATES

The plates are arranged so that the formations from which the palynomorphs were collected appear in chronological order. Plates representing suspected correlative formations (figure 6) are placed following one another. Plates of each formation locality, i.e., Vernal Frontier Formation, are numbered and treated individually from the other formation localities. Therefore, plate figures from each formation locality are numbered from "1" to the number of the last illustrated palynomorph. Also, plate explanations are handled in the same manner for each formation locality as well as the numbering of nonclassified or nonclassifiable genera or species.

The palynomorphs of each plate can be measured by the scale on the plate. The scales generally measure 0 to 50μ (0 to .050 millimeters). For the most part, the palynomorphs illustrated are proportional to that scale. A few grains illustrated may be at one half the given scale; this is noted in the plate explanation. Occasionally a species or a variety of a species is represented more than once on a plate or from plate to plate. This shows (1) that it occurs in various areas, (2) that it may occur at various stratigraphic levels or (3) illustrates morphology.

The varying number of plates representing individual formation localities depends on the variety of the palynoflora observed in the sample preparations used and/or the geologic importance of information learned from those samples. Another consideration is how often the particular formation is represented from other areas (figure 7).

INDEX TO PLATES BY FORMATION (figures 6 and 7)

Dakota Sandstone

Plate 1. Henry Mountains coal field. Shale sample taken from coal seam at outcrop on west side of main road, south of Burr Trail junction in Water Pocket Fold area.

Plate 2. Kaiparowits Plateau coal field. Coal sample taken from Seep Flat quadrangle, Kaiparowits Plateau.

Plate 3. Alton coal field. Coal samples taken from Willis Creek Canyon, Bryce Point quadrangle and Paunsaugunt Plateau. Palynomorphs are representative of both Smirl and Bald Knoll coal zones.

Plate 4. Same as plate 3.

Plate 5. Kolob coal field. Coal sample taken from Table Bench area of Markagunt Plateau.

Ferron Sandstone

Plate 6. Henry Mountains coal field. Shale and coal samples taken from exposures east of road near Burr Trail Junction, east side of Water Pocket Fold.

Plate 7. Emery coal field. "A" bed, coal samples taken from I-70 roadcut east of Salina Canyon. Spore assemblage illustrated.

Plate 8. Same as plate 7. Pollen assemblage illustrated.

Frontier Formation

Plate 9. Vernal coal field. Coal samples taken from Wardle and Blue Bell mines.

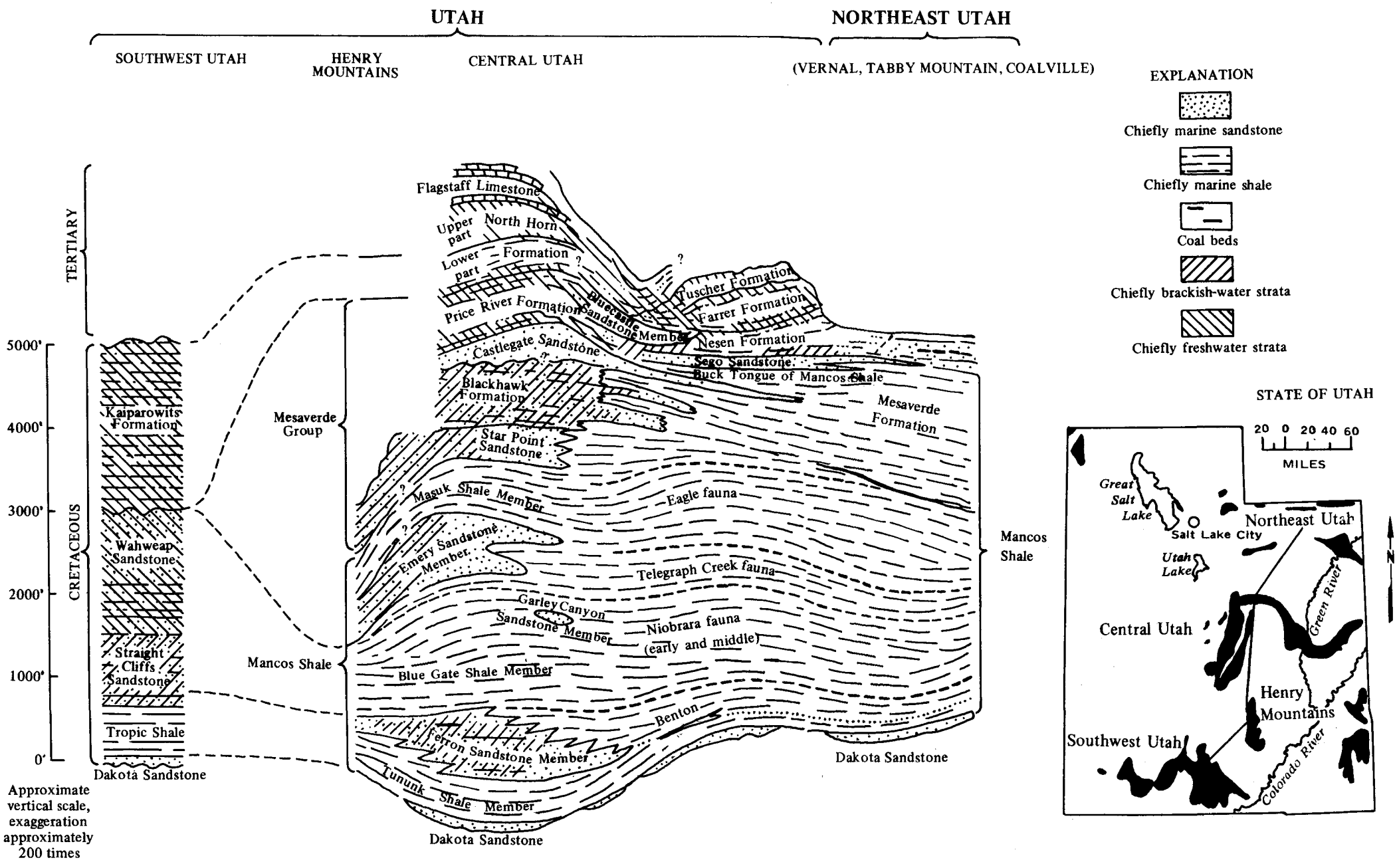


Figure 6. Diagram of correlations of Upper Cretaceous strata from southwest Utah to northeast Utah (modified from Fisher and others, 1960, pl. 2).

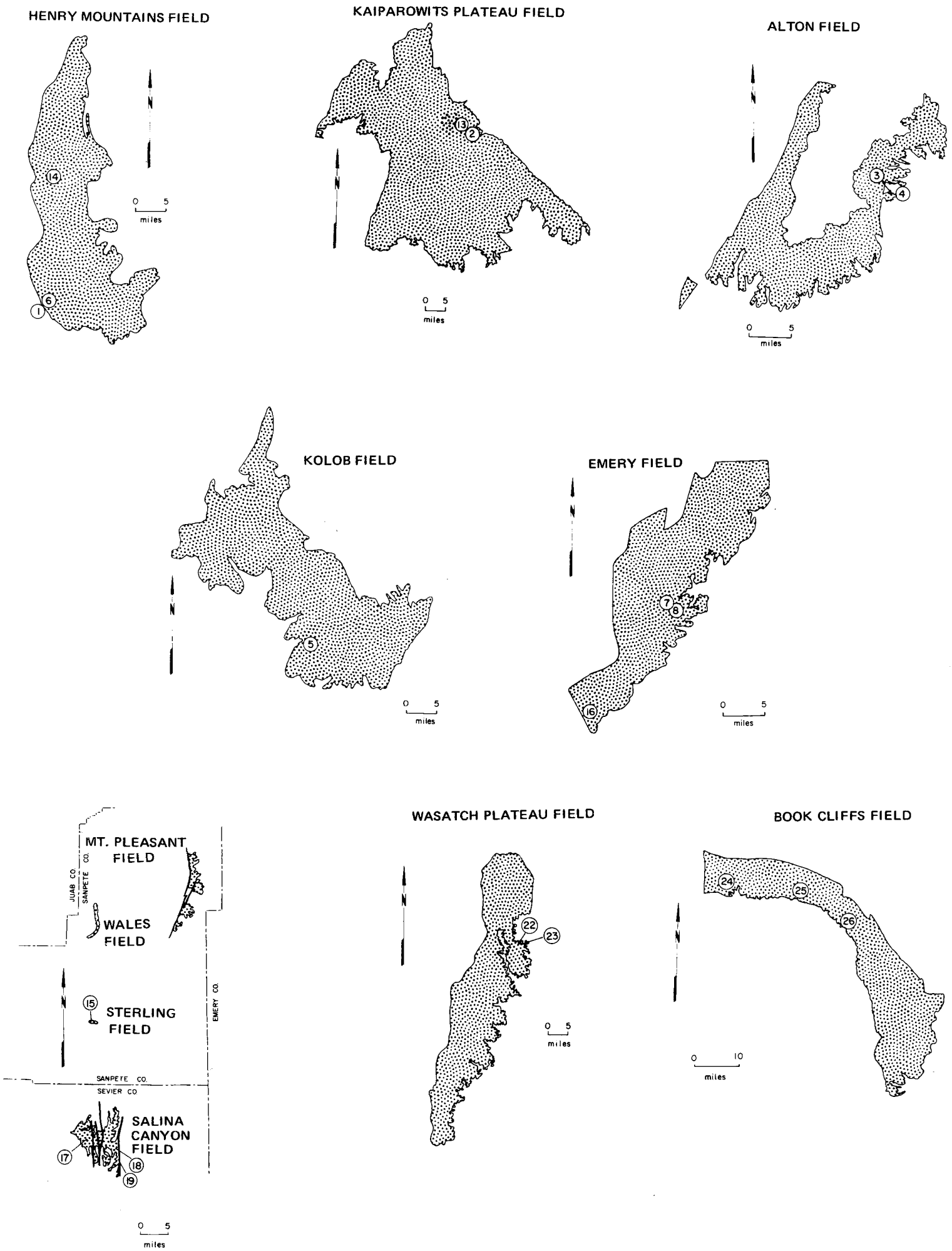
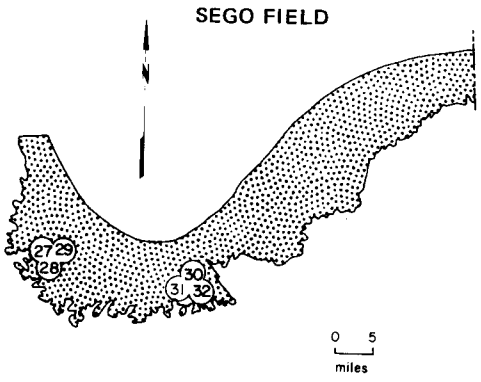
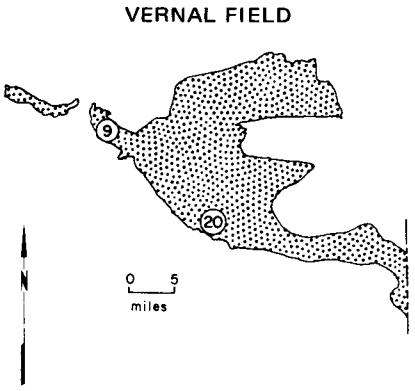
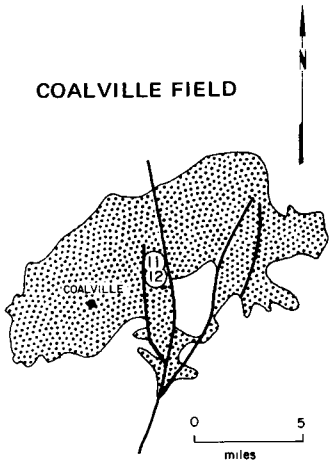
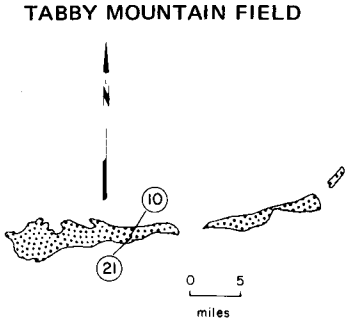


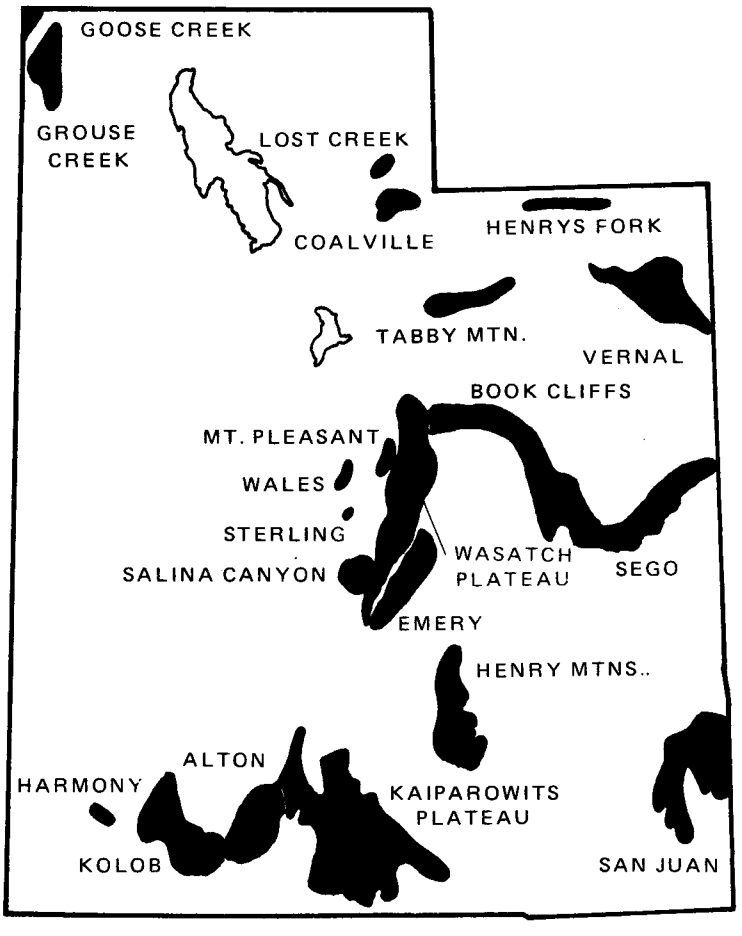
Figure 7. Index of plates by coal field (from north to south; sample localities are indicated with appropriate plate numbers).











INDEX MAP TO COAL FIELDS

Figure 7. (continued)

Plate 10. Tabby Mountain coal field. Coal samples taken from Red Creek area.

Plate 11. Coalville coal field. Coal samples taken from Chappell coal mine.

Plate 12. Same as plate 11.

Straight Cliffs Sandstone

Plate 13. Kaiparowits Plateau coal field. Coal samples taken from John Henry Member in Carcass Canyon.

Emery Sandstone

Plate 14. Henry Mountains coal field. Coal and shale samples taken from Dugout Creek mine and outcrops near Steel Butte.

Sixmile Canyon Formation

Plate 15. Sterling coal field. Coal samples collected from Morrison coal mine.

Mesaverde Group (Blackhawk Formation)

Plate 16. Emery coal field. Coal sample taken from mine near Paradise Lake.

Plate 17. Salina Canyon coal field. Coal samples taken from Wilson coal mine, Wilson bed.

Plate 18. Salina Canyon coal field. Coal samples taken from Sevier Valley mine, Ivie bed. Spore assemblage illustrated.

Plate 19. Same as plate 18. Pollen assemblage illustrated.

Plate 20. Vernal coal field. Coal and shale samples taken from Rasmussen Hollow.

Plate 21. Tabby Mountain coal field. Coal samples taken from Redden coal mine.

Plate 22. Wasatch Plateau coal field. Coal and shale samples taken from Wattis mine, Wattis bed.

Plate 23. Wasatch Plateau coal field. Coal samples taken from Wattis mine, Hiawatha bed.

Plate 24. Book Cliffs coal field. Coal samples taken from Castle Gate B seam in Hardscrabble Canyon, Castle Gate area.

Plate 25. Book Cliffs coal field. Coal samples taken from Premium coal mine, Rock Canyon bed, north of Wellington.

Plate 26. Book Cliffs coal field. Coal samples taken from Geneva coal mine, Sunnyside area.

Price River Formation

Plate 27. Book Cliffs coal field. Coal and shale samples taken from Farrer coal mine, Palisade coal zone, Sego area.

Plate 28. Same as plate 27.

Plate 29. Same as plate 27.

Plate 30. Book Cliffs coal field. Coal and shale samples taken from Chesterfield coal zone, Sego area.

Plate 31. Same as plate 30.

Plate 32. Same as plate 30.

INDEX TO PLATES BY COAL FIELD
(from north to south)

Henry Mountains coal field:
Dakota Sandstone, plate 1.
Ferron Sandstone, plate 6.
Emery Sandstone, plate 14.

Kaiparowits coal field:
Dakota Sandstone, plate 2.
Straight Cliffs Sandstone, plate 13.

Alton coal field:
Dakota Sandstone, plates 3 and 4.

Kolob coal field:
Dakota Sandstone (?), plate 5.

Emery coal field:
Ferron Sandstone, plates 7 and 8.
Mesaverde Formation (?), plate 16.

Salina Canyon coal field:
Mesaverde Group (Blackhawk Formation), plates 17, 18 and 19.

Wasatch Plateau coal field:
Blackhawk Formation, plates 22 and 23.

Sterling coal field:
Sixmile Canyon Formation, plate 15.

Book Cliffs coal field:
Blackhawk Formation, Castle Gate area, plate 24;
Wellington area, plate 25; Sunnyside area, plate 26.

Sego coal field:
Price River Formation, Sego area, plates 27 to 32.

Vernal coal field:
Frontier Formation, plate 9.
Mesaverde Formation (?), plate 20.

Tabby Mountain coal field:
Frontier Formation, plate 10.
Mesaverde Formation, plate 21.

Coalville coal field:
Frontier Formation, plates 11 and 12.

PALYNOLOGICAL ANALYSIS OF FORMATIONS

Dakota Sandstone
(Plates 1, 2, 3, 4 and 5)

Type of Palynoflora

Basically a pteridophyte-angiosperm palynoflora existed, with microplankton present in many areas. Angiosperm grains present are seldom as advanced as tricolporate and rarely as advanced as triporate. In most areas, except the Kaiparowits, no triporate grains were observed. The grains average about 30μ in length. A study by May (1972) showed that angiosperm grains occasionally dominated pteridophyte counts. A wide variety of angiosperm grain types is present, as well as pteridophyte grains. Pteridophyte spores are generally of the families Schizaeaceae, Gleicheniaceae, Cyatheaceae and Matoniaceae, and range in size from about 25μ to more than 90μ. Spores seen are alete, monolete or trilete; they

have exine sculpturing ranging from psilate *Deltoidospora* to heavily plicate forms, i.e., *Appendicisporites*.

Conclusions

1. Dinoflagellates and acritarchs found in Dakota Sandstone sediment in the Henry Mountains area (plate 1), Alton coal field (not illustrated) and in the Kolob coal field (phytoplankton not illustrated) indicate the close association between coal swamp and littoral marine environments. Acritarchs occur as far west as the King Cannel coal mine in the Kolob coal field.

2. A suspected guide fossil for the Dakota Sandstone which was seen by Agasie (1966) at Black Mesa, Arizona, and by May (1972) at the Paunsaugunt Plateau, also is seen in the Henry Mountains Dakota Sandstone (plate 1, figures 16 and 17) and in the Kolob coal field Dakota Sandstone (?). Its importance is twofold: (1) the fossil is reasonably widespread throughout the Dakota Sandstone in the western states and (2) it occurs in the Kolob area in what has been suspected as being Dakota Sandstone (plate 5, figures 19, 20 and 21).

3. From the presence of the guide fossil plus the similar morphotype assemblage found in the Kolob-Table Bench areas, the coal-bearing formation sampled apparently is Dakota Sandstone.

4. The wide variety of angiosperm pollen and the fern families represented would seem to indicate subtropical environment.

5. The age of the Dakota Sandstone appears no younger than Upper Cenomanian and no older than Upper Albian. This is substantiated more conclusively in the Alton area where the two coal zones are associated with both the top and bottom of the formation. The Turonian boundary would be indicated by the presence of frequent triporate angiosperm pollen grains. Two possible triporate grains are seen from the Kaiparowits samples (plate 2, figures 17 and 18). No such grains were located in the other Dakota Sandstone localities.

6. Abundant palynofloras exist in the Dakota Sandstone of the south Utah plateaus. The flora is particularly interesting because of the sudden burst of angiosperm pollen, which prior to the Albian is either well hidden or nonexistent.

Ferron Sandstone
(Plates 6, 7 and 8)

Type of Palynoflora

Basically a pteridophyte-angiosperm palynoflora existed during Ferron Sandstone deposition. In most respects the characteristics are the same as those in the Dakota Sandstone. The stage of evolutionary advancement of the angiosperm grains is not discernibly different from that of the Dakota. Tricolpate grains are abundant, tricolporate grains are occasionally too rare and no triporate grains were observed in either of the sample localities. Whether angiosperm grains generally dominate fern spores is difficult to determine without a more detailed study.

Gray and others (1966) attempted coal seam correlation within the Ferron Sandstone. A wide variety of fern spores existed as well as a wide variety of angiosperm pollen grains (plates 6 and 7). Other types of pollen commonly equal less than 1 percent.

Fossil phytoplankton was not observed in either of the sample localities. Since no shale samples were run, however, the proximity of the Cretaceous sea is difficult to determine.

Cobban and Reeside (1952) considered the Ferron Sandstone Turonian in age. Analysis of these two palynofloras, Henry Mountains coal and Emery coal field, seem to indicate a slightly older age because of the lack of triporate angiosperm pollen grains.

Conclusions

1. The lack of phytoplankton in the preparations sheds little light on the possibility of marine influence on the coal swamp environment. Observation of these preparations would seem to indicate a fluvial influence rather than marine.

2. The two palynofloras on plates 6, 7 and 8 have little overlap. Plate 6, figure 10, and plate 8, figure 19, as well as plate 6, figure 18, and plate 8, figure 8, seem to illustrate a slight overlap in the assemblages.

3. The wide variety of angiosperm pollen as well as the fern families represented, i.e., in the Dakota Sandstone, probably indicate a subtropical environment.

4. The age of the Ferron Sandstone based on the assemblages seen in preparing the plates would seem to indicate a Cenomanian rather than Turonian age.

Frontier Formation
(Plates 9, 10, 11 and 12)

Type of Palynoflora

An angiosperm pteridophyte palynoflora existed similar in most respects to the Ferron and Dakota Sandstone palynofloras previously described. Stratigraphically it is known to sit above the Dakota, being separated by the Mowry Shale. Walton (1957) described the Frontier as a probable correlative of the Ferron Sandstone. Evidence seen from the assemblages represented in plates 6 through 12 would seem to support this concept. Angiosperm pollen morphology is generally tricolpate with minor amounts of tricolporate forms. No triporate forms were observed. The Frontier Formation studied in Wyoming by Upshaw (1962) indicated an age of Turonian with possible Upper Cenomanian locations. A larger study of the Frontier Sandstone in the areas described on the plates in this report could possibly determine an age of Turonian, although the assemblages represented here would probably be considered Cenomanian.

Conclusions

1. The Frontier morphotype assemblage appears comparable to that of the Ferron Sandstone which would seem to corroborate Walton's (1957) conclusion that they are correlatives.

2. That tricolporates seem the most advanced type present in the samples observed from the Frontier Sandstone would indicate the age is Cenomanian.

3. From the wide variety of angiosperm pollen grains and the fern families represented a subtropical environment apparently persisted during Frontier coal swamp time.

4. Little assemblage overlap was observed between the Vernal, Tabby Mountain and Coalville Frontier localities illustrating the wide variety of vegetation existing during that time.

Straight Cliffs Formation
(Plate 13)

Type of Palynoflora

A primary evolutionary advancement among angiosperm pollen is evidenced in the Kaiparowits Straight Cliffs Formation–

triporate grains appear (plate 13, figures 20 and 21). Orlansky (1970) considered the Straight Cliffs Turonian to Coniacian in age based on a detailed palynological study. According to Orlansky (1967, p. 19): "In the Western Interior, the first appearance of triporates is in strata dated as Turonian by ammonites." The genus Proteacidites (plate 13, figure 21) occurs rarely in preparations examined for this paper (ca. 2 percent) and corresponds to the frequency observed by Orlansky (1 to 10 percent). The entire palynoflora is basically an angiosperm-pteridophyte assemblage with a wide variety of each. Fossil phytoplankton occurs in some horizons (Orlansky, 1970, plate 11) and indicates a marine influence on the coal swamp environment. Conifer pollen also is present in some horizons ranging from rare to abundant in frequency (Orlansky, 1970, p. 48 and 49).

Conclusions

1. The Kaiparowits Straight Cliffs Formation appears to have a more advanced assemblage of angiosperm pollen compared to the previously described Cenomanian assemblages. The conservative numbers of triporate grains would seem to indicate an age slightly younger than Cenomanian. Orlansky (1970) assigned an age of lower Turonian to Coniacian. Evidence derived for this report corroborates that conclusion.

2. In spite of the addition of triporates to the assemblage, the most abundant angiosperm morphotype is tricolpate. Samples from Carcass Canyon (plate 13) illustrate that angiosperm pollen can dominate the flora, although only locally.

3. The wide variety of both angiosperm and pteridophyte palynomorphs would seem to indicate a subtropical environment.

4. The presence of fossil phytoplankton as observed by Orlansky (1970) indicates a definite marine influence on coastline environments.

5. The presence of frequent conifer pollen indicates nearby upland environments.

Emery Sandstone
(Plate 14)

Type of Palynoflora

An angiosperm-pteridophyte palynoflora exists in the Henry Mountains Emery Sandstone. Evolutionary development among the angiosperms appears to be more pronounced (plate 14, figures 12 to 19). A wider variety of triporate grains indicates the trend of angiosperm evolution as evidenced by tricolpate grains present in lesser percentages. Angiosperm grains tend to dominate the pteridophyte spores (plate 14, figures 1 to 4) in this locality. Phytoplankton frequency is rare.

Conclusions

1. A trend in angiosperm triporate development above the Cenomanian-Turonian boundary is noticeable in the Straight Cliffs Sandstone and Emery Sandstone assemblages.

2. The wide variety of angiosperm pollen present as well as the fern families represented would seem to indicate a subtropical environment.

3. The age of the Emery Sandstone would be considered younger than Straight Cliffs, possibly as young as Lower Campanian.

4. Rare phytoplankton present would seem to indicate some influence from the marine environment.

Sixmile Canyon Formation
(Plate 15)

Type of Palynoflora

An angiosperm-pteridophyte assemblage occurs somewhat comparable with that of the Emery Sandstone. *Latipollis* types first appear in both formations (plate 14, figure 12, and plate 15, figures 19 to 22). Krutzsch (1959) described this as a form genus with ages beginning in the uppermost Cenomanian and Turonian of Middle Europe. In the Western Interior of the United States it seems to appear somewhat later as these formations are considered younger. A similar spore type to plate 15, figure 6, and plate 24, figure 7, was seen in the Magothy Formation of Maryland (Stover, 1962) and considered Coniacian. The *Sporopollis* type in plate 15, figure 5, corresponds with that found by Orlansky (1967, p. 51) in the Straight Cliffs Sandstone and is described as ranging from Cenomanian to Coniacian. No conifer pollen or fossil phytoplankton was observed in the preparations.

Conclusions

1. The degree of variation in triporate angiosperm pollen could corroborate correlation between the Emery Sandstone and Sixmile Canyon Formation.

2. The variety in angiosperm pollen as well as pteridophyte spores seems to indicate a subtropical environment.

3. The age of the Sixmile Canyon Formation could be as old as Coniacian and possibly as young as Lower Campanian.

4. The lack of conifer pollen probably indicates that no highland areas were present for some distance.

5. The lack of phytoplankton seems to indicate no direct influence by the Cretaceous sea.

Mesaverde Formation
(Plates 16 to 21)

Type of Palynoflora

The Mesaverde palynoflora is angiosperm-pteridophyte throughout the areas sampled, i.e., central and north Utah. The Mesaverde sampled in the Emery field (plate 16) appears to correlate well with the Salina Canyon, Mesaverde Formation, Ivie bed (plates 18 and 19), especially within the angiosperm assemblage. Similar assemblages of the *Latipollis* types (plate 16, figures 14 to 18, and plate 19, figures 10 to 12) occur in both areas. *Triporopollenites* types (plate 16, figures 21 and 22, and plate 19, figures 6, 7 and 8) appear similar, both showing the enlargement of pore structure which is characteristic of the Upper Cretaceous. Both localities have similar ratios of angiosperm pollen and pteridophyte spores and wide varieties of each occur. The Salina Canyon, Mesaverde Formation, Wilson bed, also shows the enlarging of pore structures (plate 17, figures 12, 13, 15, 16 and 17); figure 17 of plate 17 appears similar to that of figure 13, plate 19. The Mesaverde Formation of the Vernal area (plate 20) illustrates the elaboration of the pore structures on the triporate angiosperm grains. Orate forms occur (plate 16, figure 20 and plate 20, figures 12 and 14) which show one type of pore specialization. The Tabby Mountain Mesaverde Formation shows a variety of *Proteacidites* types (plate 21, figures 13 to 16), which seem characteristic of many Upper Cretaceous palynofloras of the Western Interior.

Conclusions

1. The evolutionary increase in triporate types is evident as well as specialization of the pore structures.

2. The Emery coal field, Paradise Lake, Mesaverde Formation, has affinities with the Salina Canyon, Mesaverde Formation, Ivie bed, as well as showing similarities with the Vernal, Mesaverde Formation, Rasmussen Hollow assemblage.

3. The Mesaverde is considered Campanian to Maestrictian in age based on Walton's (1944) age dating of the underlying Mancos Shale of the Uinta Basin. The palynomorph assemblage appears younger than Danian.

4. The wide variety of angiosperm pollen as well as pteridophyte spores would seem to indicate a subtropical environment.

Blackhawk Formation (Plates 22 to 26)

Type of Palynoflora

Since the Blackhawk is a member of the Mesaverde Group, similar palynofloras are to be expected, especially in the angiosperm component (compare plates 16, 18, 19, 24, 25 and 26 wherein forms similar to those on plate 25, figures 9, 10, 14, 15, 16, 17, 18, 19, 20 and 21 can be seen in various degrees of overlap). The spore component also has a degree of overlap among types, i.e., plate 26, figures 1 to 4. As in the Mesaverde palynoflora the assemblage is basically angiosperm-pteridophyte. Fern spores were less frequent in samples from the Wasatch Plateau coal field where angiosperm grains seem to dominate.

Conclusions

1. Palynofloral characteristics are similar to those of the Mesaverde assemblages (see Mesaverde Formation, Conclusions 1, 3 and 4).

2. Relative differences between the various members of the Blackhawk Formation are difficult to distinguish through this palynological study. Further sampling with statistical analysis would clarify the problem.

Price River Formation (Plates 27 to 32)

Type of Palynoflora

Basically an angiosperm-pteridophyte palynoflora exists with a wide variety of each component. One interesting addition to the assemblage, as also seen by Lohrengel (1969) in the Kaiparowits Formation of south central Utah, is the presence of the angiosperm pollen genus *Aquilapollenites* (plate 29, figures 4 to 8 and plate 32, figures 5 to 10). Pores and/or colpi are born on the ends of the wing-like protrusions. Several of the genera on plate 31, especially figures 15 to 22 and plate 32, figures 1 to 4, seem to have representatives illustrated in the plates back to and including the Straight Cliffs Formation, giving some indication of the ranges. *Proteacidites Latipolli* and *Nudopollis*, for example, range continuously from at least the Emery Sandstone to the Price River Formation age of deposition; apparently relatively few dynamic evolutionary changes have come about since the appearance of the triporate angiosperm pollen grain. Two of the observable changes in these dates that occurred were the elaboration of the pore structure and the appearance of *Aquillapollenites*. Because the Price River Formation includes tricolpate, tricolporate, and triporate (with and without thickened pores), as well as *Aquillapollenites*, it would be considered Upper Cretaceous in age. Fossil phytoplankton (plate 27, figure 5) also was discovered. The similarities between the Hell Creekian Kaiparowits Formation assemblage (Lohrengel, 1969) and the Price River Formation would suggest that their ages are also similar.

Conclusions

1. The Price River Formation assemblage is basically angiosperm-pteridophyte.

2. The environment at the time of deposition is considered subtropical.

3. Conifer pollen (plate 27, figures 1 and 2) indicate a highland area possibly adjacent to the coal swamp.

4. Fossil phytoplankton found in one shale sample from the Palisade coal zone indicates some marine influence on the coal swamp.

5. A similarity with a Kaiparowits Formation assemblage (Lohrengel, 1969) indicates an age of possibly Hell Creekian (Maestrictian-Danian) and is considered younger than the Blackhawk and Mesaverde formations.

SUMMARY

1. A succession of pteridophyte-angiosperm floras existed throughout much of the Utah area during Cretaceous times; the floral assemblages were responsible for the formation of abundant coal deposits.

2. Marine influence on the coal swamp environment is occasionally apparent because of the presence of fossil phytoplankton in some of the preparations.

3. The most primitive assemblages of palynomorphs are seen in the Dakota Sandstone, Ferron Sandstone and Frontier Formation. Angiosperm grains are generally of the tricolpate type, although some tricolporate are present. The age for these formations is, therefore, considered Cenomanian.

4. The first triporate grains appear conservatively in the Straight Cliffs Sandstone which is considered Turonian.

5. Palynomorph assemblages in formations younger than Straight Cliffs Sandstone show a consistent expansion in the types of triporate angiosperm grains present, as well as evolutionary developments, such as elaboration of exine structure and shape.

6. Differentiation in age among Senonian formations is difficult without a more detailed study. This applies to the formations younger than Straight Cliffs Sandstone.

7. The youngest formation appears to be the Price River Formation (plates 27 to 32). Based on a comparison of this palynoflora with that found by Lohrengel (1969) in the Kaiparowits Formation of south central Utah, the Price River Formation apparently is Maestrictian-Danian in age.

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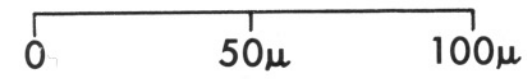


Figure
1-4. Dinoflagellates. Genus *DeFlandrea*; 70-85μ.
5-14. *Hystrichosphaeridia;* 70-100μ.
15. *Tricolpites* sp.; 31μ. Note: Does not correspond to scale on plate.,
16-17. Pollen type A; 27μ. Note: Does not correspond to scale on plate.

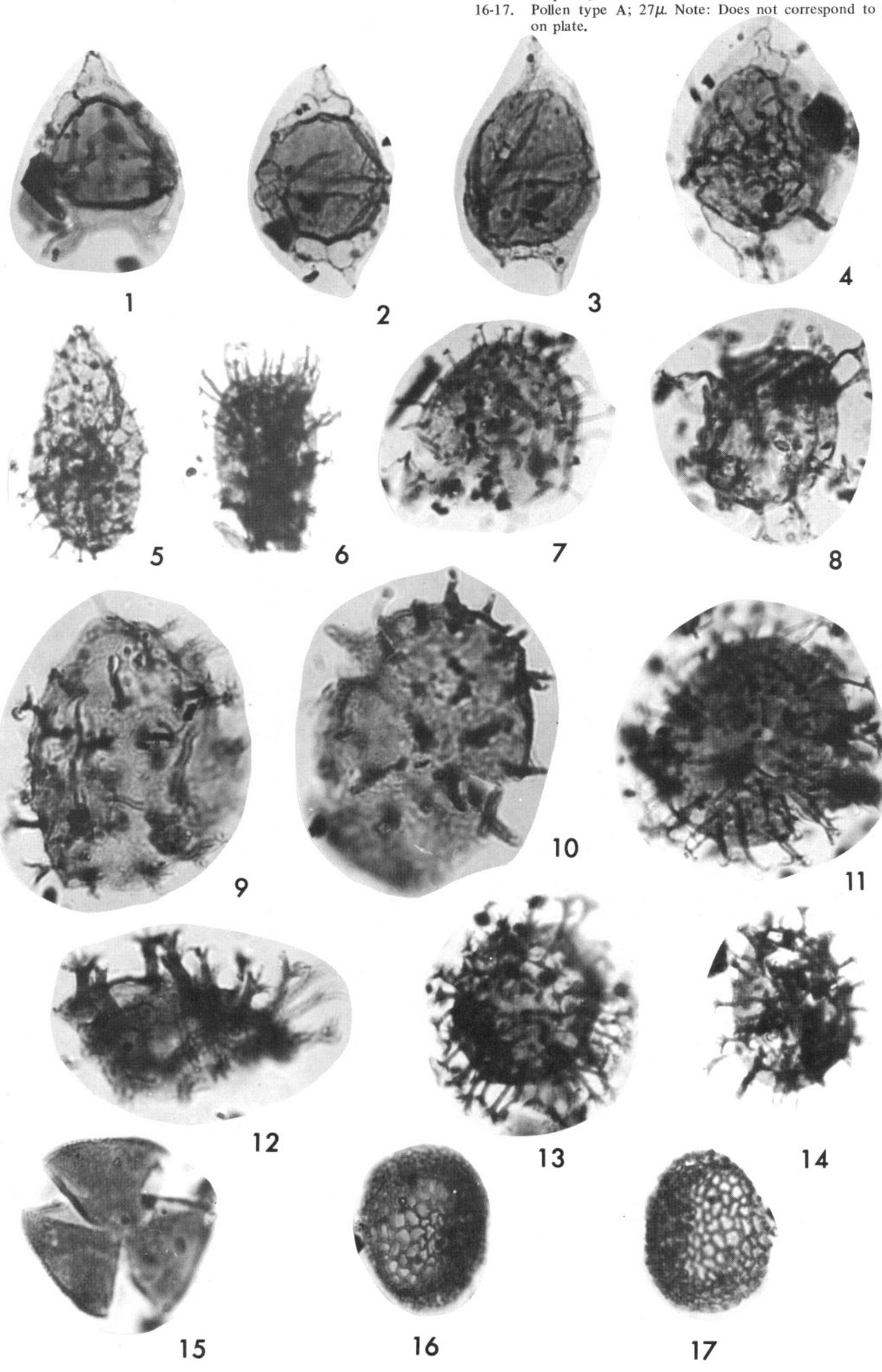


Plate 1. Henry Mountains coal field, Dakota Sandstone.

Figure

1. *Deltoidospora* sp. 1; 42μ.
2. *Deltoidospora* sp. 1; 41μ
3. *Deltoidospora* sp. 2; 38μ.
4. *Trilobozonosporites* sp.; 43μ.
5. *Cyathidites* sp; 32μ.
6. *Laevigatosporites* sp. 1; 35μ.
7. *Laevigatosporites* sp. 2; 38μ.
8. *Palmaepollenites* sp; 40μ.
9. *Retitricolpites* sp. 1; 29μ.
10. *Retitricolpites* sp. 2; 29μ.
11. *Retitricolpites* cf. sp. 2; 22μ.
12. *Retitricolpites* sp. 3; 25μ.
13. *Tricolpites* sp. 1; 33μ.
14. *Tricolpites* sp. 2; 17μ.
15. *Tricolpites* sp. 3; 18μ.
16. *Tricolpites* sp. 3; 20μ.
17. cf. *Triporopollenites* sp. 1; 24μ.
18. cf. *Triporopollenites* sp. 2; 14μ.

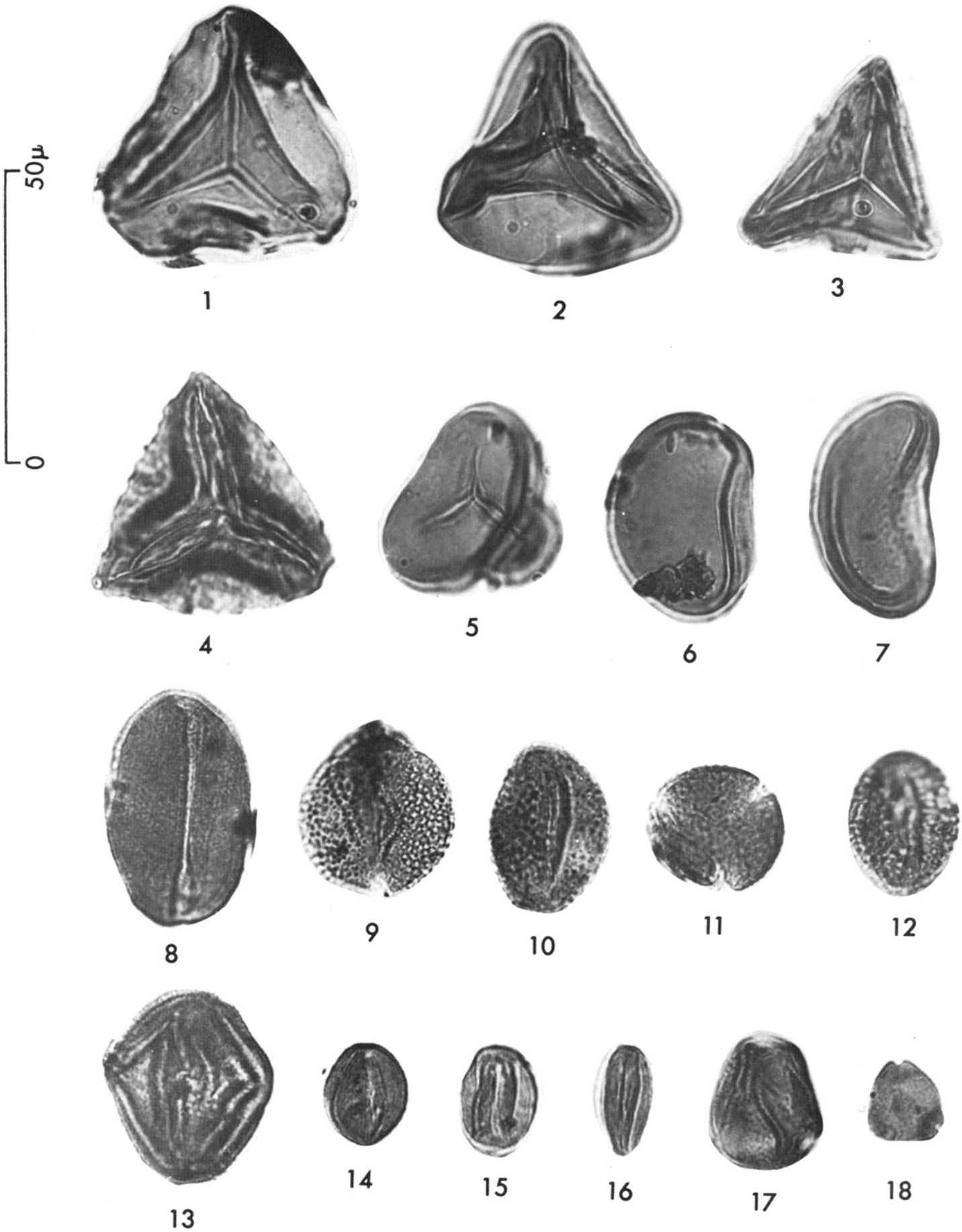


Plate 2. Kaiparowits coal field, Dakota Sandstone, Seep Flat quadrangle.

Figure

1. cf. *Punctatisporites* sp.; 48μ.
2. *Camarozonosporites* sp.; 45μ.
3. *Deltoidospora hallii* Miner; 36μ.
4. *Appendicisporites* sp.; 52μ.
5. *Gleicheniidites senonicus* (Ross) Delcourt and Sprumont; 32μ.
6. *Concavosporites* sp.; 25μ.
7. *Appendicisporites* cf. *undosus* Hedlund; 50μ.
8. *Classopollis* sp.; 34μ.
9. cf. *Pistillipollenites* sp. 1; 30μ.
10. cf. *Pistillipollenites* sp. 2; 30μ.
11. *Eucommidites* sp.; 23μ.
12. Conifer pollen type; 40μ.
13. cf. *Piceapollenites* sp.; 80μ.

