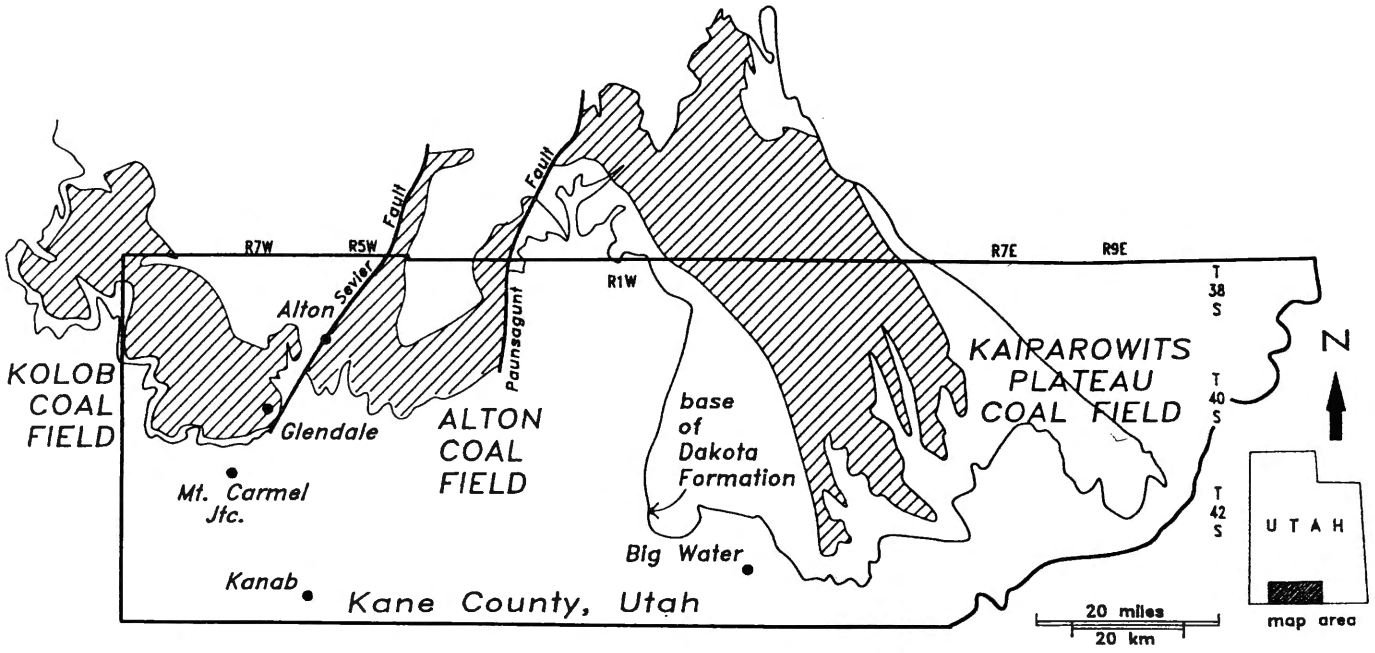
COAL IN THE STRAIGHT CLIFFS FORMATION OF THE SOUTHERN KAIPAROWITS PLATEAU REGION, KANE COUNTY, UTAH

by
Robert E. Blackett



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ABSTRACT

Data from exploratory drill holes and measured sections were combined to illustrate the distribution of coal resources within the John Henry Member of the Straight Cliffs Formation, southern Kaiparowits Plateau coal field, Utah. The main part of the coal field extends in a 25-mile (24-km) long and 18-mile (29-km) wide band NW-SE through the center of the Kaiparowits Plateau in Kane and Garfield Counties, Utah. Exploratory drill holes within this main region encountered as many as 20 coal beds of minable thickness in the John Henry Member. Total thickness of all coal beds penetrated by drill holes exceeds 80 feet (24 m) over most of the central region and exceeds 100 feet (30 m) across broad areas within this central region. A maximum total coal thickness of 149 feet (45 m), was recorded within one drill hole. To the east of the central region near Fiftymile Mountain, coal beds terminate against littoral-marine sandstone within the Straight Cliffs Formation. Southwestward, toward the East Kaibab monocline, coal beds within the John Henry Member thin and are of lesser economic importance. In the western portion of the field, the thickness of sedimentary cover above the base of the John Henry Member increases to nearly 3,000 feet (914 m) across a broad area. Because of thickening cover, drilling data are largely absent in this western portion of the coal field and, therefore, little is known about the coal beds.

INTRODUCTION

Purpose and Scope

The Utah Department of Community and Economic Development (DCED) enlisted the help of the Utah Geological Survey (UGS) to review the Bureau of Land Management's (BLM) procedures for evaluating mineral resources in wilderness study areas (WSAs). The BLM's mineral resource evaluation process involved detailed studies resulting in a series of reports by the U.S. Bureau of Mines and the U.S. Geological Survey. These reports address mineral resources in terms of identified resources and resource potential -- for example, see Bartsch-Winkler and others (1988) and Bell and others (1990). In order to validate the procedure and report to DCED, the UGS chose to perform a regional review of mineral resource information on WSAs in Kane County. Kane County WSAs were chosen for the review because of the relatively large area enclosed by WSAs, and because of the large amount of mineral information available for the region. The results of this review were documented in a previous UGS Report of Investigations (Blackett and others, 1992). Much of the review effort resulted in the compilation of coal resource information, which was too detailed to include in the Report of Investigations to DCED, for the Kaiparowits Plateau coal field.

This open-file report presents the details of the compilation of coal resource data for the Kane County portion of the Kaiparowits Plateau coal field. Generalized results from the detailed compilation of coal-resource data were presented in figure 13 (page 35) of Blackett and others (1992). The purpose of this report is to document the compilation of coal data as a basis for future, more detailed coal investigations. The John Henry Member of the Straight Cliffs Formation (late Cretaceous) was the focus for the study because its coal beds are of much greater economic importance in the Kaiparowits Plateau coal field than coal beds in the Smoky Hollow Member or the Dakota Formation.

Location and Physiography

The Kaiparowits Plateau coal field is located in eastern Kane County and south-central Garfield County and coincides roughly with the area of the Kaiparowits Plateau (figure 1). Stokes (1977) designates the Kaiparowits Plateau as a subdivision of the Colorado Plateau physiographic province. This semi-arid region is characterized by generally southward-facing terraces of resistant strata alternating with slopes of less-resistant rock, and is incised by steep-walled canyons. The communities of Kanab and Big Water (Glen Canyon City) lie to the southwest (figure 2). The towns of Escalante and Panguitch are located to the north in Garfield County.

Large parts of the region are remote with access mainly by unimproved roads and trails. U.S. Highway 89 connects communities to the north with the towns of Kanab and Big Water and Page, Arizona to the south. A few maintained public roads provide access to various parts of the study region.

Previous Work

Previous workers in the Kaiparowits region concentrated on gathering detailed surface measurements of coal beds and subsurface measurements from widely spaced, deep drill