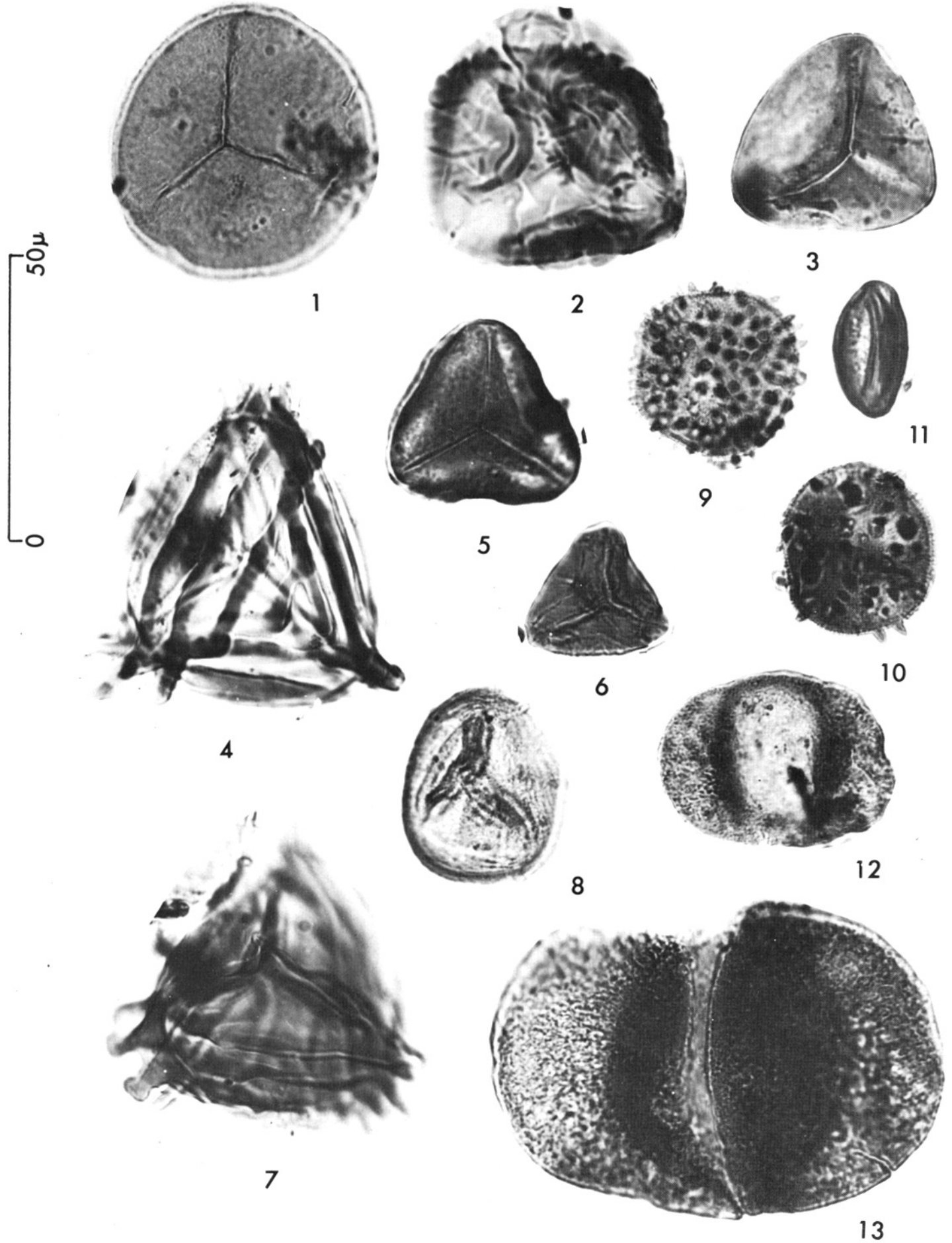


Plate 3. Alton coal field, Dakota Sandstone.

Figure

1. Pollen type A; 64μ (pollen tetrad).
2. Pollen type B; 40μ (pollen tetrad).
3. Pollen type C; 31μ.
4. *Syncolporopollenites* sp.; 28μ.
5. *Tricolpites* sp. 1; 25μ.
6. *Tricolpites* sp. 2; 39μ.
7. *Tricolpites* sp. 3; 28μ.
8. *Tricolpites* sp. 4; 28μ.
9. *Tricolpites* sp. 5; 20μ.
10. *Tricolpites* cf. sp. 2; 34μ.
11. *Tricolpites* sp. 6; 21μ.
12. *Tricolpites* sp. 7; 32μ.
13. *Tricolpites* sp. 8; 19μ.
14. *Tricolpites* sp. 9; 18μ.
15. *Tricolpites* sp. 10; 28μ.
16. *Tricolpites* cf. sp. 10; 31μ.
17. *Tricolpites* sp. 11; 12μ.
18. *Retitricolpites* sp.; 31μ.
19. Pollen type D; 25μ.

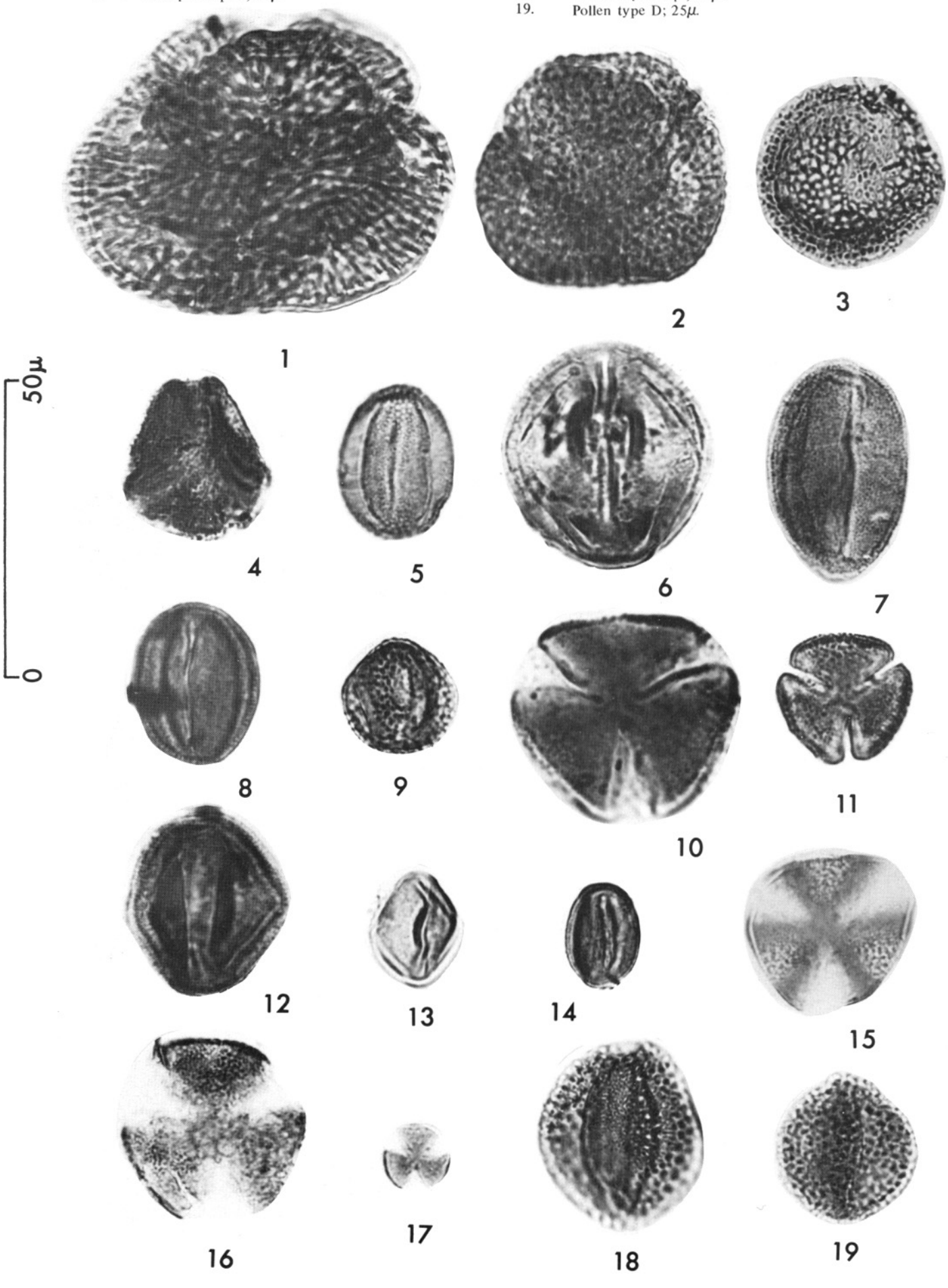


Plate 4. Alton coal field, Dakota Sandstone.

Figure

1. *Deltoidospora hallii* Miner; 40μ.
2. cf. *Deltoidospora* sp.; 35μ.
3. *Matonisporites impensus* Hedlund; 66μ.
4. *Sphagnumsporites* sp.; 23μ.
5. *Appendicisporites* sp.; 48μ.
6. *Gleicheniidites senonicus* (Ross) Delcourt and Sprumont; 29μ.
7. *Gleicheniidites* sp.; 37μ.
8. *Laevigatosporites* sp.; 23μ.
9. *Laevigatosporites psilatus*; 40μ.
10. *Tricolpites* sp.1; 27μ.
11. *Tricolpites* sp. 2; 26μ.
12. *Tricolpites* sp. 3; 26μ.
13. *Tricolpites* sp. 4; 18μ.
14. *Tricolpites* sp. 5; 16μ.
15. *Tricolpites* sp. 6; 30μ.
16. *Tricolpites* sp. 7; 24μ.
17. *Tricolpites* sp. 8; 28μ (terratoid tetracolpate).
18. *Tricolpites* sp. 9; 19μ.
19-21. Pollen type A. sp.; 27μ.
22. *Palmaepollenites* sp.; 36μ.

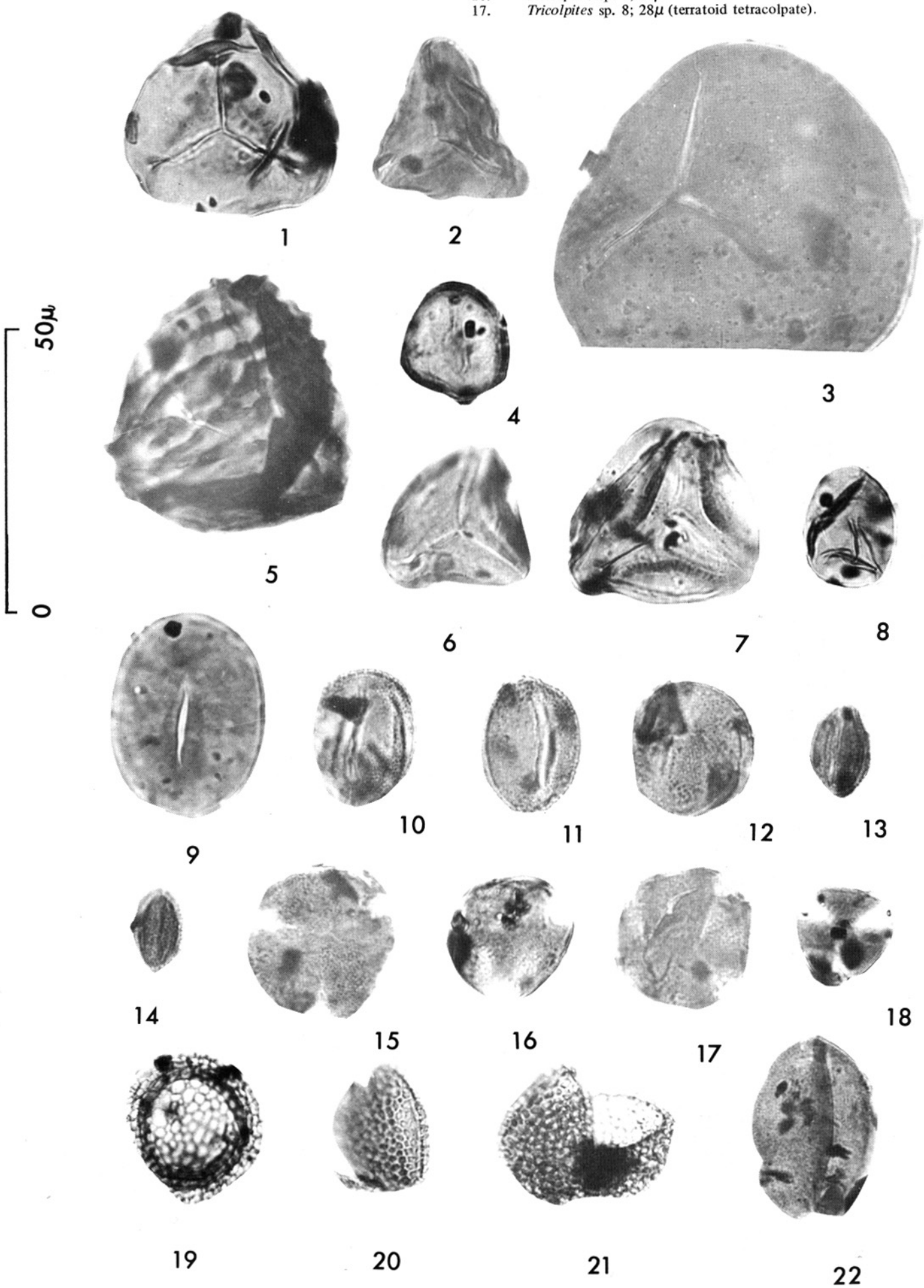


Plate 5. Kolob coal field, Dakota Sandstone.

Figure
1. *Cyathidites* sp.; 37μ.
2. *Cicatricosisporites dorogensis* R. Potonie and Gelletich; 43μ.
3. *Appendicisporites* sp.; 44μ.
4. *Cicatricosisporites crassiterminatus* Hedlund; 58μ.
5. Spore type A; 52μ.
6. *Schizosporis* sp.; 35μ.
7. Spore type B; 45μ.
8. *Ephedripites* sp.; 45μ.
9. *Tricolpites* sp. 1; 22μ.
10. *Tricolpites* sp. 2; 22μ.
11. *Classopollis* sp. 1; 26μ.
12. *Tricolpites* sp. 3; 23μ.
13. cf. *Tricolporopollenites* sp. 1; 22μ.
14. cf. *Tricolporopollenites* sp. 2; 40μ.
15. *Tricolpites* sp. 4; 36μ.
16. *Tricolpites* sp. 5; 32μ.
17. *Tricolpites* sp. 6; 23μ.
18. *Tricolpites* sp. 7; 22μ.

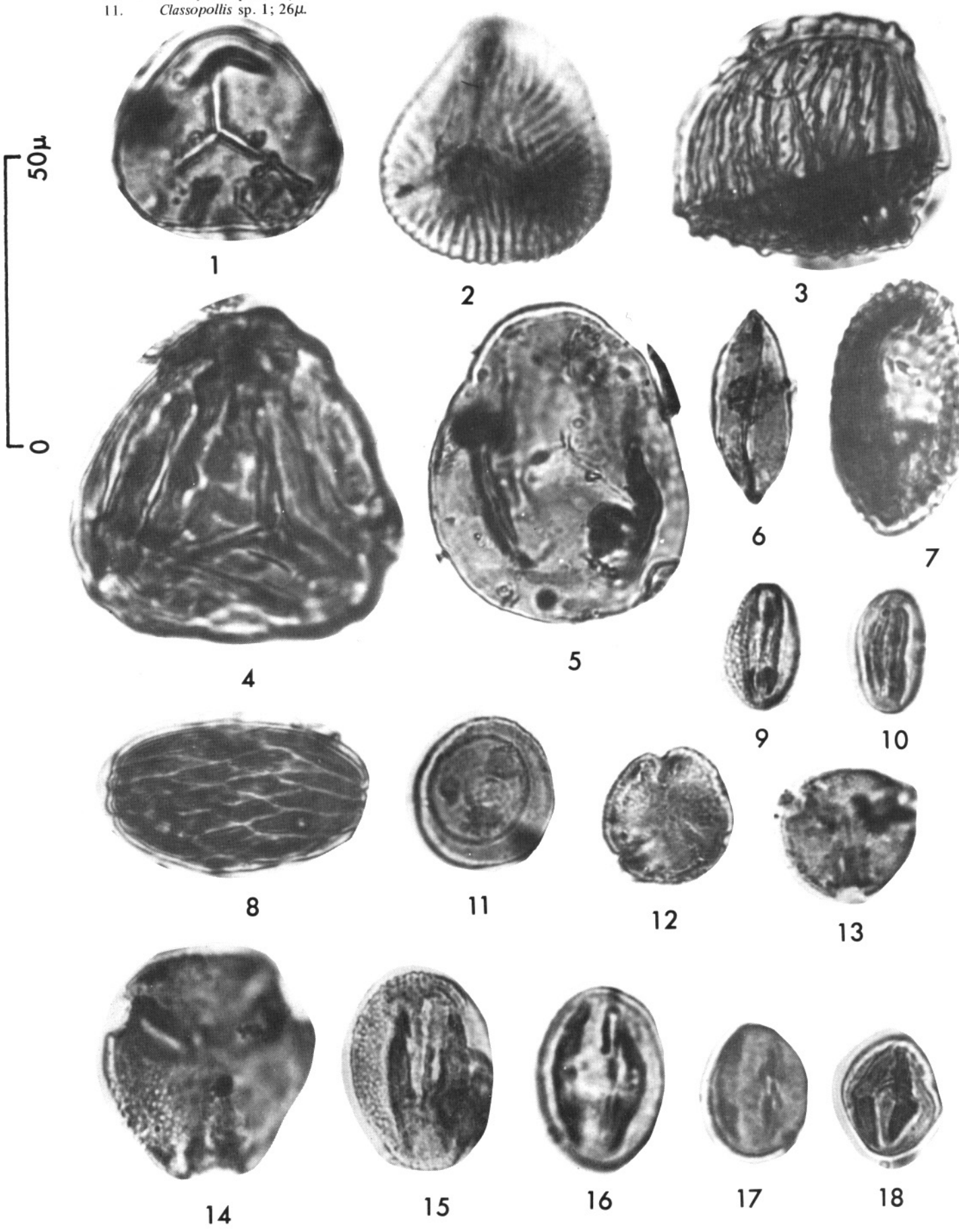
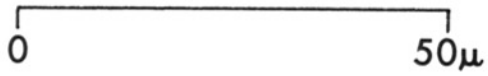
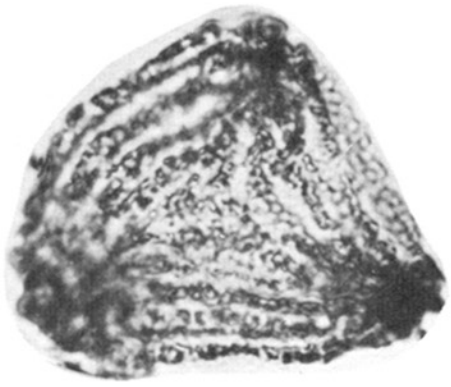


Plate 6. Henry Mountains coal field, Ferron Sandstone.

Figure

1. *Appendicisporites* sp. 1; 44μ.
2. *Appendicisporites* sp. 2; 42μ.
3. *Schizosporis* sp.; 44μ.
4. cf. *Foveosporis* sp.; 45μ.
5. *Deltoidospora* sp.; 45μ.
6. *Inaperturopollenites* sp.; 45μ.
7. Spore type A; 39μ.
8. cf. *Verrucosisporites* sp.; 39μ.
9. *Camarozonosporites rudis* (Leschik) Klaus; 44μ.
10. *Concavisporites* cf. *subgranulosis* Couper; 39μ.
11. Spore type B; 64μ.
12. cf. *Osmundacidites* sp.; 32μ.

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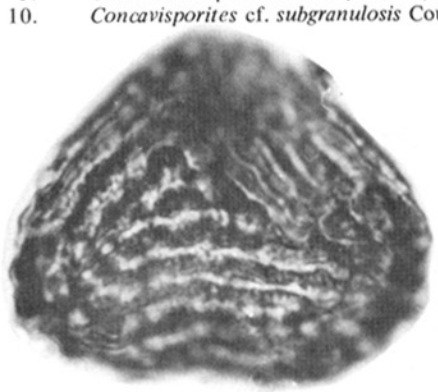
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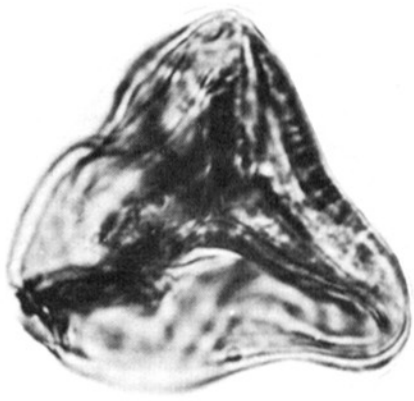
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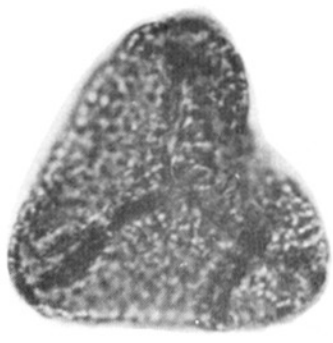
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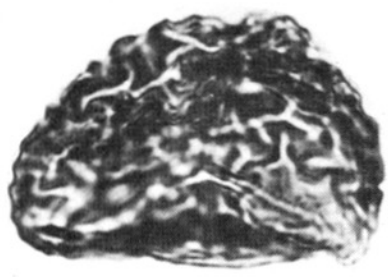
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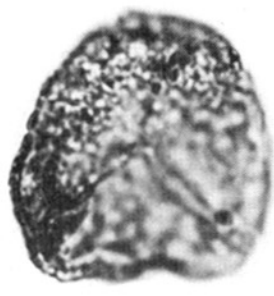
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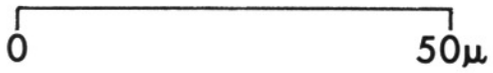
Plate 7. Emery coal field, Ferron Sandstone "A" bed.

Figure

1. *Tricolpites* sp. 1; 20μ.
2. *Tricolpites* sp. 2; 22μ.
3. *Tricolpites* sp. 3; 19μ.
4. *Tricolpites* sp. 4; 16μ.
5. *Tricolpites* sp. 5; 15μ.
6. cf. *Psilatricolpites parvulus* (Groot and Penny); 18μ.
7. *Tricolpites* sp. 6; 20μ.
8. *Tricolpites* sp. 7; 25μ.
9. *Tricolpites* sp. 8; 18μ.
10. *Tricolpites* sp. 9; 25μ.
11. *Retitricolpites* sp.; 28μ.
12. *Retitricolpites* cf. *georgensis* Brenner; 41μ.
13. *Tricolpites* sp. 10; 31μ.
14. *Tricolpites* sp. 11; 18μ.
15. *Tricolpites* sp. 12; 25μ.
16. *Tricolpites* sp. 13; 15μ.
17. *Tricolpites* sp. 14; 32μ.
18. cf. *Eucommidites* sp.; 16μ.
19. *Tricolpites* sp. 15; 24μ.
20. *Tricolpites* sp. 16; 22μ.
21. *Cycadopites* sp.; 26μ.
22. *Classopollis* sp.; 21μ.



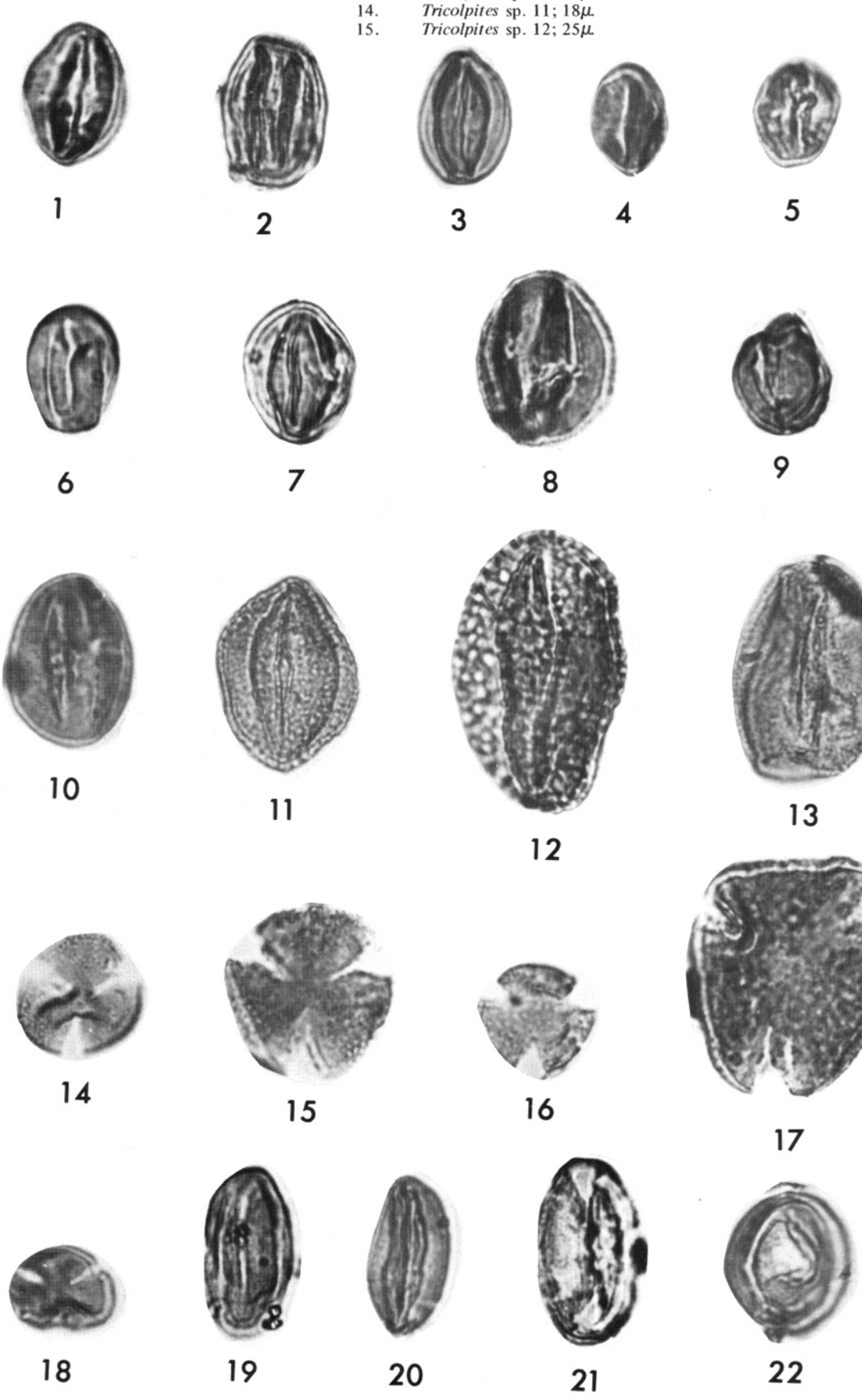


Plate 8. Emery coal field, Ferron Sandstone "A" bed.

Figure

1. *Concavisporites* sp.; 37μ.
2. *Cicatricosisporites* sp.; 52μ.
3. *Toroispora major* Stanley; 48μ.
4. cf. *Deltoidospora* sp.; 37μ.
5. cf. *Verrucosisporites* sp.; 55μ.
6. *Appendicisporites* sp.; 59μ.
7. *Tricolpites* sp.1; 24μ.
8. *Tricolpites* sp. 2; 23μ.
9. *Tricolpites* sp. 3; 22μ.
10. *Tricolpites* sp. 4; 31μ.
11. *Tricolpites* sp. 5; 28μ.
12. *Tricolpites* sp. 6; 28μ.
13. *Tricolpites* sp. 7; 29μ.
14. Pollen type A; 24μ.
15. cf. *Tricolpites* sp. 4 (above); 25μ.
16. cf. *Tricolpites* sp. 5 (above); 24μ.
17. *Tricolpites* sp. 8; 25μ.
18. *Tricolpites* sp. 9; 20μ.
19. *Tricolpites* sp. 10; 27μ.

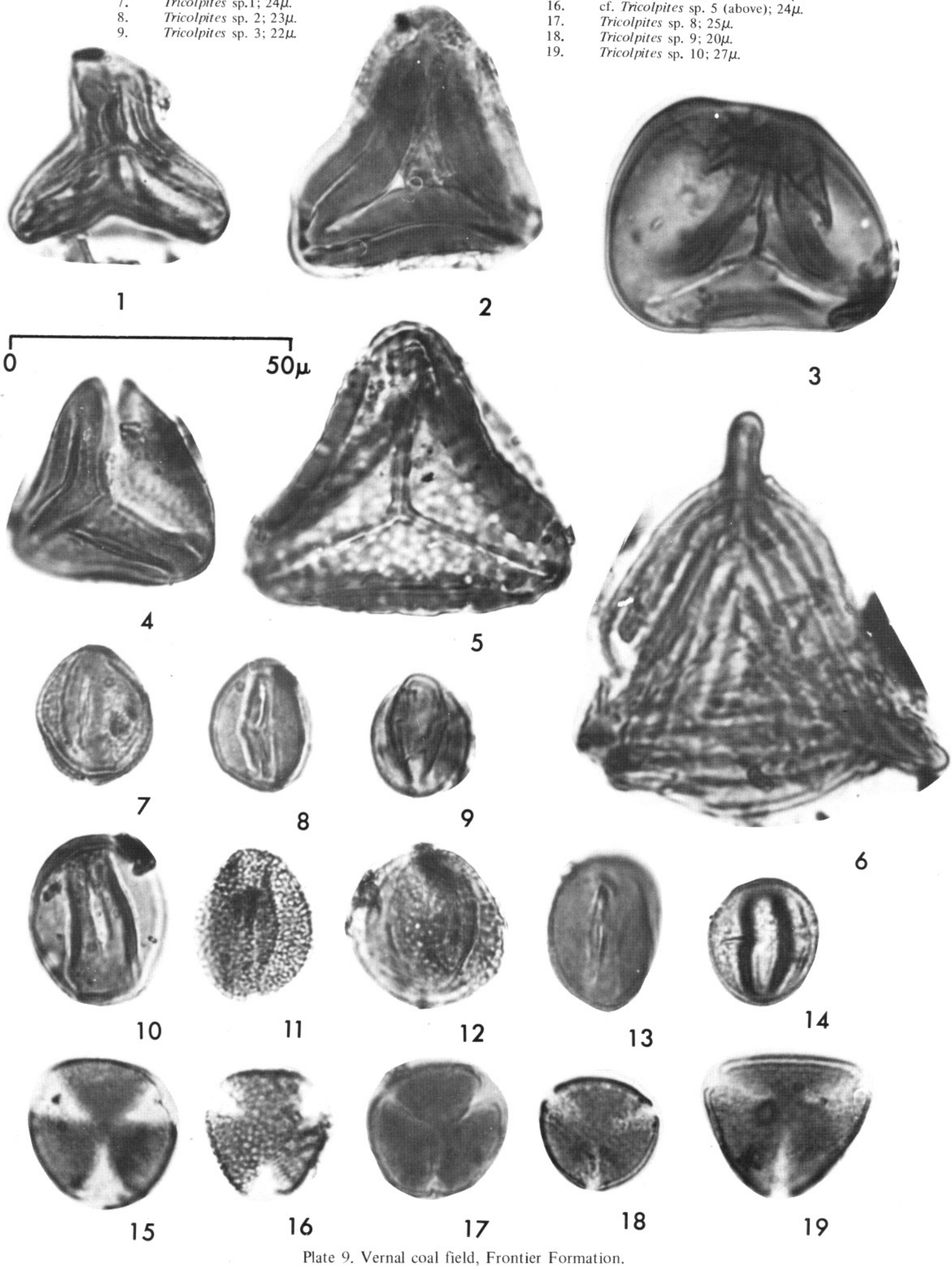


Plate 9. Vernal coal field, Frontier Formation.

Figure

1. *Concavisporites* sp.; 34μ.
2. cf. *Deltoidospora* sp.; 32μ.
3-4. *Deltoidospora hallii* Miner; 32-36μ.
5. Spore type A; 36μ.
6. Spore type B; 61μ.
7. Spore type C; 47μ.
8. *Tricolporites* sp. 1; 26μ.
9. *Tricolporites* sp. 2; 24μ.
10. *Tricolpites* sp. 1; 16μ.
11. *Tricolpites* sp. 2; 24μ.
12. *Tricolpites* sp. 3; 28μ.
13. *Retitricolpites* sp.; 16μ.
14. *Tricolpites* sp. 4; 24μ.
15. *Tricolpites* sp. 5; 23μ.
16. *Tricolpites* sp. 6; 15μ.
17. cf. *Eucommidites* sp. 1; 20μ.
18. *Tricolpites* sp. 7; 19μ.
19. *Tricolpites* sp. 8; 19μ.
20. *Tricolporites* sp. 3; 19μ (brevicolpate).
21. cf. *Eucommidites* sp. 2; 19μ.

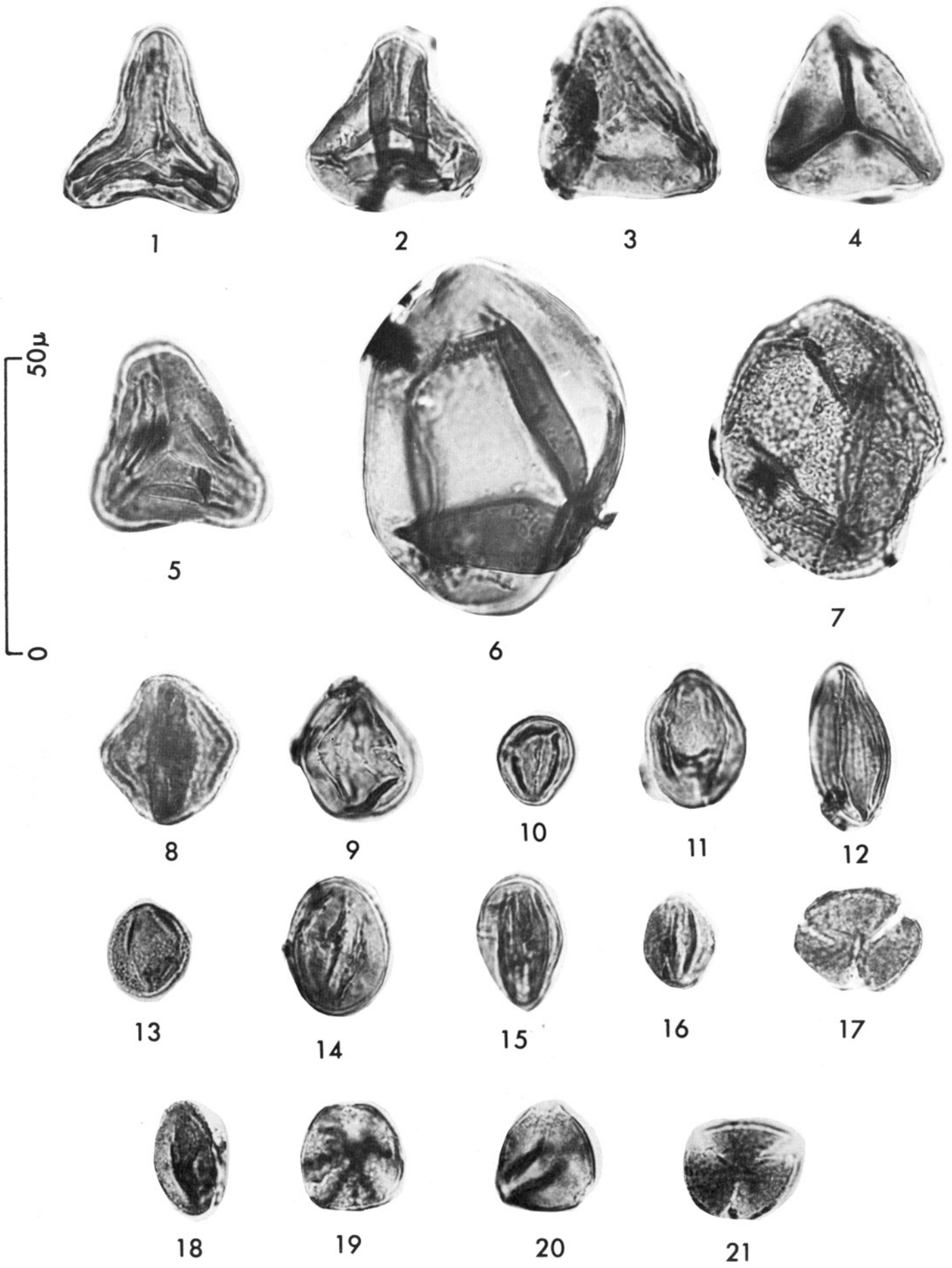


Plate 10. Tabby Mountain coal field, Frontier Formation.

Figure

1. *Appendicisporites* sp.; 72μ.
2. *Verrucosisporites* sp.; 57μ.
3. *Schizosporis* sp.; 48μ.
4. *Deltoidospora* sp. 1; 50μ.
5. *Deltoidospora* sp. 2; 42μ.
6. *Gleicheniidites* sp.; 43μ.
7. *Concavisporites* sp.; 30μ.
8. Spore type A; 35μ.
9. Spore type B; 48μ.
10. Spore type C; 33μ.
11. *Cycadopites* sp.; 36μ.
12. *Classopollis* sp.; 42μ.
13. *Monosulcites* sp.; 26μ.

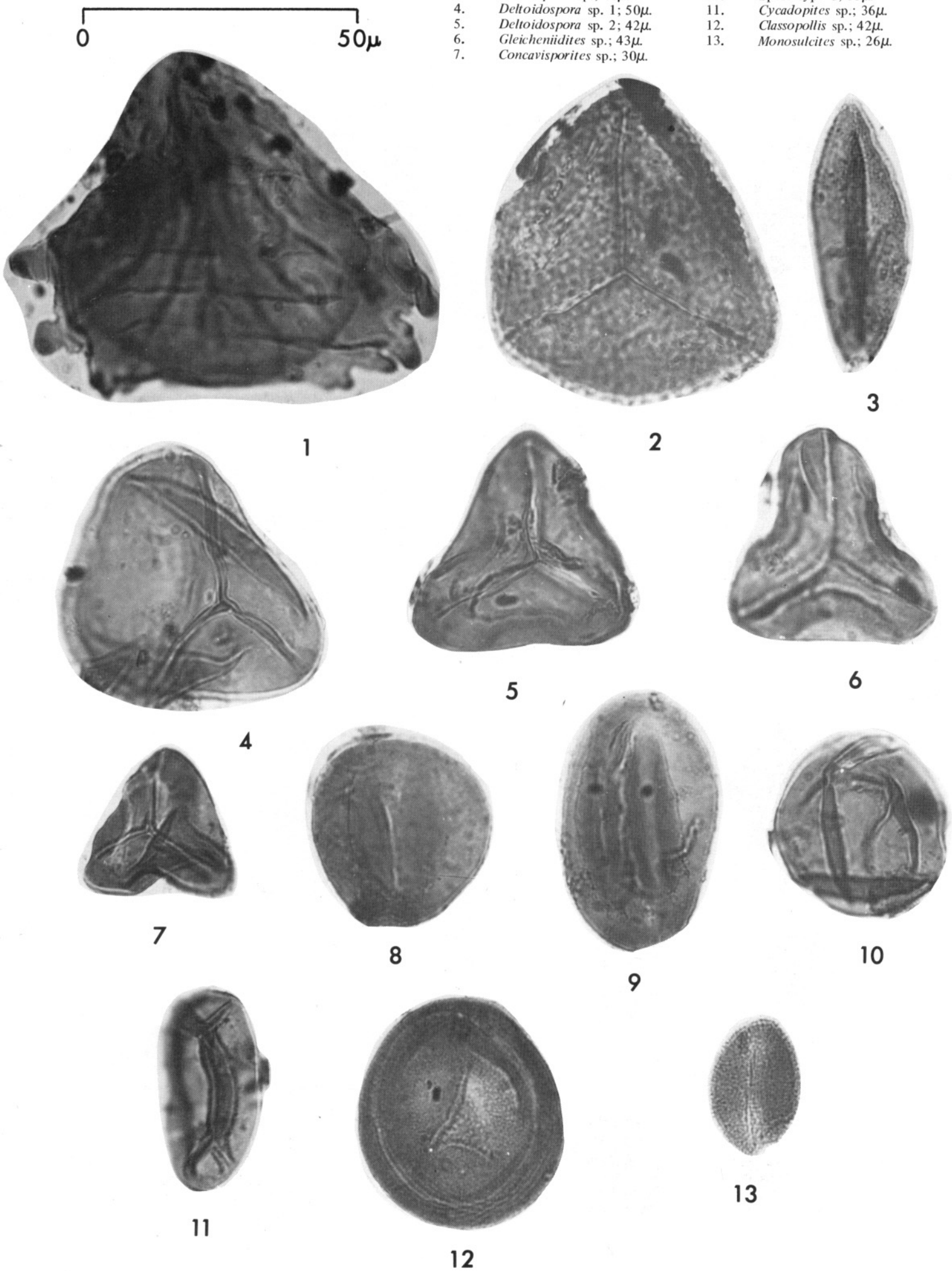


Plate 11. Coalville coal field, Frontier Formation

Figure
1. *Retitricolpites* sp. 1; 42μ.
2. *Tricolpites* sp. 1; 30μ.
3. *Tricolpites* sp. 2; 22μ.
4. *Tricolpites* cf. sp. 2; 22μ.
5. *Tricolpites* sp. 3; 23μ.
6. *Retitricolpites* sp. 2; 34μ.
7. *Tricolpites* sp. 4; 33μ.
8. *Tricolpites* sp. 5; 29μ.
9. *Tricolpites* sp. 6; 29μ.
10. cf. *Eucommidites* sp.; 25μ.
11. *Tricolpites* sp. 7; 21μ.
12. *Tricolpites* sp. 8; 24μ.
13. *Tricolpites* sp. 9; 24μ.
14. *Tricolpites* sp. 10; 25μ.
15. *Tricolpites* sp. 11; 22μ.
16. *Tricolpites* sp. 12; 26μ.
17. *Tricolpites* sp. 13; 19μ.
18. Pollen type A; 42μ.

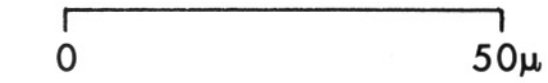
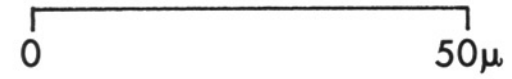


Plate 12. Coalville coal field, Frontier Formation.

Figure

1. *Deltoidospora* sp. 1; 35μ.
2. *Deltoidospora* sp. 2; 35μ.
3. *Laevigatosporites* sp.; 50μ.
4. *Schizosporis* sp.; 38μ.
5. cf. *Palmaepollenites* sp.; 34μ.
6. *Tricolpites* sp. 1; 23μ.
7. *Tricolpites* sp. 2; 21μ.
8. *Tricolpites* sp. 3; 23μ.
9. *Tricolpites* sp. 4; 20μ.
10. *Tricolpites* sp. 5; 18μ.
11. *Tricolpites* sp. 6; 22μ.
12. *Tricolpites* sp. 7; 26μ.
13. *Tricolpites* sp. 8; 31μ.
14. *Retitricolpites* sp.; 44μ.
15. *Tricolpites* sp. 9; 30μ.
16. *Tricolpites* sp. 10; 20μ.
17. *Tricolpites* sp. 11; 24μ.
18. cf. *Stephanocolpites* sp.; 30μ.
19. *Triporopollenites* sp. 1; 19μ.
20. *Triporopollenites* sp. 2; 39μ.
21. *Proteacidites* sp.; 25μ.