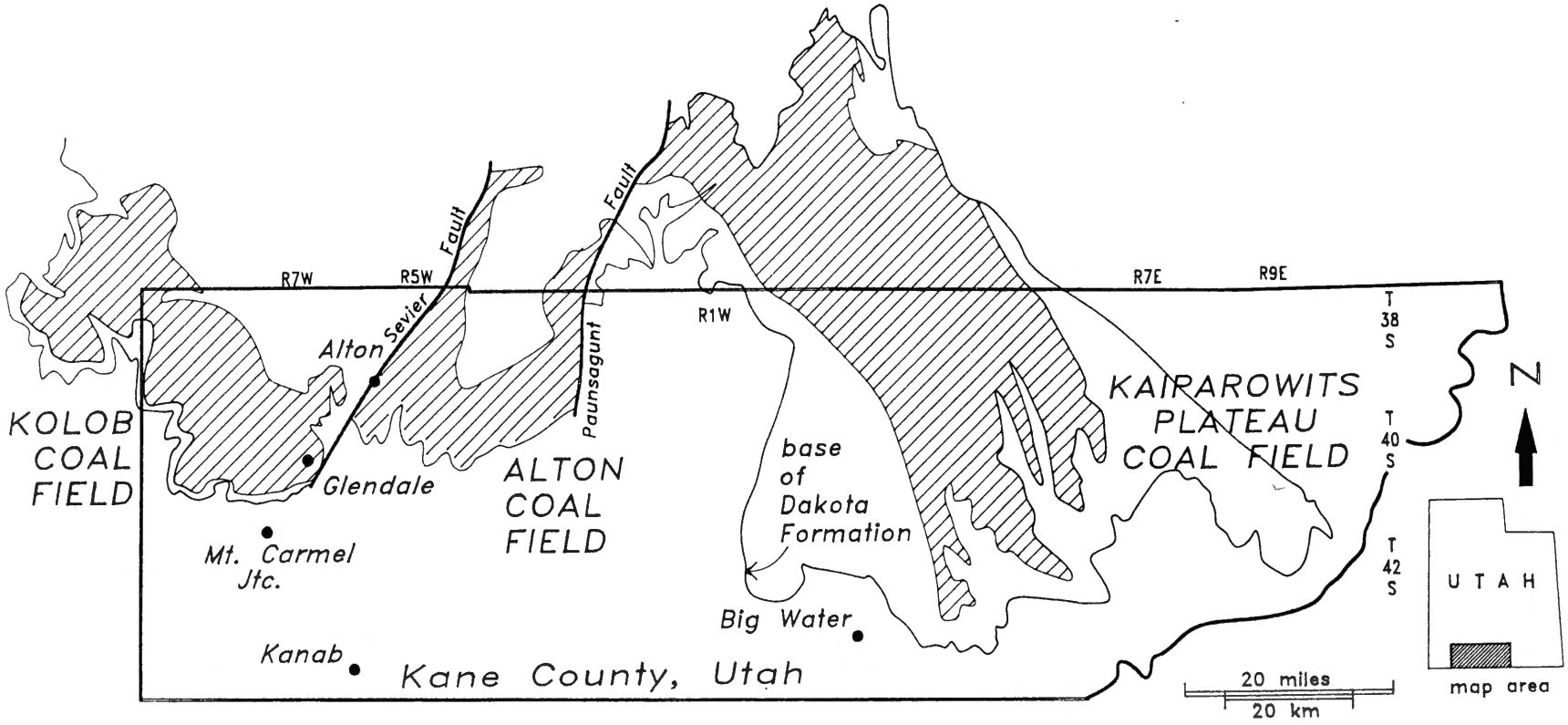

Figure 1. Extent of Cretaceous coal-bearing rocks of the study region (cross-hatch pattern), showing the locations of the Kaiparowits Plateau, Alton, and Kolob coal fields (from Doelling and Graham, 1972).

holes. Doelling and Graham (1972) measured numerous coal outcrops and compiled other coal resource information on a quadrangle by quadrangle basis. Hansen (1978a) compiled coal bed outcrop data from a number of 7.5 minute geologic quadrangle maps and data from a few drill holes to show the general distribution of coal thickness within the John Henry Member of the Straight Cliffs Formation. Using the same geologic information, Hansen (1978b) also projected the thickness of overburden above the base of the Christensen coal zone. Lidke and Sargent (1983) compiled geologic data from available oil and gas exploratory wells and prepared a series of cross-sections within the Kaiparowits basin. Doelling and Davis (1989) summarized previous work on the Kaiparowits field as part of a comprehensive examination of the geology and mineral resources of Kane County.

Doelling and Graham (1972) estimated that coal resources contained within the Kaiparowits Plateau, Kolob, and Alton coal fields (figure 1) may total more than 11 billion tons (10 billion mt), and therefore could represent about 45 percent of Utah's total coal resources. Within the Kane County portion of the Kaiparowits Plateau field, Doelling and Davis (1989) estimated the "principal coal resource" at about 4.4 billion tons (4.0 billion mt). Their "principal coal resource" included measured, indicated, and inferred coal occurring in reasonably continuous beds that are at least 4 feet (1.2 m) thick and have less than 3,000 feet (914 m) of sedimentary cover.

GEOLOGY OF THE KAIPAROWITS REGION

Structure

Sedimentary rocks in the Kaiparowits region dip generally northward at low angles and form south-facing terraces with steep-walled canyons. The most outstanding geologic feature in the region is the East Kaibab monocline (figure 2) where an impressive hogback, known as The Cockscomb, developed due to differential erosion of the structure. The East Kaibab monocline is a north-northeast-trending structure where rocks dip abruptly to the east. Dips along the monocline vary from about 15 degrees east to slightly overturned, and most often range from 40 to 60 degrees east along steeper segments. Maximum structural relief, estimated at 5,000 feet (1,524 m), occurs along the southern end of the structure. The degree of folding decreases northward and the structure eventually dies out in north-central Kane County.

The present-day Kaiparowits structural basin (figure 2), lies to the east of the East Kaibab monocline and contains gentle anticlines and synclines cut by rare, small-displacement faults (Gregory and Moore, 1931; Bissell, 1954). The Kaiparowits basin roughly coincides with a Mesozoic depositional basin where thick sedimentary deposits accumulated during the Jurassic and Cretaceous Periods.

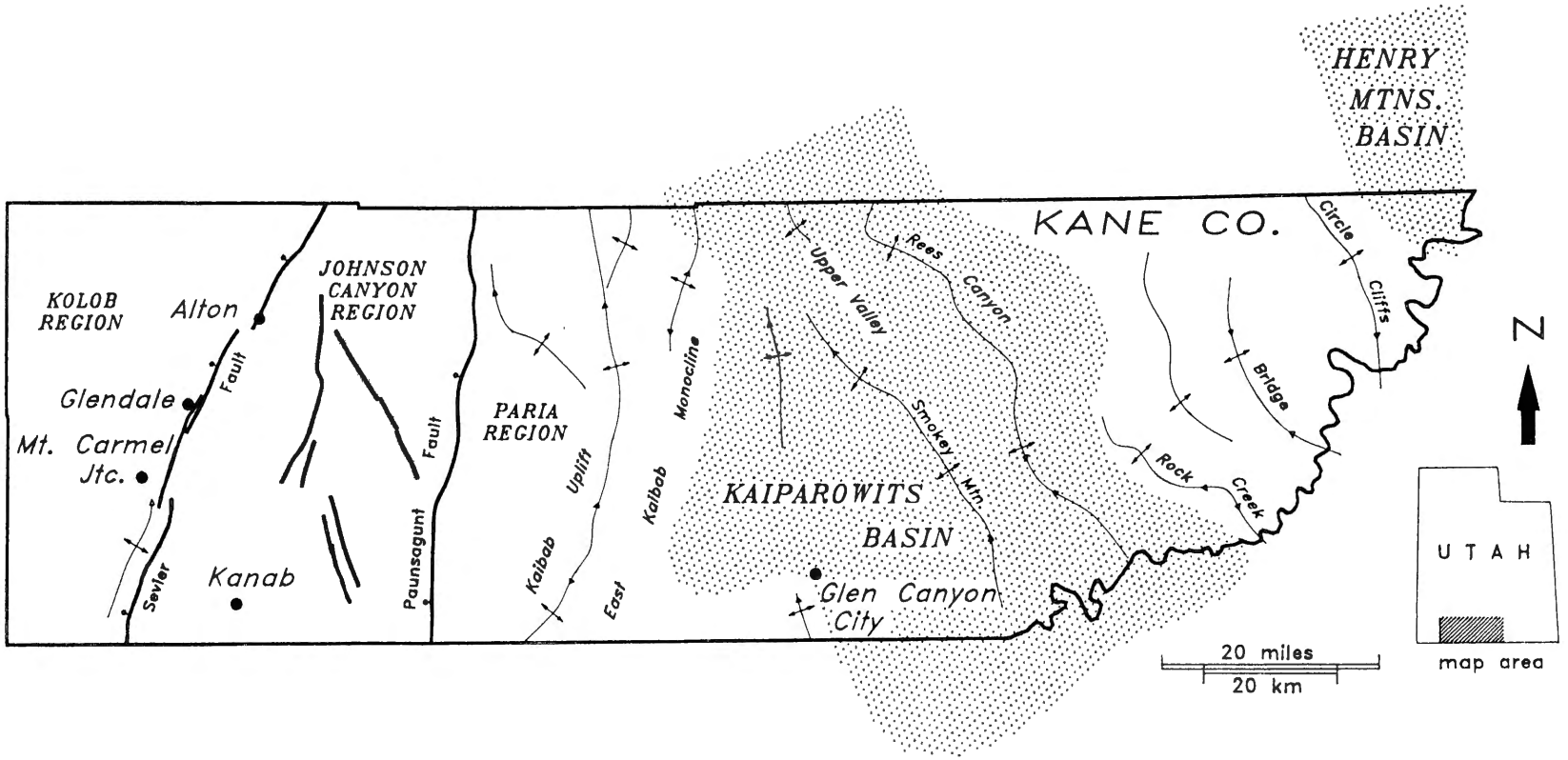

Figure 2. Generalized geologic structure of the study region, showing major faults and major anticlines. The outlines of the present day Kaiparowits and Henry Mountains structural basins are delineated by the 5,500 feet (1,676 m) structural contour line drawn on the base of the Dakota Formation. Sources of information include Peterson (1988) and Doelling and Davis (1989).

Stratigraphy

Permian through Jurassic Rocks

Exposed sedimentary rocks in the region range in age from Permian through Tertiary (figure 3). Upper Permian units that crop out along Kaibab Gulch southwest of The Cockscomb include the Hermit Shale, Toroweap Formation, and Kaibab Formation (Doelling and Davis, 1989).

Triassic-age rocks, also exposed southwest of The Cockscomb, include six members of the Moenkopi Formation and two members of the Chinle Formation (Hintze, 1988). The Moenkopi Formation consists of (from oldest to youngest) the Timpoweap, Lower Red, Virgin Limestone, Middle Red, Shnabkaib, and Upper Red Members. The Shinarump Member of the Chinle Formation is a fluvial conglomeratic sandstone unit which rests unconformable on the Moenkopi Formation. The Shinarump Member is overlain by a series of variegated mudstone and thin sandstone beds of the Petrified Forest Member.

The Glen Canyon Group, the oldest of the Jurassic divisions, consists of the Wingate Sandstone and/or Moenave Formation, Kayenta Formation, and the Navajo Sandstone. The Wingate Sandstone intertongues with the Moenave Formation whereby the Wingate dominates in the eastern Kaiparowits region while the Moenave persists westward from The Cockscomb. The Wingate and Navajo Sandstones are massive, eolian units separated by the fluvio-lacustrine Kayenta Formation. Glen Canyon Group strata thicken to the west and northwest (Peterson, 1988). The Navajo Sandstone is exposed extensively south of the Kaiparowits Plateau, and west of The Cockscomb.

The San Rafael Group, also exposed south and west of the Kaiparowits plateau, overlies the Glen Canyon Group and consists of the Page Sandstone, Carmel Formation, Entrada Sandstone, and Romana Sandstone. The lower division of the San Rafael Group (mostly the Carmel Formation) is primarily shallow, marine limestone and mudstone (Peterson, 1988). The middle division of the San Rafael Group is comprised of the Entrada Sandstone consisting of flat-bedded siltstone and cross-bedded sandstone.

In the Henry Mountains region, the upper division of the San Rafael Group consists of the Curtis Formation and the overlying Summerville Formation. In the Kaiparowits region, the Curtis is absent and the Summerville is replaced by the Romana Sandstone -- the landward facies of the Summerville (Peterson, 1988). The Curtis Formation is largely a marine sandstone with minor limestone, and the Summerville Formation consists of distinct, thin-bedded, red mudstone and siltstone. The Tidwell and Salt Wash Members of the Morrison Formation together form the lower division of the Upper Jurassic series. The Tidwell Member consists of mudstone, sandstone, and thin limestone lenses predominantly of lacustrine and eolian origin. The Salt Wash Member consists of fluvial sandstone and conglomerate and minor fluvio-lacustrine mudstone (Peterson, 1988).

The upper division of the Upper Jurassic series consists of the Brushy Basin Member of the Morrison Formation in the Henry Mountains and northern Kaiparowits regions, and the equivalent Fiftymile Member of the Morrison Formation in the southern Kaiparowits region. The Fiftymile Member represents an alluvial complex that gradually transgressed

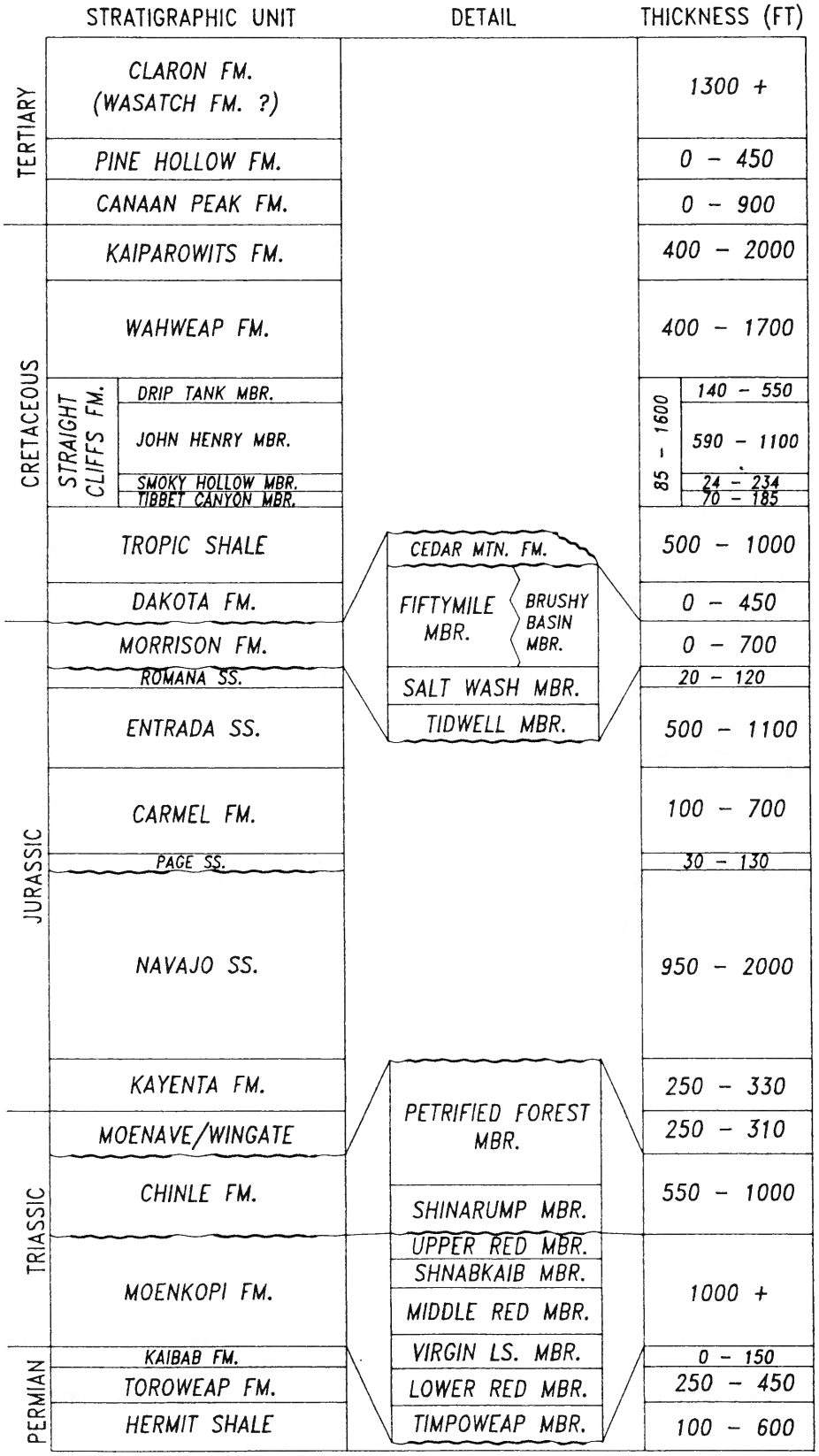

Figure 3. Generalized stratigraphy in the Kaiparowits region. Modified from Hintze (1988, Chart 100) and from Doelling and Davis (1989).

from southwest to northeast across the Kaiparowits region toward mud flat and lacustrine environments represented by the Brushy Basin Member (Hintze, 1988; Peterson, 1988).

Cretaceous and Tertiary Rocks

Lower Cretaceous rocks are absent over much of Kane County, but Hintze (1988) indicates that some remnants of the Cedar Mountain Formation are present in southeastern Kane County. The Cedar Mountain Formation, consists of interbedded fluvial sandstone and mudstone derived from western highlands of the Sevier orogenic belt.

Peterson (1969) separates Upper Cretaceous rocks into three divisions. The lower division consists of the Dakota Formation, Tropic Shale, and the Tibbet Canyon and Smoky Hollow Members of the Straight Cliffs Formation. The middle division consists of the John Henry and Drip Tank Members of the Straight Cliffs Formation and was deposited during two significant transgressive-regressive cycles (Peterson and Kirk, 1977). The upper division consists of Upper Cretaceous to Paleocene rocks including the Wahweap, Kaiparowits, Canaan Peak, and Pine Hollow Formations.

In the Kaiparowits Plateau region, the Dakota Formation consists of a thicker sequence of Cretaceous rocks than elsewhere in Utah. Economically important coal beds occur in the Dakota Formation in the Kolob and Alton coal fields in western Kane County. Dakota Formation coal beds in the Kaiparowits basin occur in structural troughs, or synclines, and are apparently related to restrictive depositional environments formed within these troughs. Dakota coals in the Kaiparowits region are thin and discontinuous. Equivalent Cretaceous rocks occurring farther to the west in Washington and Iron Counties are assigned to the Iron Springs Formation (Hintze, 1988).