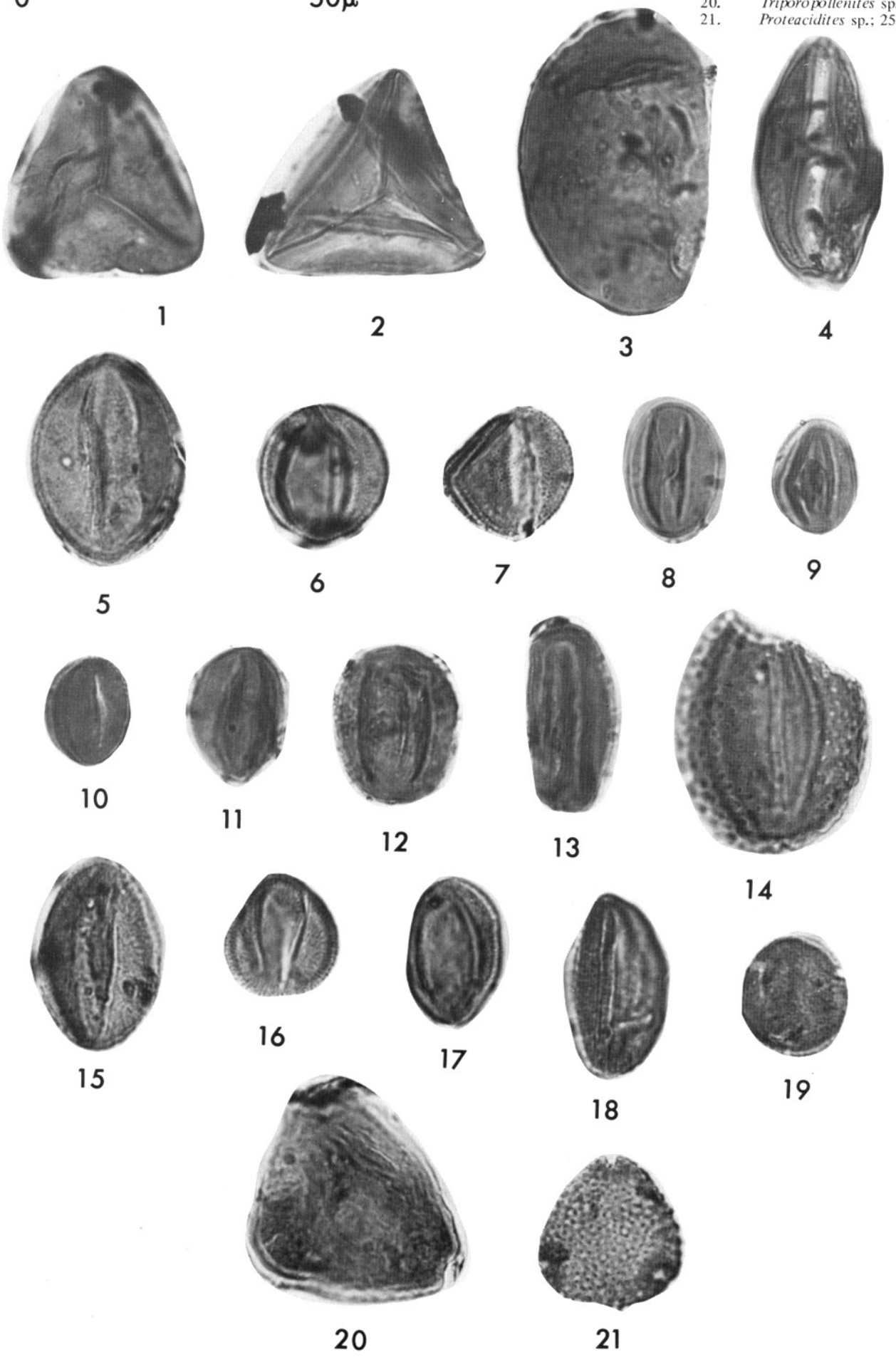
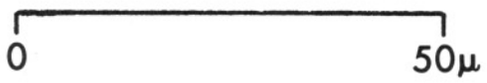


Plate 13. Kaiparowits coal field, Straight Cliffs Sandstone.

Figure

1. cf. *Gleicheniidites* sp.; 45μ.
2. Spore type C; 35μ.
3. cf. *Rouseisporites* sp.; 37μ.
4. *Palmaepollenites* sp.; 45μ.
5. *Tricolpites* sp. 8; 42μ.
6. Pollen type A; 23μ.
7. *Tricolpites* sp. 9; 16μ.
8. *Tricolpites* sp. 10; 48μ.
9. *Tricolpites* sp. 11; 28μ.
10. *Classopollis* sp. 2; 26μ.
11. *Tricolpites* sp. 12; 24μ.
12. Pollen type B; 36μ.
13. *Triporopollenites* sp. 1; 36μ.
14. *Nudopollis* sp.; 26μ.
15. *Proteacidites retusus* Anderson; 27μ.
16. *Proteacidites* sp.; 45μ.
17. *Proteacidites mollis* Samoilovitch; 35μ.
18. *Triporopollenites* sp. 2; 37μ.
19. cf. *Proteacidites retusus* Anderson; 17μ.



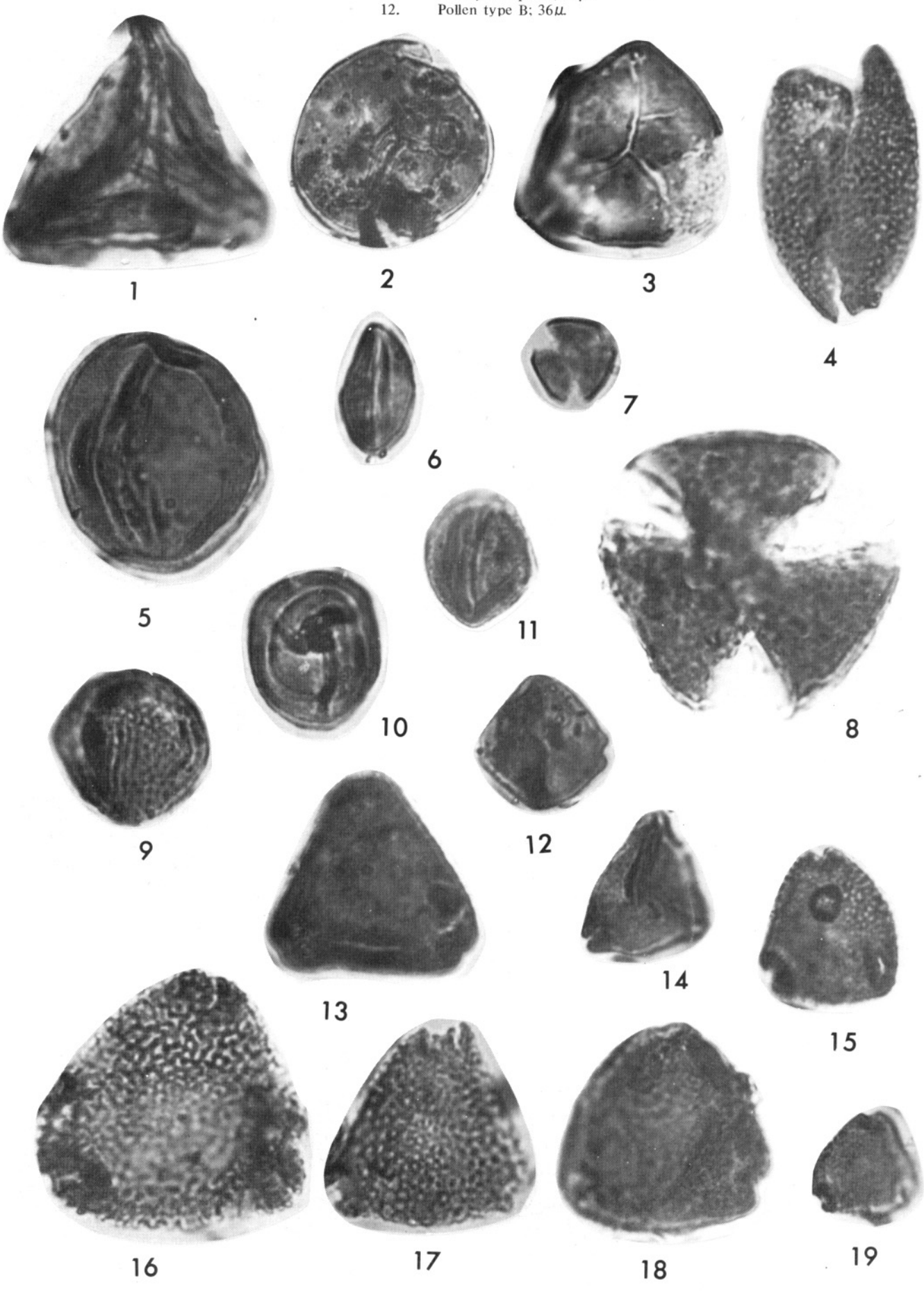


Plate 14. Henry Mountains coal field, Emery Sandstone.

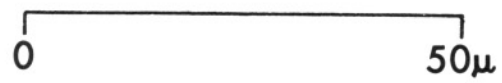
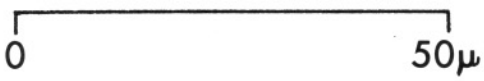


Figure
1. Spore type A; 49μ.
2. cf. *Concavisporites* sp.; 34μ.
3. *Toroispora* sp.; 41μ.
4. *Schizosporis* sp. 1; 44μ.
5. *Monosulcites* sp.1; 34μ.
6. *Monosulcites* sp. 2; 30μ.
7. *Tricolpites* sp. 1; 18μ.
8. *Tricolpites* sp. 2; 25μ.
9. *Schizosporis* sp. 2; 48μ.
10. *Tricolpites* sp. 3; 36μ.
11. *Tricolpites* sp. 4; 31μ.
12. *Tricolpites* sp. 5; 21μ.
13. *Triporopollenites* sp. 1; 18μ.
14-15. Pollen type A; 39μ.
16-17. cf. *Latipollis* sp. 1; 30-34μ.
18. *Latipollis* sp. 2; 33μ.
19. *Triporopollenites* sp. 2; 26μ.
20. *Triporopollenites* sp. 3; 29μ.
21. *Extratriporopollenites* sp.; 36μ.
22. *Triporopollenites* sp. 4; 35μ.

Plate 16. Emery coal field, Paradise Lake area, Mesaverde Formation.

Figure

1. *Deltoidospora* sp.; 33μ.
2. *Verrucosisporites* sp.; 36μ.
3. cf. *Toroispora* sp.; 33μ.
4. cf. *Concavisporites* sp.; 30μ.
5. *Sporopollis* sp.; 33μ.
6. cf. *Kuylisporites* sp.; 35μ.
7. *Laevigatosporites psilatus*; 37μ.
8. Spore type A; 50μ.
9. *Tricolpites* sp. 1; 20μ.
10. *Tricolpites* sp. 2; 16μ.
11. *Tricolpites* sp. 3; 20μ.
12. *Tricolpites* sp. 4; 23μ.
13. *Tricolpites* sp. 5; 25μ.
14. *Tricolpites* sp. 6; 24μ.
15. *Tricolporopollenites* sp.; 19μ.
16. *Proteacidites* sp. 1; 19μ.
17. *Proteacidites* sp. 2; 20μ.
18. *Triporopollenites* sp.; 20μ.
19-20. cf. *Latipollis* sp. 1; 27μ.
21-22. cf. *Latipollis* sp. 2; 17-25μ.
23. Pollen type A; 31μ.



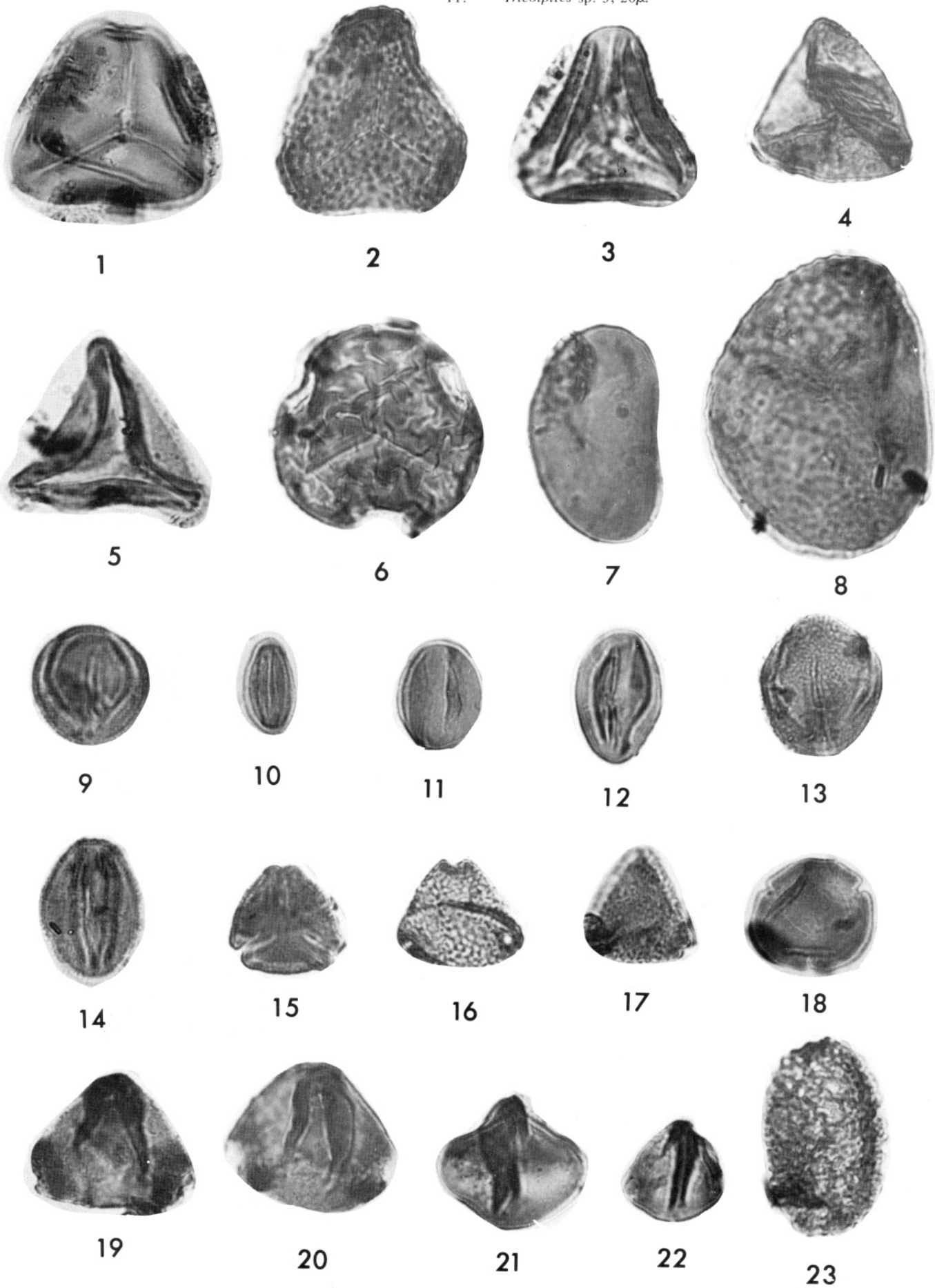


Plate 15. Sterling coal field, Sixmile Canyon Formation.

Figure
1. Spore type A; 32μ.
2. *Schizosporis* sp.; 48μ.
3. *Laevigatosporites psilatus*; 32μ.
4. *Tricolpites* sp. 1; 27μ.
5-6. *Tricolpites* sp. 2; 23-27μ.
7. *Tricolpites* sp. 3; 27μ.
8. *Tricolpites* sp. 4; 30μ.
9. *Tricolpites* sp. 5; 22μ.
10. *Tricolpites* sp. 6; 45μ.
11. *Retitricolpites* sp.; 35μ.
12-13. *Latipollis* sp; 31μ.
14. Conifer pollen type A; 58μ.
15. *Proteacidites* sp. 1; 36μ.
16. *Triporopollenites* sp.; 28μ.
17. cf. *Proteacidites* sp. 1 (above); 32μ.

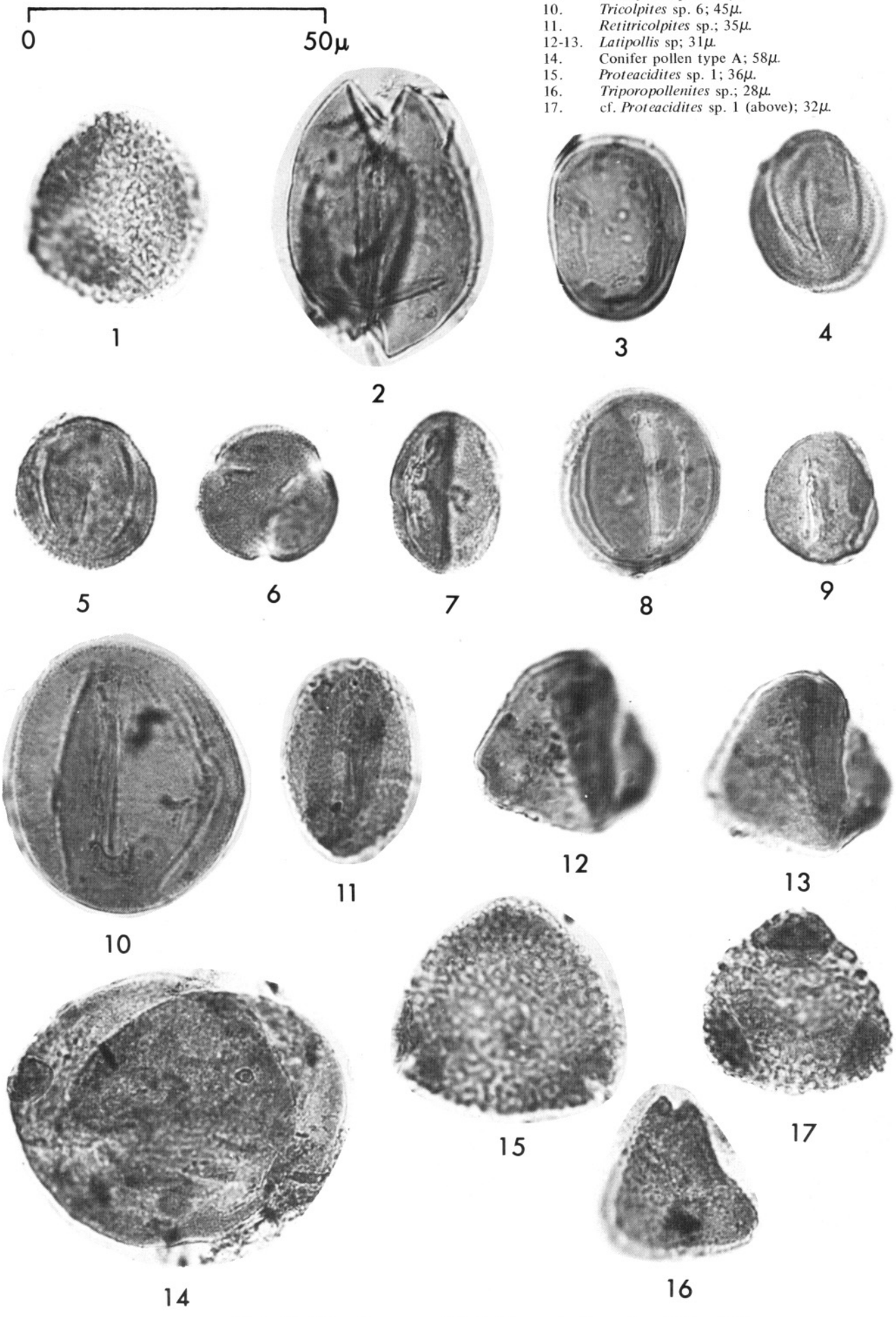
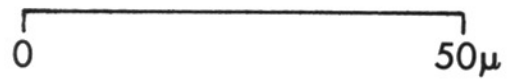


Plate 17. Salina Canyon coal field, Mesaverde Formation, Wilson bed.

Figure
1. *Leiotriletes* sp.; 62μ.
2. *Punctatisporites* sp.; 48μ.
3. *Matonisporites* sp.; 39μ.
4. Spore type A; ca. 45μ.
5. cf. *Deltoidospora* sp.; 29μ.
6. *Concavisporites* sp.; 23μ.
7. *Schizosporis* sp.; 68μ.
8. Spore type B; 57μ.
9. Spore type C; ca. 55μ.
10. Spore type D; 41μ.



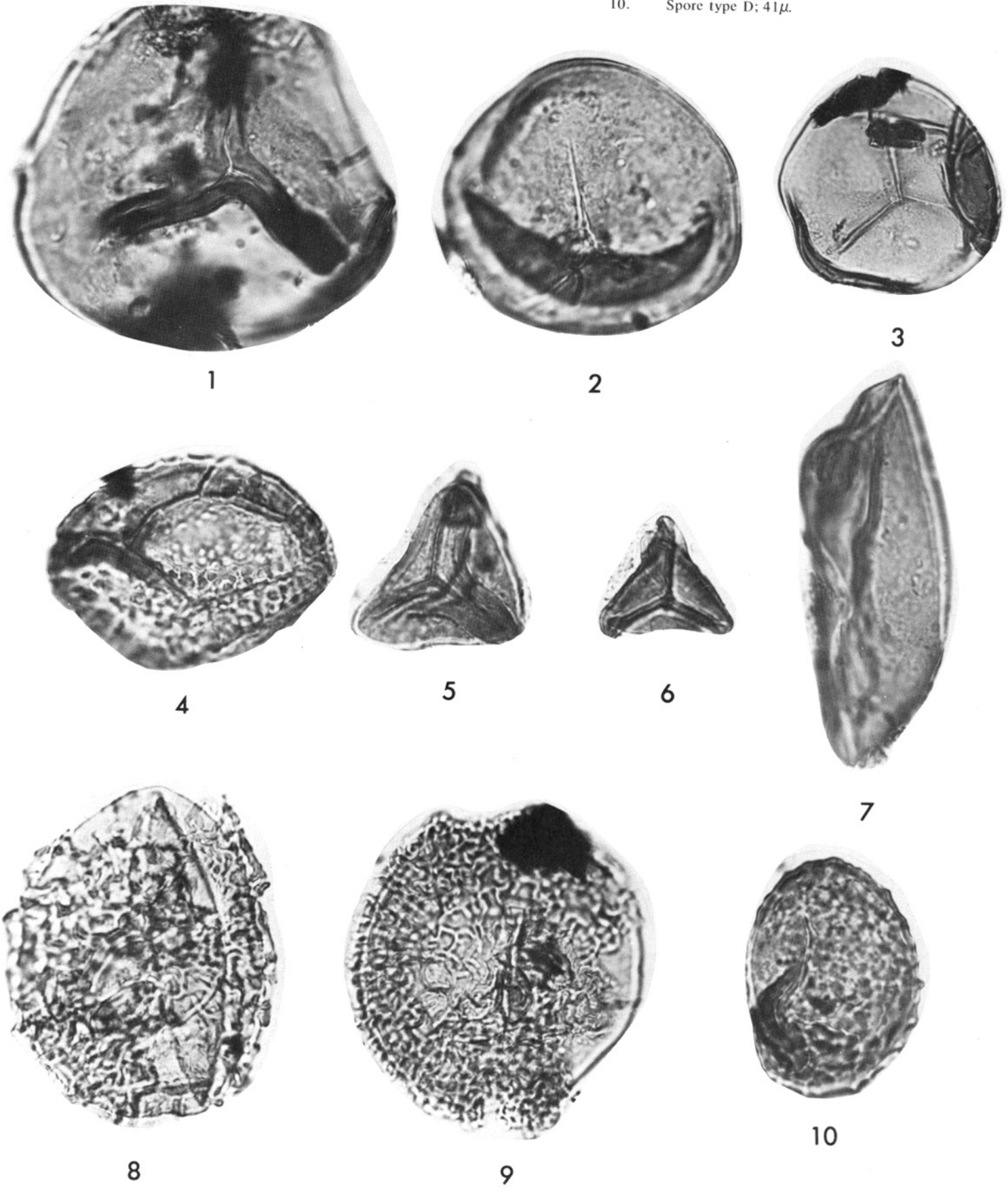


Plate 18. Salina Canyon coal field, Mesaverde Formation, Ivie bed.

Figure

1. *Retitricolpites* sp. 1; 30μ.
2. cf. *Eucommidites* sp.; 21μ.
3. *Tricolpites* sp. 1; 24μ.
4. *Retitricolpites* sp. 2; 28μ.
5. *Retitricolpites* sp. 3; 32μ.
6-7. *Triporopollenites* sp.1; 30μ.
8. *Extratriporopollenites* sp.; 31μ.
9. cf. *Nudopollis* sp.; 21μ.
10-11. *Latipollis* sp. 1; 27μ.
12. *Latipollis* sp. 2; 31μ.
13. *Triporopollenites* sp. 2; 28μ.
14. *Triporopollenites* sp. 3; 16μ.
15. *Proteacidites* sp.; 40μ.
16. Pollen type A; 29μ.
17. Pollen tetrad; 45μ.
18. *Piceapollenites* sp.; 70μ.

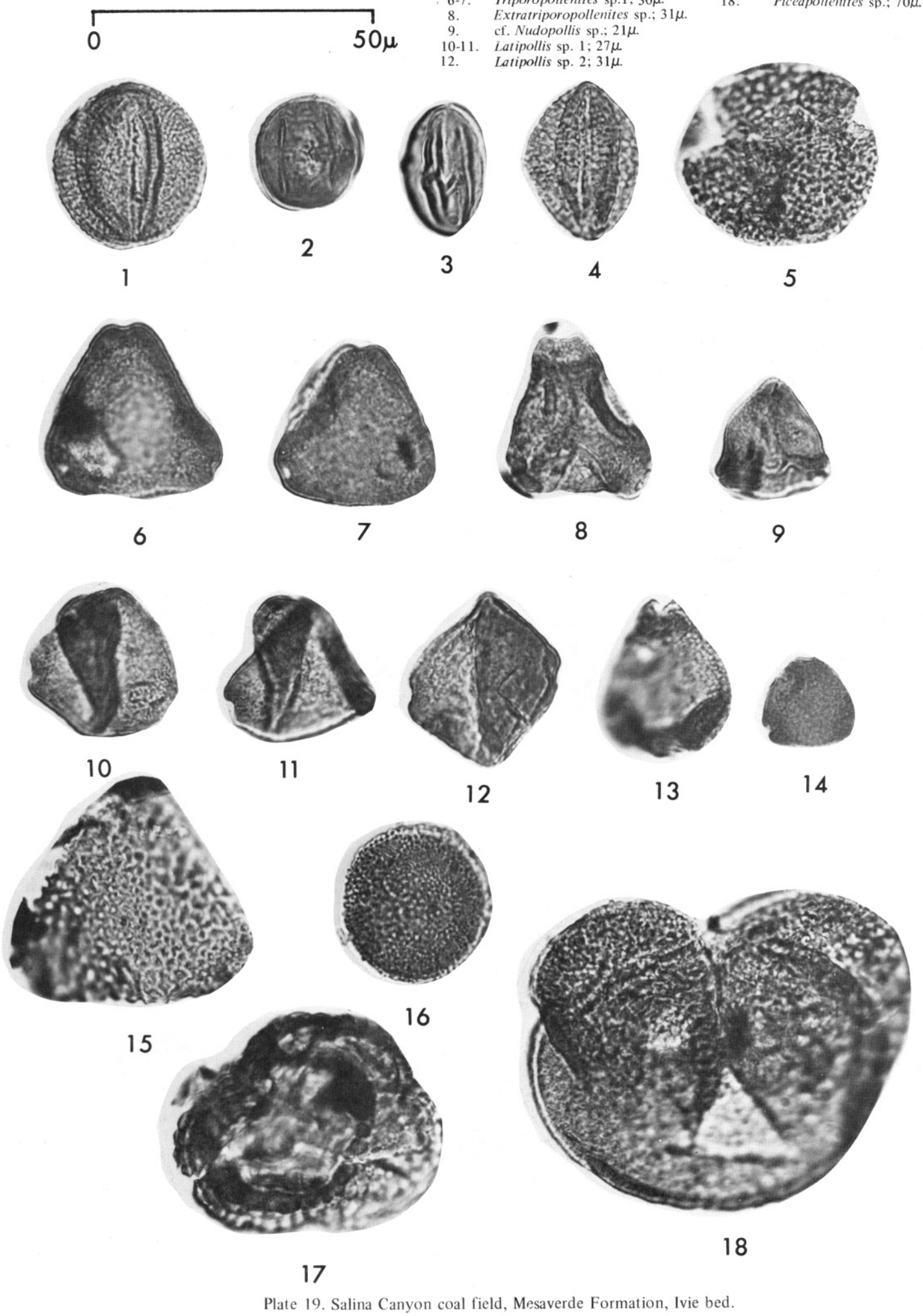


Plate 19. Salina Canyon coal field, Mesaverde Formation, Ivie bed.

Figure

1. cf. *Cicatricosisporites* sp.; 41μ.
2. *Camarozonosporites* sp.; 40μ.
3. *Deltoidospora sp.;* 44μ.
4. *Camarozonosporites* cf. *heskemensis* (Pflanzl) Krotsch; 40μ.
5. Spore type A; 37μ.
6. *Monosulcites* sp.; 40μ.
7. *Tricolporopollenites* sp.1; 28μ.
8. *Tricolpites* sp. 1; 32μ.
9. *Tricolpites* sp. 2; 30μ.
10. *Tricolpites anguloluminosis* Anderson; 32μ.
11. *Tricolpites* sp. 3; 28μ.
12. *Triporopollenites* sp. 1; orate form; ca. 38μ.
13. *Triporopollenites* sp. 2; 37μ.
14. *Triporopollenites* sp. 3; 32μ.
15. Pollen type A; 35μ.
16. cf. *Latipollis* sp.; 35μ.
17. *Triporopollenites* sp. 4; 41μ.
18. Pollen type B; 25μ.

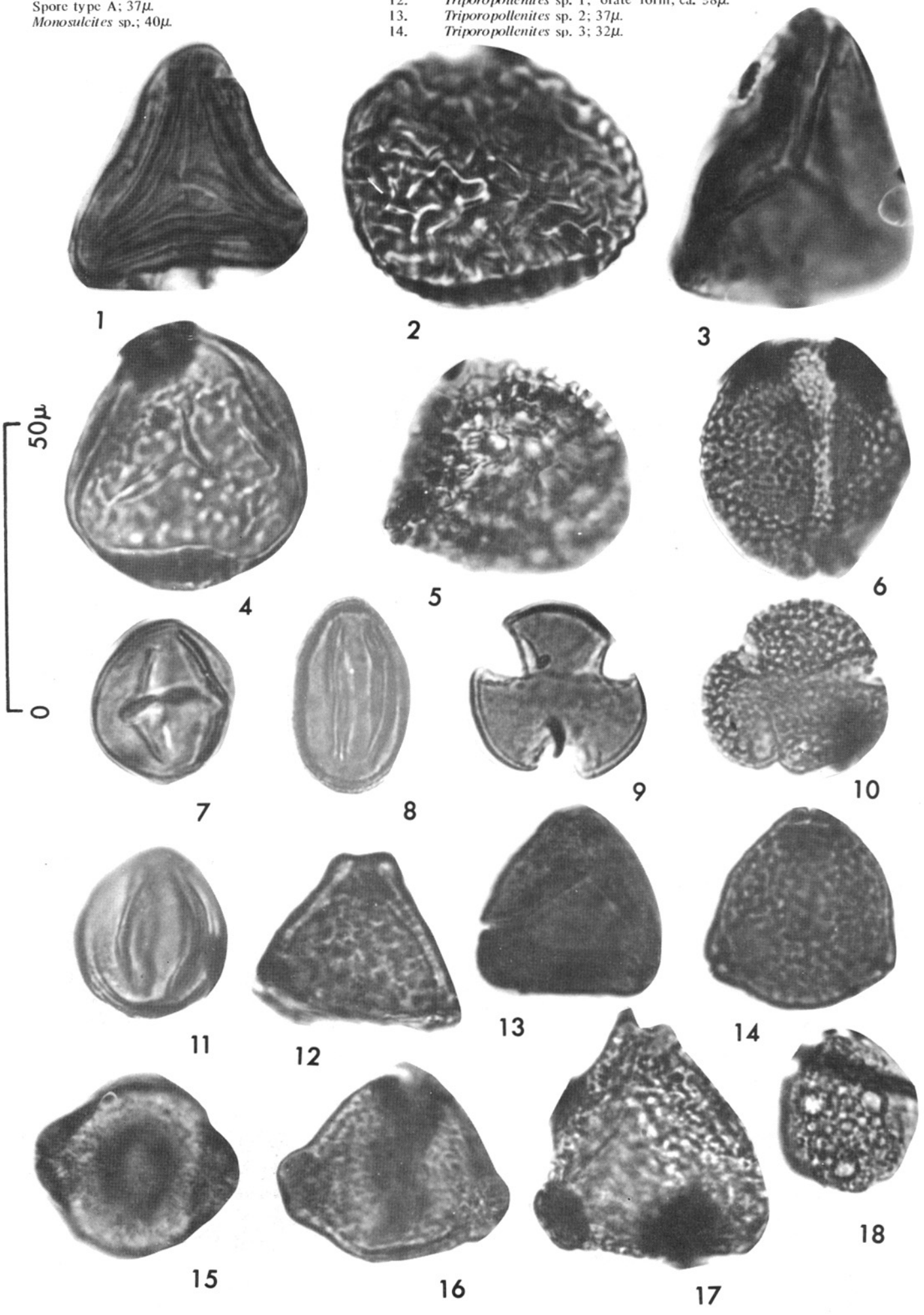
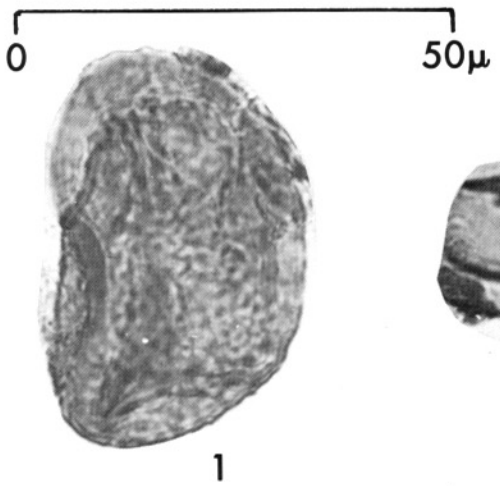


Plate 20. Vernal coal field, Mesaverde Formation, Rasmussen Hollow.

Figure

1. Spore type A; 45μ.
2. Fungal spore chain; ca. 22μ wide.
3. *Tricolpites* sp. 1; 31μ.
4. *Tricolpites* sp. 2; 34μ.
5. *Tricolpites* sp. 3; 33μ.
6. *Tricolpites* sp. 4; 21μ.
7. *Tricolpites* sp. 5; 22μ.
8. *Tricolpites* sp. 6; 22μ.
9. *Tricolpites* sp. 7; 19μ.
10. *Tricolpites* sp. 8; 19μ.
11. *Tricolpites* sp. 9; 23μ.
12. *Tricolpites* sp. 10; 24μ.
13. *Proteacidites* sp. 1; 23μ.
14. *Proteacidites* cf. sp. 1; 24μ.
15. *Proteacidites* sp. 2; 23μ.
16. *Proteacidites* sp. 3; 26μ.
17. *Monosulcites* sp.; 25μ.
18. *Triporopollenites* sp. 1; 27μ.
19. *Latipollis* sp.; 27μ.
20. *Triporopollenites* sp. 2; 13μ.
21. *Classopollis* sp.; 25μ.



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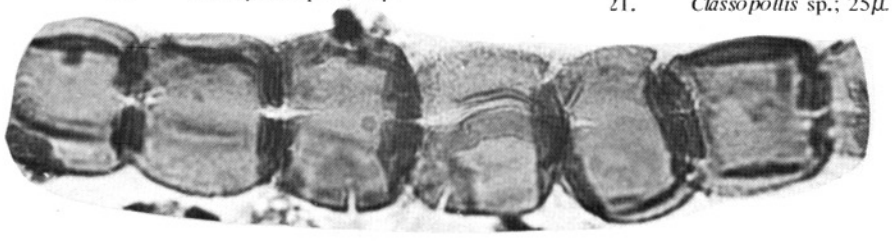

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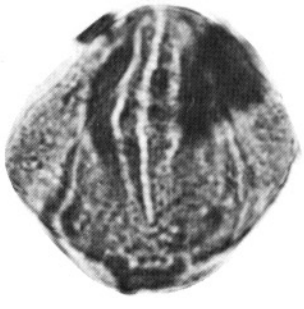

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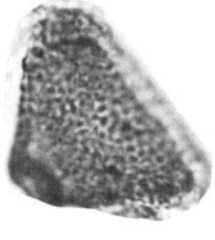

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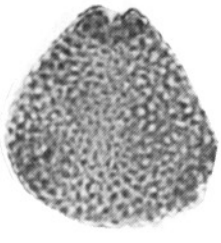

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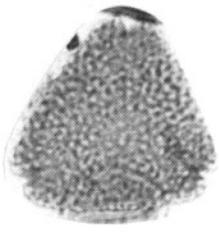

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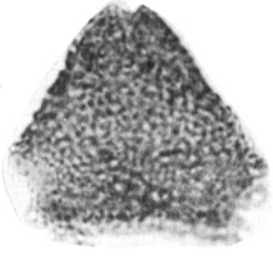

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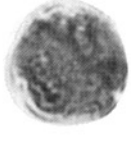

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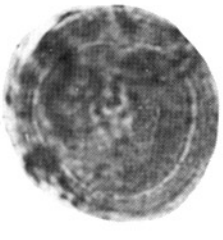


21

Plate 21. Tabby Mountain coal field, Redden coal mine, Mesaverde Formation.

Figure

1. Spore type A; 30μ.
2. Spore type B; 32μ.
3. *Tricolpites* sp. 1; 23μ.
4. *Tricolpites* sp. 2; 23μ.
5. *Abietineapollenites* sp.; 75μ.
6. *Tricolpites* sp. 3; 28μ.
7. *Tricolpites* sp. 4; 21μ.
8. *Retitricolpites* sp.; 28μ.
9. *Tricolpites* sp. 5; 21μ.
10. *Tricolpites* sp. 6; 19μ.
11. *Tricolpites* sp. 7; 37μ.
12. *Tricolporollenites* sp. 1; 17μ.
13. *Tricolpites* sp. 8; 23μ.
14. *Tricolpites* sp. 9; 22μ.
15. *Tricolporopollenites* sp. 2; 17μ.
16. cf. *Latipollis* sp. 1; 17μ.
17. *Latipollis* sp. 2; 23μ.
18. *Proteacidites* sp.; 28μ.
19. cf. *Nudopollis* sp.; 20μ.
20. *Triporopollenites* sp. 1; 31μ.
21. *Triporopollenites* sp. 2; 32μ.

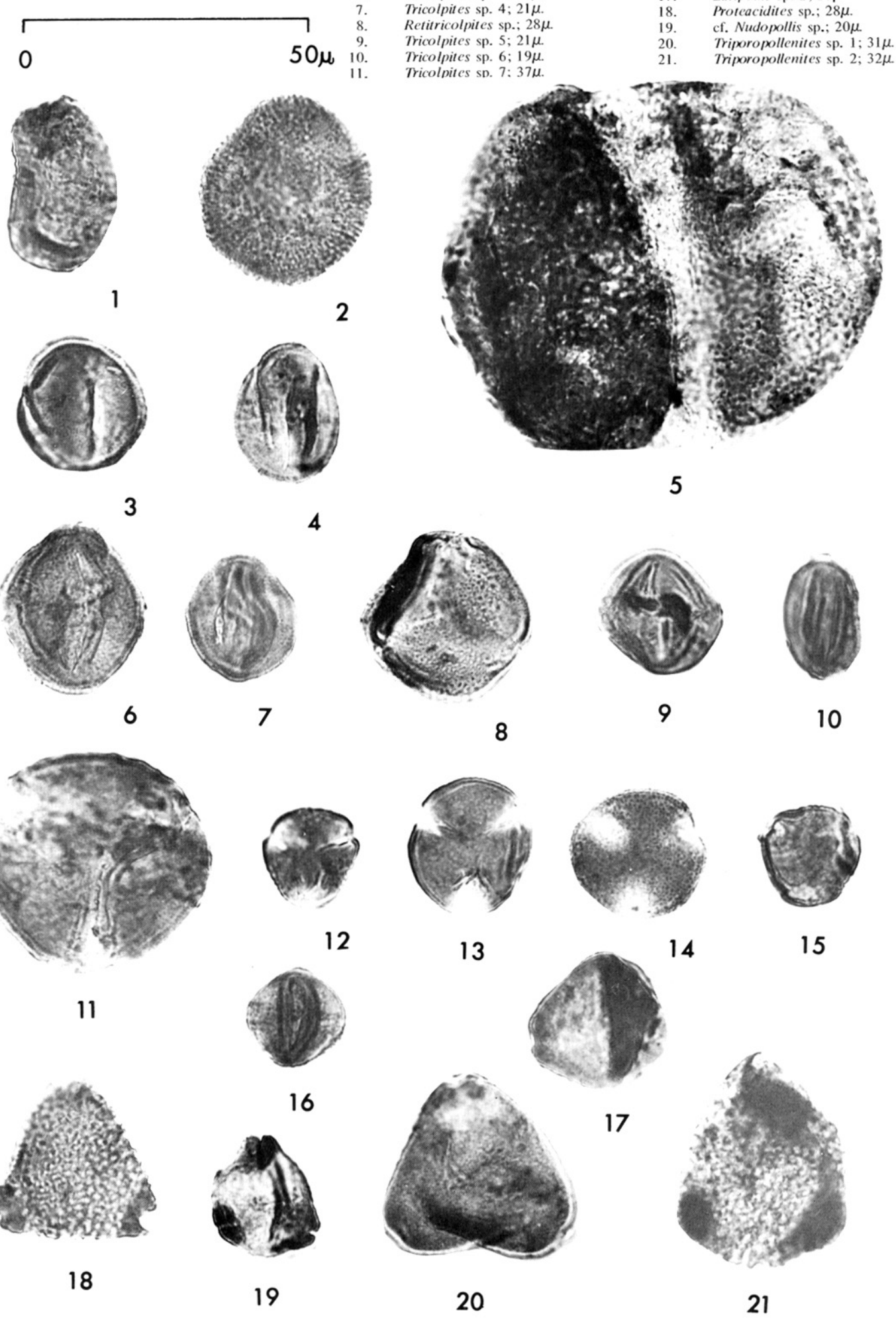


Plate 22. Wasatch Plateau coal field, Blackhawk Formation, Wattis mine-Wattis bed.

Figure

1. cf. *Sporopollis* sp. 1; 42μ.
2. cf. *Sporopollis* sp. 2; 37μ.
3. *Triporopollenites* sp. 1; ca. 40μ.
4. *Tricolpites* sp. 1; 19μ.
5. *Cycadopites* sp.; 15μ.
6. *Tricolpites* sp. 2; 22μ.
7. *Tricolpites* sp. 3; 21μ.
8. *Tricolpites* sp. 4; 21μ.
9. *Retitricolpites* sp.; 23μ.
10-11. *Liquidamber* sp.; 29μ.
12. *Triporopollenites* sp. 2; ca. 45μ.
13. cf. *Proteacidites* sp.; 35μ.
14. *Triporopollenites* sp. 3; 30μ.
15. *Tricolporopollenites* sp.; 30μ.
16. *Latipollis* sp. 1; 39μ.
17. *Latipollis* sp. 2; 44μ.
18. *Latipollis* sp. 3; 34μ.
19. cf. *Latipollis* sp. 4; 29μ.