The Tibbet Canyon Member consists mostly of marine sandstone, and the Smoky Hollow Member consists of sandstone, siltstone, and coal. Coal beds in the Smoky Hollow Member of the Straight Cliffs Formation, become thin or are absent over paleo-anticlines and upthrown fault blocks, indicating that deposition was influenced by repeated movement on folds and faults (Peterson, 1988). The Smoky Hollow Member is capped by the Calico Bed (figure 4), a fluvial unit related to a major regression of the Cretaceous shoreline (Hintze, 1988).

The John Henry Member of the Straight Cliffs Formation, which consists of marine sandstone and shale and non-marine fluvial deposits, contains the major coal zones of the Kaiparowits basin. Coal zones in the John Henry Member represent a narrow belt of coastal swamps and lagoons confined between Upper Cretaceous shoreline (barrier islands) facies to the northeast and alluvial-plain facies to the southwest. The overlying Drip Tank Member, a fluvial sandstone unit, represents the last major regression of the Cretaceous shoreline (from west to east) across the Kaiparowits basin (Peterson, 1988).

Upper division stratigraphic units, which consist of primarily lacustrine and fluvial clastic sediments of the Wahweap and Kaiparowits Formations, were deposited during the Laramide orogeny from source regions primarily to the west and southwest. They are locally truncated by the Eocene Claron Formation, a lacustrine limestone unit thought to be the equivalent of the Flagstaff Limestone in north-central Utah.

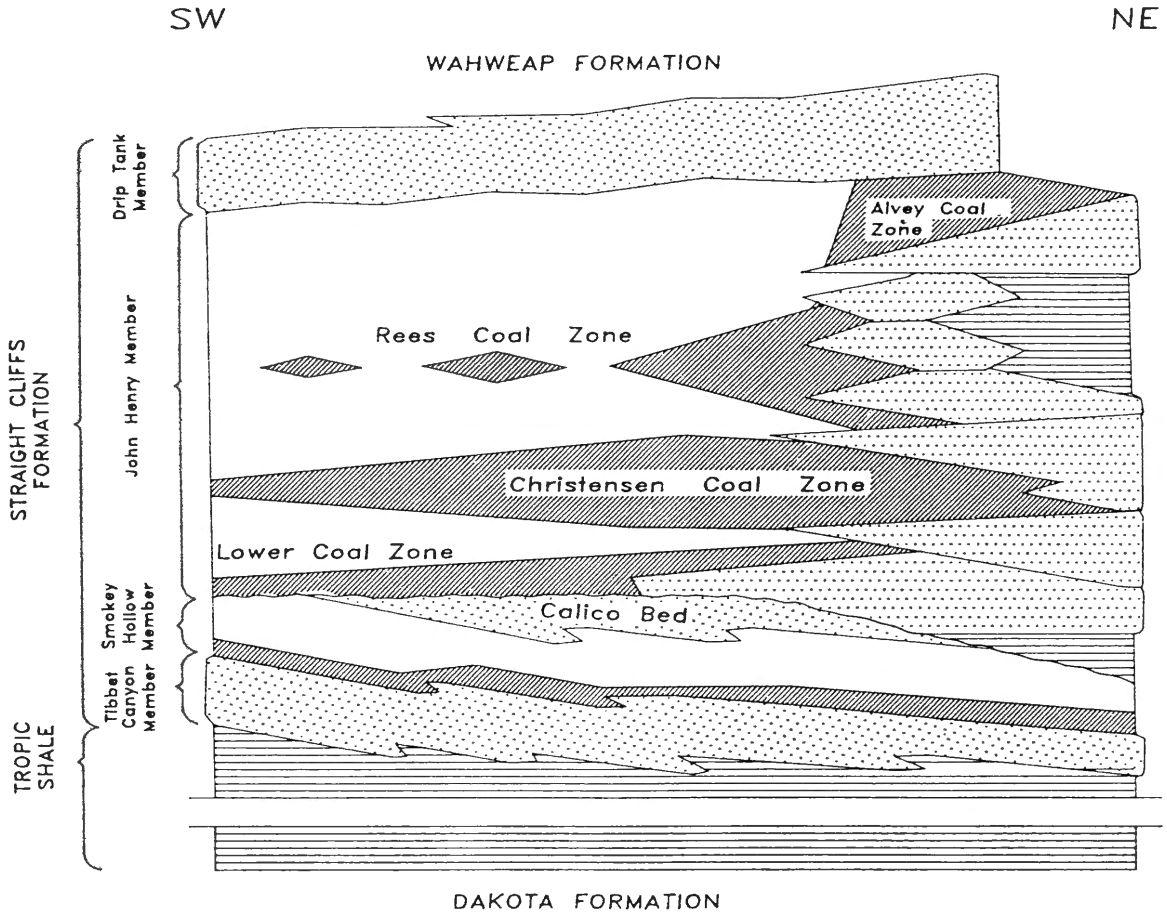

Figure 4. Stratigraphic relationships within the Straight Cliffs Formation. Slanted line pattern denotes coal zones; stipple pattern denotes fluvial deosits (Drip Tank Member and Calico Bed) and marine sandstone; horizontal line pattern denotes marine mudstone; and blank areas denote alluvial-plain facies (after Peterson, 1969 and 1989).

Holocene unconsolidated deposits include alluvial sediments, colluvium, talus, and eolian sand and silt. Stream channel sediments are found at the mouths of canyons and along the course of stream beds. Colluvium accumulates on gentle slopes, and talus accumulates at the base of steep slopes and cliffs. Eolian deposits are scattered throughout the study area.

COAL IN THE JOHN HENRY MEMBER

Coal-Bearing Rock Units

Within the Kaiparowits Plateau coal field, coal beds of commercial interest occur within the Smoky Hollow and the John Henry Members of the Straight Cliffs Formation, However the most important coal beds, often exceeding 20 feet (6.1 m) thick, are contained within the John Henry Member (figure 4). At least three of the four John Henry Member coal zones contain coal beds of commercial thickness and quality. Coal żones, in ascending order, are named the (1) Lower, (2) Christensen (Henderson in the Tropic area), (3) Rees, and (4) Alvey.

Thicker coal beds generally occur in the Christensen coal zone. The Christensen zone may contain up to four thick coal beds, the thickest usually occurring within paleo-structural troughs. Although normally discontinuous, individual coal beds in trough areas can be laterally extensive. The Christensen coal zone thins and splits southwest of Nipple Bench. Christensen coal beds are extensively burned along the outcrop in the Smoky Mountain area, producing reddish surface oxidation (Doelling and Davis, 1989).

Coal Development History

At least three small mines and a few prospects produced coal from the Straight Cliffs Formation of the Kaiparowits Plateau field in the past (plate 1). These include the Warm Creek experimental mine (section 19, T. 41 S., R. 4 E.), the Spencer No. 1 and No. 2 mines (section 3, T. 42 S., R. 3 E.), and the John Henry prospect (section 12, T. 42 S., R. 3 E.). The mines are located in the Smoky Mountain area on the southern end of the field and are now abandoned. Total production from all mines was probably less than 14,000 tons (12,700 mt), with the majority (12,000 tons or 10,900 mt) of coal production coming from the Warm Creek experimental mine. The Warm Creek mine was opened in 1971 to test underground mining conditions (Doelling and Davis, 1989).

Andalex Resources, Inc. has proposed opening a 2.5 million ton-per-year (1.44 million mt/yr) underground coal mine at Smoky Hollow near the site of the Warm Creek test mine. Andalex's property consists of 34,500 acres (13,970 ha) of federal coal leases and 1,900 acres (770 ha) of state mineral leases. Estimated mine life is 30 years. They estimate that 1.7 billion tons (1.55 billion mt) of coal reserves in-place underlie the property, and that about 440 million tons (400 million mt) of the in-place reserves are recoverable (Governor's Office of Planning and Budget, 1993).

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Coal Quality

The quality of coal in the Kaiparowits Plateau coal field varies in rank from subbituminous C to high-volatile C bituminous. Doelling and Davis (1989) reported average analyses (as-received basis) for 15 drill-hole samples from the Smoky Mountain area of the Kaiparowits Plateau (table 1). Although not specified, it is assumed that the samples were collected from coal beds in the John Henry Member of the Straight Cliffs Formation. Proximate and ultimate analyses indicate that these coals are high-volatile C bituminous in rank.

Andalex Resources, Inc. (1991) reported the anticipated quality of coal from their proposed five-year mine plan based upon analyses of core samples from nine large-diameter drill holes (table 1).

Table 1. Average of coal analyses (as-received basis) from the Smoky Mountain area.

	Doelling and Davis (1989)	Andalex (1991)
Proximate Analysis	Percent	Percent
Moisture	9.47	9.08
Volatile Matter	38.17	41.06
Fixed Carbon	43.67	44.90
Ash	7.67	4.80
BTU/lb	11,369	11,964
Ultimate Analysis		
Carbon	65.08	---
Oxygen	11.91	---
Hydrogen	4.48	---
Sulfur	0.47	---
Parr Formula BTU/lb	11,837	---

Study Methodology

Thicknesses of coal beds (greater than one foot; 0.3 m) were compiled from published coal measurements and from unpublished, drilling data contained in confidential UGS files. The information includes data from 560 coal outcrop measurements reported by Doelling and

Graham (1972), coal-bed intercepts taken from 156 proprietary drill logs, and information from published reports on the Kaiparowits Plateau coal field by Hansen (1978a, 1978b) and Lidke and Sargent (1983).

Coal thicknesses from measured sections and drill holes were used to separate coal resource areas based on the continuity, thickness, and number of coal beds present within the John Henry Member. These resource areas are presented with respect to WSAs in Blackett and others (1992).

Measured-Section Data

Locations of nearly 560 coal measured sections were taken from Doelling and Graham (1972) and plotted onto 1:100,000-scale base maps. The corresponding thicknesses of coal beds and interbeds for each measured section were entered into a computer data file where one character-string line (one record) represents one measured section. Each line, or record, in the data file consists of a series of space-delimited alphanumeric characters and has the following general structure:

1. record number (map location)
2. coal zone designation
3. material type (coal, rock, burn, or carbonaceous shale)
4. thickness (in feet)

An example of a record from the file is shown below:

CT6 100 C 7.7 R 1 C 0.8 R 1.5 C 0.2

Each set of space-delimited characters represents a data field. In the example, CT6 represents the point location shown on plate 1. The prefix "CT" refers to the name of the 7.5 minute quadrangle from Doelling and Graham (1972) where the point is located -- in this case, the Collet Top quadrangle. Quadrangle codes are listed in appendix A. The next set of characters, following a space, refer to the name of the coal zone. The designation "100" refers to the Alvey Coal Zone. The following list shows codes assigned to coal zones:

CODE	COAL ZONE
<u>Straight Cliffs Formation</u>	
100	John Henry Member, Alvey coal zone
200	John Henry Member, Rees coal zone
300	John Henry Member, Christensen coal zone
400	Smoky Hollow Member, Smoky Hollow coal zone
500	Smoky Hollow Member, Lower coal zone

CODE	COAL ZONE
Dakota Formation	
600	Dakota coal zone

The next character is always "C" indicating the first coal bed at the top of the measured section. A numeric value follows and represents the thickness, in feet, of the coal bed. In the example, the uppermost coal bed is 7.7 feet thick. The next character (in most cases) is an "R", which is a symbol for rock or interbeds, followed by a thickness in feet and alternating space-delimited, coal/thickness/interbed/thickness designations to the end of the record. Other material symbols included in the data file are "B" indicating a burned zone, and "P" indicating poor exposure. A summary of measured sections from this file is presented in appendix A. The file, named KMEAS.DAT, is included on diskette as part of this report.

Drill-Hole Data

Because large areas of the Kaiparowits field lie beneath deep cover, it was necessary to review and summarize proprietary drilling data from UGS confidential files. In accordance with a Memorandum of Understanding with the BLM, the UGS is designated as a "Secondary Office of Control" for federal coal data for Utah and may use these data to confirm findings, develop geologic models, produce derivative maps, sections and reports, and develop regional syntheses. The UGS, however, is not permitted under the Memorandum of Understanding to release specific mineral resource data (Bureau of Land Management, 1992).

The type of information encountered within the proprietary data set ranged in quality from detailed reports on drilling activities including interpreted electric logs, results of coring, and analytical reports on individual coal beds to hand-written notes of coal intercepts. Because the project scope did not include a complete evaluation of all drilling data, only drilling records of good quality (geophysical logs or core descriptions) with a spacing of roughly one drill hole per square mile were used. Records from about 170 drill holes were selected. Typically, locations of drill holes were given in terms of direction and distance from section lines, or as section subdivisions. In some cases only an approximate location was available.

After interpreting the geophysical logs and other drilling data, coal intercepts in each of the holes were generalized for a summary report permitting a regional-scale display of coal for the southern part of the Kaiparowits field (plate 1). Without disclosing specific coal intercepts, the summary (appendix B) shows drill-hole index numbers, total depth of the hole, total thickness of coal contained in all beds (minimum thickness of 1 ft; 0.3 m), total thickness of coal contained in beds with a thickness of 4 feet (1.2 m) or more, and the thickness of the thickest bed.

SUMMARY AND CONCLUSIONS

Measured-section and drilling data indicate that coal bed thicknesses in the John Henry Member vary considerably throughout the southern part of the Kaiparowits Plateau coal field. Isopleth lines, depicting the total thickness of coal in all beds (minimum thickness of 1 ft; 0.3 m) based upon drilling data in appendix B, are shown on plate 1. No correlations were made and no coal zone names were assigned. Presumably, most coal beds belong to the Christensen coal zone. The thickest coal accumulation lies in a 15- to 18-mile (24- to 29-km) wide band trending roughly N. 30° W. through the center of the plateau for a distance of nearly 30 miles (48 km), and probably reflects the principal position of Cretaceous coal-forming swamps (Peterson, 1988).

Total thickness of coal in the John Henry Member varies greatly. A maximum thickness of nearly 150 feet (46 m) occurs near the north-central part of the study area. To the east, in the vicinity of Fiftymile Mountain, coal beds in the John Henry Member thin and pinch out against marine sandstone. Southwest of Nipple Bench the coal beds become thinner and eventually pinch out near the East Kaibab monocline (The Cockscomb). The 1,970-ft (600-m) and 2,950-ft (900-m) overburden contours (from Hansen, 1978b), depict the thickness of cover from the surface to the base of the Christensen (Henderson) coal zone. Virtually no exploratory drill holes are found in the western part of the region where the cover exceeds 1970 feet (600 m). Thick cover extends northward along the east side of the East Kaibab monocline toward Canaan Peak and Upper Valley. Coal beds of minable thickness may occur beneath this region, but more drilling is necessary in order to confirm their existence.

This investigation provides a preliminary framework for additional, more detailed subsurface studies on Kaiparowits Plateau coals. The drilling data used in this investigation represent only a small part of the proprietary files. Detailed analyses of all the proprietary Kaiparowits coal data could be of much use to resource planners, coal operators, and research geologists should the data be released into the public domain.

ACKNOWLEDGMENTS

Mike Shubat, Dave Tabet, Bob Gloyn, and Bryce Tripp of the UGS, and Jim Kohler of the BLM reviewed the report and provided many helpful suggestions. Jim Parker of the UGS generated the detailed coal map (plate 1) using the UGS's CAD system.

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APPENDIX A:

Summary of measured-section data from Doelling and Graham (1972). All thicknesses in feet. The ASCII-format data-file (KMEAS.DAT) and the Pascal program file (KMEAS.PAS) to generate the summary listing are available on diskette.

Quadrangle codes used in Appendix A

BC	Basin Canyon
BN	Nipple Butte NE
CA	Carcass Canyon
CH	Calico Peak/Horse Flat
CT	Collet Top
DR	Death Ridge
EN	East of the Navajo
GN	Gunsight Butte NW
HE	Henrieville
NB	Nipple Butte NW
NE	Needle Eye Point
NS	Nipple Butte SE
NW	Nipple Butte SW
PC	Pete's Cove
PN	Paria NW
SB	Slick Rock Bench
SF	Seep Flat
SM	Ship Mountain Point