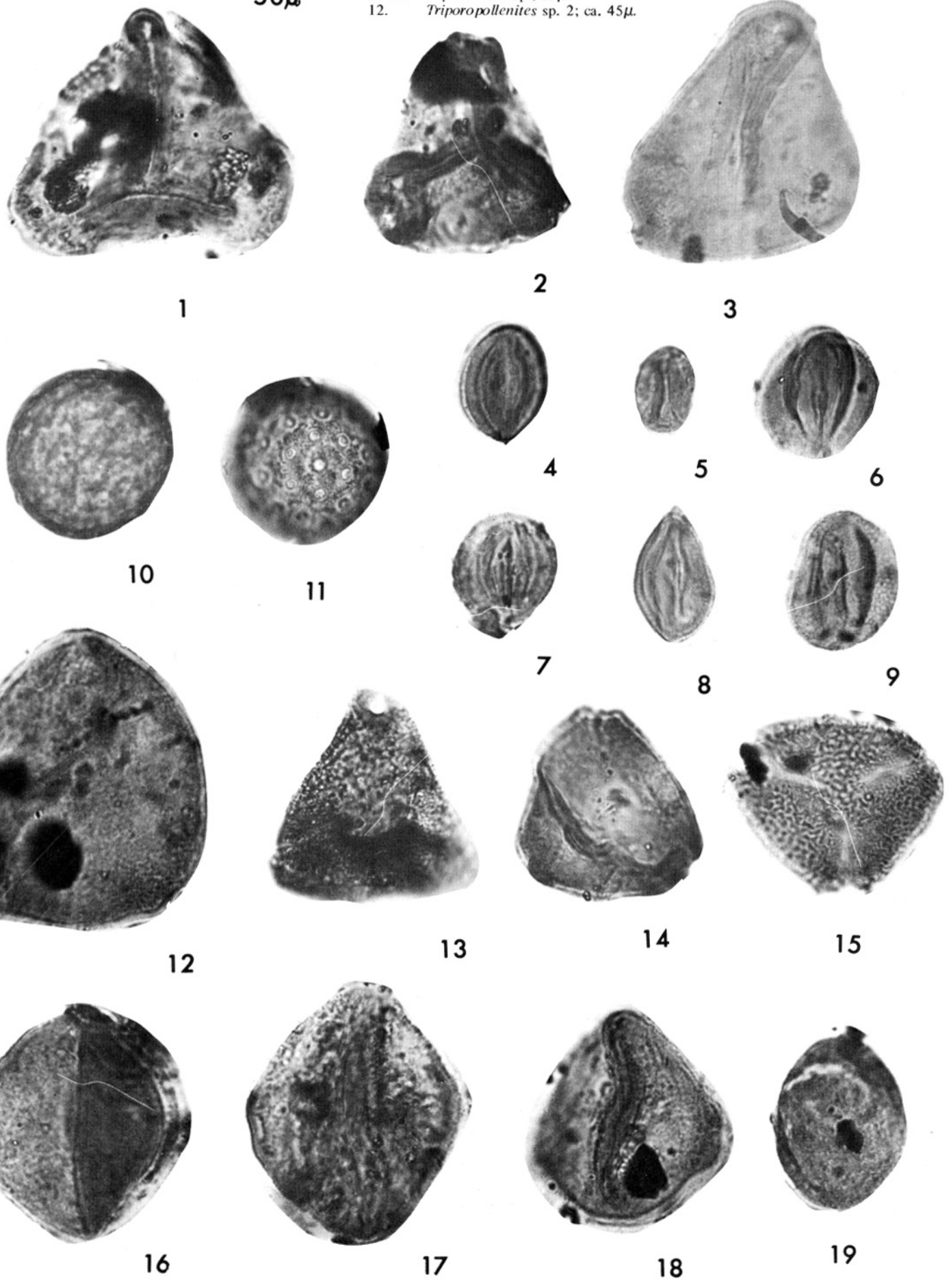
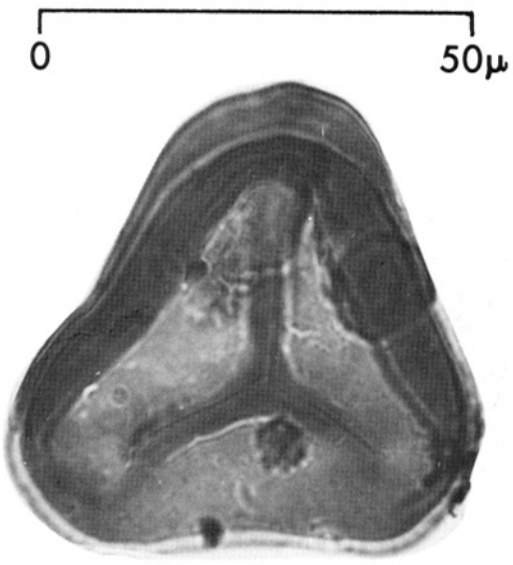


Plate 23. Wasatch Plateau coal field, Blackhawk Formation, Wattis mine-Hiawatha bed.

Figure
1. cf. *Leiotriletes* sp.; 58μ.
2. cf. *Lycopodiumsporites* sp.; 37μ.
3. cf. *Deltoidospora* sp.; 30μ.
4. *Sporopollis* sp.; 31μ.
5. *Camarozonosporites* sp.; 35μ.
6. Spore type A; 43μ.
7. Spore type B; 33μ.
8. Spore type C; 30μ.
9. *Cycadopites* sp.; 24μ.
10. *Classopollis* sp.; 22μ.
11. Spore type D; 23μ.
12. *Tricolpites* sp. 1; 24μ.
13. *Tricolpites* sp. 2; 21μ.
14. *Tricolpites* sp. 3; 18μ.
15. *Tricolpites* sp. 4; 23μ.
16. *Tricolpites* sp. 5; 32μ.
17. *Tricolpites* sp. 6; 38μ.
18. *Eucommidites* sp.; 17μ.
19. *Proteacidites* sp.; 28μ.
20. *Triporopollenites* sp. 1; 14μ.
21. *Latipollis* sp.; 22μ.



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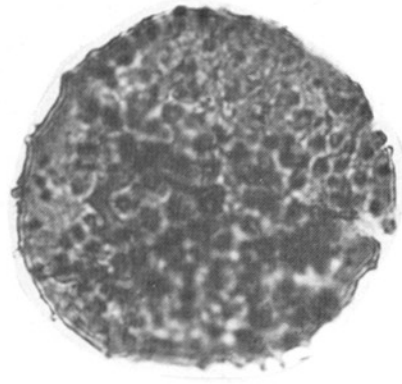
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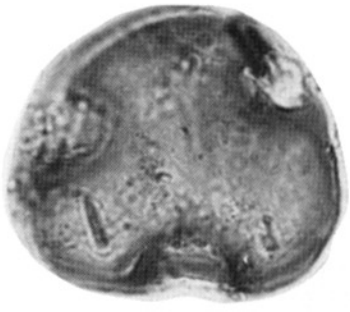
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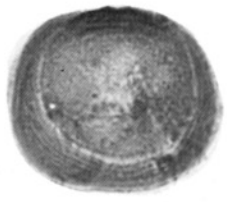
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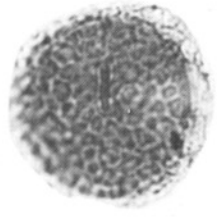
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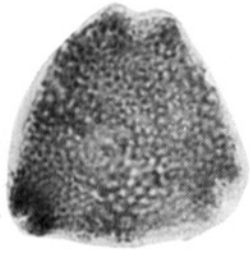
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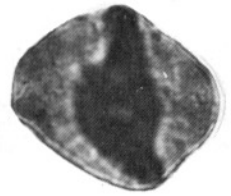
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Plate 24. Book Cliffs coal field, Castle Gate area, Blackhawk Formation, Castle Gate B seam.

Figure
1-2. cf. *Cicatricosisporites* sp.; 32μ.
3. *Deltoidospora* sp.; 34μ.
4. Spore type A; 45μ.
5. Spore type B; 34μ.
6. Spore type C; 37μ.
7-8. Spore type D; 37-42μ.
9. *Tricolpites angululuminosis* Anderson; 30μ.
10. *Retitricolpites* sp.; 23μ.
11. *Tricolpites* sp. 1; 36μ.
12. *Tricolpites* sp. 2; 25μ.
13. *Tricolpites* sp. 3; 39μ.
14. *Proteacidites* sp.; 38μ.
15. *Triporopollenites* sp. 1; 26μ.
16. *Triporopollenites* cf. sp. 1; 29μ.
17-18. *Latipollis* sp.; 22-26μ.
19. cf. *Extratriporopollenites* sp.; 25μ.
20. *Triporopollenites* sp. 2; 27μ.
21. *Triporopollenites* sp. 3; 14μ.

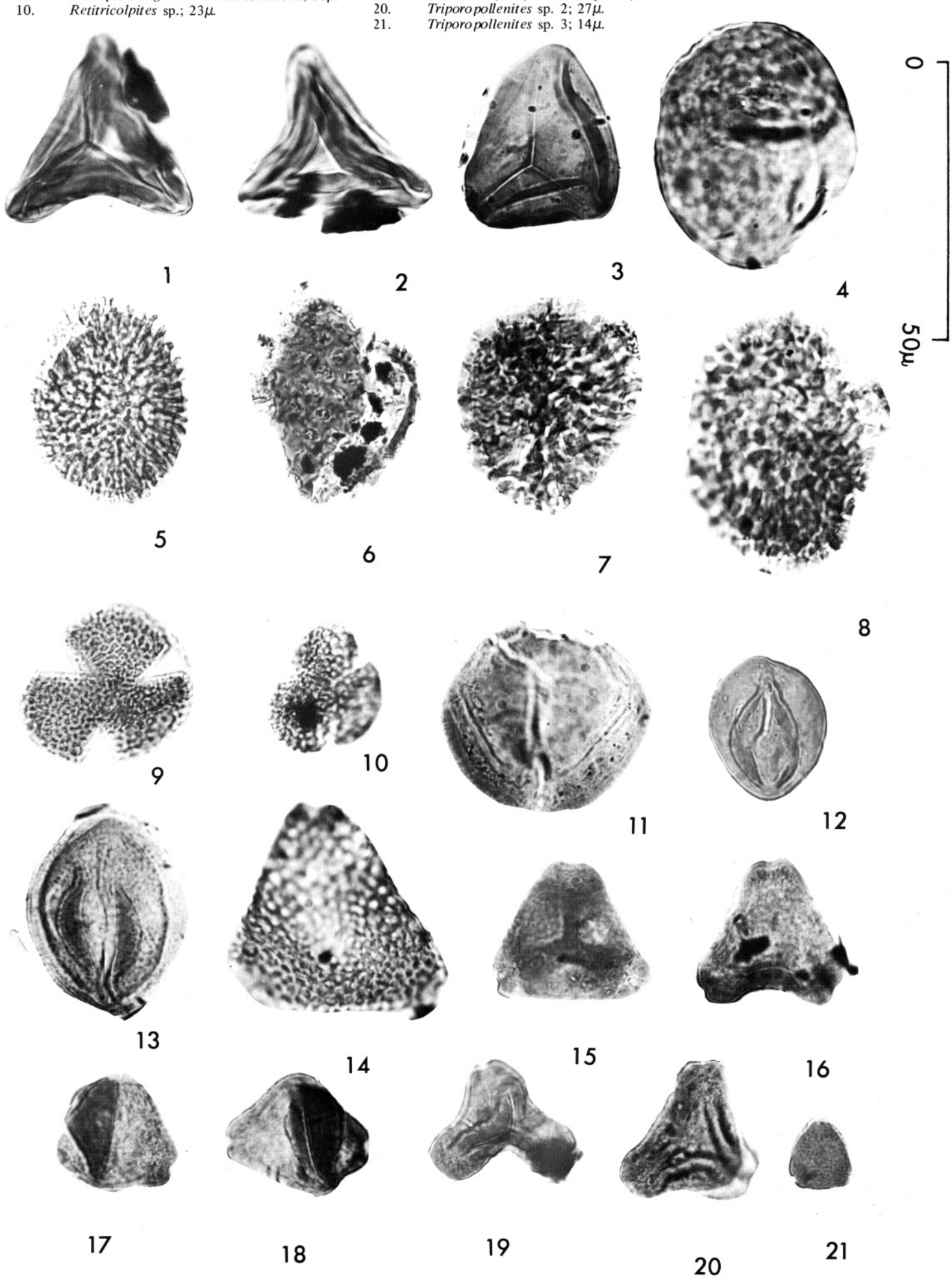


Plate 25. Book Cliffs coal field, Blackhawk Formation, Premium coal mine.

Figure

1. *Deltoidospora* sp.; 30μ.
2. *Camarozonosporites* sp. 1; 35μ.
3. *Camarozonosporites* sp. 2; 29μ.
4. *Camarozonosporites* sp. 3; 30μ.
5. *Sphagnumsporites* sp. 1; 25μ.
6. *Sphagnumsporites* sp. 2; 29μ.
7. Spore type A; 35μ.
8. Spore type B; 56μ.
9. Fungal spore chain; ca. 22μ (½ scale).
10. *Tricolpites* sp. 1; 21μ.
11. *Tricolpites* sp. 2; 18μ
12. *Tricolpites* sp. 3; 15μ.
13. *Tricolpites angululuminosis* Anderson; 22μ.
14. Tetraporate type–possible terratoid (cf. no. 15); 21μ.
15. *Triporopollenites* sp. 1; 22μ.
16-17. *Triporopollenites* sp. 2; 24-30μ.
18. *Triporopollenites* sp. 3; 27μ.
19. *Triporopollenites* cf. sp. 3; 26μ.
20. *Proteacidites* sp.; 30μ.
21. *Latipollis* sp.; 22μ.

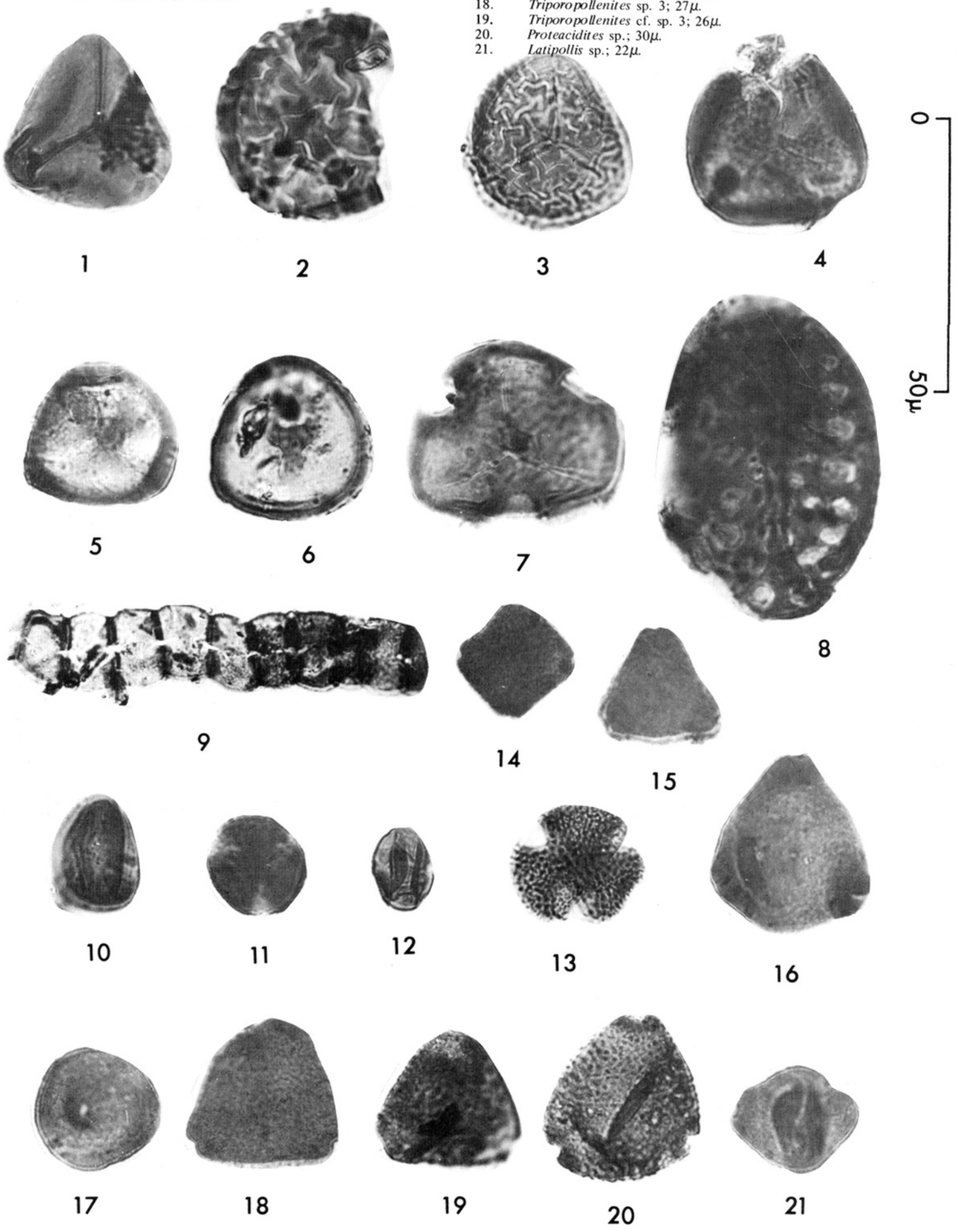


Plate 26. Book Cliffs coal field, Sunnyside area, Blackhawk Formation, Geneva coal mine.

Figure
1. *Piceapollenites* sp.; 86μ.
2. *Podocarpidites* sp.; 68μ.
3. Pentaporate angiosperm grain; 160μ (½ scale).
4. Enlarged view of pore structure and reticulum; 160μ (½ scale).
5. cf. *DeFlandrea* sp.; 80μ (½ scale).
6. *Tricolpites* sp.; 34μ.
7. *Tricolporopollenites* sp.; 31μ.
8. *Triporopollenites* sp.; 29μ.

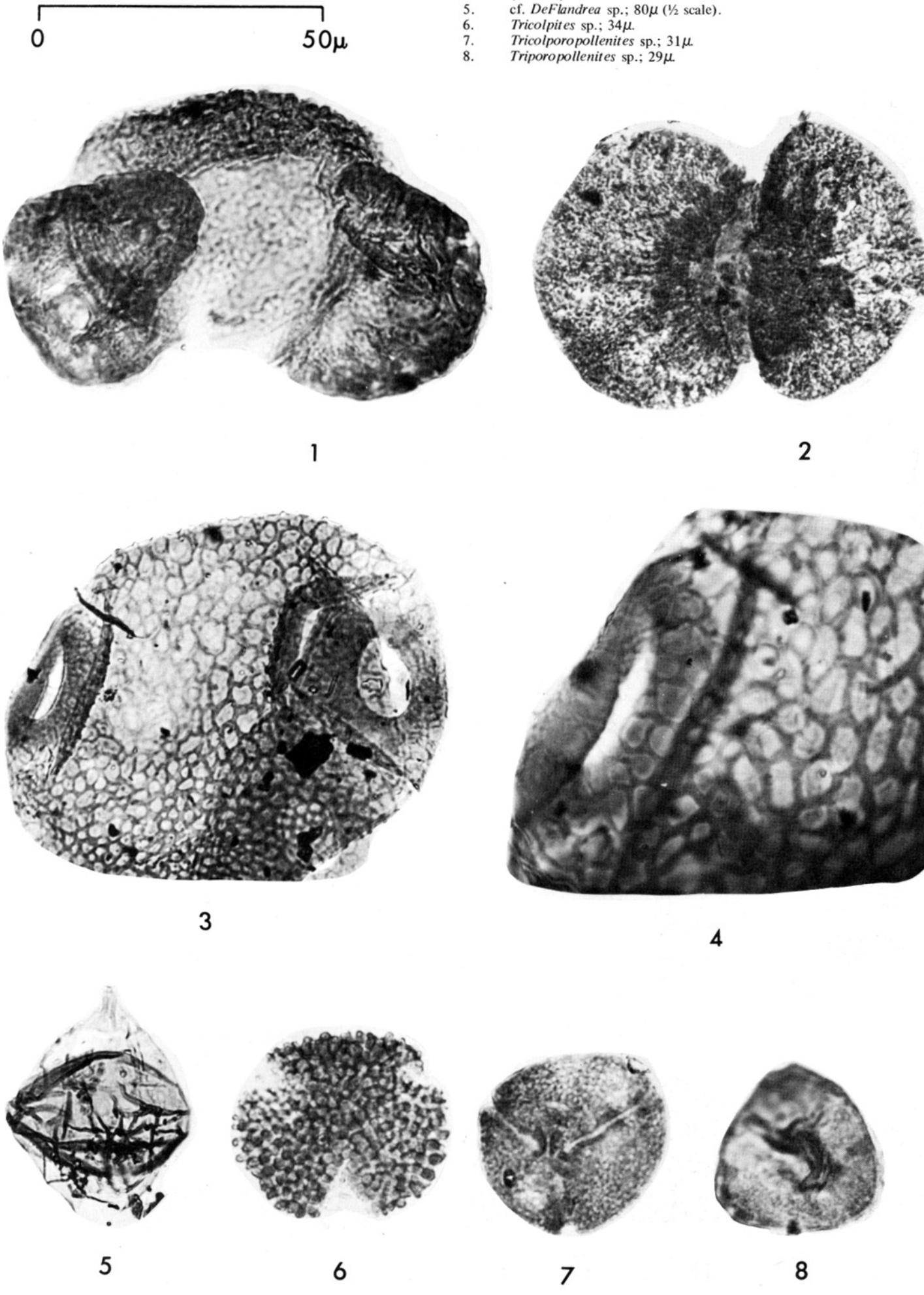


Plate 27. Book Cliffs coal field, Sego area, Price River Formation, Palisade coal zone.

Figure
1. *Balmeisporites* sp. 1; 75μ.
2. Spore type A; 60μ.
3. *Echinatispora* sp.; 35μ.
4. Spore type B; 47-58μ.
5. *Balmeisporites* sp. 2; 54μ.
6. *Loranthacites* cf. *macrosolenoides* N. Mtchedlishvili, *in* Samoilovitch and others (1961); 64μ.

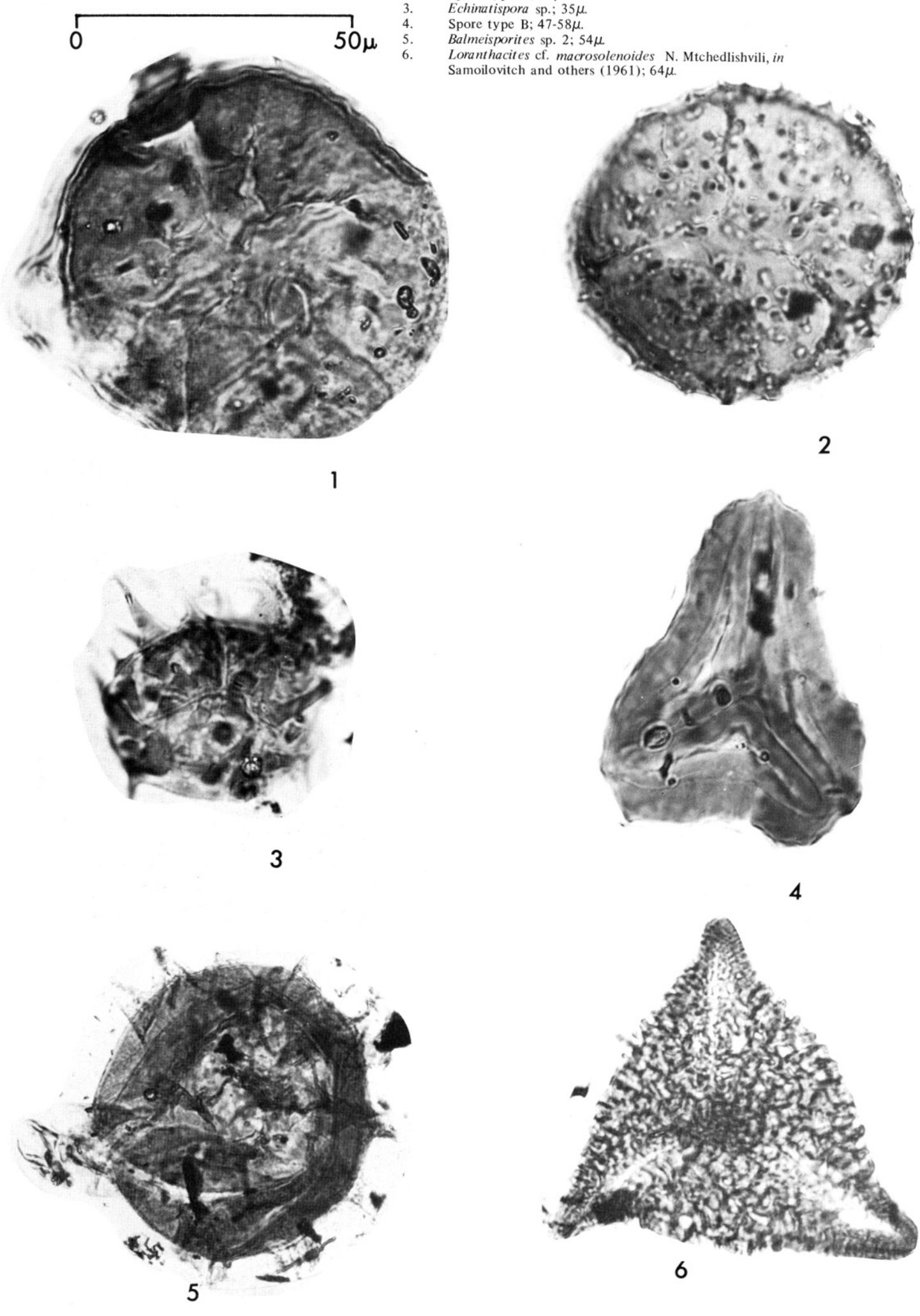


Plate 28. Book Cliffs coal field, Sego area, Price River Formation, Palisade coal zone.

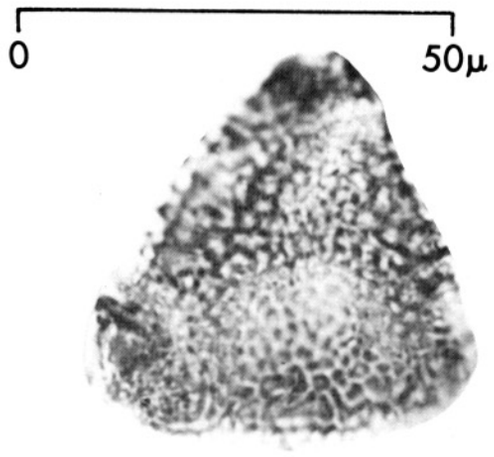


Figure
1. *Proteacidites* sp.; 44μ.
2. *Extratriporopollenites* sp.; 27μ.
3. Pollen type A; 32μ.
4, 5, 7 and 8. *Mancicorpus anchoriforme* N. Mtchedlishvili, *in* Samoilovitch and others (1961); 55-80μ.
6, 9,10. *Manicicorpus* cf. *notabile* N. Mtchedlishvili, *in* Samoilovitch and others (1961); 60-68μ.

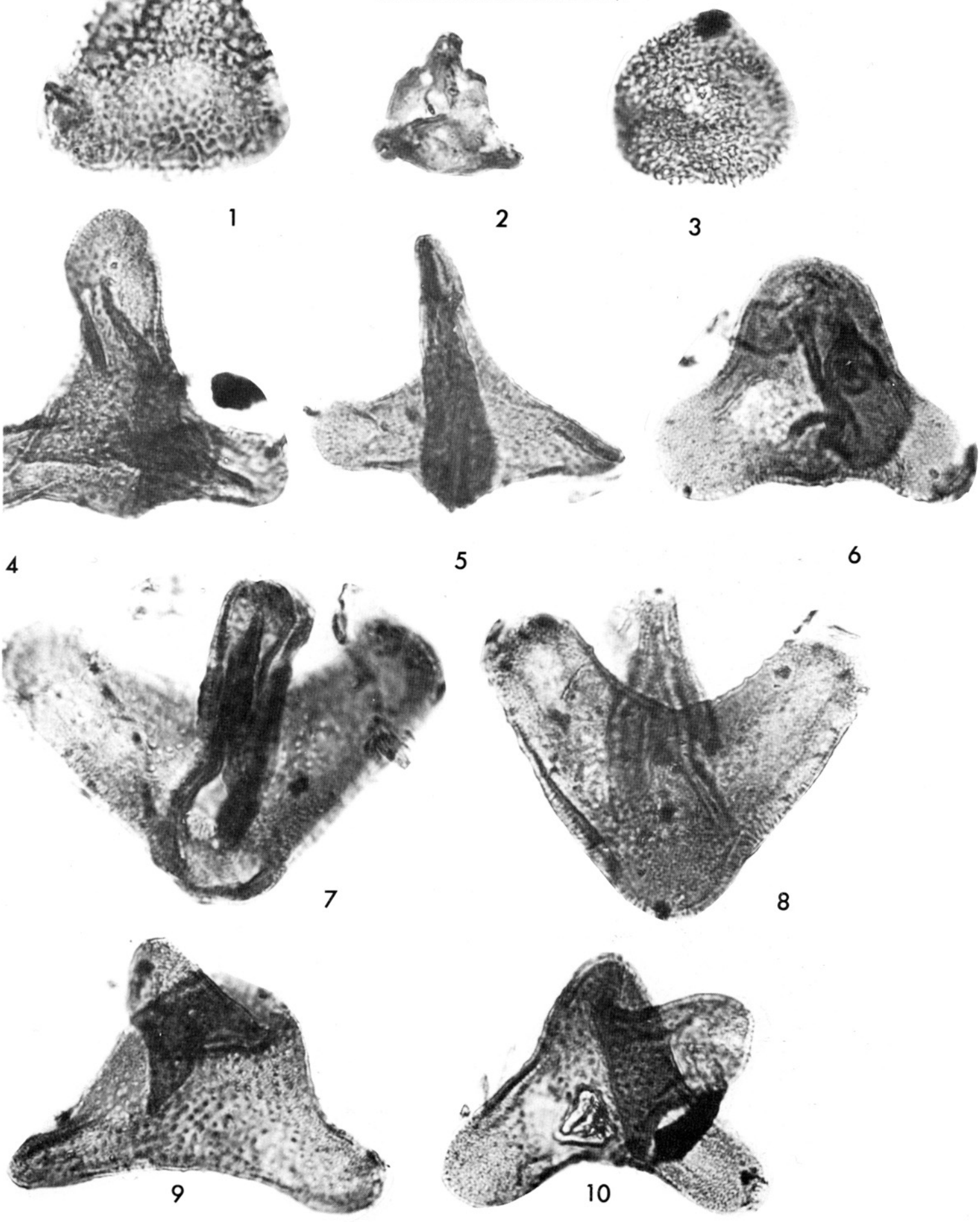
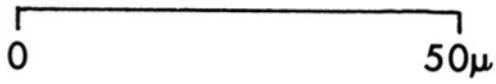


Plate 29. Book Cliffs coal field, Sego area, Price River Formation, Chesterfield coal zone.

Figure
1. cf. *Hymenophyllumsporites* sp.; 66μ.
2. *Concavissimisporites* sp.; 58μ.
3. cf. *Reticuloidosporites* sp.; 60μ.
4. Spore type A; 45μ.
5. Spore type B; 34μ.
6. Spore type C; 43μ.
7. *Inaperturopollenites* sp.; 48μ.



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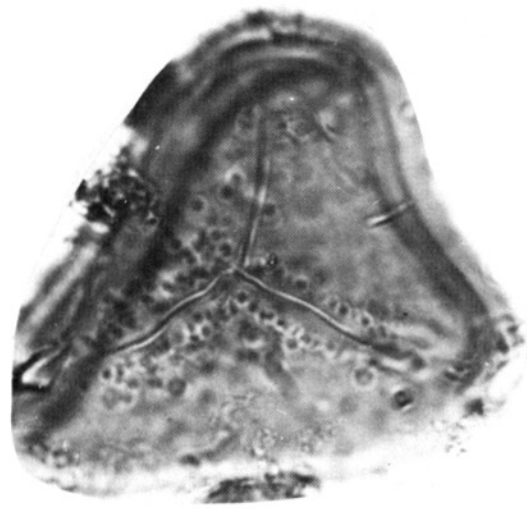

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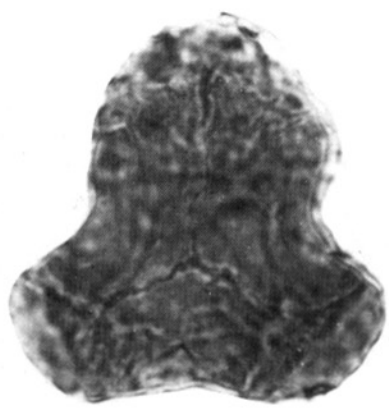

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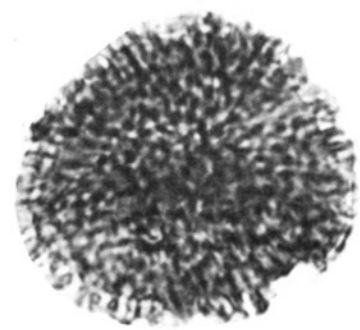

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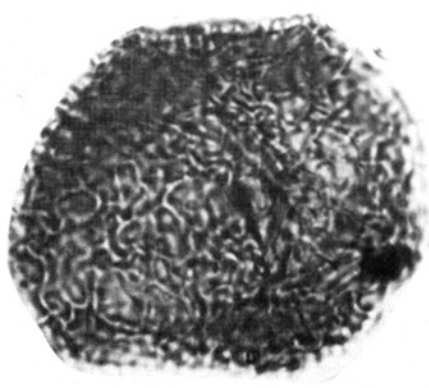

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Plate 30. Book Cliffs coal field, Sego area, Price River Formation, Chesterfield coal zone.

Figure

1. *Tricolpites* sp. 1; 55μ.
2. cf. *Tricolpites* sp. 1; 42μ.
3. *Tricolpites* sp. 2; 41μ.
4. *Tricolpites* sp. 3; 37μ.
5-6. *Tricolpites* sp. 4; 37μ.
7. cf. *Latipollis* sp. 1; 36μ.
8. *Tricolpites* sp. 5; 35μ.
9. cf. *Tricolpites* sp. 4; 25μ.
10. *Latipollis* sp. 2; 37μ.
11. *Tricolpites* sp. 6; 39μ.
12. *Tricolpites* sp. 7; 35μ.
13. cf. *Tricolpites* sp. 4 (possible terratoid); 32μ.
14. *Tricolporopollenites* sp. 1; 34μ.
15. *Syncolporopollenites* sp.; 27μ.
16. *Sporopollis* sp.; 25μ.
17. *Tricolporopollenites* sp. 2; 32μ.
18. *Triporopollenites* sp. 1; 28μ.
19. *Triporopollenites* sp. 2; 25μ.
20. *Nudopollis* sp.; 32μ.
21. *Triporopollenites* sp. 3; 27μ.
22. *Triporopollenites* sp. 4; 27μ.

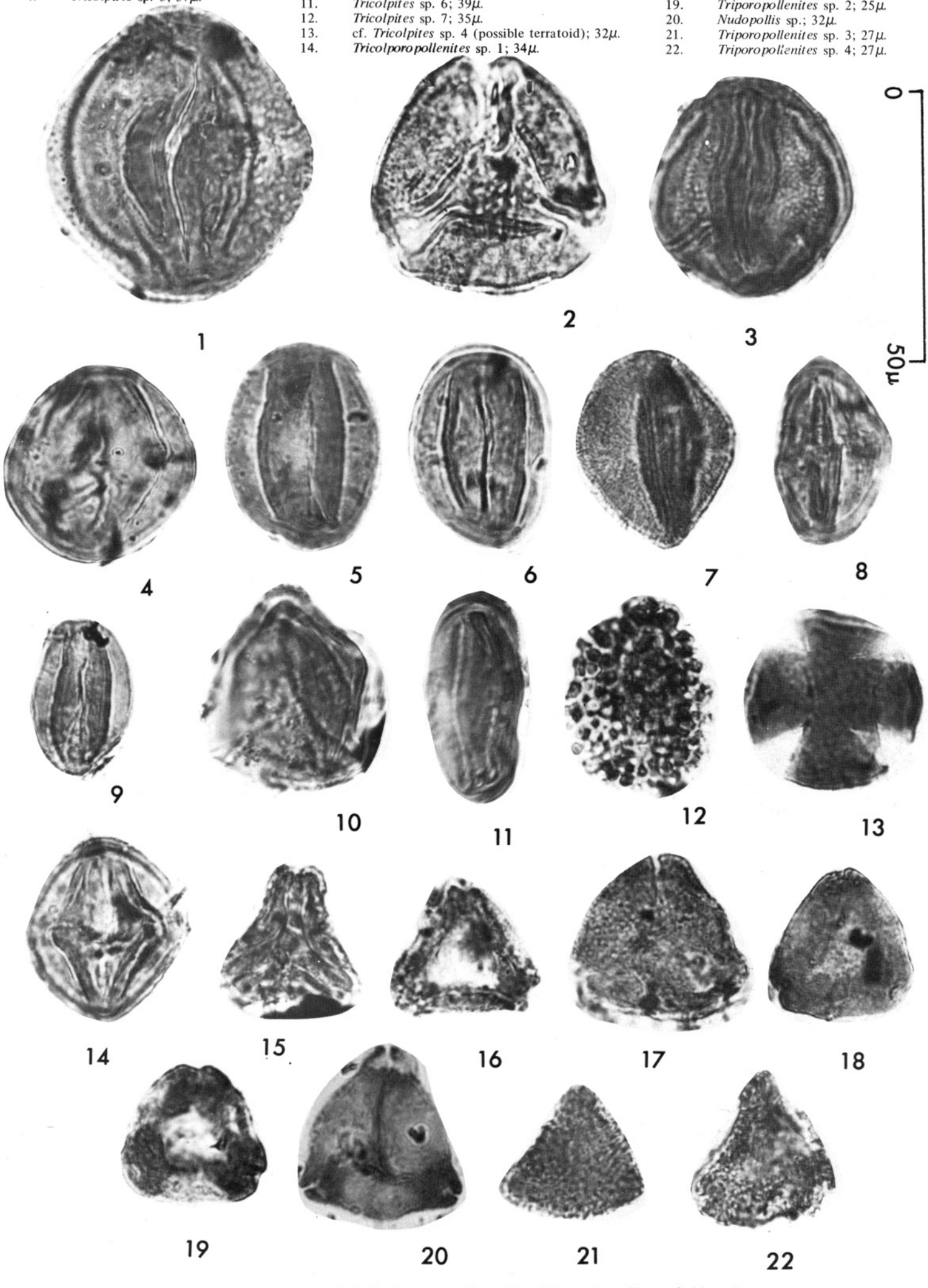
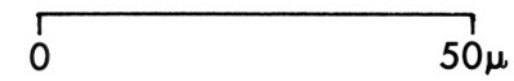
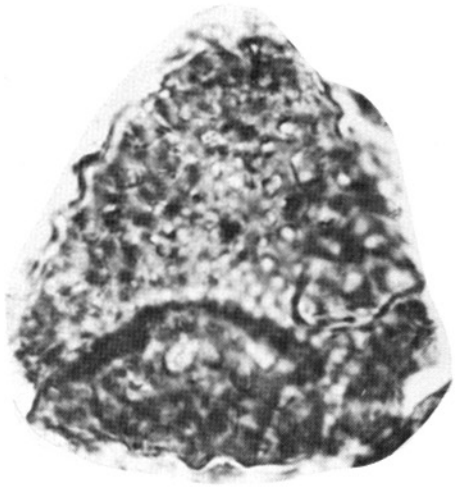


Plate 31. Book Cliffs coal field, Sego area, Price River Formation, Chesterfield coal zone.

Figure
1. *Proteacidites* sp. 1; 50μ.
2. *Proteacidites* sp. 2; 41μ.
3. *Proteacidites* sp. 3; 38μ.
4. *Proteacidites* sp. 4; 27μ.
5-6. *Projectoporites* sp.; 45-50μ.
7-8. *Mancicorpus solidum* N. Mtchedlishvili, *in* Samoilovitch and others (1961); 45-50μ.
9. *Mancicorpus* sp. 1; 49μ.
10. *Mancicorpus* cf. *anchoriforme* N. Mtchedlishvilii, *in* Samoilovitch and others (1961); ca. 55μ.
11. *Mancicorpus* sp. 2; 48μ.
12. *Monosulcites* sp.; 32μ.

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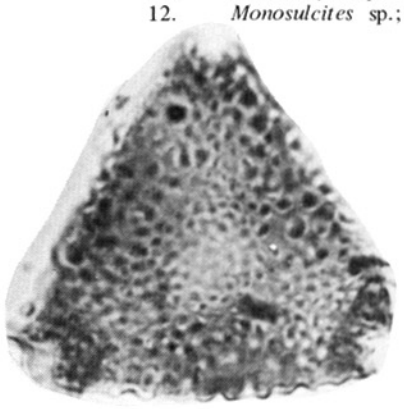
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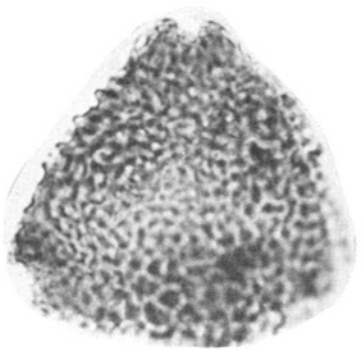
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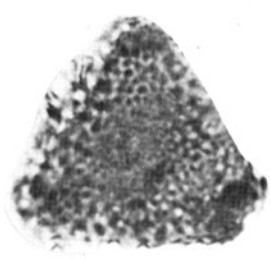
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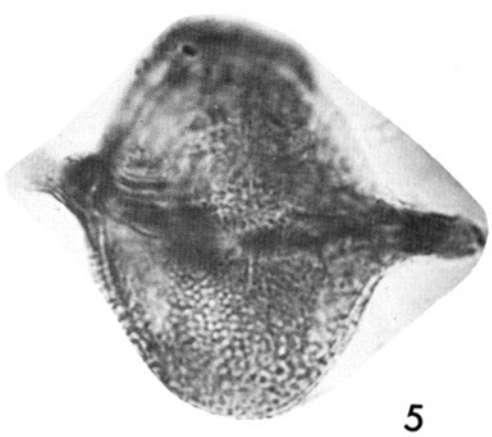
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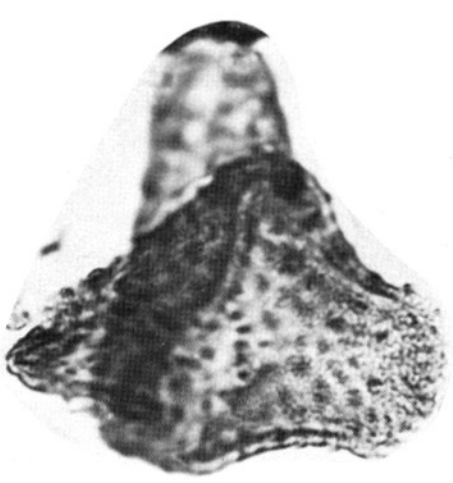
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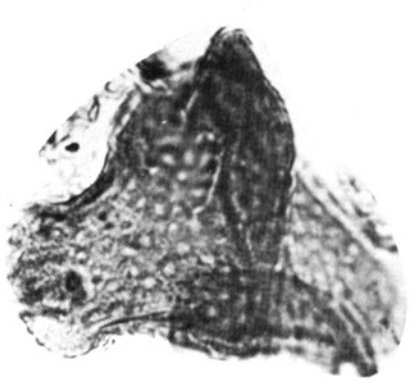
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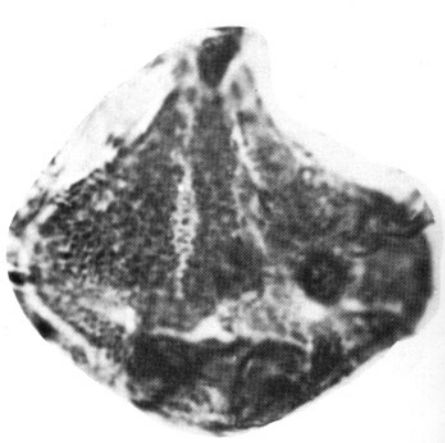
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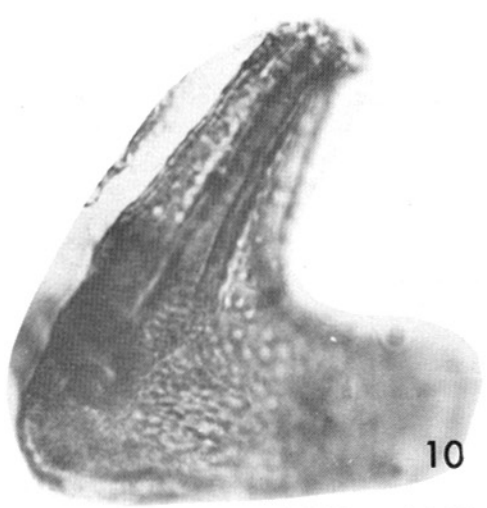
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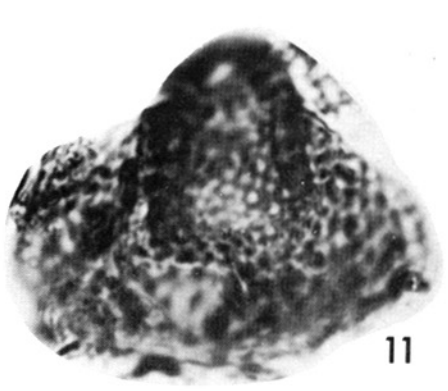
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Plate 32. Book Cliffs coal field, Sego area, Price River Formation, Chesterfield coal zone.

COAL IN UTAH – 1970

by H. H. Doelling[1]

GEOLOGY AND GEOGRAPHY

Physiographic Provinces

Utah contains three major physiographic provinces: (1) the Basin and Range, (2) Rocky Mountains and (3) the Colorado Plateaus (figure 1). Of the twenty-two coal and lignite fields in Utah, two are in the Basin and Range, five are in the Rocky Mountains and fifteen are in the Colorado Plateaus physiographic province.

The Basin and Range in west Utah consists mostly of a series of north-south trending mountain ranges separated by wide flat valleys. The rocks in the mountain ranges are mostly Paleozoic in age, were mostly deposited under marine geosynclinal conditions and presently are tightly folded and badly faulted. The valleys are filled with Tertiary and Quaternary debris deposited under fluvial or lacustrine conditions. The two coal fields, Harmony and Goose Creek–Grouse Creek, are widely separated and the carbonaceous beds were developed under separate circumstances. Neither field is large or important; the coal and lignite are high in ash, the beds are thin and the potential for achieving significant production is nil. The Harmony field is marginal to the Colorado Plateaus Province and its coal is related in origin to the coal fields there (Upper Cretaceous). The Goose Creek-Grouse Creek lignite was formed in a pair of small inter-range basins in Late Tertiary time, probably in swampy environments created on a floodplain or adjacent to a lake.

The Rocky Mountains Province lies in the northeast part of Utah. The high and rugged mountains present barriers to transportation and make access difficult. The rocks are usually folded and faulted, but the folding is open and the faults are widely spaced and simple. The coal in the province was formed under the same set of conditions as in the Colorado Plateaus Province indicating the youth of the mountains. The Rocky Mountains in Utah consist of the Uinta and Wasatch ranges. They form a recumbent "T" in northeast Utah with the Uinta Mountains forming the east-west shaft and the Wasatch Mountains forming the north-south crossbar. Three coal fields are designated along the flanks of the Uinta Mountains and two just north of where the two ranges join. All the coal fields are characterized by moderate to steeply dipping coal. The fields are not the most important to Utah; they were opened to supply local markets and their relative production has been small. At present one field is active.

The Colorado Plateaus Province in east and southeast Utah is characterized by a series of plateaus deeply incised by canyons cut by tributary streams of the Green and Colorado rivers. Most of the rocks are flat lying or warped into gentle anticlines, synclines, domes and basins. In a few places steeply dipping monoclines and long high-angle faults occur or the beds are steeply domed by laccolithic intrusions. The physical appearance of these structural features is spectacular and impressive, but they are the exception rather than the rule. The plateau surfaces are in several benches, one lying above the other. The coal appears along the canyons and cliffs of several of these benches and is often quickly buried by overlying benches. This limits mining to narrow strips along the plateau edges. Nevertheless, most of Utah's coal production has been derived from these strips. Fifteen coal fields are designated; four had active mines in 1970. Most of Utah's reserve is located in the Colorado Plateaus physiographic province.

The cliffs and canyons of the plateau region present chasms that are difficult to cross and walls that are almost impossible to climb. Good roads are often lacking and much of the area is uninhabited. All this has hindered past development of many of the coal fields. Some of the largest bodies of reserve have not yet been seriously tapped. Because of the rapid overburden increase behind the coal outcrop, almost all the production from Utah has been from deep mines. The few areas where strip-mining may take place represent only a small percentage of the total reserve.

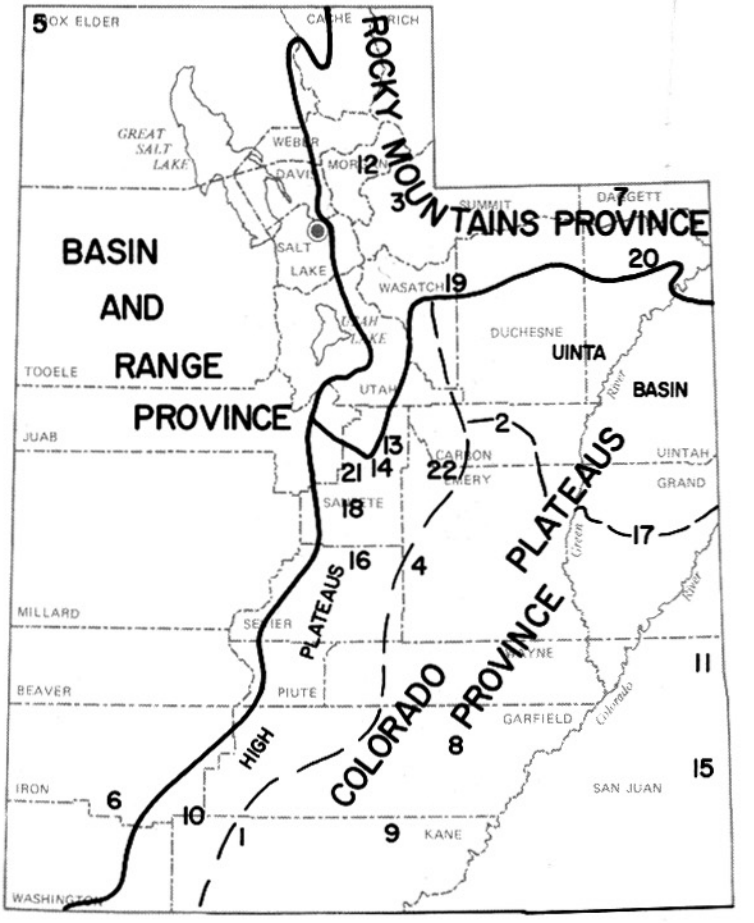


Figure 1. Physiographic provinces of Utah showing approximate locations of coal fields.

1. Alton	9. Kaiparowits Plateau	16. Salina Canyon
2. Book Cliffs	10. Kolob	17. Sego
3. Coalville	11. La Sal	18. Sterling
4. Emery	12. Lost Creek	19. Tabby Mountain
5. Goose-Grouse Creek	13. Milburn	20. Vernal
6. Harmony	14. Mt. Pleasant	21. Wales
7. Henrys Fork	15. San Juan	22. Wasatch Plateau
8. Henry Mountains		

Stratigraphy

Coal in Utah occurs in many formations of varying ages. Coal beds exceeding 4 feet thick, however, are limited to three geologic periods and approximately nine formations; only the Cretaceous has produced coal in appreciable quantity. The generalized outcrop pattern for the period is shown on figure 2 along with areas undoubtedly underlain with the strata. Unfortunately, the buried Cretaceous is partly under deep cover or is situated in areas of complex geology. Six formations listed on figure 3 contain most of the reserve and their geneses are all related to the same Upper Cretaceous events that took place in Utah. All are related to the incursion of marine waters that extended into Utah from the east as far as the east boundary of the present-day Basin and Range physiographic province. This boundary often is termed the Wasatch-Las Vegas line. The source of the Cretaceous sediments was mainly west of the line and to the south in Arizona. East Utah was generally one of subsidence and deposition from latest Lower Cretaceous time and throughout the Upper Cretaceous. As the land subsided the sea moved toward the line and when an orogenic event elevated the west highlands, the shoreline was pushed eastward for a time. Eventually the belts of tectonic disturbances migrated eastward and the sea finally was displaced completely and pushed out of Utah.

[1] Economic geologist, Utah Geological and Mineralogical Survey.

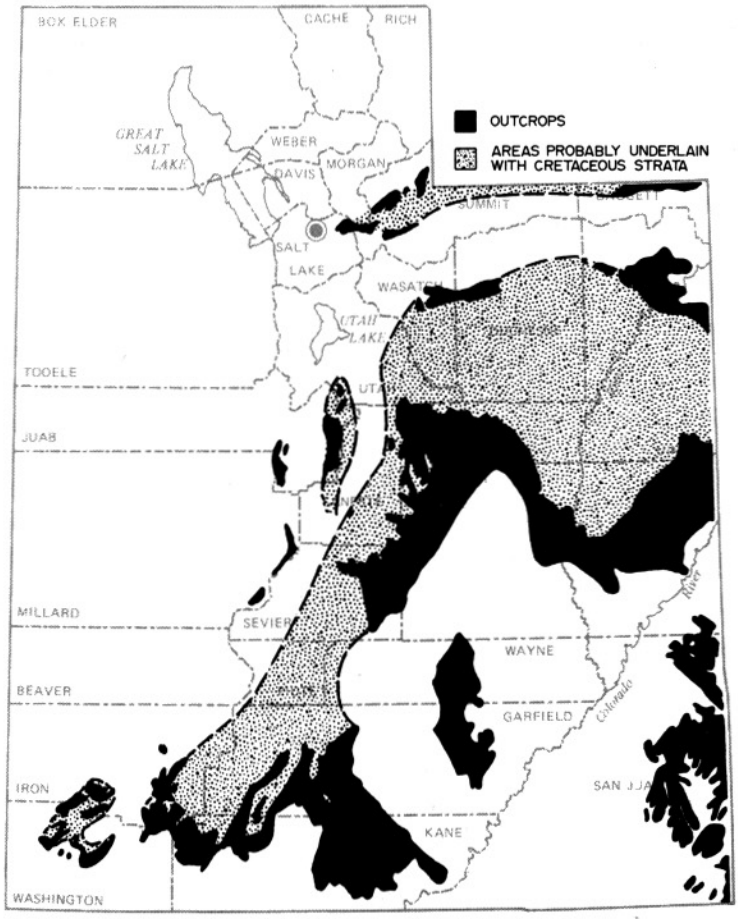


Figure 2. Generalized Cretaceous outcrop pattern in Utah. Stippled areas represent Cretaceous rocks under deep cover or in areas of complex geology.

The mixed shoreline environments migrated with each transgression and regression of the sea and conditions for coaliferous accumulation were often well developed. Lagoons and swamps behind barrier beaches or in other protected places were able to persist long enough to produce the carbonaceous matter to make the up-to-25-foot coal beds and were large enough to cover two to three townships in prime areas. The coal beds formed under transgressive conditions are generally near the top of the formation, such as the Dakota coal in the Kolob and Alton fields, the Ferron and Frontier coal in the Henry Mountains, Tabby Mountain and Vernal fields and perhaps the Emery coal of the Henry Mountains field. The regressive coal normally occurs near the bottom of the formation, such as the Blackhawk coal of the Wasatch Plateau and Book Cliffs fields and of the Neslen Member coal in the Sego field (figure 4).

The individual coal bed is elongated roughly north-south, thins toward its east margin, splits and then thins toward its west margin. To the north and south the individual bed thins and finally pinches out, but another coal bed usually stratigraphically overlaps above or below the first. The quality of a bed is normally uniform except along its west boundary where ash and sulfur content increase. Westward these constituents increase uniformly or irregularly.

The rocks that encase the coal are mainly sandstones and shale; the sandstones are as lenticular as the coal. They are generally yellow-gray, tan or brown, fine-to coarse-grained, thin-bedded to massive cliff formers of littoral or fluvial origin. Interbedded between the sandstones are the shales and mudstones of marine, paludal and fluvial origin plus subordinate amounts of shaley sandstone. The mudstones contain varying amounts of carbonaceous matter and coal.

Structure

The three physiographic provinces have characteristic internal structures. The Basin and Range is exemplified by fault block mountain ranges in which the internal structure is characterized by tight folds, complex fault systems and thrust faults separated by wide valleys filled with fluvial and lacustrine sediments of Late Tertiary and Quaternary age. Although two coal fields are associated with this province, only one is specifically related to it—the Goose Creek-Grouse Creek field in the northwest corner of Utah. Only a part of it has been mapped structurally. Here Upper Tertiary lignites and carbonaceous shales occur in the intermontane valleys; the strata are gently warped but complexly faulted.

A zone of transition occurs between the Basin and Range and the Colorado Plateaus Province proper. This subprovince is known as the High Plateaus of Utah. The structures are more nearly related to those expected in the Colorado Plateaus Province but the Basin and Range influence is often noticeable. The following coal fields have High Plateaus structure: Harmony, Kolob, Milburn, Mt. Pleasant, Salina Canyon, Sterling and Wales.

Large areas of igneous rock, notably volcanics, occur intermittently in the area. They cover the coal-bearing strata and cause local steep folding. Lava terminates the Wasatch Plateau field at its

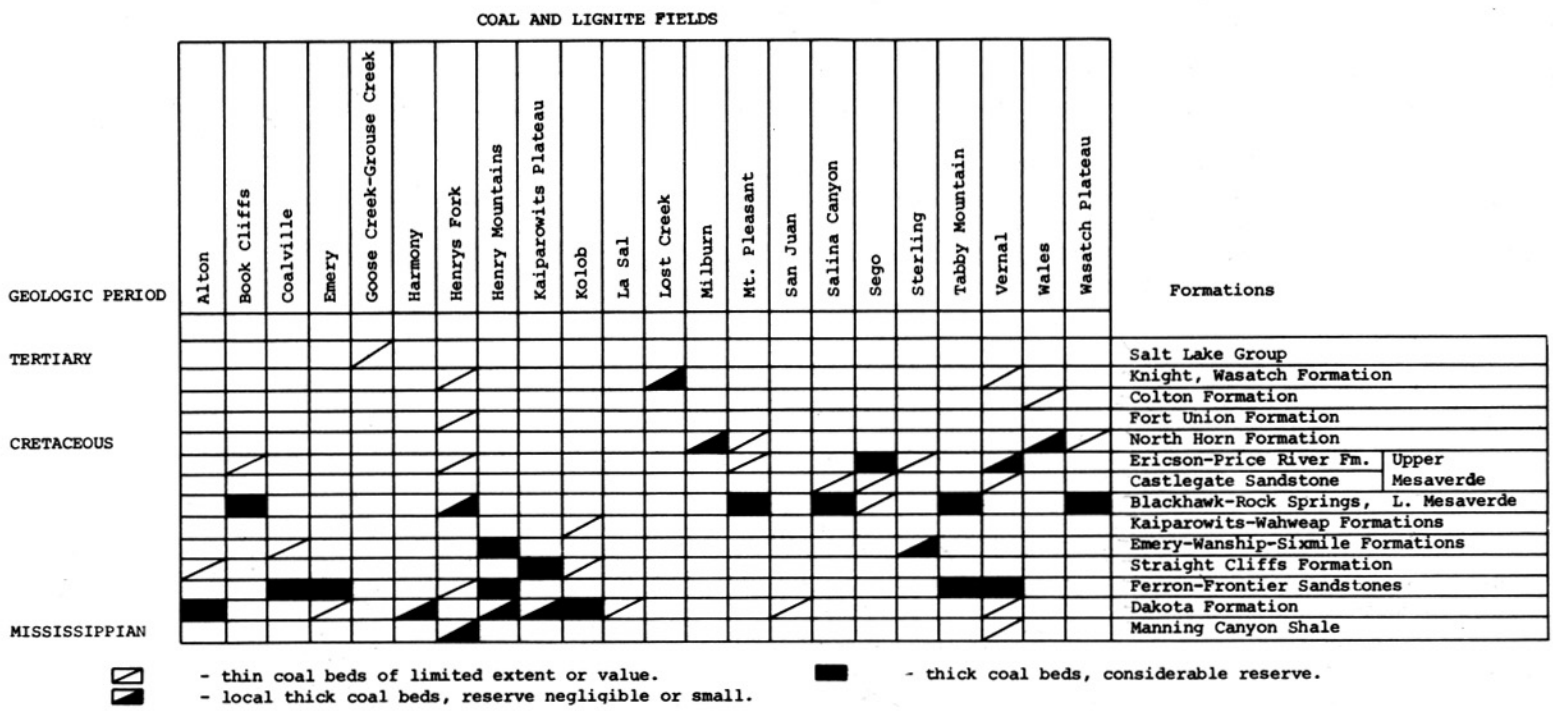


Figure 3. Stratigraphy of Utah coal fields.

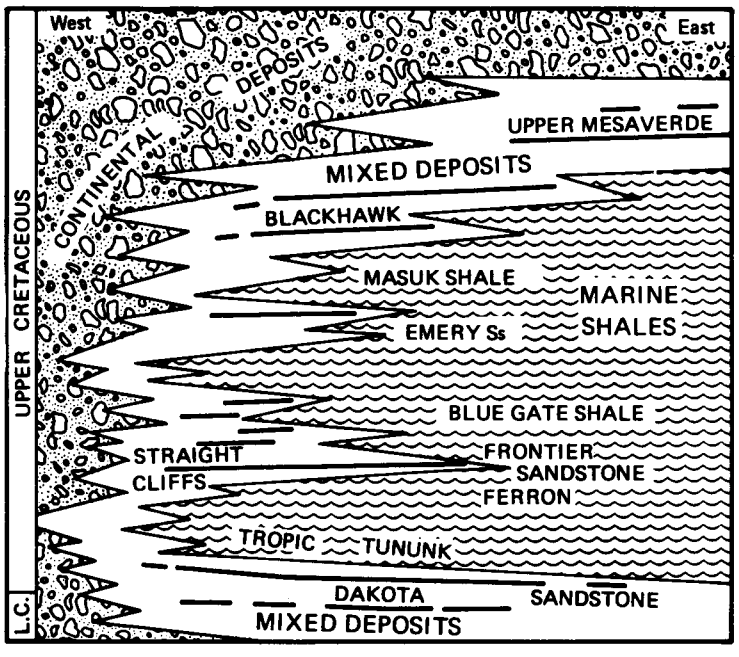


Figure 4. Generalized east-west diagram of Cretaceous environments of Utah.

south end and the Harmony beds are steeply tilted adjacent to a laccolithic body. Impressive fault zones that extend for hundreds of miles parallel the Wasatch-Las Vegas line. These affect the coal in the Wasatch Plateau, Mt. Pleasant, Salina Canyon and Kolob fields but are spaced far enough apart for mining to be profitable. Moderate to steep tectonic folding is prevalent in a few fields that are transitional to the Rocky Mountains Province as well as to the Basin and Range Province. The two small fields of Wales and Sterling belong to this group. Thrusting may be involved as well.

The Uinta Basin is a subprovince in the north part of the Colorado Plateaus province. It is a deep structural basin filled with Cretaceous and Tertiary sediments. The coal-bearing beds crop out along its south margin in the Book Cliffs and Sego fields. The strike of the beds follows the edge of the basin which is physically marked by an escarpment known as the Book Cliffs. Faulting is negligible along this line and the beds dip gently to moderately into the basin. Immediately at the cliff front dips are normally less than 10 degrees, but farther back they can increase to as much as 20 degrees. This dip plus the thick overburden of Tertiary rock renders the coal fields to narrow strips along the cliffs.

The major part of the remainder of the Colorado Plateaus Province consists of gently warped strata: anticlines, synclines, domes and basins. Unfortunately the Cretaceous strata have been eroded out of much of it and the coal is often undeveloped in the remaining patches. The best preservation has been in the larger basins and synclines (Henry Mountains Basin, Kaiparowits Basin, Paunsaugunt syncline). The La Sal and Henry Mountains have domed the rocks around them and several long impressive monoclines have deformed the strata (Kaiparowits Plateau, Henry Mountains fields), but these affect only small areas and a small part of the reserve. Serious faulting is rare.

The structure of the Rocky Mountains Province consists of open folds and boundary faults. The Wasatch Range is more complex and adds internal faults, thrusts and igneous intrusions not found in the simple anticlinal fold of the Uinta Mountains. Five coal fields lie marginal to the Rocky Mountains in Utah. The Henrys Fork, Vernal and Tabby Mountain fields are on the flanks of the Uintas and the strata dip moderately to steeply away from the range. In the Vernal field two small ranges are related to the Uinta fold, also anticlinal in nature, and the strata have wrapped themselves around them. Faults are usually not a problem except where the boundary faults cut the strata. Locally displacements are large. The remaining two fields (Coalville and Lost Creek) are caught between the two mountain ranges. The Coalville field is much like a field marginal to the Uintas, but some folds and faults parallel the Wasatch range and are superimposed upon Uinta-type structures. The Lost Creek field is not typical; Tertiary strata contain the coal, dips are gentle and faulting is unimportant.

LOCATION AND COVERAGE

The Utah coal fields fall into five national regions on the U. S. Geological Survey coal map of the United States (Trumbull, 1960):

National Region

I. Hams Fork
   1. Lost Creek
   2. Coalville
   3. Evanston Extension

II. Green River
   1. Henrys Fork

III. Uinta
   1. Tabby Mountain
   2. Vernal
   3. Sego
   4. Book Cliffs
   5. Wasatch Plateau
   6. Emery
   7. Wales
   8. Mt. Pleasant
   9. Milburn
   10. Sterling
   11. Salina Canyon

IV. San Juan
   1. La Sal
   2. San Juan

V. Southwestern Utah
   1. Harmony
   2. Kolob
   3. Alton
   4. Kaiparowits Plateau
   5. Henry Mountains

The list presents good natural divisions but does not subdivide the fields into the most useful arrangement for a discussion of Utah coal. The divisions as presented in Monographs 1 to 3 are as follows (figure 5):

Monograph 1
- Region I (Southwestern Utah)
  1. Kaiparowits Plateau
  2. Alton
  3. Kolob
  4. Harmony

Monograph 2
- Region II (Northern Utah)
  1. Goose Creek-Grouse Creek
  2. Lost Creek
  3. Coalville
  4. Henrys Fork
  5. Tabby Mountain
  6. Vernal
- Region III (Eastern Utah)
  1. Sego
  2. La Sal
  3. San Juan
  4. Henry Mountains

Monograph 3
- Region IV (Central Utah)
  1. Book Cliffs
  2. Wasatch Plateau
  3. Emery
  4. Milburn
  5. Mt. Pleasant
  6. Wales
  7. Sterling
  8. Salina Canyon

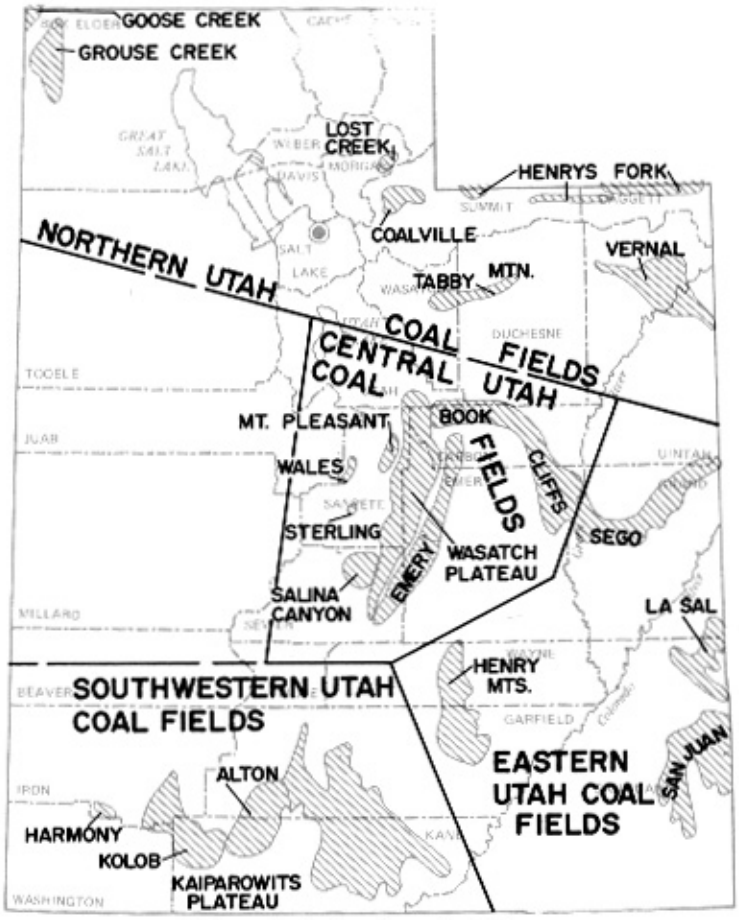


Figure 5. Coal regions in Utah.

Seven of Utah's twenty-nine counties have had no coal reported. The distribution of reserve, however, is not equal. Five counties each have more than one billion tons of reserve and seven have reserves greater than 100 million but less than one billion tons. Fifteen counties have had some production, but more than 95 percent of the coal have come from Carbon and Emery counties.

In Monographs 1 to 3 the twenty-two coal fields are discussed in sixteen field reports each subdivided into quadrangles. The quadrangles maps are usually sized at 7½ minutes and scaled at 1.5 inches equal one mile. A quadrangle index of the state shows their locations (figure 6). In addition smaller-scaled maps give regional or general data.

PRODUCTION OF COAL IN UTAH

The first production of coal in Utah is difficult to pinpoint. Three early areas were the Kolob, Wales and Coalville fields. The Kolob field, Iron County, along with nearby iron deposits was discovered by a Mormon exploration party during the winter of 1849 to 1850. According to Huntley, Emmons and Becker (1885, p. 489) the Kolob field was worked in a small way since 1852. Averitt (1962, p. 54) notes that coal was first mined in 1854 from the Leyson mine in Right Hand Canyon. Huntley and others (1885, p. 488) report that coal at Wales in Sanpete County had been worked since 1855. Clark (1914, p. 489) notes that Wales claims the distinction of producing the first coal mined in Utah. He indicates that activity began in 1857. In 1854 the territorial legislature of Utah offered a reward of $1,000 for the first discovery of minable coal within 40 miles of Salt Lake City (Hawkes, 1959, p. 12); it was claimed in 1859 when the first coal mine was developed in the Coalville field. The Kolob, Wales and Coalville areas had small intermittent production at first. Coalville became the first important coal center in Utah about 1870. It still had its troubles, but modest production was maintained continuously thereafter to the present. The more important coal fields were developed later–the Wasatch Plateau in 1874 and the Book Cliffs in 1889.

The rate of production is shown on figure 7 and table 1 illustrates 100 years of coal mining in Utah. Figure 7 shows two peaks, one following World War I and a second following World War II. In 1970 the twenty-three active mines in the state employed 1,136 employees, 388 of whom work at the surface only. Four mines produced more than 500,000 tons, seven between 100,000 and 500,000 tons, seven between 10,000 to 100,000 tons and the remaining five produced less than 10,000 tons. Active mines were located in the Book Cliffs field (ten), Wasatch Plateau field (nine), Emery field (two), Coalville field (one) and Alton fields (one). Two of these mines were deactivated during 1970.

Table 1. Annual Utah coal production, 1870 to 1970 (thousands of short tons).

Year	Total	Coking Coal[1]	Year	Total	Coking Coal[1]
1870	6	–	1921	4,079	280
1871	8	–	1922	4,991	322
1872	10	–	1923	4,720	486
1873	16	–	1924	4,488	484
1874	22	–	1925	4,690	589
1875	33	–	1926	4,374	551
1876	50	–	1927	4,781	473
1877	50	–	1928	4,843	466
1878	67	–	1929	5,161	515
1879	225	–	1930	4,257	421
1880	225	–	1931	3,350	283
1881	225	–	1932	2,852	211
1882	250	–	1933	2,675	170
1883	250	–	1934	2,406	245
1884	250	–	1935	2,947	238
1885	213	–	1936	3,247	234
1886	200	–	1937	3,809	301
1887	180	–	1938	2,947	280
1888	260	–	1939	3,285	365
1889	237	–	1940	3,576	408
1890	318	–	1941	4,077	458
1891	371	–	1942	5,517	578
1892	361	–	1943	6,666	1,632
1893	418	–	1944	7,119	2,342
1894	447	–	1945	6,679	1,989
1895	473	–	1946	5,994	1,462
1896	503	–	1947	7,429	2,405
1897	582	–	1948	6,978	2,319
1898	673	–	1949	6,160	2,446
1899	878	–	1950	6,670	2,417
1900	1,234	–	1951	6,139	2,388
1901	1,392	–	1952	6,151	2,245
1902	1,641	–	1953	6,544	2,997
1903	1,762	140	1954	5,012	2,058
1904	1,493	199	1955	6,296	2,815
1905	1,332	248	1956	6,545	2,979
1906	1,773	317	1957	6,858	3,176
1907	1,948	410	1958	5,511	2,667
1908	1,847	299	1959	4,644	2,309
1909	2,267	343	1960	4,955	2,394
1910	2,518	274	1961	5,168	2,649
1911	2,513	301	1962	4,297	1,894
1912	3,016	562	1963	4,541	2,244
1913	3,255	607	1964	4,733	2,298
1914	3,103	636	1965	4,992	2,524
1915	3,109	548	1966	4,666	2,154
1916	3,567	772	1967	4,196	1,848
1917	4,125	1,027	1968	4,316	1,821
1918	5,137	791	1969	4,673	2,034
1919	4,631	392	1970	4,743	2,039
1920	6,005	427			
			TOTAL	309,575	81,196

[1]Total used for coking purposes. (Some coking coal has been used for other purposes.)

Coal production has centered in the Carbon-Emery county area (figures 8 to 10 and tables 2 to 3). The largest high-quality reserve is centered there and the presence of coking coal, its nearness to Utah markets and the good railroad service to Utah and western markets make for its high activity.

Although most of the other areas in Utah were discovered early, they were hampered in their continued development for

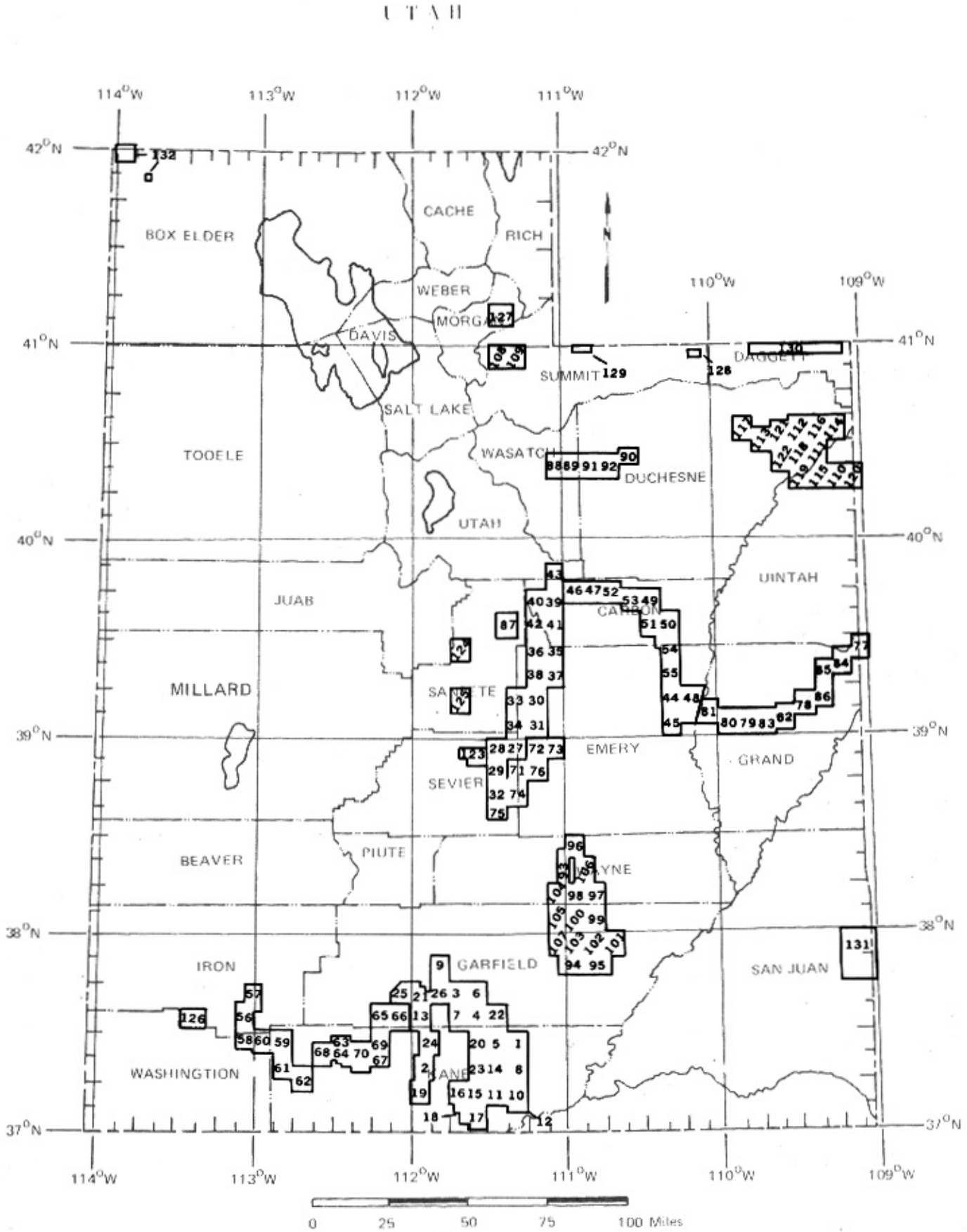


Figure 6. Index of coal quadrangles in Utah (see table 4).

Figure 7. Utah coal production to 1970.

several reasons. Many of the smaller fields thrived for a time in the early years because of a local market, but as the Carbon-Emery coals were developed and could be competitively shipped to other places in the state, they gradually were curtailed and finally shut down. Such coal fields include Vernal, Tabby Mountain, Sterling, Lost Creek, San Juan and Wales. Most of these fields have small reserves in thin split seams with coal either high in sulfur or in ash. Coalville operated in a similar situation but has continued to operate on a modest scale because of a few important advantages—its seams are relatively thick, unsplit and even though the coal is of subbituminous rank, it is of reasonably good quality. It is also close to the heavily populated and industrialized part of Utah.

The huge reserves of southwest Utah have not been seriously tapped because of (1) lack of appreciable local market (except Kolob field), (2) distance to large market areas, (3) no railroad or good roads, (4) inaccessibility and remoteness, (5) lack of coking coal or other special quality coal, (6) high sulfur content in some

Table 2. Total coal field production through 1970 (thousands of short tons).

Rank	Field	Activity: Initial Year	Activity: Last Production	Tonnage	State Total (percent)
1	Book Cliffs	1889	[1]	208,800	65.4
2	Wasatch Plateau	1874	[1]	99,481	31.2
3	Coalville	1859	[1]	4,244	1.3
4	Sego	1900	1954	2,650	0.8
5	Emery	1881	[1]	1,640	0.5
6	Kolob	1852	1969	776	0.2
7	Wales	1885	1955	665	0.2
8	Salina Canyon	1900	1953	430	0.1
9	Vernal	1890	1957	251	0 1
10	Sterling	1888	1935?	60	–
11	Alton	1930?	1970	50	–
12	Kaiparowits Plateau	1893?	1964 [2]	25	–
13	Henry Mountains	1908	1955? [2]	9	–
14	Tabby Mountain	1890	1949 [2]	2	–
15	Lost Creek	1900	1920 [2]	1	–
16	San Juan	1927	1948 [2]	0.3	
17	Harmony			0.2	
			Total	319,084.5	

[1] Still active.
[2] Intermittent activity, often many years of inactivity.

fields (especially Kolob-Harmony) and (7) pressure brought to bear by preservationist and environmental groups attempting to halt industrial and mining development.

Construction of several coal-fired power plants has been contemplated in southwest Utah. If they are built, the coal will be mined seriously for the first time and the dominance of Carbon-Emery production will be challenged.

The Utah coal fields and county production figure (319 million tons; tables 2 and 3) is higher than the annual figure (310 million tons; table 1). To determine the higher figure all mine total productions through 1970 were added; the second figure was derived from several sources, but mostly from U. S. Bureau of Mines Minerals Yearbooks. Some estimating is included in both,

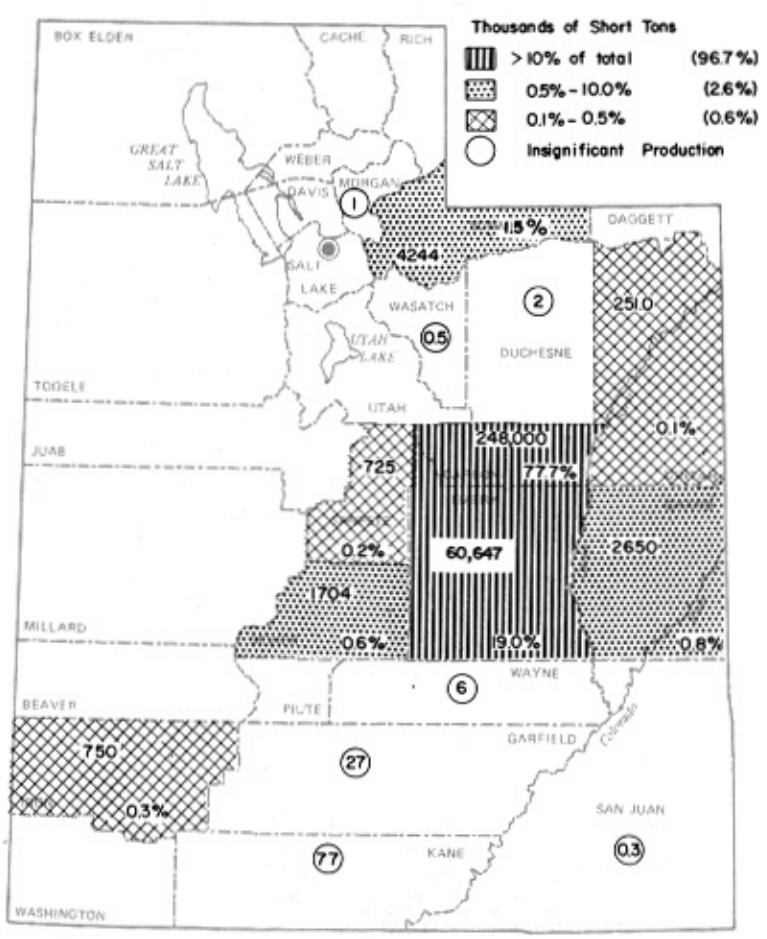


Figure 8. Utah coal production by county through 1970.

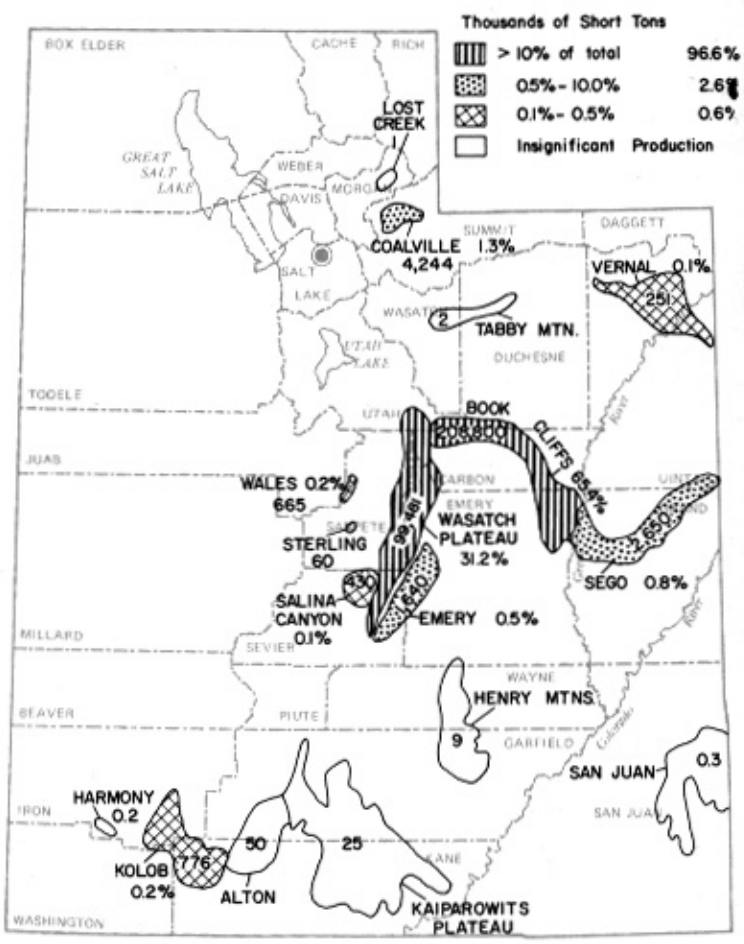


Figure 9. Utah coal production by coal field through 1970.

Table 3. Total coal production by county through 1970 (thousands of short tons).

Rank	County	Activity: Initial Year	Activity: Last Production	Tonnage	State Total (percent)
1	Carbon	1878	[1]	248,000	77.7
2	Emery	1874	[1]	60,647	19.0
3	Summit	1859	[1]	4,244	1.3
4	Grand	1900	1954	2,650	0.8
5	Sevier	1900	[1] and [2]	1,704	0.6
6	Iron	1852	1969	750	0.3
7	Sanpete	1855	1955	725	0.2
8	Uintah	1890	1957	251	0.1
9	Kane	1910	1970[2]	77.2	–
10	Garfield	1893	1964[2]	27	–
11	Wayne	1908	1945?[2]	6	–
12	Duchesne	1900	1949[2]	1.5	–
13	Morgan	1900	1920[2]	1	–
14	Wasatch	1890	1910?[2]	0.5	–
15	San Juan	1927	1948[2]	0.3	–
				319,084.5	

[1]Still active.
[2]Intermittent activity, often many years of inactivity.

but even with some error, the totals are thought to be within a percentage point of being accurate. The difference is mainly attributed to early mined coal, unreported tonnages and differences in estimating early year production figures.

The total value of the coal as sold at the mine mouth is estimated to be $1,153,589,000 or an average of $3.61 per ton. The present value is at least two dollars higher. Over 26 percent of the production have been in coking coal and in 1970, 43 percent was mined for this purpose.

RESERVES

Generally reserves are listed in four categories:

Class I *Measured reserves* based on adequate exploration and development data; properly correlated; control no more than ½ mile apart.

Class II *Indicated reserves* based on geologic measurement supplemented by limited drill-hole information and limited to 1½ miles from a control point.

Class III *Inferred reserves* based on geologic inference and projection of the habit of the coal beyond 1½ miles from control points.

Class IV *Potential reserves* based on geographic and geologic position with little supporting data; includes coal up to 3,000 feet of cover.

Most of the Utah reserve is based on surface measurements which are not always as reliable as the drill. The reserve, therefore, is oftentimes minimal inasmuch as surface measurements are usually smaller than what a drill ascertains. Class I and II figures are combined in these reports; no attempt was made to separate the more reliable figure. The first three reserve classes constitute the principal reserve and more nearly reflect the immediate potential of a quadrangle or area.

Although coal as thin as 14 inches has been mined in other areas, a 4-foot minable limit was set for the Utah coal reports. In most cases the reserve under 4 feet has been eliminated as well as coal at a depth greater than 3,000 feet. The reserves were calculated for one hundred thirty-two quadrangles or map areas and then added to prepare the field or area totals. Table 4 represents the original coal reserves of Utah considering the previous limitations with the presently (1970) available knowledge.

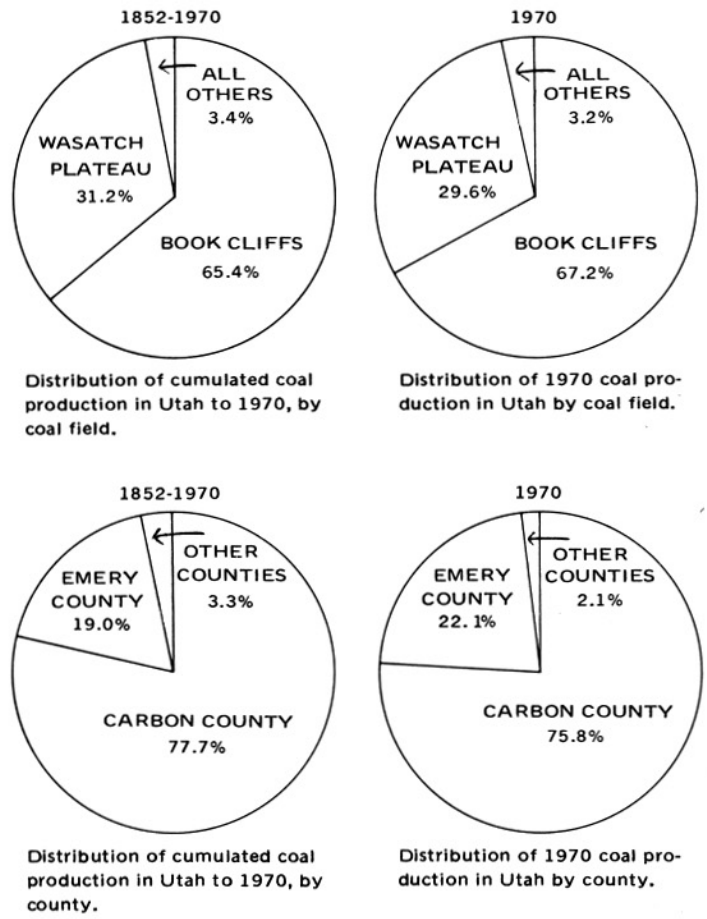


Figure 10. Distribution of coal production in Utah by coal field and county.