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
BC1	Alvey	0.5	0.5	1	0.5
BC2	Alvey	1.5	1.5	1	1.5
BC3	Alvey	2.0	2.0	1	2.0
BC4	Alvey	1.7	2.0	2	1.2
BC5	Rees	1.1	10.0	2	1.0
BC6	Christensen	3.8	10.0	4	2.0
BC7	Christensen	5.1	11.6	4	3.0
BC8	Christensen	2.5	2.5	1	2.5
BC9	Lower Zone	5.0	10.2	3	4.0
BN12A	Lower Zone	0.0	22.6	0	0.0
BN15A	Lower Zone	2.0	5.5	2	1.0
BN16A	Lower Zone	2.3	2.3	1	2.3
BN4B	Christensen	1.0	1.0	1	1.0
BN5B	Christensen	3.0	46.4	3	1.0
BN7B	Christensen	5.2	24.2	2	3.2
BN9B	Christensen	1.0	1.0	1	1.0
BN10B	Christensen	1.0	1.0	1	1.0
BN11B	Christensen	1.0	110.0	1	1.0
BN12B	Christensen	1.0	166.5	1	1.0
BN13B	Christensen	4.0	64.6	4	1.0
BN14B	Christensen	1.0	1.0	1	1.0
BN15B	Christensen	1.7	18.2	1	1.7
BN16B	Christensen	0.0	23.5	0	0.0
BN17B	Christensen	5.6	71.4	4	2.4
BN18B	Christensen	0.0	43.5	0	0.0
BN1C	Christensen	8.5	44.2	3	6.5
BN2C	Christensen	10.7	86.2	2	9.7
BN3C	Christensen	9.5	99.7	7	3.1
BN4C	Christensen	25.3	211.5	11	8.6
BN5C	Christensen	4.0	180.7	3	2.0
BN6C1	Christensen	26.3	90.5	6	12.6
BN6C2	Christensen	34.1	97.1	7	17.3
BN7C	Christensen	1.0	1.0	1	1.0
BN8C	Christensen	1.7	55.0	1	1.7
BN9C	Christensen	5.3	73.7	3	2.1
BN10C	Christensen	0.0	57.8	0	0.0
BN11C	Christensen	19.3	128.9	7	4.6
BN12C	Christensen	26.1	64.1	7	5.8
BN13C	Christensen	8.0	221.0	8	1.0
BN14C	Christensen	22.8	104.2	7	7.0
BN15C	Christensen	1.0	48.8	1	1.0
BN16C	Christensen	1.0	222.3	1	1.0
BN17C	Christensen	13.8	133.0	7	4.2
BN18C	Christensen	1.0	126.6	1	1.0
BN1D	Rees	4.0	32.3	3	2.0
BN4D	Rees	3.6	45.7	2	2.5
BN6D	Rees	5.6	70.4	3	3.6
BN12D	Rees	5.2	127.7	4	2.2
BN14D	Rees	4.0	98.5	4	1.0
BN15D	Rees	0.0	11.0	0	0.0
BN16D	Rees	0.0	37.9	0	0.0
BN18D	Rees	9.0	31.0	4	4.0
BN1E	Alvey	2.5	16.1	3	1.2
BN2E	Rees	13.0	15.2	5	9.8

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
BN3E	Rees	3.3	4.2	4	1.9
BN4E	Rees	3.1	3.1	1	3.1
BN5E	Christensen	2.5	2.5	1	2.5
BN6E	Christensen	4.4	5.8	3	3.1
BN7E	Christensen	7.1	7.9	3	3.4
BN8E	Christensen	3.0	3.0	1	3.0
BN9E	Lower Zone	2.6	2.6	1	2.6
BN10E	Lower Zone	3.2	3.2	1	3.2
CA2	Alvey	5.5	28.5	3	2.5
CA4	Alvey	1.0	1.0	1	1.0
CA5	Alvey	1.0	1.0	1	1.0
CA6	Alvey	4.0	12.0	2	3.0
CA7	Alvey	7.0	15.0	2	3.5
CA8	Alvey	6.0	11.5	2	3.0
CA9	Alvey	8.5	15.5	2	5.5
CA10	Alvey	3.7	3.7	1	3.7
CA11	Alvey	1.5	1.5	1	1.5
CA12	Alvey	8.5	10.0	3	3.5
CA13	Alvey	5.8	9.3	3	3.0
CA14	Alvey	4.5	22.0	2	2.5
CA15	Alvey	4.4	14.4	4	3.5
CA16	Alvey	4.5	4.5	1	4.5
CA17	Alvey	9.5	27.5	4	4.5
CA18	Alvey	8.0	8.0	1	8.0
CA19	Alvey	4.5	4.5	1	4.5
CA27	Alvey	1.0	1.0	1	1.0
CA28	Alvey	2.0	2.0	1	2.0
CA29	Alvey	5.5	7.0	2	4.5
CA30	Alvey	5.0	5.0	1	5.0
CA31	Alvey	18.0	29.0	2	16.5
CA32	Alvey	11.0	11.0	1	11.0
CA33	Alvey	5.0	5.0	1	5.0
CA34	Alvey	6.0	6.0	1	6.0
CA35	Alvey	14.5	25.0	2	11.0
CA36	Alvey	5.0	5.0	1	5.0
CA37	Alvey	8.0	8.0	1	8.0
CA39	Alvey	4.0	4.0	1	4.0
CA42	Alvey	2.0	3.0	2	1.0
CA43	Alvey	3.0	3.0	1	3.0
CA45	Alvey	2.0	2.0	1	2.0
CA46	Alvey	7.0	7.0	1	7.0
CA47	Alvey	3.5	3.5	1	3.5
CA48	Alvey	1.3	5.3	2	1.0
CA50	Alvey	15.4	16.0	2	11.4
CA52	Alvey	7.3	7.3	1	7.3
CA58	Alvey	8.5	8.5	1	8.5
CA59	Alvey	10.5	10.5	1	10.5
CA60	Alvey	8.5	8.5	1	8.5
CA61	Alvey	8.0	8.5	2	7.0
CA62	Alvey	7.5	7.7	2	6.0
CA63	Alvey	6.0	6.0	1	6.0
CA64	Alvey	3.2	4.5	2	1.6
CA65	Alvey	5.5	13.5	4	2.0
CA66	Alvey	4.3	4.3	1	4.3

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
CA67	Alvey	7.5	12.5	2	4.5
CA68	Alvey	2.0	2.0	1	2.0
CA69	Alvey	0.5	0.5	1	0.5
CA70	Alvey	1.0	1.0	1	1.0
CA71	Alvey	3.0	3.0	1	3.0
CA72	Alvey	4.5	5.5	2	3.0
CA73	Alvey	17.0	18.0	2	14.0
CA75	Alvey	3.5	3.5	1	3.5
CA77	Alvey	4.0	4.0	1	4.0
CA78	Rees	4.8	4.8	1	4.8
CA79	Rees	1.0	1.0	1	1.0
CA80	Rees	2.0	2.0	1	2.0
CA81	Rees	2.0	2.0	1	2.0
CA82	Rees	8.0	24.0	3	3.5
CA85	Rees	6.5	14.0	3	3.0
CA86	Rees	4.0	4.0	1	4.0
CA87	Rees	6.6	6.6	1	6.6
CA88	Rees	2.0	2.0	1	2.0
CA89	Rees	2.0	2.0	1	2.0
CA90	Rees	2.0	2.0	1	2.0
CA91	Rees	2.0	2.0	1	2.0
CA92	Rees	1.0	1.0	1	1.0
CA93	Rees	1.5	2.5	2	1.0
CA94	Rees	3.8	3.8	1	3.8
CA98	Rees	2.0	2.0	1	2.0
CA100	Rees	5.5	8.5	3	3.0
CA101	Rees	2.0	2.0	1	2.0
CA102	Rees	4.0	4.0	1	4.0
CA103	Christensen	3.0	3.0	1	3.0
CA104	Christensen	4.0	4.0	1	4.0
CA105	Christensen	5.0	5.0	1	5.0
CA106	Christensen	4.0	4.0	1	4.0
CA107	Christensen	6.0	6.0	1	6.0
CA108	Christensen	7.0	7.5	2	4.5
CA109	Christensen	6.0	56.0	2	5.0
CA110	Christensen	3.5	3.5	1	3.5
CA111	Christensen	2.5	2.5	1	2.5
CA112	Christensen	4.0	4.0	1	4.0
CA113	Christensen	6.5	34.5	3	2.8
CA114	Christensen	1.0	1.0	1	1.0
CA115	Christensen	1.9	2.2	2	1.2
CA116	Christensen	6.0	11.5	3	4.5
CA118	Christensen	4.0	6.0	2	3.0
CA119	Christensen	6.5	11.5	3	3.0
CA120	Christensen	5.0	5.0	1	5.0
CA121	Christensen	8.0	11.5	2	7.0
CA122	Christensen	6.0	6.0	1	6.0
CA123	Christensen	4.0	4.0	1	4.0
CA124	Christensen	4.0	4.0	1	4.0
CA125	Christensen	5.0	5.0	1	5.0
CA126	Christensen	6.0	6.0	1	6.0
CA127	Christensen	7.0	13.0	3	4.0
CA128	Christensen	6.3	6.3	1	6.3
CA129	Christensen	9.0	12.0	2	6.5

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
CA133	Christensen	1.5	1.5	1	1.5
CA136	Christensen	3.5	5.5	2	2.5
CA138	Christensen	6.0	17.0	2	4.5
CA139	Christensen	4.5	4.5	1	4.5
CA140	Christensen	7.0	25.0	2	5.5
CA141	Christensen	5.5	10.0	2	4.0
CA142	Christensen	11.7	53.2	4	7.0
CA144	Christensen	31.0	113.0	7	7.0
CA145	Christensen	30.3	113.8	6	7.5
CA146	Christensen	11.0	11.0	1	11.0
CA147	Christensen	4.4	4.8	3	2.3
CA148	Christensen	3.5	9.5	2	2.5
CA149	Christensen	14.0	28.5	3	10.0
CA150	Christensen	9.0	9.0	1	9.0
CA151	Christensen	7.5	18.3	2	5.5
CA152	Christensen	3.8	5.3	2	2.5
CA153	Christensen	4.5	4.5	1	4.5
CA154	Christensen	8.9	13.7	4	4.7
CA156	Lower Zone	1.0	1.0	1	1.0
CC20	Alvey	5.0	5.0	1	5.0
CC21	Alvey	3.3	3.3	1	3.3
CC23	Alvey	8.0	8.0	1	8.0
CC24	Alvey	2.1	2.1	1	2.1
CC32	Alvey	9.0	9.0	1	9.0
CC33	Alvey	5.0	5.0	1	5.0
CC34	Alvey	8.1	8.8	2	7.0
CC35	Alvey	13.2	41.4	3	9.0
CC52	Rees	0.8	9.6	3	0.4
CC53	Rees	3.9	3.9	1	3.9
CC59	Rees	5.0	5.0	1	5.0
CC74	Christensen	6.0	6.0	1	6.0
CC75	Christensen	10.0	10.0	1	10.0
CC76	Christensen	3.5	3.5	1	3.5
CC77	Christensen	13.0	13.0	1	13.0
CH1	Dakota	3.5	3.5	1	3.5
CH2	Dakota	2.5	2.5	1	2.5
CT1	Alvey	5.4	5.4	1	5.4
CT2	Alvey	4.5	4.5	1	4.5
CT3	Alvey	8.3	8.8	2	4.8
CT4	Alvey	3.0	3.0	1	3.0
CT5	Alvey	1.5	1.5	1	1.5
CT6	Alvey	8.6	11.1	3	7.6
CT7	Alvey	2.4	2.4	1	2.4
CT9	Alvey	2.5	3.9	2	2.0
CT10	Alvey	12.0	12.0	1	12.0
CT11	Alvey	11.6	18.0	4	9.3
CT12	Alvey	10.2	12.6	4	7.3
CT13	Alvey	6.0	6.0	1	6.0
CT14	Alvey	2.3	2.3	1	2.3
CT15	Alvey	5.0	5.0	1	5.0
CT16	Alvey	8.4	51.8	3	3.4
CT17	Alvey	4.7	16.2	2	3.3
CT18	Alvey	6.0	6.0	1	6.0
CT19	Alvey	17.0	33.0	4	7.0

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
CT21	Alvey	1.5	1.5	1	1.5
CT22	Alvey	3.5	3.5	1	3.5
CT23	Alvey	4.0	4.5	2	3.0
CT24	Alvey	3.0	3.0	1	3.0
CT25	Alvey	3.7	7.7	4	2.0
CT26	Alvey	2.0	2.0	1	2.0
CT27	Alvey	1.8	3.0	2	1.5
CT28	Alvey	2.3	2.6	2	1.8
CT29	Alvey	3.0	3.0	1	3.0
CT30	Alvey	1.0	1.0	1	1.0
CT31	Alvey	4.5	6.7	2	2.5
CT32	Alvey	4.4	4.4	1	4.4
CT33	Alvey	3.4	5.4	2	3.0
CT34	Alvey	7.5	7.5	1	7.5
CT35	Alvey	6.0	6.0	1	6.0
CT36	Alvey	4.0	4.0	1	4.0
CT37	Alvey	3.1	4.2	3	2.0
CT38	Alvey	5.3	5.4	2	2.8
CT39	Alvey	3.0	3.0	1	3.0
CT40	Alvey	5.4	5.4	1	5.4
CT41	Alvey	7.8	7.8	1	7.8
CT42	Alvey	3.8	3.8	1	3.8
CT43	Alvey	4.7	4.7	1	4.7
CT44	Alvey	4.5	7.3	2	2.9
CT45	Alvey	4.7	7.2	2	3.5
CT46	Alvey	1.5	3.0	2	1.0
CT49	Alvey	4.9	14.7	3	2.0
CT50	Alvey	2.7	4.7	2	1.5
CT51	Alvey	1.6	5.1	2	0.8
CT52	Alvey	4.8	8.8	2	3.3
CT53	Alvey	5.0	5.0	1	5.0
CT54	Alvey	7.0	7.0	1	7.0
CT55	Alvey	2.0	2.0	1	2.0
CT56	Alvey	5.0	5.0	1	5.0
CT57	Alvey	14.0	14.0	1	14.0
CT58	Alvey	5.0	5.7	2	4.5
CT59	Alvey	8.8	10.3	3	6.0
CT60	Alvey	7.4	8.4	3	2.8
CT61	Alvey	10.7	28.1	4	3.4
CT62	Alvey	15.8	26.7	4	6.5
CT63	Alvey	11.0	11.0	1	11.0
CT64	Alvey	4.5	4.5	1	4.5
CT65	Alvey	6.1	11.4	2	5.8
CT66	Alvey	5.4	5.4	1	5.4
CT67	Alvey	4.0	22.0	2	3.5
CT68	Rees	6.1	34.8	4	2.3
CT69	Rees	3.0	3.0	1	3.0
CT70	Rees	4.1	7.6	2	2.5
CT71	Rees	5.3	11.5	3	4.5
CT72	Rees	3.2	3.2	1	3.2
CT73	Rees	2.8	2.8	1	2.8
CT74	Christensen	3.0	3.0	1	3.0
CT75	Christensen	19.7	35.5	3	7.3
CT76	Christensen	14.2	23.4	3	6.4

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
CT77	Christensen	26.0	107.0	10	14.8
DC1	Alvey	1.6	4.8	2	1.3
DC2	Alvey	1.0	1.0	1	1.0
DC3	Alvey	1.5	1.5	1	1.5
DC4	Alvey	2.3	2.3	1	2.3
DC5	Alvey	5.0	5.0	1	5.0
DC6	Alvey	5.0	5.0	1	5.0
DC7	Alvey	7.2	7.2	1	7.2
DC8	Alvey	6.0	6.0	1	6.0
DC9	Alvey	3.7	4.0	2	3.2
DC10	Alvey	9.0	13.8	2	7.5
DC11	Alvey	8.0	11.2	2	6.5
DC12	Alvey	10.5	10.8	2	9.0
DC13	Alvey	5.4	5.7	2	4.5
DC14	Alvey	5.0	5.0	1	5.0
DC15	Alvey	3.0	3.0	1	3.0
DC16	Alvey	9.0	9.8	3	6.0
DC17	Alvey	13.0	14.5	3	10.0
DC18	Alvey	9.4	15.6	4	5.0
DC19	Alvey	7.5	13.8	3	4.0
DC20	Alvey	5.0	5.0	1	5.0
DC21	Alvey	4.5	5.0	2	4.0
DC22	Alvey	5.4	7.7	4	3.0
DC23	Alvey	2.0	2.0	1	2.0
DC24	Alvey	1.0	1.0	1	1.0
DC25	Rees	4.0	5.0	2	3.0
DC26	Rees	1.0	1.0	1	1.0
DC27	Rees	1.0	1.0	1	1.0
DC28	Rees	1.8	1.8	1	1.8
DC29	Rees	0.8	0.8	1	0.8
DC30	Christensen	16.0	22.0	2	8.0
DC31	Christensen	8.0	8.0	1	8.0
DC32	Christensen	5.0	28.3	2	4.0
DC33	Christensen	6.0	6.4	2	5.0
DC34	Christensen	4.0	4.0	1	4.0
DC35	Christensen	10.2	10.8	3	6.2
DC36	Christensen	3.3	6.0	2	2.3
DC37	Christensen	9.0	83.7	3	5.0
DC38	Christensen	16.8	19.3	2	15.0
DC39	Christensen	5.5	27.3	3	3.0
DC40	Christensen	26.9	114.3	5	8.0
DC41	Christensen	21.4	87.4	6	4.8
DC42	Dakota	1.5	1.5	1	1.5
DC43	Dakota	3.5	5.0	2	2.5
DC44	Dakota	3.7	4.4	2	3.0
DC45	Dakota	4.5	4.8	2	3.5
DC46	Dakota	5.0	5.0	1	5.0
DC47	Dakota	5.0	5.0	1	5.0
DC48	Dakota	5.0	5.0	1	5.0
DC49	Dakota	5.0	5.0	1	5.0
DC50	Dakota	2.5	2.5	1	2.5
DC51	Dakota	4.7	4.9	2	2.5
DC52	Dakota	5.0	6.8	2	4.0
DC53	Dakota	4.3	4.7	2	3.0