Tables 4 to 7 and figures 11, 12 and 13 show that coal in Utah is concentrated in the central and southwest area; all but one quadrangle having 200 million or more tons of reserve fall in these areas. Fifteen quadrangles, eight in southwest Utah and seven in central Utah, each have more than 500 million tons of reserve. The fifteen quadrangles hold 41.6 percent of the total reserve.

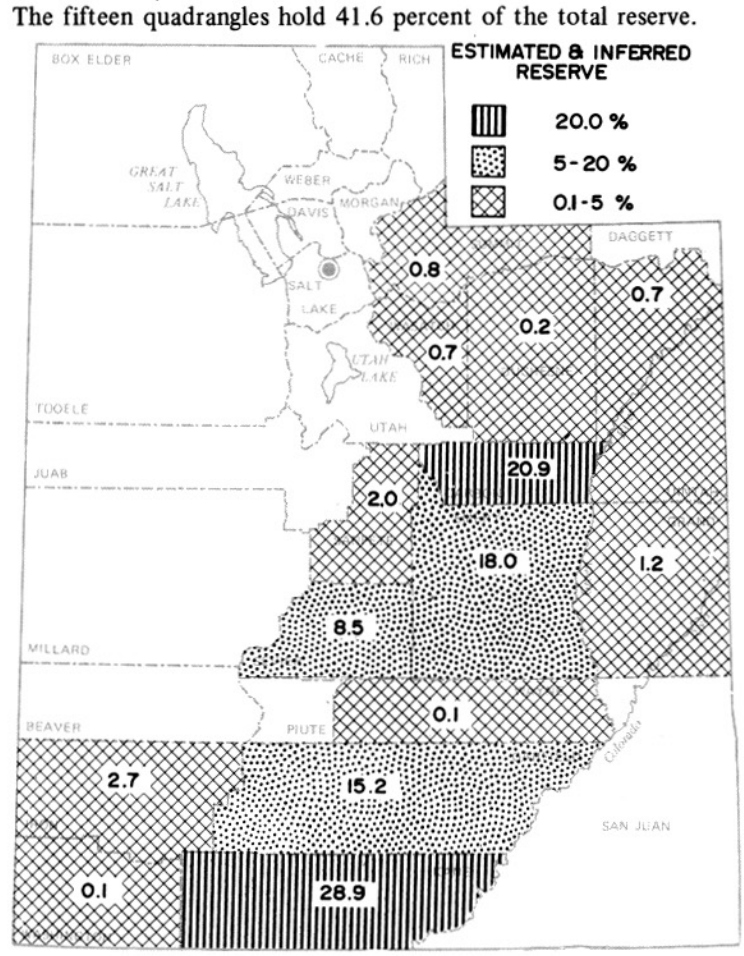


Figure 11. Distribution of Utah coal reserves by county

Table 4. Original Utah coal reserve (millions of short tons).

Quadrangle	I and II	III	IV	Principal	Total Coal
KAIPAROWITS PLATEAU FIELD					
1. Basin Canyon	–	–	[1]	–	[2]
2. Calico Peak-Horse Flat	–	–	[1]	–	[2]
3. Canaan Creek	288.0	109.8	[1]	397.8	–
4. Carcass Canyon	433.9	195.0	[1]	629.0	–
5. Collet Top	198.0	271.8	[1]	469.8	–
6. Dave Canyon	151.0	19.4	[1]	170.4	–
7. Death Ridge	169.8	890.4	[1]	1,060.2	–
8. East of the Navajo	15.4	12.2	[1]	27.6	–
9. Griffin Point	286.6	162.5	[1]	449.1	–
10. Gunsight Butte NE	17.9	–	[1]	17.9	–
11. Gunsight Butte NW	230.2	199.7	[1]	429.9	–
12. Gunsight Butte SE	–	–	[1]	–	[2]
13. Henrieville	26.4	17.0	[1]	43.4	–
14. Needle Eye Point	295.4	388.0	[1]	683.4	–
15. Nipple Butte NE	212.5	59.7	[1]	272.2	–
16. Nipple Butte NW	–	–	[1]	–	[2]
17. Nipple Butte SE	33.3	5.0	[1]	38.3	–
18. Nipple Butte SW	–	–	[1]	–	–
19. Paria NW	0.4	–	[1]	0.4	–
20. Petes Cove	122.4	686.2	[1]	808.6	–
21. Pine Lake	297.0	314.0	[1]	611.0	–
22. Seep Flat	19.2	8.9	[1]	28.1	–
23. Ship Mtn. Point	963.0	302.8	[1]	1,265.8	–
24. Slickrock Bench-Bulter Valley	0.5	–	[1]	0.5	–
25. Tropic Canyon	160.0	161.0	[1]	321.0	–
26. Upper Valley	57.3	89.7	[1]	147.0	–
Other areas	6.6	–	[1]	6.6	–
Total	3,984.8	3,893.2	7,320.0	7,878.0	15,198.0
WASATCH PLATEAU FIELD					
27. Acord Lakes NE	164.9		[1]	164.9	–
28. Acord Lakes NW	491.3		[1]	491.3	–
29. Acord Lakes SW	300.4		[1]	300.4	–
30. Castle Dale NW	377.7		[1]	377.7	–
31. Castle Dale SW	24.3			24.3	–
32. Emery 3 NW	134.5		[1]	134.5	–
33. Ferron Canyon	57.7		[1]	57.7	–
34. Flagstaff Peak	392.2		[1]	392.2	–
35. Hiawatha NE	466.1		[1]	466.1	–
36. Hiawatha NW	764.4		[1]	764.4	–
37. Hiawatha SE	110.2		[1]	110.2	–
38. Hiawatha SW	538.0		[1]	538.0	–
39. Scofield NE	608.8		[1]	608.8	–
40. Scofield NW	594.7		[1]	594.7	–
41. Scofield SE	302.6		[1]	302.6	–
42. Scofield SW	461.9		[1]	461.9	–
43. Soldier Summit SE	462.3		[1]	462.3	–
Other areas	126.9			126.9	–
Total	6,378.9		3,888.0	6,378.9	10,266.9
BOOK CLIFFS FIELD					
44. Beckwith Peak NE	–	–	–	–	[2]
45. Beckwith Peak SE	–	–	–	–	[2]
46. Castlegate-Kyune	567.0	368.0	127.0	935.0	1,062.0
47. Castlegate Matts Summit	529.4	188.0	–	717.4	717.4
48. Gunnison Butte W	–		–	–	[2]

Table 4. (continued)

Quadrangle	I and II	III	IV	Principal	Total Coal
49. Sunnyside NW	196.0	–	–	196.0	196.0
50. Sunnyside SE	358.5	–	–	358.5	358.5
51. Sunnyside SW	123.4	–	–	123.4	123.4
52. Wellington-Minnie Maud W	126.9	209.0	30.0	335.9	365.9
53. Wellington NE	323.2	206.7	–	529.9	529.9
54. Woodside NE	399.4	–	93.6	399.4	493.0
55. Woodside SE	72.0	–	–	72.0	72.0
Other areas	–	–	265.0	–	265.0
Total	2,695.8	971.7	515.6	3,667.5	4,183.1
KOLOB FIELD					
56. Cedar Mtn.	202.6	25.7	–	228.3	228.3
57. Coal Creek	58.8	71.8	–	130.6	130.6
58. Kolob Peak	–	50.6	–	50.6	50.6
59. Orderville Canyon NE	99.5	461.7	–	561.2	561.2
60. Orderville Canyon NW	–	177.2	–	177.2	177.2
61. Orderville Canyon SE	158.0	45.5	–	203.5	203.5
62. Orderville SW	189.8	207.8	–	397.6	397.6
Other areas	–	265.3	–	265.3	265.3
Total	708.7	1,305.6	–	2,014.3	2,014.3
ALTON FIELD					
63. Alton	102.4	418.2	197.1	520.6	717.7
64. Bald Knoll	142.2	154.5	–	296.7	296.7
65. Bryce Point	57.0	54.7	72.3	111.7	184.0
66. Cannonville	–	–	–	–	[2]
67. Deer Spring Point	–	–	–	–	[2]
68 Orderville NE-SE	135.3	–	–	135.3	135.3
69. Rainbow Point	71.0	48.6	12.4	119.6	132.0
70. Skutumpah Creek-Podunk Creek	135.9	189.6	79.0	325.5	404.5
Other areas	–	–	278.7	–	278.7
Total	643.8	865.6	639.5	1,509.4	2,148.9
EMERY FIELD					
71. Acord Lake SE	209.2	289.2	381.6	498.4	880.0
72. Emery East	150.7	181.9	133.1	332.6	465.7
73. Emery 1 NE	–	–	–	–	[2]
74. Emery 3 NE	131.8	50.0	–	181.8	181.8
32. Emery 3 NW[3]	72.0	98.2	119.8	170.2	290.0
75. Emery 3 SW	34.8	–	–	34.8	34.8
76. Mesa Butte	78.0	–	–	78.0	78.0
Other areas	–	134.6	–	134.6	134.6
Total	676.5	753.9	634.5	1,430.4	2,064.9
SEGO FIELD					
77. Colorado Line	–	–	–	–	[2]
78. Cottonwood Creek	–	–	–	–	[2]
79. Floy Canyon SE	–	17.9	–	17.9	17.9
80. Floy Canyon SW	–	–	–	–	[2]
81. Gunnision Butte E	–	–	–	–	[2]
82. Sego Canyon SE	9.0	52.9	–	61.9	61.9
83. Sego Canyon SW	148.1	57.8	–	205.9	205.9
84. West Bitter Creek	–	–	–	–	[2]
85. Westwater Creek North	–	7.9	–	7.9	7.9
86. Westwater Creek South	–	–	–	–	[2]
Total	157.1	136.5	–	293.6	293.6

Table 4. (continued)

Quadrangle	I and II	III	IV	Principal	Total Coal
MT. PLEASANT FIELD					
87. Mt. Pleasant Huntington Reservoir	100.3	148.8	–	249.1	249.1
Total	100.3	148.8	–	249.1	249.1
TABBY MTN. FIELD					
88. Currant Creek	38.4	38.3	539.2	76.7	615.9
89. Raspberry Knoll	80.7	44.7	628.5	125.4	753.9
90. Rock Creek	–	–	75.1	–	75.1
91. Tabby Mtn.	18.4	–	324.3	18.4	342.7
92. Tabiona	5.3	5.4	60.0	10.7	70.7
Total	142.8	88.4	1,627.1	231.2	1,858.3
HENRY MTNS. FIELD					
93. Caineville	0.8	–	–	0.8	0.8
94. Cave Point	27.4	–	105.4	27.4	132.8
95. Cow Flat	4.2	–	–	4.2	4.2
96. Factory Butte NW	22.8	–	–	22.8	[2]22.8
97. Mt. Ellen NE	–	–	–	–	[4]
98. Mt. Ellen NW	–	–	–	–	[4]
99. Mt. Ellen SE	–	–	–	–	[2]
100. Mt. Ellen SW	62.9	19.1	50.1	82.0	132.1
101. Mt. Hillers NW	–	–	–	–	[2]
102. Mt. Pennell NE	–	–	–	–	[4]
103. Mt. Pennell NW	35.5	9.5	103.8	45.0	148.8
104. Notom NE	–	–	–	–	[4]
105. Notom SE	48.8	–	52.2	48.8	101.0
106. Steamboat Point	–	–	–	–	[2]
107. Wagon Box Mesa NE	–	–	–	–	[4]
Total	202.4	28.6	311.5	230.4	542.5
COALVILLE FIELD					
108. Coalville	–	–	–	–	[4]
109. Turner Hollow	156.0	–	–	156.0	156.0
Other areas		30.0	–	30.0	30.0
Total	156.0	30.0	–	186.0	186.0
VERNAL FIELD					
110. Cliff Ridge	–	3.1	–	3.1	3.1
111. Dinosaur Quarry	–	–	–	–	[2]
112. Donkey Flat	22.7	37.5	–	60.2	60.2
113. Dry Fork-Vernal NW	18.8	–	–	18.8	[2]18.8
114. Island Park	–	–	–	–	[2]
115. Jensen	–	–	–	–	[2]
116. Jensen Ridge	–	–	–	–	[2]
117. Lake Mtn.	25.4	–	–	25.4	25.4
118. Naples	5.2	30.3	–	35.5	35.5
119. Rasmussen Hollow	1.6	3.1	–	4.7	4.7
120. Snake John Reef	–	5.1	–	5.1	5.1
121. Steinaker Res. Vernal NE	18.9	5.5	–	24.4	[2]24.4
122. Vernal NE-SE	–	–	–	–	[2]
Total	92.5	84.6	–	177.1	177.1
SALINA CANYON FIELD					
123. Salina Canyon	86.4		–	86.4	86.4
Total	86.4		–	86.4	86.4
WALES FIELD					
124. Wales	12.2	–	–	12.2	12.2
Total	12.2	–	–	12.2	12.2
STERLING FIELD					
125. Sterling	–	2.0	–	2.0	2.0
Total	–	2.0	–	2.0	2.0
HARMONY FIELD					
126. Page Ranch Stoddard Mtn.	–	1.3	–	1.3	1.3
Total	–	1.3	–	1.3	1.3
LOST CREEK FIELD					
127. Lost Creek	1.1	–	–	1.1	1.1
Total	1.1	–	–	1.1	1.1
HENRYS FORK FIELD					
128. Beaver Creek to Burnt Fork	–	–	–	–	[2]
129. Evanston Extension	–	–	?	–	–
130. Flaming Gorge	–	–	–	–	[2]
Total	–	–	?	–	–
SAN JUAN FIELD					
131. Eastland	–	–	?	–	–
Total	–	–	?	–	–
GOOSE CREEK–GROUSE CREEK FIELD					
132. Goose Creek NE Cotton Thomas B	–	–	–	–	[2]
Total	–	–	–	–	–
Utah Total	12,806.7	11,542.8	14,936.2	24,349.5	39,285.7

[1]Included with field total.
[2]Thin coal beds only.
[3]Also part of Wasatch Plateau field, only Emery reserves shown here.
[4]Included with an adjacent quadrangle.

Although fifteen counties are listed as coal counties, five contain more than 1 billion tons or 91.5 percent of the reserve.

The Blackhawk, Straight Cliffs and Dakota formations contain 90.2 percent of the reserve. The Blackhawk is the dominant unit of central Utah and the Straight Cliffs and Dakota are developed in southwest Utah. Table 7 reveals that 51.4 percent of the reserve are under less than 1,000 feet of cover. The calculations do not reflect true conditions; the potential reserve increases with depth and as they become converted to principal reserve by drill-hole exploration, the percentages for each 1,000 feet of cover should approach equality. In southwest Utah little coal occurs deeper than 2,000 feet, however, and the two remaining divisions should equalize.

Almost all the coal has come from underground mines. Claims of more than 70 percent recoverability are reported from individual seams. When the productivity of a given acreage, however, is compared with the reserve estimates of a principal investigator, the percentage of recovery drops to about 30 percent; this isn't the case in fields having one or two important seams, but in more complicated areas where multiple seams are prevalent. In single seam areas 40 to 60 percent can be expected. At least one-third of the state's principal reserve will be recoverable. On this basis Utah's remaining recoverable reserve is shown on table 8 and distributed as shown on figure 14. Recoverability will be considerably higher in select areas and as technologies and demands improve in the future so might the total recoverable percentage increase.

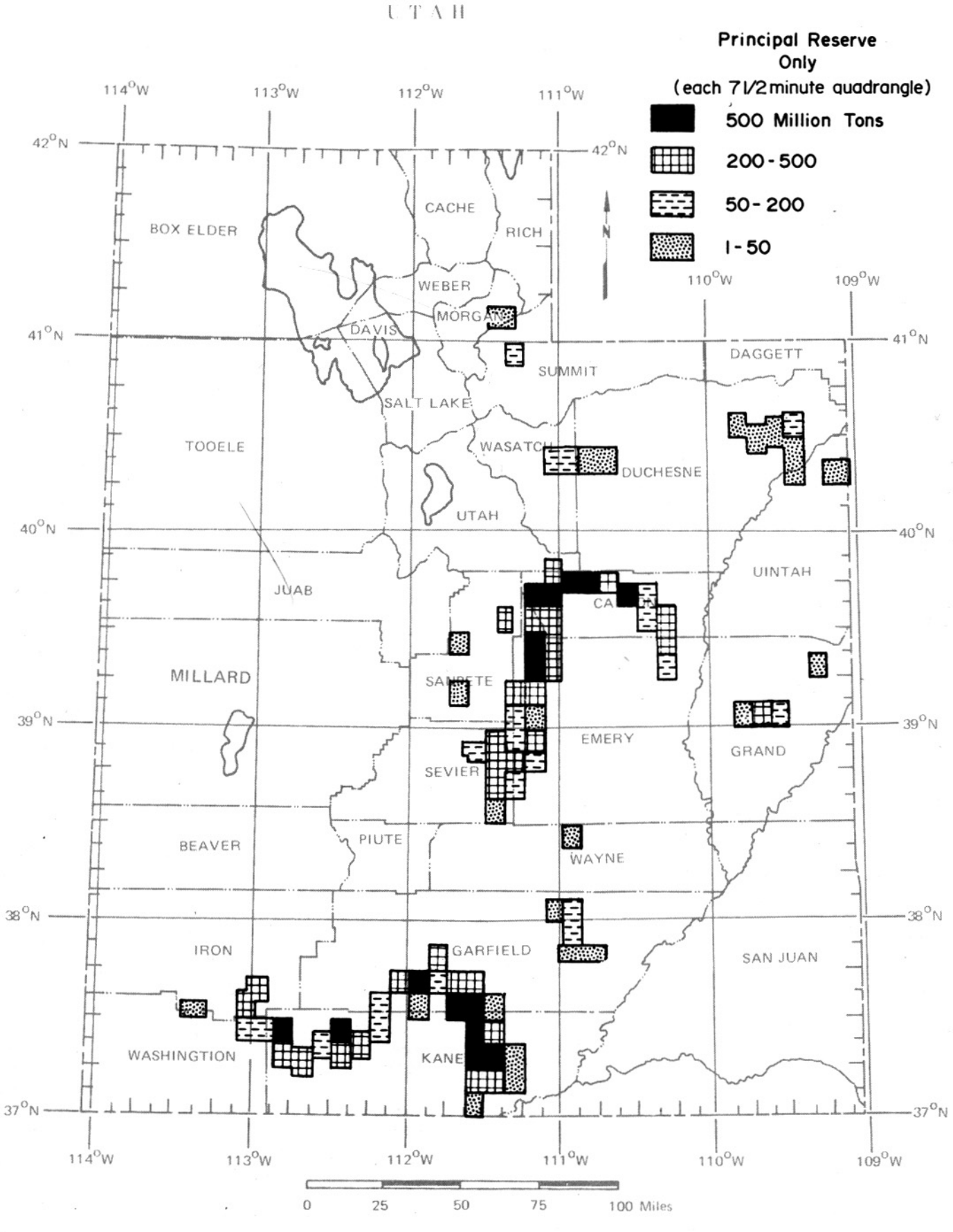


Figure 12. Distribution of Utah coal reserves by quadrangle.

Table 5. Original principal reserve by formation (millions of short tons).

Formation	Reserve	Percent
1. Blackhawk Formation	10,549.9	43.3
2. Straight Cliffs Formation	7,834.1	32.2
3. Dakota Formation	3,570.4	14.7
4. Ferron-Frontier	1,885.9	7.8
5. Upper Mesaverde (Price River)	306.5	1.2
6. Emery-Sixmile	189.4	0.7
7. North Horn-Wasatch	13.3	0.1
Total Coal	24,349.5	100.0

Table 6. Original principal reserve by county (millions of short tons).

County	Reserve	Percent	Position
Beaver	–		
Box Elder	–		
Cache	–		
Carbon	5,096.3	20.9	2
Daggett	–		
Davis	–		
Duchesne	53.9	0.2	12
Emery	4,388.8	18.0	3
Garfield	3,698.5	15.2	4
Grand	293.6	1.2	8
Iron	650.8	2.7	6
Juab	–		
Kane	7,016.9	28.9	1
Millard	–		
Morgan	1.1		15
Piute	–		
Rich	–		
Salt Lake	–		
San Juan	–		
Sanpete	489.5	2.0	7
Sevier	2,070.8	8.5	5
Summit	186.0	0.8	9
Tooele	–		
Uintah	177.1	0.7	11
Utah	–		
Wasatch	177.3	0.7	10
Washington	25.3	0.1	13
Wayne	23.6	0.1	14
Weber			
Total	24,349.5	100.0	

Table 7: Original principal reserve (millions of short tons).

Field	Overburden (feet) 0-1,000	Percent	1,000-2,000	Percent	2,000-3,000	Percent	Total Coal
1. Kaiparowits Plateau	5,365.9	68.1	2,135.3	27.1	376.8	4.8	7,878.0
2. Wasatch Plateau	2,690.2	42.2	2,706.1	42.4	982.6	15.4	6,357.1
3. Book Cliffs	1,261.4	34.4	1,456.7	39.7	949.4	25.9	3,667.5
4. Kolob	472.7	23.5	1,340.0	66.5	201.6	10.0	2,014.3
5. Alton	947.9	62.8	373.9	24.8	187.6	12.4	1,509.4
6. Emery	1,086.4	76.0	344.0	24.0	–	–	1,430.4
7. Sego	148.9	50.7	103.6	35.3	41.1	14.0	293.6
8. Mt. Pleasant	–	–	249.1	100.0	–	–	249.1
9. Tabby Mountain	77.1	33.3	77.0	33.3	77.1	33.3	231.2
10. Henry Mtns.	231.0	100.0	–		–		231.0
11. Coalville	93.0	50.0	46.5	25.0	46.5	25.0	186.0
12. Vernal	64.9	36.8	57.5	32.4	54.7	31.0	177.1
13. Salina Canyon	69.1	80.0	17.3	20.0	–		86.4
14. Wales	8.0	65.6	4.2	34.4	–	–	12.2
15. Sterling	1.0	50.0	1.0	50.0	–	–	2.0
16. Harmony	1.3	100.0	–	–	–	–	1.3
17. Lost Creek	1.1	100.0	–	–	–	–	1.1
Total	12,519.9	51.4	8,912.2	36.6	2,917.4	12.0	24,349.5

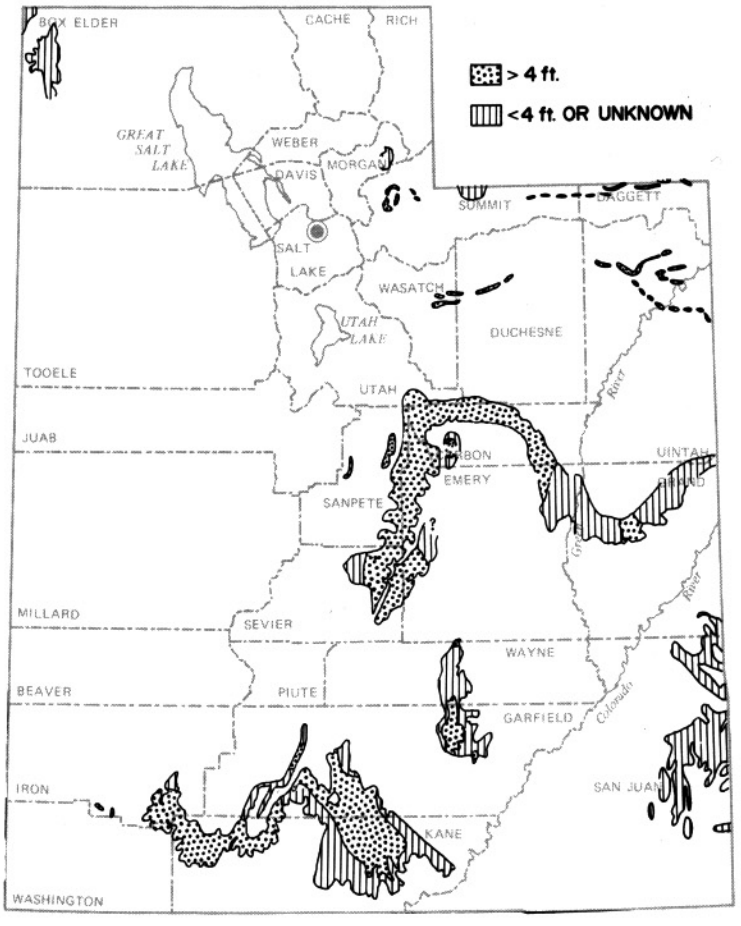


Figure 13. Areas in Utah with coal less than 3,000 feet below the surface.

QUALITY OF COAL

The quality of coal is important to coal rank and calorific value, but also to sulfur and other environmental pollutants. The bulk of past analytical work has identified the proximate condition of Utah coal; except for the traditional mining areas, this is the only adequate data. Fortunately plenty of sulfur analyses were added to the proximate analyses. Tests for coking quality were abandoned once it was sufficiently determined that the coal would not coke. The only areas of Utah containing coking coal are Sunnyside and Woodside, both in the Book Cliffs coal field.

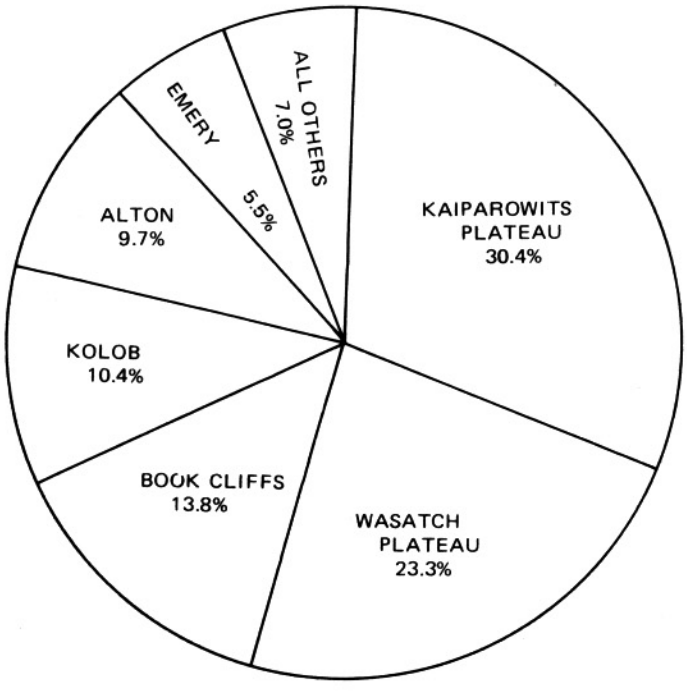


Figure 14. Distribution of recoverable remaining reserves in Utah, 1970, by field.

Table 8. Utah coal budget.

Field	Principal Reserve x 10^6 (tons)	Eliminated by mining x 10^3 (tons)	Estimated Percent Total Recoverability	Remaining Reserve x 10^6 (tons)	Recoverable Reserve x 10^6 (tons)
Kaiparowits Plateau	7,878.0	83.0	30	7,877.9	2,363.4
Wasatch Plateau	6,378.9	331,603.0	30	6,047.3	1,814.2
Book Cliffs	3,667.5	596,571.0	35	3,070.9	1,074.8
Kolob	2,014.3	1,940.0	40	2,012.4	804.9
Alton	1,509.4	100.0	50[1]	1,509.3	754.7
Emery	1,430.4	5,467.0	30	1,424.9	427.5
Sego	293.6	5,889.0	45	287.7	129.5
Mt. Pleasant	249.1	–	40	249.1	99.6
Tabby Mountain	231.2	7.0	30	231.2	69.4
Henry Mountains	231.0	20.0	45[1]	231.0	103.9
Coalville	186.0	14,147.0	30	171.9	51.6
Vernal	177.1	836.7	30	176.3	52.9
Salina Canyon	86.4	1,228.6	35	85.2	29.8
Wales	12.2	2,217.0	30	10.0	3.0
Sterling	2.0	200.0	30	1.8	0.5
Harmony	1.3	0.7	30	1.3	0.4
Lost Creek	1.1	3.0	35	1.1	0.4
Total	24,349.5		33		7,780.5

[1] If part of coal is strip-mined.

The rank of Utah coal ranges from the lowest form of lignite to semianthracite. The upper and lower divisions are rare and the bulk of the reserve ranges between subbituminous C and high-volatile B bituminous coal (table 9). Thirty-two rank determinations were made of the fields and important areas; eight determinations were made in areas where the sampling occurred dominantly at the outcrop rather than in mines or from drill-hole cores. Five of these indicate coal of subbituminous rank; the remainder are high-volatile C bituminous coals. The dominant portion of Utah coal is thought to be high-volatile B or C bituminous coal and the five subbituminous areas may prove to be of a higher rank when mines are developed to extend beyond the outcrop. The best coal of Utah in rank and in low sulfur and ash coupled with considerable reserve are those in the north half of the Wasatch Plateau field and in the Book Cliffs field (high-volatile B bituminous). Tables 10 to 16 summarize the proximate constituents for the field and principal areas. Percents in parentheses estimate the true average where bias is present in the other figure because of too many samples from a particular mine or area.

The principal deleterious constituents of coal are sulfur and ash. Little is known about the sulfur in Utah coal and much analytical work specifically related to sulfur determination needs to be done, especially for the undeveloped areas. Much of the sampling in these areas is from outcrops in which prevention of contamination is difficult. Known data seem to indicate that sulfur content varies little within a particular field or area. Occasional local pockets of high sulfur, however, are encountered almost everywhere. When all analyses of an area are arranged from the lowest to the highest, the curve rises rapidly to a maximum number slightly less than the overall average and then tapers off, quickly at first and then more gradually until the higher determinations are reached (figure 15).

In most cases the analyses made in the high-sulfur part of figure 15 are from (1) outcrops, (2) remote localities of the field or area, (3) thin beds or seams or (4) have been obtained from old or less reliable sources. The samples at B are mostly obtained from the active mines or from drill cores. Most coal samples are channeled, that is, taken from the top to the bottom of the seam. Sometimes in mining, the upper few inches of coal are left as well as the lower few inches. In these parts of the seam the ash content is generally higher; thin splits of shale and bone and interspersed sand usually are concentrated in these areas. No specific examples are available where the coal bed has been subdivided to locate where the sulfur is concentrated. Coal mined in some areas may well be of better quality than that anticipated because of selective mining. A direct correlation between ash content and sulfur content is suspected. Thus where numerous splits in the coal occur in the upper and lower few inches of each seam, the sulfur content

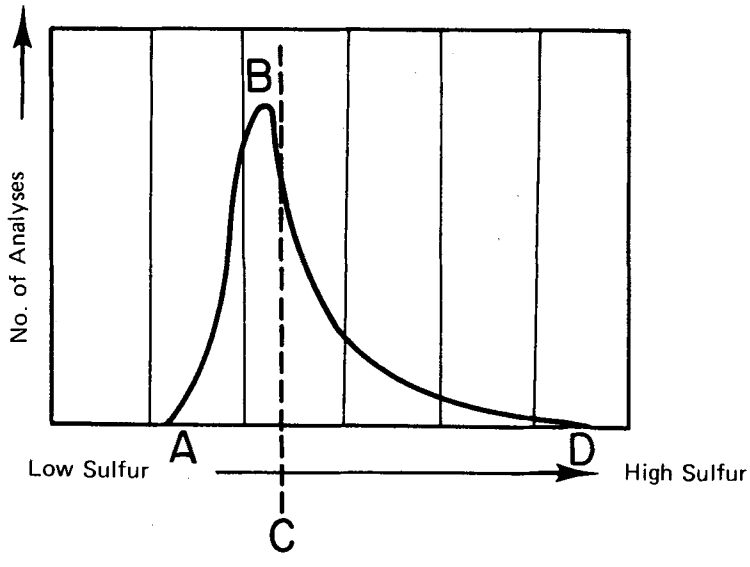


Figure 15. Generalized percent sulfur content–number of analyses chart. (A) Lowest sulfur analysis. (B) Maximum number of analyses with a given sulfur content. (C) Average sulfur content. (D) Highest sulfur analysis.

might be expected to increase, sometimes substantially. Stratigraphic details indicate the shales are full of gypsum; they may give some hint as to why the upper and lower contacts are of higher sulfur content. In one abandoned mine, stalactites of delicate gypsum crystals up to 1 foot long were observed growing from the sandstone roof. The sulfur content of the entire coal seam is less than 1 percent. The condition of coal seams in the Vernal Frontier, Kolob, Henry Mountains Ferron, San Juan, Henrys Fork, Manning Canyon, Harmony and Wales fields is one of relatively thin and/or badly split seams. All the seams have more than 1.5 percent sulfur content. Exceptions are the Sego and Sterling coal fields where thin and often split seams are combined with low-sulfur coals. The Sego and Sterling fields have not been adequately sampled, however. In the one hundred and four Utah samples analyzed by Walker and Hartner (1966, p. 36-38) for forms of sulfur, an average of 2 percent of the sulfur content is sulfate, 19 percent are pyritic and 79 percent are organic. Most individual samples fall in the range of 1 to 3 percent sulfate, 10 to 25 percent pyrite and 70 to 90 percent organic sulfur. The coal contains little sulfur in the form of sulfate, but the contaminating influence of containing rock is mostly sulfate suggesting the possibility of some sort of conversion in the coal, perhaps bacterially. Table 17 and figures 16 to 18 relate the sulfur content of Utah coal to areas and reserve on the basis of percent sulfur in as-received coal to pounds of sulfur per million Btu.

Table 9. General quality characteristics of Utah coal.

Field and Area	Rank	Ash	Sulfur		MMF[1] Btu	Remarks
			Pounds per million Btu	Percent		
Kaiparowits Plateau						
Smoky Mtn.	Hi-vol. C bit.	L	L	L	12,151	many drill-hole samples
Escalante	Hi-vol. C bit.	L	M	L	11,090	A
Tropic	Subbituminous B	H	M	L	10,134	A
Wasatch Plateau						
North five quads.	Hi-vol. C bit.	L	L	L	12,977	B
Hiawatha	Hi-vol. B bit.	L	VL	L	13,642	B
South eight quads.	Hi-vol. C bit.	L	VL	L	12,570	–
Book Cliffs						
Castlegate	Hi-vol. B bit.	L	VL	L	13,737	B
Soldier Canyon	Hi-vol. B bit.	L	VL	VL	13,489	B
Sunnyside	Hi-vol. B bit.	L	M	M	13,442	B
Woodside	Hi-vol. B bit.	L	L	L	13,558	B
Kolob						
Cedar City	Hi-vol. C bit.	H	VH	VH	11,151	B
Orderville	Hi-vol. C bit.	H	H	H	11,525	–
Alton						
Alton	Hi-vol. C bit.	L	M	M	10,808	B
Skutumpah	Subbituminous C	L	M	L	8,877	A
Cannonville	Subbituminous C	VH	M	L	8,744	A
Emery	Hi-vol. C bit.	M	M	L	12,463	–
Sego	Hi-vol. C bit.	H	L	L	12,350	B
Mt. Pleasant	Hi-vol. A bit.	M	L	L	14,014	
Tabby Mountain						
Frontier	Subbituminous C	H	M	L	9,036	A
Mesaverde	Hi-vol. C bit.	L	M	M	10,538	–
Henry Mountains						
Emery	Hi-vol. C bit.	M	L	L	12,410	A
Dakota-Ferron	Hi-vol. B bit.	H	H	H	13,718	rank too high bias in sample?
Coalville	Subbituminous A	VL	H	M	11,109	B
Vernal						
Mesaverde	Subbituminous C	VH	M	L	9,265	A
Frontier	Hi-vol. C bit.	VH	H	M	11,741	B
Salina Canyon	Hi-vol. C bit.	M	VL	VL	12,652	B
Wales	Hi-vol. C bit.	VH	VH	VH	11,466	B
Sterling	Hi-vol. C bit.	L	L	L	12,483	B
Harmony	Hi-vol. C bit.	VH	VH	VH	12,255	B some semi-anthracite
Lost Creek	Subbituminous B	VH	L	L	10,391	–
Henrys Fork						
Manning Canyon	Hi-vol. C bit.	VH	VH	H	11,983	A
San Juan	Hi-vol. B bit.	VH	VH	H	13,616	rank too high bias in sample?

[1]Moist, mineral free coal.

A - mostly oxidized outcrop coal.

B - mostly mine or tipple samples.

Key		Percent Ash	Lbs. Btu x 10^6 Sulfur	Percent Sulfur
Very high	(VH)	>12.0	>2.4	>3.0
High	(H)	10-12	1.2-2.4	2.0-3.0
Medium	(M)	8-10	0.8-1.2	1.0-2.0
Low	(L)	5-8	0.5-0.8	0.5-1.0
Very low	(VL)	<5.0	<0.5	<0.5

Table 10. Moisture content of Utah coal.

Field and Area	No. Analyses	Percent	
		Average	Range
Kaiparowits Plateau	137	11.3	3.6-28.7
a. Smoky Mtn. area	77	9.6	3.7-24.2
b. Escalante area	40	10.5	3.6-24.8
c. Tropic area	20	19.5	9.4-28.7
Wasatch Plateau	914	6.1	0.7-14.5
a. North five quads.	210	7.2	2.7-14.5
b. Hiawatha quads.	608	5.4	0.7-13.2
c. South eight quads.	25	8.8	5.6-13.9
Book Cliffs	1,298	4.6(4.8)	0.6-24.5
a. Castlegate area	875	4.3	0.6-24.5
b. Soldier Canyon	233	4.8	2.2- 8.5
c. Sunnyside	79	5.0	3.1- 7.9
d. Woodside	111	5.5	1.9- 9.8
Kolob	95	8.6(10.2)	2.8-17.6
a. Cedar City	86	8.2	2.8-17.3
b. Orderville	9	12.1	4.8-17.6
Alton	28	17.8	8.8-28.3
a. Alton	13	17.0	11.4-20.6
b. Skutumpah	11	19.3	12.5-28.3
c. Cannonville	4	15.8	8.8-21.7

Table 10. (continued)

Field and Area	No. Analyses	Percent	
		Average	Range
Emery	47	7.4	2.3-23.6
Sego	27	9.1	5.2-20.0
Mt. Pleasant	7	3.4	2.4- 4.7
Tabby Mountain	7	16.9	10.1-27.4
a. Frontier zone	3	19.4	14.8-27.4
b. Mesaverde zone	4	15.0	10.1-19.2
Henry Mountains	16	8.0	4.5-13.9
a. Emery zone	13	9.8	5.7-13.9
b. Ferron and Dakota	3	5.3	4.5- 5.9
Coalville	53	12.0	1.2-17.1
Vernal	36	9.3	5.5-15.3
a. Mesaverde zone	2	12.8	12.5-13.1
b. Frontier zone	34	9.1	5.5-15.3
Salina Canyon	13	7.6	5.7-14.9
Wales	12	5.0	1.2-14.2
Sterling	1	8.2	8.2
Harmony	11	6.7	2.6-11.0
Lost Creek	2	17.9	17.6-18.1
Henrys Fork	2	5.4	2.3- 8.4
San Juan	2	3.5	2.7- 4.3

Table 11. Volatile matter content of Utah coal.

Field and Area	No. Analyses	Percent Average	Percent Range
Kaiparowits Plateau	164	43.6[1]	21.9-57.5
a. Smoky Mtn. area	91	42.4[1]	21.9-57.4
b. Escalante area	53	45.4[1]	37.5-57.5
c. Tropic area	20	44.4[1]	35.7-48.0
Wasatch Plateau	773	42.0	34.4-54.3
a. North five quads.	188	41.3	35.3-54.3
b. Hiawatha quads.	563	42.3	36.3-46.4
c. South eight quads.	22	38.2	34.4-41.0
Book Cliffs	1,198	41.2 (39.3)	16.4-64.3
a. Castlegate	820	42.6	31.4-64.3
b. Soldier Canyon	218	38.6	30.9-45.7
c. Sunnyside	63	38.2	33.9-42.9
d. Woodside	97	37.5	16.4-44.7
Kolob	95	39.8	33.4-46.9
a. Cedar City	86	39.8	33.4-46.1
b. Orderville	9	40.1	37.0-46.9
Alton	27	41.2[1]	35.5-47.4
a. Alton	12	40.2[1]	37.5-44.6
b. Skutumpah	11	43.6[1]	39.2-47.4
c. Cannonville	4	37.9[1]	35.5-40.7
Emery	46	38.0	32.6-43.9
Sego	23	34.7	28.7-42.2
Mt. Pleasant	7	42.9	41.8-45.2
Tabby Mountain	7	36.3	32.0-39.9
a. Frontier zone	3	33.5	32.0-36.5
b. Mesaverde zone	4	38.4	37.0-39.9
Henry Mountains	16	37.9	32.0-61.8
a. Emery zone	13	36.5	32.0-38.5
b. Ferron and Dakota	3	44.1	33.6-61.8
Coalville	52	38.4	31.4-46.9
Vernal	36	39.6[1]	32.5-46.9
a. Mesaverde zone	2	42.7[1]	38.4-46.9
b. Frontier zone	34	39.4[1]	32.5-43.0
Salina Canyon	11	41.2	34.4-45.5
Wales	13	34.2	21.0-43.2
Sterling	1	42.6	42.6
Harmony	11	10.4	4.4-13.4
Lost Creek	2	27.6	27.4-27.8
Henrys Fork	2	35.3	32.1-38.5
San Juan	2	28.2	24.1-32.3

[1] Dry coal.

Table 12. Fixed carbon content of Utah coal.

Field and Area	No. Analyses	Percent Average	Percent Range
Kaiparowits Plateau	164	47.3[1]	22.8-71.5
a. Smoky Mtn. area	91	48.7[1]	22.8-71.5
b. Escalante area	53	46.8[1]	38.5-53.6
c. Tropic area	20	41.8[1]	31.2-47.1
Wasatch Plateau	773	45.4	28.3-54.4
a. North five quads.	188	45.2	28.3-53.5
b. Hiawatha quads.	563	45.4	35.1-51.2
c. South eight quads.	22	47.1	43.3-54.4
Book Cliffs	1,197	47.4 (49.1)	28.3-74.3
a. Castlegate	819	46.4	28.3-52.1
b. Soldier Canyon	218	49.3	44.0-52.9
c. Sunnyside	63	50.5	44.8-54.2
d. Woodside	97	50.1	41.6-74.3
Kolob	95	41.7(39.2)	26.7-50.3
a. Cedar City	86	42.3	26.7-50.3
b. Orderville	9	36.0	27.3-46.0
Alton	27	47.6[1]	37.8-54.0
a. Alton	12	50.3[1]	40.5-54.0
b. Skutumpah	11	46.7[1]	40.7-53.8
c. Cannonville	4	41.6[1]	37.8-43.5
Emery	46	45.7	33.3-51.9
Sego	23	46.8	38.4-52.6
Mt. Pleasant	7	45.6	43.9-48.9
Tabby Mountain	7	39.0	35.6-45.7
a. Frontier zone	3	36.9	35.6-37.9
b. Mesaverde zone	4	40.5	37.6-45.7
Henry Mountains	16	43.3	35.7-49.1
a. Emery zone	13	43.9	35.7-49.1
b. Dakota and Ferron	3	40.7	36.3-44.9
Coalville	53	44.7	40.5-64.5
Vernal	36	48.0[1]	39.5-54.2
a. Mesaverde zone	2	39.9[1]	39.5-40.2
b. Frontier zone	34	48.5[1]	40.1-54.2
Salina Canyon	11	41.1	36.3-48.3
Wales	13	46.4	24.6-55.5
Sterling	1	43.2	43.2
Harmony	11	56.0	36.1-71.7
Lost Creek	2	36.1	35.3-36.9
Henrys Fork	2	47.0	45.0-48.9
San Juan	2	47.3	42.3-52.3

[1] Dry coal.

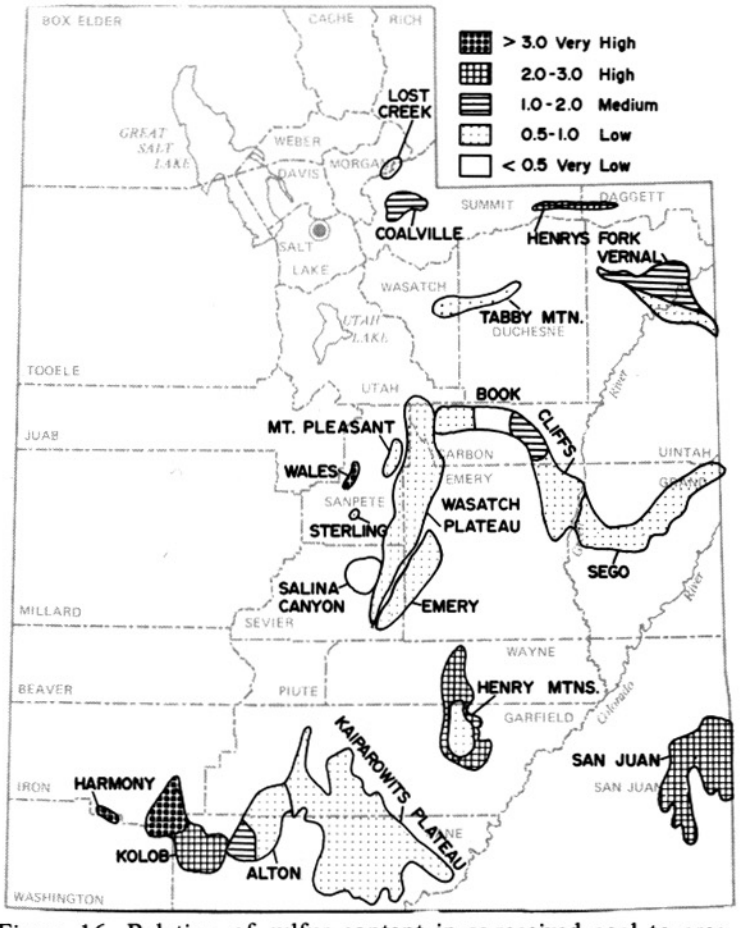


Figure 16. Relation of sulfur content in as-received coal to area.

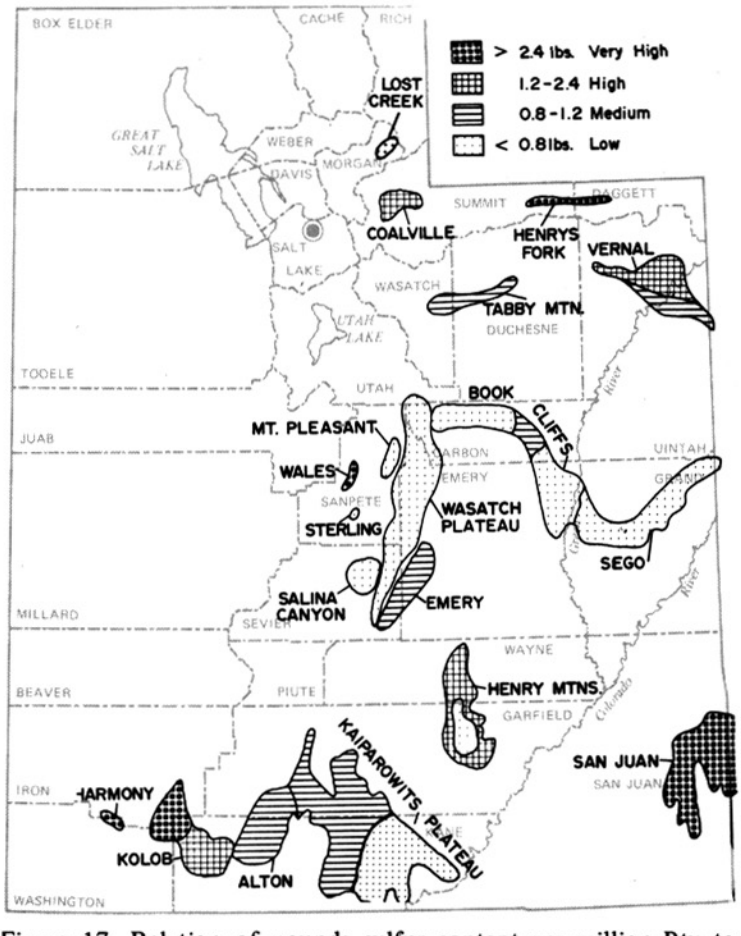


Figure 17. Relation of pounds sulfur content per million Btu to area.

Table 13. Sulfur content of Utah coal.

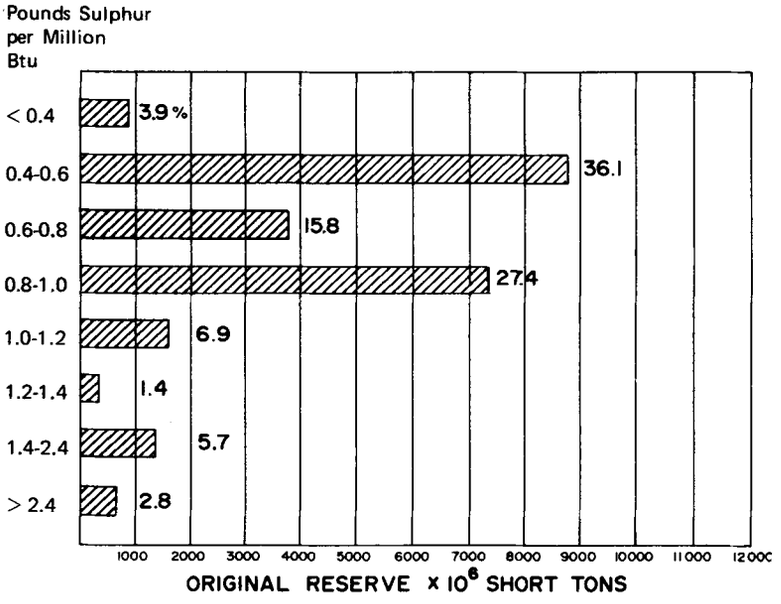
Field and Area	No. Analyses	Percent Average	Percent Range
Kaiparowits Plateau	129	0.87[1]	0.26-3.40
a. Smoky Mtn. area	91	0.75[1]	0.26-1.50
b. Escalante area	24	1.26[1] (0.98)	0.42-3.40
c. Tropic area	14	0.98[1]	0.60-1.73
Wasatch Plateau	722	0.60	0.23-1.60
a. North five quads.	159	0.64	0.31-1.60
b. Hiawatha quads.	538	0.59	0.23-1.50
c. South eight quads.	25	0.56	0.30-0.90
Book Cliffs	1,149	0.58(0.85)	0.10-3.00
a. Castlegate	784	0.53	0.10-2.10
b. Soldier Canyon	206	0.49	0.30-1.00
c. Sunnyside	67	1.09	0.50-3.00
d. Woodside	92	0.70	0.50-1.15
Kolob	76	5.34(3.99)	1.10-7.30
a. Cedar City	67	5.76	1.11-7.30
b. Orderville	9	2.21	1.10-4.03
Alton	28	1.16[1]	0.46-2.30
a. Alton	13	1.33[1]	0.50-2.30
b. Skutumpah	11	1.07[1]	0.46-2.30
c. Cannonville	4	0.87	0.70-1.20
Emery	46	0.99	0.31-4.66
Sego	27	0.60	0.37-1.00
Mt. Pleasant	7	0.80	0.50-1.60
Tabby Mountain	7	0.87	0.60-1.47
a. Frontier zone	3	0.70	0.60-0.83
b. Mesaverde zone	4	1.00	0.69-1.47
Henry Mountains	16	1.26	0.46-3.20
a. Emery zone	13	0.87	0.46-1.70
b. Ferron and Dakota	3	2.93	2.50-3.20
Coalville	41	1.32	0.33-2.00
Vernal	36	1.60[1]	0.30-2.60
a. Mesaverde zone	2	0.80[1]	0.30-1.20
b. Frontier zone	34	1.60[1]	0.60-2.60
Salina Canyon	12	0.45	0.32-0.60
Wales	8	4.30	2.88-6.79
Sterling	1	0.9	0.9
Harmony	11	3.31	1.88-4.44
Lost Creek	2	0.53	0.46-0.60
Henrys Fork	2	2.86	0.52-5.2
San Juan	2	2.90	2.00-3.80

[1] Dry coal.

Table 14. Ash content of Utah coal.

Field and Area	No. Analyses	Percent Average	Percent Range
Kaiparowits Plateau	165	9.0[1]	3.4-33.0
a. Smoky Mtn. area	91	8.6[1]	3.6-19.8
b. Escalante area	54	7.8[1]	3.4-24.9
c. Tropic area	20	13.8[1]	7.7-33.0
Wasatch Plateau	812	6.5	1.4-18.3
a. North five quads.	204	6.1	2.6-13.5
b. Hiawatha quads.	583	6.6	2.8-18.3
c. South eight quads.	25	6.7	1.4-10.0
Book Cliffs	1,238	6.7	3.4-13.2
a. Castlegate	845	6.6	3.8-13.2
b. Soldier Canyon	225	7.0	3.4-12.6
c. Sunnyside	68	6.4	4.2-11.9
d. Woodside	100	6.7	3.8-11.4
Kolob	96	10.9	3.2-27.1
a. Cedar City	87	10.8	3.2-27.1
b. Orderville	9	11.5	3.9-23.2
Alton	28	11.2[1]	4.7-25.7
a. Alton	13	9.4[1]	6.3-14.9
b. Skutumpah	11	9.8[1]	4.7-14.6
c. Cannonville	4	20.5[1]	15.8-25.7
Emery	47	8.9	4.0-23.6
Sego	27	11.1	4.2-19.0
Mt. Pleasant	7	8.1	5.1-11.3
Tabby Mountain	7	8.1	2.6-17.6
a. Frontier zone	3	10.2	2.6-17.6
b. Mesaverde zone	4	6.6	5.9- 8.2
Henry Mountains	16	9.7	1.9-18.8
a. Emery zone	13	9.4	4.9-18.8
b. Ferron and Dakota	3	10.8	1.9-16.0
Coalville	54	4.4	1.5-14.5
Vernal	36	12.8[1]	6.9-27.4
a. Mesaverde zone	2	17.5[1]	12.9-22.1
b. Frontier zone	34	12.5[1]	6.9-27.4
Salina Canyon	13	9.6	4.2-13.2
Wales	13	14.8	4.0-29.2
Sterling	1	6.1	6.1
Harmony	11	26.6	11.1-43.0
Lost Creek	2	18.5	17.8-19.2
Henrys Fork	2	12.4	10.3-14.5
San Juan	2	21.0	11.1-30.9

[1] Dry coal.



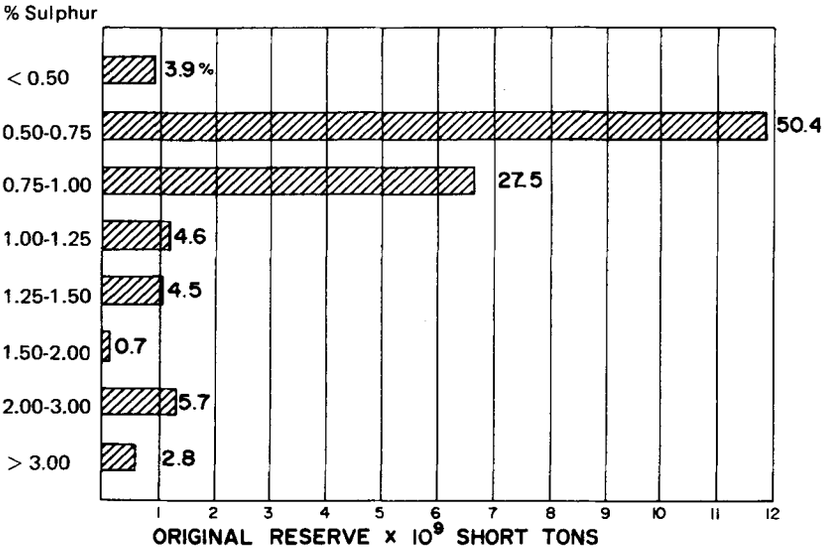


Figure 18. Relation of pounds of sulfur per million Btu to reserves.

Table 15. Btu/lb content of Utah coal.

Field and Area	No. Analyses	Percent Average	Percent Range
Kaiparowits Plateau	161	11,999[1]	8,499-14,236
a. Smoky Mtn. area	91	12,401[1]	10,736-13,746
b. Escalante area	53	11,563[1]	8,499-14,236
c. Tropic area	17	11,207[1]	8,826-12,699
Wasatch Plateau	788	12,589	10,250-13,690
a. North five quads.	184	12,200	10,250-13,650
b. Hiawatha quads.	582	12,744	10,800-13,690
c. South eight quads.	22	11,727	10,540-12,400
Book Cliffs	1,242	12,762	7,045-14,220
a. Castlegate	854	12,825	7,045-13,530
b. Soldier Canyon	225	12,531	11,390-13,390
c. Sunnyside	58	12,648	9,530-13,660
d. Woodside	105	12,664	10,860-14,220
Kolob	73	10,474	8,480-11,430
a. Cedar City	64	10,492	8,480-11,430
b. Orderville	9	10,344	9,508-11,297
Alton	27	10,770	8,080-12,329
a. Alton	12	12,070[1]	10,782-12,329
b. Skutumpah	11	10,166[1]	8,580-11,758
c. Cannonville	4	8,530[1]	8,080- 9,723

[1] Dry coal.

Table 15. (continued)

Field and Area	No. Analyses	Percent Average	Percent Range
Emery	44	11,424	7,823-12,970
Sego	18	10,940	9,000-12,150
Mt. Pleasant	7	12,890	12,440-13,290
Tabby Mountain	7	9,130	7,430-10,382
a. Frontier zone	3	8,110	7,430- 8,830
b. Mesaverde zone	4	9,895	8,723-10,382
Henry Mountains	16	11,484	9,015-14,308
a. Emery zone	13	11,253	9,015-12,954
b. Ferron and Dakota	3	12,486	10,840-14,308
Coalville	45	10,728	8,870-12,851
Vernal	36	11,367[1]	6,810-13,003
a. Mesaverde	2	8,950[1]	8,110- 9,790
b. Frontier	34	11,509[1]	6,810-13,003
Salina Canyon	11	11,367	9,690-12,080
Wales	6	10,119	6,554-11,857
Sterling	1	11,767	11,767
Harmony	11	9,123	7,690-10,700
Lost Creek	2	8,372	8,180- 8,563
Henrys Fork	2	10,710	8,870-12,550
San Juan	2	10,890	9,300-12,480

[1] Dry coal.

Table 16. Average proximate analyses for Utah coal fields. (Tables 10 to 15 do not total 100 percent in most cases because different numbers of samples for each constituent were used to determine averages. This summary equates everything to 100 percent and converts all constituents to the dry basis.

Field and Area	Moisture AR[1]	Volatile Matter AR	Volatile Matter Dry	Fixed Carbon AR	Fixed Carbon Dry	Ash AR	Ash Dry	Sulfur AR	Sulfur Dry	Btu/lb AR	Btu/lb Dry
Kaiparowits Plateau											
Smoky Mountain area	9.6	–	42.5	–	48.8	–	8.7	–	0.75	–	12,401
Escalante area	10.5	–	45.4	–	46.8	–	7.8	–	1.26	–	11,563
Tropic area	19.5	–	44.4	–	41.8	–	13.8	–	0.98	–	11,207
Wasatch Plateau											
North five quads.	7.2	41.4	44.6	45.3	48.8	6.1	6.6	0.64	0.69	12,200	13,147
Hiawatha quads.	5.4	42.4	44.8	45.5	48.1	6.7	7.1	0.59	0.62	12,744	13,470
South eight quads.	8.0	38.2	41.5	47.1	51.2	6.7	7.3	0.56	0.61	11,727	12,747
Book Cliffs											
Castlegate area	4.3	42.6	44.5	46.5	48.6	6.6	6.9	0.53	0.55	12,825	13,402
Soldier Canyon area	4.8	38.7	40.6	49.4	51.9	7.1	7.5	0.49	0.51	12,531	13,158
Sunnyside area	5.1	38.1	40.2	50.4	53.1	6.4	6.7	1.09	1.15	12,648	13,331
Woodside area	5.5	37.6	39.8	50.2	53.1	6.7	7.1	0.70	0.74	12,664	13,399
Kolob											
Cedar City area	8.2	39.4	42.9	41.8	45.5	10.6	11.6	5.76	6.27	10,492	11,426
Orderville area	12.1	40.2	45.7	36.2	41.2	11.5	13.1	2.21	2.51	10,344	11,771
Alton											
Alton area	17.0	–	40.2	–	50.4	–	9.4	–	1.33	–	12,070
Skutumpah area	19.3	–	43.6	–	46.6	–	9.8	–	1.07	–	10,166
Cannonville area	15.8	–	37.9	–	41.6	–	20.5	–	0.87	–	8,530
Emery	7.4	38.0	41.0	45.7	49.4	8.9	9.6	0.99	1.07	11,424	12,338
Sego	8.9	34.1	37.4	46.1	50.6	10.9	12.0	0.60	0.66	10,940	12,012
Mt. Pleasant	3.4	42.9	44.4	45.6	47.3	8.1	8.4	0.80	0.83	12,890	13,341
Tabby Mountain											
Frontier zone	19.4	33.5	41.6	36.9	45.8	10.2	12.6	0.70	0.87	8,110	10,065
Mesaverde zone	14.9	38.2	44.9	40.3	47.4	6.6	7.8	1.00	1.18	9,895	11,627
Henry Mountains											
Emery zone	9.8	36.6	40.6	44.1	48.9	9.5	10.5	0.87	0.96	11,253	12,480
Ferron and Dakota zones	5.3	43.7	46.1	40.3	42.6	10.7	11.3	2.93	3.10	12,486	13,185
Coalville	12.0	38.6	43.8	44.9	51.1	4.5	5.1	1.32	1.50	10,728	12,187
Vernal											
Mesaverde zone	12.8	–	42.7	–	39.8	–	17.5	–	0.80	–	8,950
Frontier zone	9.1	–	39.3	–	48.3	–	12.4	–	1.60	–	11,509
Salina Canyon	7.6	41.4	44.8	41.3	44.7	9.7	10.5	0.45	0.49	11,367	12,299
Wales	5.0	34.1	36.0	46.2	48.5	14.7	15.5	4.30	4.53	10,119	10,655
Sterling	8.2	42.6	46.4	43.1	47.0	6.1	6.6	0.90	0.98	11,767	12,874
Harmony	6.7	10.4	11.2	56.2	60.2	26.7	28.6	3.31	3.54	9,123	9,780
Lost Creek	17.9	27.6	33.6	36.0	43.9	18.5	22.5	0.53	0.65	8,372	10,197
Henrys Fork											
Manning Canyon Shale	5.4	35.3	37.3	46.9	49.6	12.4	13.1	2.86	3.02	10,710	11,320
San Juan	3.5	28.2	29.2	47.3	49.0	21.0	21.8	2.90	3.00	10,890	11,282

[1] As-received.

Table 17. Pounds of sulfur per million Btu compared to principal reserve.

Field and Area	Pounds	Reserve (tons x 10^6)
1. Book Cliffs-Soldier Canyon	0.391	865.8
2. Salina Canyon	0.396	86.4
3. Book Cliffs-Castlegate	0.413	1,652.4
4. Wasatch Plateau-Hiawatha	0.463	1,878.7
5. Wasatch Plateau-South 8 quads.	0.478	2,069.9
6. Wasatch Plateau-North 5 quads.	0.525	2,430.3
7. Sego	0.548	293.6
8. Book Cliffs-Woodside	0.553	471.4
9. Kaiparowits-Smoky Mtn.	0.607	3,404.0
10. Mt. Pleasant	0.633	1.1
11. Lost Creek	0.765	2.0
12. Sterling	0.773	186.9
13. Henry Mountains-Emery	0.847	3,490.9
14. Kaiparowits-Escalante	0.850	3,491.1
15. Kaiparowits-Tropic	0.854	982.9
16. Book Cliffs-Sunnyside	0.862	677.9
17. Tabby Mountain-Frontier	0.863	63.2
18. Emery	0.867	1,430.4
19. Vernal-Mesaverde	0.897	12.9
20. Tabby Mountain-Mesaverde	1.011	168.0
21. Alton-Cannonville	1.016	171.5
22. Alton-Skutumpah	1.048	437.8
23. Alton-Alton	1.098	900.1
24. Coalville	1.230	186.0
25. Vernal-Frontier	1.386	164.2
26. Kolob-Orderville	2.127	1,339.5
27. Henry Mountains-Dakota, Ferron	2.347	44.1
28. San Juan	2.663	–
29. Henrys Fork-Manning Canyon	2.670	–
30. Harmony	3.628	1.3
31. Wales	4.249	12.2
32. Kolob-Cedar City	5.490	674.8

Ash, the unburnable part of coal, leaves a residue of clinker or in the form of fine particulate matter. For pollution control and environmental protection, expense must be allotted for its control and disposal. Users of coal will always choose low-ash coal and, therefore, some of the coal is prepared to lower ash content. In these processes the lower ash product is produced at the expense of a percentage of the initial input. Thus some of the coal is lost or must be sold at a low price and the price for the clean coal must go up.

Another important property of the ash is how the ash reacts during the burning process–whether it coagulates in large or small lumps, whether it produces mostly fines. The composition of the ash, whether harmful substances may be volatized and expelled into the atmosphere during burning, must be considered. Through technological advance, more than 99 percent of the fine particulate matter can be removed from the flues of coal-fired power plants so they are not dispersed in the atmosphere. Evenso a plant with an ash content of 8 percent burning 20,000 tons per day would still expel 8 tons per day. Abernethy, Peterson and Gibson (1969, p. 23) ran spectrochemical analyses of coal ash for trace elements; the results are summarized in table 18. The samples are mostly from Carbon and Emery counties.

Table 18. Spectrochemical analyses of twenty-two Utah coals.

Trace Element	Average Ash (percent)	Trace Element	Average Ash (percent)
Arsenic	.0002	Niobium	.0035
Boron	.0877	Neodymium	.0043
Barium	.1150	Nickel	.0052
Beryllium	.0003	Lead	.0024
Cobalt	.0067	Rubidium	.0027
Chromium	.0088	Scandium	.0037
Copper	.0039	Selenium	.0014
Gallium	.0031	Strontium	.1432
Germanium	.0007	Vanadium	.0118
Lanthanum	.0091	Yttrium	.0066
Lithium	.0099	Zinc	.0111
Manganese	.0159	Zirconium	.0855
Molybdenum	.0013		

Most trace elements are enriched in coal, except manganese, chromium, copper, nickel and rubidium. Some of the above elements are valuable and ash piles of some coals eventually may become ore bodies. Gold is often found in greater than crustal

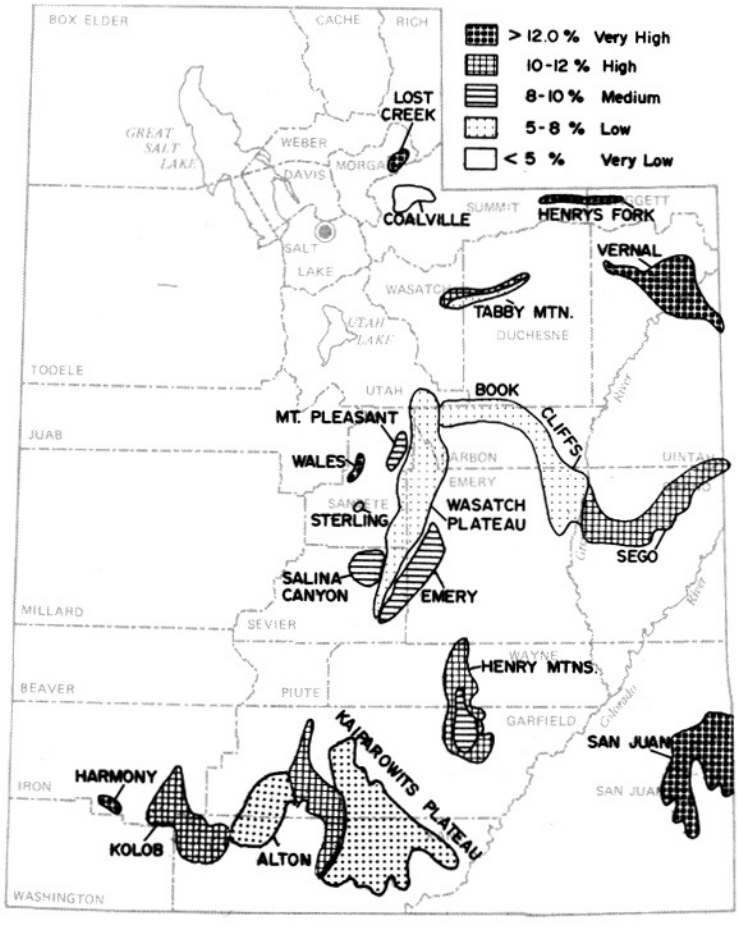


Figure 19. Relation of ash content of Utah coal (as-received) to area.

abundances in coal. This is true in the Wales field, Sanpete County (Stone, 1912, p. 63-64). Some electric generating plants produce

Table 19. Relation of ash content of Utah coal to principal reserve.

Field and Area	Average ash content, percent	Reserve (tons x 10^6)
Kaiparowits Plateau	9.1[1]	
a. Smoky Mtn. area	8.6[1]	3,404.0
b. Escalante area	7.8[1]	3,491.1
c. Tropic area	13.8	982.9
Wasatch Plateau	6.5	
a. North five quads.	6.1	2,430.3
b. Hiawatha quads.	6.6	1,878.7
c. South eight quads.	6.7	2,069.9
Book Cliffs	6.7	
a. Castlegate	6.6	1,652.4
b. Soldier Canyon	7.0	865.8
c. Sunnyside	6.4	677.9
d. Woodside	6.7	471.4
Kolob	10.9	
a. Cedar City	10.8	674.8
b. Orderville	11.5	1,339.5
Alton	11.2[1]	
a. Alton	9.4[1]	900.1
b. Skutumpah	9.8[1]	437.8
c. Cannonville	20.5[1]	171.5
Emery	8.9	1,430.4
Sego	11.1	293.6
Mt. Pleasant	8.1	1.1
Tabby Mountain	8.1	
a. Frontier zone	10.2	63.2
b. Mesaverde zone	6.6	168.0
Henry Mountains	9.7	
a. Emery zone	9.4	3,490.9
b. Ferron and Dakota	10.8	44.1
Coalville	4.4	186.0
Vernal	12.8[1]	
a. Mesaverde zone	17.5[1]	12.9
b. Frontier zone	12.5[1]	164.2
Salina Canyon	9.6	86.4
Wales	14.8	12.2
Sterling	6.1	186.9
Harmony	26.6	1.3
Lost Creek	18.5	2.0
Henrys Fork	12.4	–
San Juan	21.0	–

[1] Dry coal.

light-weight aggregate from the ash of the coal they burn. Figure 19 and table 19 relate ash content to field and reserve.

To illustrate the effect of weathering on outcrop coal the Btu/lb determinations of the Escalante area of the Kaiparowits Plateau are assembled and averaged as to sample origin (figure 20). Outcrop versus mine sampling produces a difference of more than 1,000 Btu/lb.

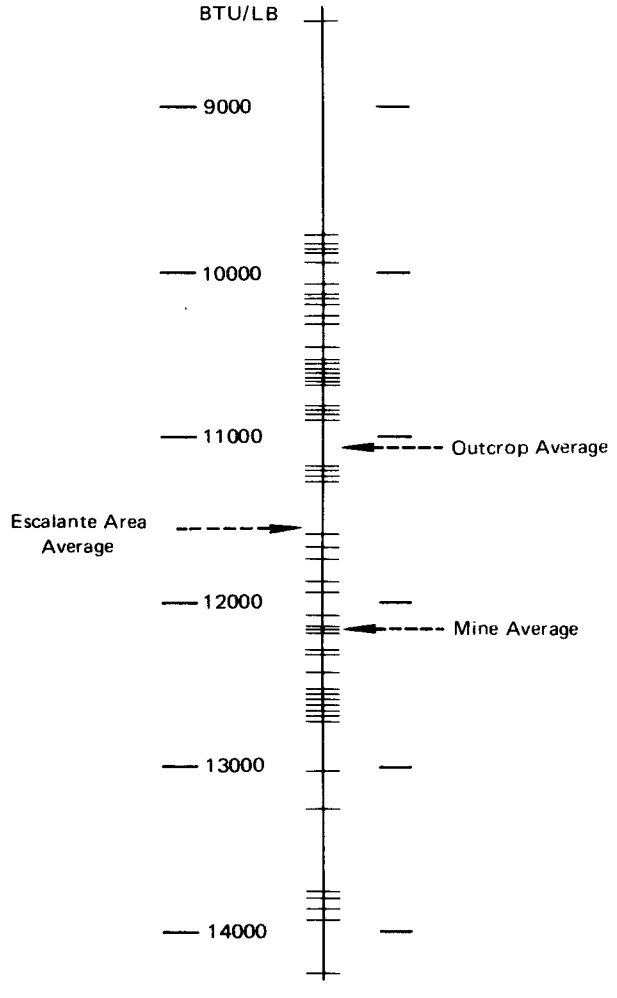


Figure 20. Average of Btu/lb determinations according to sample origin, Escalante area.

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ECONOMIC EVALUATION OF UTAH COAL – 1972

by Claude P. Heiner[1]

INTRODUCTION

The nation's demand for coal can be expected to grow at an average rate of 3 to 5.3 percent per year, according to the U. S. Bureau of Mines. Abundant coal reserves in Utah could substantially lessen the burden once areas of low-sulfur, minable coal are identified and evaluated.

This study focuses on the economic considerations in evaluating Utah coal.

COAL QUALITY

Commercial coals produced in the Book Cliffs, Wasatch Plateau and Emery coal fields are classed as bituminous B and C rank with high-volatile content and Btu/lb ranging from 11,500 to 13,000 on an as-received basis (see *Coal in Utah–1970,* by H. H. Doelling, tables 9 to 16, p. 555 to 558). Generally the coals are noncoking although large tonnages from the Sunnyside district, Book Cliffs coal field, have coking tendencies suitable for blending with stronger coking coals produced in the Colorado, Oklahoma-Arkansas and Appalachian areas. All coals, except from the Sunnyside area, are valuable chiefly for steam-generating or industrial processes; wide variations of coal quality in the south Utah fields (Kaiparowits Plateau, Kolob, Alton and in smaller outlying fields) occur in:

1. *Moisture content* – bed moisture; total moisture depends on mine sprinkling, washing or transport of coal slurry by pipeline.
2. *Ash content* – inherent ash plus rock and boney coal. Ash analysis – fusing characteristics.
3. *Sulfur content* – pyritic, sulfate and organic forms.
4. *Volatile matter content* – quality affects Btu content; 35 to 45 percent of coal weight.
5. *Fixed carbon content* – high heat content, generally 40 to 50 percent of coal weight.
6. *Btu/lb content* – depends on coal rank and contained impurities of moisture, ash, sulfur, nitrogen and oxygen.

In Utah underground mines, coal quality generally improves with depth (i.e., with distance from outcrop). Especially in the Sunnyside area, the deeper coal contains less oxygen, therefore, has better coking quality than the near-outcrop coal. Cover over the coal seam appears less important than distance down-pitch from the coal outcrops where stagnant water conditions appear to protect the coal from oxidation. Increased depth, however, offsets the improvement–mining costs are increased and extraction of the deeper, better coal becomes more difficult.

Moisture

Bed moisture ranges from 4 to 6 percent in most Utah commercial coals (Book Cliffs, Wasatch Plateau and Emery fields), except Coalville subbituminous coal (12 to 14 percent moisture). South Utah coal fields (Kaiparowits Plateau, Kolob and Alton) are higher moisture coals and may require more expensive preparation prior to burning. Following heavy sprinkling of underground coal to allay all possible dust, natural coal moisture is increased appreciably on slack sizes, probably up to 5 percent (12 gal/ton coal to limit respirable dust in mine air to 2 to 3 mg/cubic meter of air). Experience in the Book Cliffs and portions of the Wasatch Plateau fields shows the following moisture content in actual shipments (table 1):

[1] Independent consultant, Salt Lake City, Utah.

Table 1. Moisture content of shipped coal, Book Cliffs and Wasatch Plateau coal fields.

	Percent	
	November-February	April-October
Raw coal, total moisture	8-10[1]	5-7
Washed coal, *no heat drying*	9-10[1]	7-9[2]
Washed coal, *heat dried*	6-8	4-6

[1] Results in freezing problems in railroad cars during cold weather.
[2] Export coal limit 7 percent moisture.

The reduction of coal slurry moisture for final pulverization can be accomplished by close control of slurry and through improvements in mechanical dewatering (filters and centrifuges). Heated air infusions prior to or at time of final pulverization further reduce moisture content to bone dry condition before burning in the boilers. Normal drying and pulverization of Utah slack coals for power plants, smelters and cement kilns can be accomplished by standard unit pulverizers, ball or tube mills as each installation requires.

If technology continues to advance in reducing moisture content to design levels, as now appears probable, many high-moisture Utah coals (Alton, Escalante and Tropic fields of south Utah, as well as the Kaiparowits Plateau field coals in general) eventually may be successfully transported in slurry form. Thus new markets may open in Arizona, Nevada and California.

Ash and Mineral Constituents of Ash

Raw Utah commercial slack coals (Book Cliffs, Wasatch Plateau and Emery fields) contain from 6 to 12 percent ash content, because of rock, bone and clay variations. Wet washing of raw coal levels ash and pyritic sulfur content by eliminating impurities on specific gravity basis. Commercial shipment of raw Utah coals over great distances by rail is not economically feasible because impurities reduce coal value, either for coking or boiler plant use.

High-ash constituents of raw coal are generally refractory (high silica) in nature, resulting in high-fusion coal ash as burned in combustion processes; certain Utah coal seams, however, contain impurities with high lime and iron content rendering the raw coal low fusion and the washed coal high fusion. Washing is intended to produce saleable coal of constant ash content and fusing characteristics, both advantageous to coal users.

All Utah coal areas can produce coal with satisfactory ash analysis. In some areas (Castlegate, Hiawatha, south Wasatch Plateau, Alton) ash-fusing characteristics justify "wet bottom" boiler installations; in general, however, the coals are all suitable for "dry bottom" nonslagging operation. More research and study must be given to ash analysis and fusing characteristics for all Utah coal fields before specific recommendations can be made. Total alkali content ($Na_2O + K_2O$) of ash runs less than 5.7 percent in all coals tested so far.

U. S. Bureau of Mines analyses show grindability of Utah coals by the Hardgrove method ranges between 41 to 55 (higher grindability values indicate lower pulverization costs). Grinding and

pulverization are considered satisfactory for use in power plant boilers, cement kilns and smelters where coal is burned in pulverized form. Power requirements to grind coal affect cost as a result of coal hardness, but Utah fields in general compare favorably in pulverization costs with other Intermountain coals.

Because of the high investment cost of modern plants and the elimination and disposal cost of 5 to 20 percent of the raw product in Utah washeries, the washing process substantially increases the cost of coal to consumers. Assuming a raw coal cost of $5 per ton and a 10 percent loss in washing, cost of washed coal can be increased $ .75 to $1.00 per ton more than the raw product.

Advantages of higher-cost wet washed coals are summarized as follows:

1. Substantially better operation and higher efficiency in coal burning or coking processes.

2. Lower freight costs in transporting burnable coal to points of consumption and lower costs of coal slurry pipelining and handling the slurry (dewatering, drying and pulverization) at receiving end of pipeline; high variable clay and ash content prevent even flow of coal slurry through pipeline and cause poor performance of mechanical dewatering devices at receiving end.

3. Environmental advantages of less particulate matter in stack gases – possibly lower sulfur content – which lowers investment and operating costs of electrostatic precipitation and scrubbing by sulfur removal processes.

Slack coals have not proven feasible to dry clean over air tables unless such sizes are pre-dried by heat. Wet cleaning by Baum-type jigs of 3- by 0-size has proved the most economical to date at Utah coal washeries; because jigs do not satisfactorily clean fine sizes, oil flotation of fine sizes followed by mechanical dewatering or filtering produces lower ash and sulfur of fine sizes.

Sulfur

Utah coals generally are considered low sulfur (½ to 1 percent), but sulfur content of individual seams within the coal fields varies greatly (table 2). The largest coal producers located in the Book Cliffs and Wasatch Plateau fields produce coal ranging between 0.4 and 1.2 percent sulfur (washed basis 0.4 and 0.75 percent), compared with most Midwest or East coals which show 2 to 4 percent sulfur in many cases. High-sulfur areas, however, are numerous in Utah.

Sulfur content is detrimental to coal value, even though some high-sulfur content aids in the precipitation of particulate matter by electrostatic means in large power plant stacks. Wet scrubbing of gases to remove excess sulfur and particulate matter gives some promise that levels of particulates eventually will be reduced; no test unit, however, has so far operated long enough to assure continued satisfactory operation. Cost of operating the scrubber systems may be relatively high because of maintenance and ash disposal problems.

Utah coals, in general, present no unusual problems in electrostatic precipitation or scrubber systems to eliminate particulate matter from stack gases.

Volatile Matter

Volatile matter content of Utah coals approximates 35 to 45 percent by weight. It affects total heat value, the exact contribution being a function of the contained carbon and hydrogen content, valuable constituents of coal burning in many industrial processes; inert portions (nitrogen and oxygen) detract from Btu values. Burning coal efficiently in pulverized form depends entirely on volatile matter content.

Table 2. Sulfur content of Utah coal fields.

	No. Samples	Percent Sulfur	
		Average	Range
Principal Producing Fields			
Book Cliffs–Blackhawk Formation	1,149	0.85	0.10-3.00
Castlegate quadrangle	784	0.53	0.10-2.10
Soldier Canyon quadrangle	206	0.49	0.30-1.00
Sunnyside quadrangle	67	1.09(r)	0.50-3.00
Woodside	92	0.70	0.50-1.15
Wasatch Plateau–Blackhawk Formation	722	0.60	0.23-1.60
Five north quadrangles to Clear Creek	159	0.64	0.31-1.60
Hiawatha area	538	0.59	0.23-1.50
Eight south quadrangles to Ivie Creek	25	0.56	0.30-0.90
Emery–Ferron Formation	46	0.99	0.31-4.66
Major Reserve Areas–Inactive			
Kaiparowits Plateau–Straight Cliffs Formation			
Smoky Mountain area, general	91	0.75(d)	0.26-1.50
Resources Company	53	0.50	0.24-1.40
Escalante area	24	0.98(d)	0.42-3.40
Tropic area	14	0.98(d)	0.60-1.73
Kolob–Dakota Formation	76	3.99	1.10-7.30
Cedar City	67	5.76	1.11-7.30
Orderville	9	2.21	1.10-4.03
Alton–Dakota Formation	28	1.16(d)	0.46-2.30
Sego–Wasatch Formation	27	0.60	0.37-1.00
Minor Fields, Total[1]	231	1.85	0.30-6.79

[1] Includes: Mt. Pleasant, Tabby Mountain, San Juan, Henry Mountains, Coalville, Vernal, Salina Canyon, Wales, Sterling, Harmony, Lost Creek and others.
d - dry basis
r - raw coal – washed 0.75

Utah coking coal contains relatively small percentages of uncombined oxygen in volatile matter (approximately 25 percent), while most noncoking coal runs considerably higher (up to 40 percent); increasing oxygen content reduces or eliminates entirely the coking tendency, proportionately reducing Btu values.

Fixed Carbon

Fixed carbon content is the most valuable constituent of Utah coal with regards to heating value; carbon alone has 14,580 Btu/lb (free hydrogen in coal runs more than 34,000 Btu/lb). Utah coals range from 9,000 to 13,000 Btu/lb, the lower values resulting from impurities associated with the coal. Utah coking coals have relatively high fixed carbon (53 to 56 percent) and high-volatile content (including oxygen). In coking processes, substantially all moisture and volatile matter are driven off by oven heating; the remaining fixed carbon and ash (60 to 65 percent of coal by weight) forms coke for burning in iron blast furnaces.

Btu/lb

The Btu content of Utah coals varies widely between coal fields depending on rank and contained impurities of moisture, ash, sulfur, nitrogen and oxygen of particular coals. Coal from Emery or south Wasatch Plateau fields is slightly higher quality than coals from Kaiparowits Plateau or Black Mesa and is substantially better than Alton field coal with regards to Btu, moisture, sulfur and ash content (see *Coal in Utah–1970,* by H. H. Doelling, tables 9 to 16, p. 555-558).

The total cost of coal or other fossil fuel at the point of consumption, expressed in cents per million Btu heat content, principally determines market demand. Basically, the cost at point of consumption depends primarily on coal price at the mine as increased by cost of freight or transport to point of consumption.

Mine mouth plants, such as the Huntington plant now under construction and the projected Nipple Point plant on Kaiparowits Plateau, have the advantage of eliminating transport costs from mine to power plant, thus reducing coal cost to consuming plant (table 3); cost advantage of Black Mesa strip coal over Utah underground coal is apparent. In its 1971 annual report, the Southern California Edison Co. states:

> The cost of fuel at Edison's major thermal generating stations in 1971 averaged 38.9 cents per million Btu's as compared to 31.1 cents in 1970. Similar costs for 1972 are estimated to be 43.4 cents. Total fuel costs for 1971 increased to $164.9 million, 30.3 percent higher than the $126.6 million expended in 1970. It is anticipated that these costs will exceed $200 million in 1972, or average more than ½ million dollars per day.

Table 3. Typical coal analyses and estimated mine prices.

	Carbon-Emery, Utah	Kaiparowits Plateau, Utah[1]	Black Mesa, Arizona[2]
Moisture (percent)	7.0	10.6	10.0
Ash (percent)	7.0	7.6	8.0
Volatile matter (percent)	40.4	37.9	39.2
Fixed carbon (percent)	45.6	43.9	42.8
Sulfur (percent)	0.50	0.48	0.45
Btu/lb	12,400	11,270	11,080
Million Btu per ton	24.80	22.54	22.16
Mine price (or cost)	$7.00[3]	$7.00[4]	$4.50[5]
Cost per million Btu at mine	$ .283	$ .311	$ .203

[1] Underground coal: major primary reserve area including Smoky Mountain area.
[2] Strip coal: contract analysis before slurry preparation.
[3] Approximate price level of commercial coal sales, September 1972. Underground coal.
[4] Estimated by author to cover all potential mine operators' mining costs and profit; based on labor rates and general price level comparable to September 1972 conditions, Carbon-Emery County field. Underground coal.
[5] Estimated by author; based on published Peabody Coal Co. contract price in 1964 as escalated to 1972 conditions. Strip coal.

The competitive position of Utah coal in the fast-growing market for electric-power generation in Utah and southwest areas has changed dramatically in the last few years. Coal from the Kaiparowits Plateau and Alton fields as well as from nearby Black Mesa (Arizona) might well offer substantial savings to Southern California Edison, Nevada Power Co. and Arizona Public Service Co. compared with natural gas or oil costs (table 4), particularly considering transport of strip coal by slurry pipeline where labor costs are minimal and capital costs maximum.[1] Costs of high voltage transmission from generating station to point of consumption are not here considered.

[1] Eighty to eighty-five percent of the total costs of pipelining are capital costs and are committed at time of pipeline construction; transport costs are regulated by contract and are, therefore, relatively stable and predictable.

Table 4. Approximate cost comparisons of delivered coal per million Btu.

	Cents per million Btu[1]
Southern California Edison – average gas and oil, 1972	43.4
Nevada Power Company – coal by rail, 1972	35.0-37.0
Kaiparowits Plateau, Utah – Nipple Butte Plant	28.5
Black Mesa, Arizona – Mohave Plant, Nevada; Navajo Plant, Arizona	27.2

[1] Based on reported facts and performance at three locations in south Utah and Black Mesa, Arizona (table 3) and the following assumptions:

a. Union labor rates same as Sept. 1972.
b. Cost of equipment and supplies same as 1972.
c. Kaiparowits Plateau deep-mines cost related to known Carbon County, Utah, mines.
d. Black Mesa field and possibly Alton field strip coal (Alton field has strip-mining conditions believed similar to Black Mesa).
e. Slurry pipeline operation and costs-per-ton-moved same from both Black Mesa and Alton areas.
f. Cost to transport coal from Black Mesa to Navajo plant by belt conveyor and surface railroad (65 miles) estimated same per-ton as transport from Black Mesa to Mohave, Nevada, plant by slurry pipeline (275 miles).
g. Price coal from Black Mesa arrived at from published reports ($4 per ton) of Peabody Coal Co. in 1964 contract as escalated to 1972 conditions.
h. Coal analyses obtained from records of Southern California Edison Co., Resources Co. and Utah Geological and Mineralogical Survey.
i. Sufficient water for pipelining, if possible, to be obtained from drilling near Alton, Utah; scrubbing of high sulfur of Alton coals to be accomplished at generating stations, Nevada.

In addition to the Kaiparowits Plateau and Alton coal fields of south Utah, large, low-cost reserves – some strippable – have been proven in the Emery field (Emery and Sevier counties) and in south quadrangles of the Wasatch Plateau field where pipelining or high-voltage transmission to south Nevada or south California areas eventually may prove feasible. Direct distances for pipelining or transmission to Las Vegas and the Mohave plant (Bullhead City) from these fields are about as follows:

	Miles
Emery, Utah, to Mohave Plant	350
Emery, Utah, to Las Vegas (Arrow Canyon site)	275
Paradise Lake, Utah, to Mohave Plant	310
Paradise Lake, Utah, to Las Vegas (Arrow Canyon site)	235

COAL AND COMPETITIVE FUELS

Availability of Natural Gas

If demands on gas continue to increase and the rate of new discoveries lags, by late 1975 gas supply to many western industrial and and electrial generating plants may be cut off; further, electric generating plants may have to assume an increasing share of the cost burden of natural gas production prior to 1975. Reliance for increased base load operation will likely be placed on coal.

According to the American Gas Association (March 29, 1972):

> U. S. gas consumption last year exceeded the pace of discovering gas reserves for the third time in the last four years. U. S. proven reserves of natural gas declined 4 percent in 1971 to 278.8 trillion cubic feet. New production rose slightly in 1971 to 22.1 trillion cubic feet from 22 trillion but the increase was the smallest since 1945.

Mountain Fuel Supply Co. confirms that available supplies of natural gas for base load electric power generation in Utah or for large-scale industrial consumption are becoming increasingly scarce. Mountain Fuel's sales of all gas (residential and commercial 40 percent; industrial 60 percent) during 1970 exceeded new discoveries, including development and purchases, which resulted in an actual decline in gas reserves. The trend will continue unless sizeable new gas reserves are discovered; this can only be accomplished by renewed and expanded drilling programs. Mountain Fuel recently (February 1972) increased rates $4,845,000 per year, about a 9-percent increase from 1970 to 1971, a substantial portion to be used in expanding drilling programs.

Until recently Utah Power and Light Company has had sufficient supplies of natural gas and residual fuel oil at its Salt Lake City Gadsby generating plant (260 mw) at costs fully competitive to or lower than coal. Because of the worsening gas supply and stoppage of residual fuel oil supply from a nearby refinery, however, the company has converted the facility to coal, effective in late 1972. The company recently purchased coal properties in Emery County with estimated recoverable resources of 50 million tons; mining operations for at least 35 years at a rate exceeding 1 million tons per year will provide the fuel requirements of Gadsby, Hale and Carbon generating plants.

Within the past 18 months Utah Power and Light Co. also has contracted with Peabody Coal Co. (division of Kennecott Copper Corp.) for production of total coal requirements of a large power plant projected in the area of Deer Creek, Huntington Canyon (March 1971, press release):

A new electric generating plant at Huntington Canyon, near Price, Utah, is to be constructed. The first generating unit will have capability of 430 mw and is scheduled for completion spring of 1974. Future plans contemplate as much as 2,000 mw capability, costing from $300 to $400 million. Annual coal consumption for the first unit will be 1.2 million tons to be delivered by 2-mile belt conveyor to plant site; coal is of good quality, low sulfur and ash content and is lower in price than any other fuel currently available to the company. [At full capacity of 2,000 mw, coal use at these new and projected plants will approximate 6 million tons per year.]

The increasingly serious nationwide shortage of natural gas and the need either of (1) imports of liquefied gas from foreign sources or (2) gasification of petroleum by-products is typified by the following (*Chemical Week*, February 23, 1972):

More gas imports are essential... Transcontinental Gas Pipe Line Corp.... has requested that the Office of Emergency Preparedness ease restrictions on imports of liquefied natural gas and crude oil for synthetic natural gas production. The company says it will need the gas to meet its sales commitments during the next 4 or 5 years, adding that it already has supply problems and will probably cut shipments 12 percent this year.

In its petition to OEP the company cites studies indicating that natural gas discoveries and reserves in the U. S. will not be adequate to supply the country's needs over the next decade. To meet the expected deficit, Transco has a three-phase program that would provide up to 1 billion cu ft/day of pipeline-quality gas by '77. Included: facilities to produce 250 million cu ft/day of gas from naphtha gasification, about 460 million cu ft/day from crude gasification and up to 300 million cu ft/day from imported liquified natural gas. Over-all cost: about $500 million.

The *Wall Street Journal* (February 28, 1972) states:

A Federal Power Commission staff report on the outlook for natural gas confirms what home-owners have been hearing so often lately: their fuel bills are likely to soar within the next several years.

The study, covering the next 18 years to 1990, suggests that domestic production of natural gas won't be sufficient to meet expanding demand after 1975 and that the nation will have to rely instead on more expensive imported and synthetic gas supplies. By 1990 such supplemental gas sources will supply fully 40 percent of U. S.' needs. The cost of imported natural gas or synthetic gas from naphtha gasification will be high (estimated in excess of $1.50/mcf, more than double present costs) and our nation's balance of international payments will be seriously and adversely affected by large purchases of gas or oil derivatives from foreign sources. Thus development of badly needed U. S. reserves of all fuels may have to slow down.

Efforts to Alleviate Natural Gas Shortage

Coal Gasification

To alleviate the worsening gas shortage and the increasingly high costs of discovering new reserves in the U. S., the Department of Interior has actively sponsored investigations and research projects over the past 10 to 15 years looking to gasification of vast coal reserves. Much of the research work was done in cooperation with the American Gas Association whose philosophy is:

Coal gasification will permit this vast source of domestic energy [coal] to be delivered to [gas] consuming centers as clean, sulfur-free gas through a network of 900,000 miles of underground pipelines. We believe that this joint [Interior–AGA] research project is a necessary forerunner for the most efficient and economical program [of gasification] on which an entirely new industry would be based. The primary goal is to solve the gas supply problem in the quickest and most economically realistic way.

The following report of the American Gas Association (November 1970) advocates coal gasification through the cooperative efforts of the Interior Department and the AGA:

Coal Gasification Research: Coal gasification research in the United States during the past 10 to 15 years has been funded by the Office of Coal Research, the Bureau of Mines, the American Gas Association and a few private firms. Approximate expenditures previously committed or currently planned by each group are as follows:

	(millions of dollars)
Office of Coal Research	46.5
U. S. Bureau of Mines	10.0
American Gas Association	7.2
Private firms (estimated)	8.0
Total	71.7

In addition to the foregoing expenditures, an accelerated coal gasification research program was recently announced, which will be jointly funded by the Department of the Interior and the American Gas Association. The program, which will be administered by the Office of Coal Research and AGA will involve planned expenditures of $296 million over the next 8 years. During the first 4-year period (1972 to 1975) planned expenditures are $30 million per year, of which $20 million and $10 million will be provided by the Department of the Interior and AGA, respectively. The coal gasification processes which are currently in the most advanced stages of development and which appear technically and economically feasible will be further developed by intensive pilot plant programs during the first four years.

In the second phase of the program (1976 to 1979) the construction and operation of a demonstration plant is planned. The demonstration plant will embody the optimum combination of components and sections of the various processes which have been tested in the pilot plants. Expenditures of $176 million have been planned for the demonstration phase of the program. The formula for funding during this phase is yet to be determined. Following completion of the demonstration phase, optimized processes for coal gasification will be available for commercial applications.

The processes and projects which are planned for inclusion in the accelerated research program are listed below:

HYGAS Process – fluidized bed hydrogasification of coal with hydrogen-rich gas produced in two ways: (1) by the electrothermal gasification of residual char and (2) by the steam-oxygen gasification of residual char. The process was developed at the Institute of Gas Technology under the sponsorship of OCR and AGA. The 3-ton/hour pilot plant was completed in May 1971 and has undergone shakedown and initial start-up.

CSG (CO_2 Acceptor) Process – fluidized bed gasification of lignite with recirculating acceptor material (limestone or dolomite) which provides heat for the steam-carbon reaction. The process was developed by Consolidation Coal Co. under sponsorship of OCR. Stearns-Roger Corp. was contracted to construct and operate the pilot plant, which is in final stages of completion at Rapid City, South Dakota.

BI-Gas (Two-State Super Pressure) Process – fluidized bed slagging gasification with steam-oxygen to produce hydrogen-rich gas. The process was developed by Bituminous Coal Research, Inc., under sponsorship of OCR. The planned construction of a pilot plant near Homer City, Pa., was recently announced.

Steam-Iron Hydrogren Process – reaction of steam with iron to produce hot, high-pressure hydrogen/steam mixtures for subsequent use in hydrogasification. This process was developed under private sponsorship and is ready for pilot plant testing.

Further evaluation of the German developed Lurgi Process – steam-oxygen gasification of coal to produce hydrogen-rich gas. This process has been used commercially for many years to produce low-Btu town gas. The feasibility of building Lurgi plants in the United States is currently being evaluated by private firms.

The Bureau of Mines has developed the Synthane Gasification Process under independent financing by the Department of the Interior. This process involves fluidized bed gasification and combines pretreatment, carbonization and steam-oxygen gasification in one reaction vessel. A contract has been awarded for the design of a pilot plant.

FMC Corp. and Bechtel Corp. have announced the proposed development of the COGAS Process for the simultaneous production of pipeline-quality gas and synthetic crude oil from coal. The two firms are seeking to establish a consortium to further develop the process.

To acquire, build and equip the six-mine complex would require: six separate mine openings, each with capacity of 1 million tons per year, 4,450 tons per day, two-shift basis; three mines to begin production six months ahead of gasification plant

operation, the gasification plant assumed operational in mid-1979 or 1980.

It is possible that new approaches to coal gasification may be developed in the future; however, the events and results of the investigations, which have been carried out over the past 15 years, strongly indicate that the first generation of commercial gasification plants will embody combinations or variants of the processes and components which are currently at the bench-scale or pilot plant stages of development. Analogous to the progress which has been made in many other scientific fields, further advancements will undoubtedly be made in coal gasification technology through the combination of continued research and experience gained in actual plant operation.

Conversion of Coal to Liquid Fuels Research: No commercial process has been developed in the United States for the conversion of coal to liquid fuels. However, the Bergius-Farben Process, developed in Germany, was demonstrated on a limited-scale in a pilot plant operated by the Bureau of Mines. Although technically feasible, the process is not economically attractive.

Since 1962 the Office of Coal Research has sponsored research on the conversion of coal to liquid fuels. The major projects which have been sponsored by OCR are the following:

Project	Contractor	Duration of OCR sponsorship	Total OCR funds expended or planned
COED	FMC Corp.	May 1962-Nov. 1971	$ 9,734,000
Gasoline	Ralph M. Parsons Co. and Consolidation Coal	May 1962-Nov. 1971	22,510,000
H-Coal	Hydrocarbon Research, Inc.	Feb. 1965-Feb. 1968	2,064,000
Seacoke	Atlantic Richfield Co.	Aug. 1964-Feb. 1970	968,000
			$35,276,000

These and other research projects sponsored by the Office of Coal Research have contributed much to the understanding and final solution of the practical, overall problems connected with coal liquefaction but have not as yet resulted in design of an economically feasible plant or process for coal liquefaction.

The IGT project compares to Utah's existing coal mines (operating in 1970) as follows (table 5):

Table 5. Comparison of IGT coal gasification project with Utah's operating mines (1970).

	1980 Six New Mines 225 Days/Year		1970 23 Older Mines 220 Days/Year	
Production	5,600,000	tons/year	4,743,000	tons/year
	25,000	tons/day	23,715	tons/day
Employees	2,500[1]		1,474	
Underground	1,930[1]	(77.3 percent)		(77.3 percent)
Surface	570[1]	(22.7 percent)		(22.7 percent)
Assumed tons per man day	20 to 10[1]		16.1	

[1]Estimated by author.

To employ and train the 2,500 necessary men and to solve incidental housing problems would require a minimum of 3 years (author's estimate).

Since coal costs only about half the manufacturing cost of high Btu gas as envisaged by IGT, the total cost of coal gas will greatly exceed the cost and sales price of present natural gas sold in Utah as shown by table 6 (assumptions are based on 1970 published results of Mountain Fuel Supply natural gas sales compared to gasification costs, also to 1972 labor and supplies costs of more efficient Utah coal mines applied to production in 1980 comparisons):

Table 6. Comparison of coal gas and natural gas costs.

	1970 Conditions Mountain Fuel Supply Records	1980 Conditions (1972 basic costs) IGT Estimate Coal Price $6.00/ton[1]		
Total gas revenues (Utah only)	$54,372,000			
Million cubic feet[2]	126,263			
	Per MCF	Cost At Plant Site (per MCF)	Transport Distribution To Consumer	Total
Average price	$.431[3]	$.610-.710	$.20[4]	$.90[4]
Residential-commercial	.640[3]	1.080	.20[4]	1.28[4]
Industrial	.257[3]	.409	.20[4]	.609[4]

[1]Average 1972 coal price; Utah mines more nearly $7/ton – 1980 price likely $10/ton; estimated by author.
[2]Includes distribution and transport to consumer.
[3]Residential-commercial: 40 percent; industrial 60 percent.
[4]Estimated by author.

Conclusions

Technology and costs of mining, shipping, storing and burning coal in large industrial or utility boilers are well established following many years of experience; technology and costs of coal gasification are uncertain. At least 5 years of research and testing to clearly define technological problems and costs of a coal gasification program will be required prior to final construction of planned facilities.

Because Utah has only deep, higher-cost underground coal reserves – small strippable acreage – it is doubtful that a major low-cost gasification plant based on present technology can be economically justified for state coal lands. Utah's overall reserves are sufficient to supply the plant, but gas produced from deep-mined coal is high-cost fuel compared with direct coal burning at mine mouth generating plants.

Availability of Fuel Oil

Industrial and electric generating plants' fuel oil supplies are decreasing, giving no promise of future relief or even of supporting present levels. Much of the oil supplying Salt Lake City's refining complex yields a small percentage of residual fuel and production costs of oil from shales or tar-sands are high and refinery processing to produce useable gasoline and residual fuel oil products is expensive.

For years Utah Power and Light Co. (UP&L) has utilized large quantities of residual fuel oil from nearby Standard Oil Co. refinery for power generation at the Gadsby Plant, approximately equivalent to 420,000 tons of Utah coal per year, while natural gas use has approximated 100,000 tons equivalent coal per year. Beginning October 1972, UP&L has advised loss of this source of oil for boiler plant use, requiring full replacement by new coal production. Possible future discoveries of large crude oil reserves in Intermountain fields could alter the situation, thus partly relieving coal of the additional demand, but at present no such major oil discoveries are foreseeable.

According to press releases, declining availability of residual oil and natural gas influenced UP&L's purchase of the Emery County coal mine and properties of the Church of Jesus Christ of Latter-day Saints. Production at the mine will increase from 80,000 to 100,000 tons to more than 1,000,000 tons per year, total increased production going to generating plants within Utah.

Quality of this coal is excellent for steam generation as shown by the following approximate analysis:

	Estimated (percent)
Moisture	7.5
Dry basis:	
Ash	6.9
Volatile	44.2
Fixed carbon	48.9
Sulfur	0.6
	Estimated
Btu (dry basis)	13,420
Ash (softening temperature)	2,140°F
Grindability (Hardgrove)	50

Extraction of Oil from Tar Sands

Atlantic Richfield Oil Co. president, T. F. Bradshaw, sees no possibility of producing oil from shales or tar-sands until price of conventional crude oil rises further. "Future conventional supplies are likely to be high-cost gas and oil with which synthetics can compete."

However, "If technological problems of making synthetic fuels out of coal are compounded by the uncertainties of price controls and regulatory delays, oil companies are simply going to put their money elsewhere," declares J. G. McLean, president Continental Oil Company. Companies want legislation on leasing federal lands and environmental procedures before committing money to shale or coal projects. The Federal Trade Commission is now investigating entry of oil companies into coal and other energy fields. Most of the coal for gas or oil synthetic fuel plants will be strip-mined by large, financially capable companies, not by small commercial concerns.

Chemical Week (April (?) 1972) described a possible new source of oil from refuse materials:

> Synthetic low-sulfur fuel oil can be produced from garbage in a new pyrolysis unit, according to Occidental Petroleum's Garrett Research and Development Co., Inc. (La Verne, California). A 4-ton/day pilot plant, said to be capable of producing a barrel of oil from a ton of garbage, is now in operation. The process does not require hydrogenation and operates at near-atmospheric pressure ... can extract $6 of useable materials per ton at a cost of $5 per ton.

Conclusions

(1) Utah has only small reserves of low-cost strippable coal and cannot produce coal in the foreseeable future for synthetic oil or gas production.

(2) Before production of oil from shale or liquefaction of coal becomes economically feasible, conventional crude oil prices must increase considerably.

(3) Utah's deep-mined coal can best be utilized in direct power production at mine mouth plants or burning in other industrial and heat processes, rather than in synthetic fuel production.

MINING COSTS

Tables 7 and 8 break down estimated costs for a proposed underground coal mine.

Table 7. Estimated investment required for a new Utah underground mine.

Assumptions:	
Coal seam thickness	8 feet
Pitch of coal seam	10 to 15% (maximum)
Roof	Generally good; floor, hard
Major faults	None
Minor faults (up to 10 feet)	A few
Production	500,000 tons raw coal per year 2,220 TPD, 225 days per year
Employees	240 (20 absentees) 20 salaried
Required reserves	10,000,000 tons recoverable

Equipment – general[1]

Four continuous mining units, AC, complete with shuttle cars, roof bolters, underground coal breakers, 1,000 KVA power centers, battery service cars, rock dusters, fire suppression systems, power cable, telephone lines, belt conveyors (36"), etc., as detailed.

Total investment	$5,250,000 =$10.50/ton annual capacity

[1]Equipment needed:

4 continuous miners AC (or equivalent other units)	$760,000
9 shuttle cars (3 as spares – 1 per section) 7 ton	450,000
4 roof bolters (1 as spare)	120,000
3 belt feeder breakers	75,000
3 battery powered supply cars and chargers	85,000
3 1,000 KVA transformer power centers	70,000
Belt conveyor 8,000 feet 36" including 2 drives (rope line, main line haulage)	400,000
Belt conveyor 10,000 feet 30" including 2 drives (rope line)	450,000
Main line bulk rock dusting distributor	20,000
2 self-propelled bulk rock dusters	8,000
1 bulk rock dust bin	20,000
2 fans and housings	60,000
Mine development and stoppings (main slopes, water systems, fire suppressions, room and pillar)	200,000
Raw coal preparation plant with 1,000-ton bin and primary crusher	140,000
Front-end dozer (loader) for coal storage	115,000
Trucks and automobiles	50,000
Outside substation	70,000
Outside water supply system	30,000
Bath house and change house (60 men)	55,000
Shop building complete with equipment	120,000
Material warehouse and supplies	100,000
Mine office building	50,000
Safety factor	300,000
Subtotal	$3,750,000
Other – Railroad – Washery	1,500,000[2]
	$5,250,000[3]

[2]If railroad facilities are necessary, train loading requirement about (includes silo or ground stockpile facilities) $750,000
If washery is required, add $750,000
Total $1,500,000

[3]The foregoing capital costs do not include:
a. Cost of coal lands or leases.
b. Cost of shafts for coal haulage, transport of men and materials or air shafts to reach coal seam.
c. Water supply and water rights from distant streams.
d. Employee housing or townsite facilities.

Table 8. Mining cost estimate for proposed 500,000-ton annual mining operation.

		15 TPMD[1]	25 TPMD
Labor costs:			
Day rate force		$2.75[2]	$1.65[2]
Supervision		0.35	0.35
Labor benefits			
Union royalty	$0.60		
Vacation	0.08		
Holidays	0.06		
Bonus	0.03		
Payroll taxes	0.28		
		1.05	1.05

(continued on next page)

Table 8. (continued)

		15 TPMD[1]	25 TPMD
Materials and supplies:			
Power, roof control, repairs, ventilation, safety, electrical, lubricants, hydraulics, etc.		1.50	1.50
Overhead and indirect:			
Government royalty, minimum	0.15		
Property tax	0.05		
Safety assessments	0.05		
Other	0.05		
		0.30	0.30
Depreciation/amortization:			
Interest 15 percent[3]		1.50	1.50
Total estimated cost		$7.45[4]	$6.35[4]

[1]Tons per man day.
[2]$41.12 ÷ 15 tpmd = $2.75/ton.
$41.12 ÷ 25 tpmd = $1.65/ton.
[3]Assumes $5.25 million capital investment
15-year life $350,000/yr
Interest 8 percent 400,000/yr
$750,000/yr = $1.50/ton
[4]Excludes general office, administration and sales costs.

Note: basic assumptions (table 8):

1. United Mine Workers Association labor force. Average day rate including normal overtime component (10 percent) to approximate $41.12, same as union contract dated November 15, 1971; union royalty rate at $ .60/ton.

2. Productivity may average 15 tons per man day. Nationwide productivity (underground mines) declined from 15.61 in 1969 to 13.76 in 1970. A further decline is anticipated in 1971 and 1972 because of additional safety regulations as well as more stringent enforcement of the Coal Mine Inspection Act. To assume a productivity factor in excess of 15 tons per day is unrealistic in view of federal safety regulations and mining conditions within the state of Utah.

3. Capital cost to approximate $10.50 per ton of annual capacity assuming raw coal deliveries. Coal washing facilities, if needed, to add at least $1.50 per ton of annual capacity to initial capital requirement. Total cost in excess of $10.50 per ton annual capacity is possible.

4. Materials and supplies cost at 1972 levels. Government royalty rate is assumed at $.15/ton; however, BLM threatens substantial increases for new leases or renewals of present leases.

5. Assuming 1 to 4, total cost of coal will amount to approximately $7.45 per ton under present known conditions, excluding general office, administration and sales costs.

Some of the assumptions and conclusions may be found incorrect depending on developing mine conditions, competitive situations, government regulations (assessments, fines, closure and withdrawal orders imposed by U. S. Bureau of Mines), strikes at mines, ports, transportation facilities or plants of large consumers and possible changing quality restrictions of coke plants and other large coal consumers. The estimates are based on known economic factors as well as on assumed normal mine working conditions heretofore experienced by Utah and other western underground operators.

LEGISLATION AFFECTING COAL DEVELOPMENT

In recent years, much new legislation seriously affecting coal mines throughout the United States has been passed into law. Foremost is "The Federal Coal Mine Inspection Act of 1969," which became effective April 1, 1970, with increasingly tremendous impact – production and costwise – on all underground coal mines since that time. Likewise, new administrative regulations and guidelines of the Department of Interior, regarding lease and coal mining operations on public lands, have been promulgated and put into effect, some of which are already seriously affecting present operations and will doubtless have great impact on planning of future development of coal lands throughout the western states.

In addition, recent regulations and guidelines covering air pollution, ecology and the environment issued by the Environmental Protection Agency (a division of Department of Health, Education and Welfare) are already having their effect on coal mine production and planned development.

The EPA's Standards (December 1971) for new coal-fired steam generators with more than 250 million Btu per hour (10 tons Utah coal per hour, approximately equal 100 kw, capacity) are as follows:

1. Sulfur dioxide (maximum two-hour average): 1.2 lb per million Btu heat input (equal to use of coal with approximately 0.7 percent sulfur). Most Utah commerical coals meet this standard. Total Utah reserves, however, include large tonnages of higher-sulfur coal (certain areas of Kaiparowits Plateau reserves with sulfur exceeding 1.09 percent, Alton field 1.16 percent, Emery field 0.99 percent, particularly in undeveloped coal fields of Utah; see *Coal in Utah–1970,* table 13, p. 557).

2. Particulate matter (maximum two-hour average): 0.10 lb per million Btu heat input; visible emissions not to exceed 20 percent opacity, except for two minutes in any one hour, emissions may reach 40 percent opacity. The standard can best be met by efficient coal burning within the boiler at high temperature with volatile hydrocarbons from coal; coal washed to remove high-ash material burns more efficiently than raw high-ash coal. Finally, precipitation of unburned coal (cinders, smoke and fly-ash) by electrostatic methods or wet-scrubbing at the stack prior to release in the atmosphere can remove 99½ percent of particulates from stack gases.

3. Nitrogen oxides (maximum two-hour average): 0.70 lb per million Btu input. Because most Utah coals have a similar nitrogen content (1.4 to 1.5 nitrogen, maf basis), nitrous oxide effects possibly may be reduced by improving the designs of coal burning and boiler plant facilities and by introducing excess amounts of air into the combustion chamber. Processes to reduce nitrous oxide effects will add to the cost of coal as burned.

The following excerpts from the 1971 annual reports of the Nevada Power Company, Southern California Edison Company and Arizona Public Service Corporation describe the high investment cost of meeting stringent air pollution standards:

Nevada Power Company, Las Vegas, Nevada

To meet the stringent air pollution standards of Clark County we signed contracts in October 1971 for highly sophisticated air pollution control equipment for Reid Gardner Station (100 mw) costing nearly $8 million. . .

Certain environmental organizations . . . have commenced litigation seeking to enjoin the company and various other parties from certain actions in connection with construction and operation of generating plants . . . as part of the Navajo (2,310 mw) and Mohave (1,580 mw) projects. In addition, similar litigation filed against a major fuel supplier (Peabody Coal Co.) of these projects could impair its ability to fulfill the fuel requirements of the projects, which could result in the Company having to curtail electric power deliveries to its customers.

Southern California Edison Company, Los Angeles, California

Under study at the Mohave Generating Station is a series of pilot plant tests of seven different scrubbing systems designed to reduce the amount of sulfur dioxide and particulate material in exhaust emissions. Further work is necessary in testing these systems for possible installation in coal-fired generating stations. Although the feasibility of some of these devices has yet to be established, it is presently estimated that the manufacture and installation of commercially proven equipment could exceed $60 million. New air emission standards affecting the Mohave Station (1,580 mw) are expected to make it necessary to install this type of equipment, in which the Company's share of investment would be 56 percent ($34½ million).

Increasingly stringent air and water quality standards imposed in Nevada and New Mexico, in which the Company's share of total capacity is 1,700 mw, will require the Company to participate with other co-owners of the Mohave and Four Corners projects in the installation of air pollution equipment, the type and costs of which are not presently known but could involve added investment by the Company alone in excess of $60 million.

Arizona Public Service Corp.

The three-unit Navajo Power Plant (2,210 mw capacity) now under construction near Page, Arizona, is a prime example of the enormous financial burden environment-protection measures are adding to the construction of new generating facilities. Approximately 25.3 percent or $138.4 million of the total cost of this jointly owned plant will be required for environmental protection.

The EPA standards on sulfur content of burned coal eventually may be relaxed to permit burning of low-cost higher sulfur coals from Utah fields in remote areas (see *Coal in Utah–1970*, table 13, p. 557), particularly where sulfur removal by electrostatic and scrubbing processes will ameliorate objectionable and harmful effects of the high-sulfur content of coal.

Further, proposed federal laws strictly regulating strip-mining operations and guidelines overriding state regulations are being considered by Congress. These new (since 1968) laws, regulations and guidelines, including newly devised legal and administrative procedures and penalities, have and increasingly will have tremendous impact on coal production, cost of coal produced, and hence the cost and operations of coal-related and dependent industries including: electric power plants (private and public utilities), gasification and liquefaction plants and industrial plants (sugar, cement, smelters, etc.).

The following illustrates the impact on cost of the federal regulations on coal mine operations (1,000 tons per day, 50 employees; National Coal Association news release, 1972)

Productivity, which had shown an uninterrupted growth pattern since the early 1950's, reached a zenith in 1969 of 19.9 tons per man day including both strip and underground mines, 15.6 tons for underground mines only. During 1970, reflecting the effects of the initial regulations promulgated by the Act, underground productivity declined to 13.8 (11.9 percent) tons per man. On the other hand, strip coal registered a slight gain to 36.0 tons per man. Underground productivity for 1971 is expected to decline further from 1970. Whether or not productivity will later resume its historical growth pattern as these mines are re-equipped to meet the requirements of the Act is at this time highly problematical–no change for the better is yet evident. It is certain, however, that mine costs to this date, including higher union labor costs approved by Pay Board in November 1971, have increased over 1970 conditions from $1.50 to $2.00 per ton, depending on individual mine conditions; the Federal Price Board, however, has not approved higher coal prices to offset increased costs.

One large coal operator (Peabody Coal Co.) states in its 1971 annual report: "Adding to the cost of producing coal, 22 additional mining regulations were imposed during the year under the 1969 Federal Coal Mine Act." Newly promulgated regulations to control noise levels, fire suppression on all electric mine equipment, mine lighting and other matters will seriously affect productivity and costs in 1972 over 1971 conditions.

About the only way a Utah commercial coal operator can, under present and impending conditions, long survive is to be taken over either by a public utility or a large industrial company needing captive mine production. Since the general commercial market at present prices for independent producers in Utah appears insufficient for the productive capacity of existing mines, the result – already (1972) in evidence – is price-cutting and poor competitive practices, further evidence of an inexorable movement to widespread financial difficulties of underground mines.

In summary, legislation, regulations and guideline procedures, both enacted and proposed on a federal level since 1968, have and will continue to have an increasingly tremendous effect on all phases of Utah coal mine development and may well limit the economic expansion of the state's coal resources.

EXPORTATION OF UTAH COAL

Aside from limited test shipments to South America and European countries in 1971, all exports of Utah coal (Sunnyside mines) were of coking quality, principally for Japanese steel mills. During 1971, a severe recession in the Japanese economy resulted in reduced steel plant operations and reduced coking coal importations. Because of the higher costs for U. S. coals, compared to Australian or west Canadian coals, demand for U. S. coals dropped precipitously.

Other than special grades of strong coking eastern U. S. coals, the Sunnyside coal is higher cost to Japanese mills than most competitive coals (table 9). The Japanese classify Sunnyside as "soft" coking coal comparable to certain Australian (New South Wales) or Russian high-volatile coal which is economically more desirable. Most demand at the Japanese mills is for medium- and low-volatile coals rather than high-volatile "soft" coking coals.

Table 9. Comparison of quality and cost of coal shipped to Japan during the first half of 1971.

	Percent[1]			ASTM	Cost comparison
	Volatile matter	Ash	Sulfur	Coke Button[2]	Long Ton Price f.o.b. Vessel[1]
U.S.A. Eastern seaboard					
Medium volatile	28.5	6.0	0.70	7-9	$20.03
Low volatile	16-19	5.5	0.80	7-9	20.34
Canadian					
Balmer B. C.	19-22	9.5	0.40	6-8	14.11
Smokey River	21-24	8.5	0.50	5-7	13.85
Australian					
Goonyella					
Med. volatile	25-27	8.5	0.70	6-8	12.84
Big Ben-Rathluba					
High volatile	35-37	8.5	0.60	6	11.05
Russian					
Kosnetsky					
High volatile	38-42	8.5	0.60	–	9.35
Utah – U.S.A.					
Sunnyside					
High volatile	39-41	6.5	1.00[3]	5	14.50

[1]Source–Japanese Trading Companies, 1970-1971.
[2]Free swelling index.
[3]Maximum allowable analysis of western United States coals.

Exports of U. S. coals were seriously affected by prolonged strikes at West Coast ports and at U. S. coal mines (1971). But despite increased labor costs of coal production, the recent upward revaluation of Japanese currency and the devaluation of U. S. currency have reduced substantially (est. 6.1 percent) the cost of U. S. coal (at West Coast ports) to the Japanese in terms of U. S. currency (table 10).

Because of (1) the relatively weak coking quality of Utah coking coal and (2) the higher cost, substantial continuing exports of Utah coking coal to Japan are doubtful, except under conditions of temporary shortages of more desirable coking coals.

UTAH COKING COAL

Because of the relatively high-sulfur content of certain Utah coking coals and deleterious effects of coke sulfur in iron blast-furnace operations, causing brittleness in steel products and high costs for its removal in the furnace, as much sulfur and ash as possible must be removed before the coal is coked and used in blast furnaces in the form of coke. Typical analyses of washed

PERCENT OF TOTAL

	1930	1940	1950	1960	1970	1980	1980*
POWER GENERATION	3.3	9.7	4.6	12.2	18.4	78.7	38.3
RAILROAD AND EXPORT	14.1	19.0	3.3	0.3	9.1	2.8	8.2
METALLURGICAL	9.9	11.4	36.2	48.3	43.0	10.2	29.4
INDUSTRIAL AND COMMERCIAL	72.7	59.9	55.9	39.2	29.5	8.3	24.1

*WITHOUT ANTICIPATED SOUTHWESTERN UTAH PRODUCTION

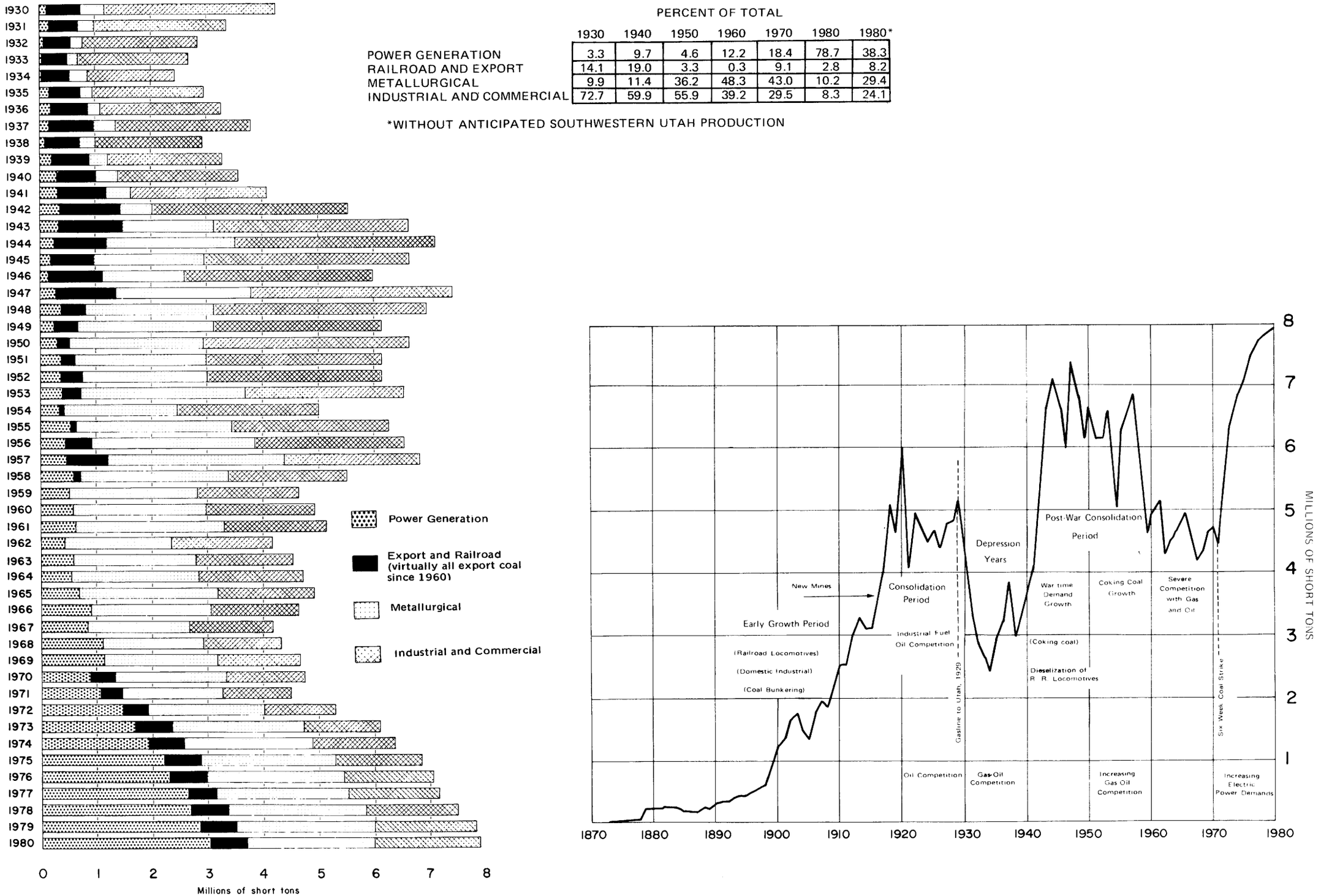


Figure 1. Utah coal consumption by use, historical and projected, 1930 to 1980 (does not include anticipated southwestern Utah production from 1971).

Table 10. Comparison of 1970 and 1973 contract price of U. S. coal to Japan.

	1970	March 1972
Value of Yen	$.00278	$.00325
Coal price/long ton (Utah Sunnyside) f.o.b. vessel	$14.50	$12.40
Reduction: $14.50 – 12.40 = $2.10/ton = 14.50 percent		
Add: Escalation due mainly to labor contract – 10 percent x 12.40 mainly to labor contract		1.25 (estimated)
Total price after escalation and revaluation[1] (Reduction .85/ton or 5.9 percent)		$13.65

[1]Does not include increased costs under provisions of the Federal Coal Mine Health and Safety Act of 1969; these increased costs are substantial, but as yet undetermined due to present (1972) litigation over fines and assessments between operators and U. S. Bureau of Mines inspectors; tabulation also excludes certain administrative costs.

Utah coking coals and examples of coking results with different coal blends in production of blast furnace coke show the following (table 11):

Table 11. Analyses of washed Utah and Colorado coking coals and coking results of different coal blends.[1]

	Sunnyside (Utah)	Geneva (Utah)	Somerset (Colorado)	Allen (Colorado)
Moisture	4.7	5.4	6.3	2.1
Dry basis[2]				
Volatile	37.8	40.0	40.5	39.3
Fixed carbon	54.3	54.2	51.6	50.9
Ash	7.9	5.8	7.9	9.8
Sulfur	0.83	0.85	0.46	0.55
Ultimate analysis-maf				
Carbon	82.3	80.9	81.9[4]	82.9
Hydrogen	5.7	5.8	6.0[4]	5.9
Nitrogen	1.8	1.8	1.7[4]	1.8
Sulfur	0.9	0.9	0.5[4]	0.6
Oxygen	9.3	10.6	9.9[4]	8.8
Heating value Btu (maf)	14,820	14,680	14,570	15,160
Coke Button (fsi)[3]	5½	5½	3	8½
Coking Index[3]	1.15	1.05	1.06	1.17

[1]Landers, Gomez and Boley, 1967, p. 36, 37.
[2]Calculated from as-rec'd basis.
[3]Landers, Gomez and Boley, 1967, p. 37.
[4]Supplied by author.

Utah coals must be blended with lower-sulfur, stronger coking coals from Colorado, New Mexico, Oklahoma-Arkansas or the eastern United States coal fields in order to produce strong and suitable cokes for use in large iron blast furnaces. Blending percentages vary with particular installations (table 11). Higher-grade coal reserves are believed adequate to meet Utah coal-blending requirements for many years; these special purpose coals are substantially more costly than Utah coals.

The future production estimates of Utah coking coal mainly depend on (1) the level of steel production at U. S. Steel's Geneva plant and Kaiser Steel's Fontana, California, plant and (2) cost of production and rail freight rates as compared with other sources of useable coal. Table 12 shows the relative sizes of coking operations of these plants.

Table 12. Estimated capacities of U. S. Steel's and Kaiser Steel's coking operations.

	No. coke ovens	Total coal required (tons/year)[1]	Utah coal in blends (tons/year)[2]
U. S. Steel Geneva plant	252	1,900,000	650,000
Kaiser Steel Fontana, California	315	1,800,000	1,190,000
Total Utah coal[2]			1,840,000[1]

[1]Estimated by author.
[2]1970 conditions; may be replaced by other high-volatile coking coals from Colorado and/or New Mexico depending on availability and cost.

FORECAST

Until 1950, chief markets for Utah's coal production included widespread commercial (domestic and retail), industrial and railroad outlets, plus increasing shipments to steel plants beginning in 1942. Coal usage to generate power increased appreciably in the mid-1950's and by 1972 became the most promising future market for Utah coal properties. Post-World War II demand from steel mills and for export supported coking-coal mines in east Carbon (Sunnyside-Horse Canyon) until late 1970, but such outlets do not appear promising for increased production in the future. Declining sales to domestic, retail and general commercial markets also point to a static or weakening coal market to other than electric power generating plants.

Utah's coal production, 1870 to 1980, with events that influenced it, is shown on figure 1. The projected 1972 to 1980 period is based on increasing electric power demands.

Because Utah's coal deposits are mainly buried deep, labor productivity is low and mining costs are high, intensified by:

1. Widespread unionization of mining properties; union contracts contain increasingly high wage and royalty rates, costly fringe benefits and rules restricting management prerogatives;

2. Inflationary costs of supplies and high costs of machinery, including much newly designed, untried equipment recently required by the U. S. Bureau of Mines. Underground coal mining, capital and labor intensive, occasionally requires more than $10 per ton of annual capacity for new, projected mines, as compared with less than $5 per ton of capacity in typical Wyoming-Montana strip operations;

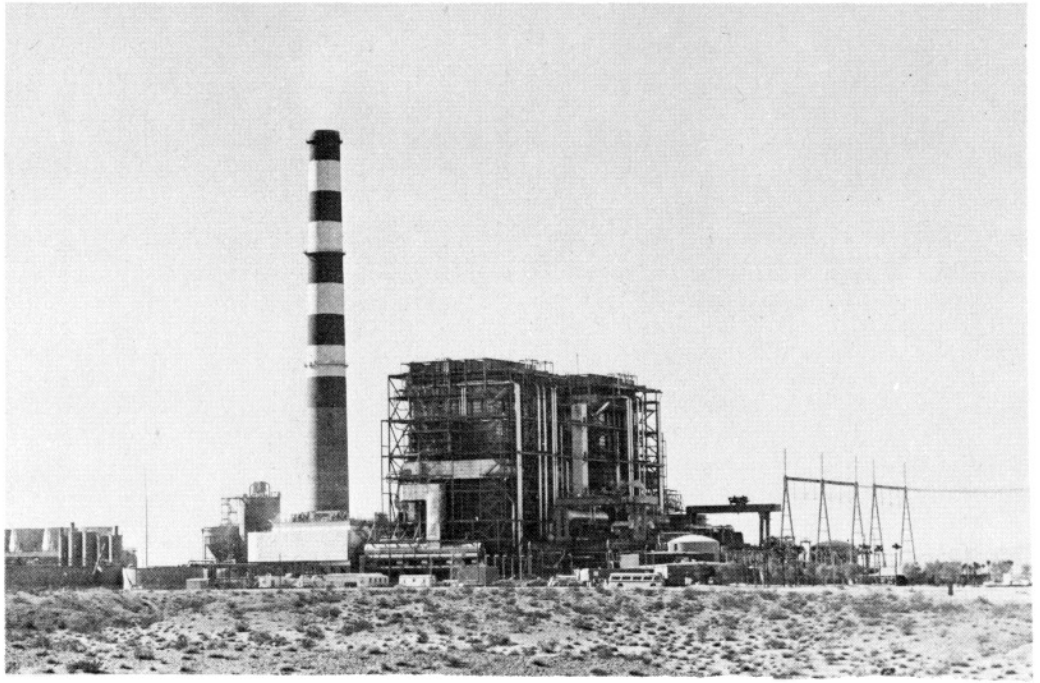
3. U. S. Bureau of Mines regulations complying with Federal Coal Mine Health and Safety Act of 1969, detailed control underground mining operations, excessive fining and assessing and withdrawing miners arbitrarily. Reports and mine maps required by various government agencies also sustantially increase office expenses. From declining markets for Utah coal and a negative financial outlook facing commercial operators, higher coal prices are inevitable with worsening operating conditions and possible closure of weaker commercial coal operations. Only captive mines appear promising depending on demand, operator and his ability to pay increasing operating coasts.

REFERENCES

Doelling, H. H., 1972, Coal in Utah, *in* Central Utah coal fields: Utah Geol. and Mineralog. Survey Mono. Ser. No. 3, p. 555-558.

Landers, W. S., Manuel Gomez and C. C. Boley, 1967, Coking properties of selected Utah coals and blends: U. S. Bur. Mines Rept. Inv. 6948, p. 36 and 37.

Mohave Power plant, located on the west side of the Colorado River in Clark County, Nevada, one mile west of Bullhead City, Arizona. The station includes two 790,000-kw coal-fired generating units. Coal is supplied via slurry pipeline from the open-pit mines at Black Mesa Basin in a mixture of 50 percent coal and 50 percent water at the rate of 660 tons per hour.



Black Mesa coal mine, Arizona, showing coal about 14 feet thick.

Open pit mine, Black Mesa Basin, Arizona.