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
DC54	Dakota	1.5	1.5	1	1.5
DC56	Dakota	17.3	34.6	4	5.7
DR12	Alvey	6.0	6.0	1	6.0
DR14	Alvey	1.4	1.4	1	1.4
DR15	Alvey	14.0	20.0	2	10.0
DR23	Rees	6.0	6.0	1	6.0
DR24	Rees	3.0	3.0	1	3.0
DR25	Rees	2.0	4.0	2	1.0
DR26	Rees	2.2	27.2	2	1.2
DR27	Rees	5.0	5.0	1	5.0
DR29	Rees	4.6	6.1	3	3.0
DR34	Christensen	7.5	15.0	2	5.0
DR35	Christensen	4.8	5.8	2	4.0
DR37	Christensen	7.0	7.0	1	7.0
DR38	Christensen	2.0	2.0	1	2.0
DR39	Christensen	1.4	1.4	1	1.4
DR40	Christensen	5.8	7.3	2	4.5
DR41	Christensen	4.6	4.6	1	4.6
EN1	Alvey	1.0	1.0	1	1.0
EN2	Alvey	2.9	2.9	1	2.9
EN3	Alvey	5.0	7.0	2	3.0
EN4	Alvey	2.5	2.5	1	2.5
EN5	Alvey	4.6	4.6	1	4.6
EN6	Rees	2.3	2.3	1	2.3
EN7	Rees	2.4	2.4	1	2.4
EN8	Rees	4.6	4.6	1	4.6
EN9	Christensen	1.5	1.5	1	1.5
EN10	Christensen	7.0	7.0	1	7.0
EN11	Christensen	2.0	2.0	1	2.0
EN12	Christensen	5.0	5.0	1	5.0
EN13	Lower Zone	3.5	3.8	2	2.2
EN14	Lower Zone	3.1	3.4	2	2.8
EN15	Lower Zone	5.0	5.0	1	5.0
GN3A	Lower Zone	2.0	7.0	2	1.0
GN5A	Lower Zone	2.9	2.9	1	2.9
GN7A	Lower Zone	5.8	13.3	2	4.8
GN8A	Lower Zone	2.8	2.8	1	2.8
GN9A	Lower Zone	2.9	4.5	2	1.9
GN10A	Lower Zone	1.2	1.2	1	1.2
GN20A	Lower Zone	3.4	21.8	3	1.4
GN22A	Lower Zone	2.2	13.9	2	1.2
GN23A	Lower Zone	1.1	1.1	1	1.1
GN2B	Christensen	14.2	143.9	12	1.6
GN3B	Christensen	14.0	108.0	13	1.8
GN4B	Christensen	5.0	120.4	5	1.0
GN5B	Christensen	6.3	120.8	4	2.5
GN6B	Christensen	3.0	91.8	3	1.0
GN7B	Christensen	10.9	126.0	10	1.6
GN9B	Christensen	4.1	70.3	4	1.1
GN10B	Christensen	8.0	111.0	7	1.4
GN11B	Christensen	5.3	89.0	4	2.3
GN12B	Christensen	6.3	60.0	5	1.8
GN13B	Christensen	6.0	48.2	5	1.6
GN14B	Christensen	8.4	103.4	7	1.9

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
GN15B	Christensen	8.3	80.2	4	3.6
GN16B	Christensen	9.2	95.1	6	3.2
GN17B	Christensen	8.3	67.5	8	1.2
GN18B	Christensen	11.1	34.7	7	3.2
GN19B	Christensen	7.5	42.7	6	2.2
GN20B	Christensen	10.1	98.7	7	4.1
GN21B	Christensen	11.4	84.7	7	3.2
GN22B	Christensen	12.4	43.3	5	5.4
GN23B	Christensen	7.8	65.1	5	3.5
GN24B	Christensen	18.6	82.7	6	5.8
GN17C	Christensen	18.0	113.4	11	5.3
GN19C	Christensen	33.1	100.1	5	11.8
GN20C	Christensen	18.0	95.2	8	8.1
GN21C	Christensen	10.5	56.1	7	2.8
GN22C	Christensen	9.5	37.3	5	3.8
GN23C	Christensen	10.9	149.5	8	2.1
GN24C	Christensen	40.7	117.3	11	15.1
GN7D	Rees	3.3	108.2	3	1.3
GN19D	Rees	12.5	133.1	6	7.3
GN20D	Rees	29.4	114.9	8	9.7
GN24D	Rees	31.4	178.3	12	9.6
HE1	Christensen	7.0	9.5	2	4.5
HE2	Christensen	4.7	5.5	2	4.2
HE4	Christensen	1.0	1.0	1	1.0
HE5	Christensen	0.6	0.6	1	0.6
HE6	Christensen	1.0	1.0	1	1.0
HE7	Christensen	4.0	10.0	2	2.5
HE8	Dakota	0.5	0.5	1	0.5
HE9	Dakota	2.8	14.0	3	1.0
HE10	Dakota	13.5	13.5	1	13.5
HE11	Dakota	18.8	103.7	7	6.0
NB3A	Lower Zone	0.0	10.0	0	0.0
NB4A	Lower Zone	1.0	15.0	1	1.0
NB5A	Lower Zone	0.0	3.0	0	0.0
NB6A	Lower Zone	1.0	4.8	1	1.0
NB7A	Lower Zone	1.0	4.0	1	1.0
NB8A	Lower Zone	1.0	6.1	1	1.0
NB1B	Christensen	1.0	1.0	1	1.0
NB4B	Christensen	0.0	16.5	0	0.0
NB5B	Christensen	0.0	1.5	0	0.0
NB6B	Christensen	0.0	3.8	0	0.0
NB7B	Christensen	3.5	14.5	2	2.5
NB8B	Christensen	1.0	91.3	1	1.0
NB9B	Christensen	0.0	3.8	0	0.0
NB10B	Christensen	2.3	2.3	1	2.3
NB1C	Rees	9.0	159.0	9	1.0
NB2C	Rees	2.0	7.8	2	1.0
NB3C	Rees	1.0	1.0	1	1.0
NB6C	Rees	3.0	78.3	3	1.0
NB7C	Rees	4.0	47.5	4	1.0
NB8C	Rees	3.5	26.5	3	1.5
NB9C	Rees	2.3	21.3	2	1.3
NE1	Alvey	1.0	1.0	1	1.0
NE2	Alvey	6.8	9.8	3	2.8

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
NE3	Alvey	3.5	6.7	2	2.2
NE4	Alvey	2.3	2.3	1	2.3
NE5	Rees	4.3	8.0	2	2.8
NE6	Rees	2.2	4.2	2	2.0
NE7	Rees	2.0	2.4	2	1.7
NE8	Rees	6.9	9.3	2	4.0
NE9	Rees	7.0	7.0	1	7.0
NE10	Rees	14.0	24.5	2	7.0
NE11	Rees	5.0	20.3	3	2.5
NE12	Rees	2.4	3.7	2	2.0
NE13	Rees	3.0	3.0	1	3.0
NE14	Rees	4.5	4.5	1	4.5
NE15	Rees	9.5	13.0	3	4.0
NE16	Rees	3.3	3.4	2	3.0
NE17	Rees	2.0	2.0	1	2.0
NE18	Rees	5.0	5.0	1	5.0
NE19	Christensen	1.3	1.3	1	1.3
NE20	Christensen	14.0	20.0	3	12.0
NE21	Christensen	7.8	7.8	1	7.8
NE22	Christensen	9.0	9.8	3	5.0
NE23	Christensen	3.5	3.5	1	3.5
NE24	Christensen	10.9	23.3	3	8.5
NE25	Christensen	4.7	4.7	1	4.7
NE26	Christensen	3.0	3.0	1	3.0
NE27	Christensen	16.0	19.0	2	10.0
NE28	Christensen	5.0	5.0	1	5.0
NE29	Christensen	5.0	5.0	1	5.0
NE30	Christensen	6.4	17.4	5	2.8
NE31	Christensen	0.4	0.4	1	0.4
NE32	Christensen	2.8	3.3	2	2.5
NE33	Christensen	3.0	7.0	2	2.0
NE34	Christensen	6.2	17.9	3	3.0
NE35	Christensen	8.0	39.2	4	3.8
NE36	Christensen	3.8	4.8	3	1.7
NE37	Christensen	2.8	2.8	1	2.8
NE38	Christensen	2.3	2.3	1	2.3
NE39	Christensen	3.8	3.8	1	3.8
NE40	Christensen	11.5	12.2	3	11.0
NE41	Christensen	2.0	2.5	2	1.5
NE42	Christensen	2.3	2.6	2	1.5
NE43	Christensen	4.9	8.8	4	2.0
NE44	Christensen	3.9	7.8	4	1.6
NE45	Christensen	3.0	3.0	1	3.0
NE46	Christensen	2.5	2.5	1	2.5
NE47	Christensen	8.5	14.0	2	4.5
NE48	Christensen	6.0	11.0	2	3.0
NE49	Christensen	6.3	6.3	1	6.3
NE50	Lower Zone	3.8	3.8	1	3.8
NE51	Lower Zone	4.6	10.9	2	3.3
NE53	Lower Zone	2.3	2.9	2	1.8
NE54	Lower Zone	7.0	40.1	4	3.0
NE55	Lower Zone	2.9	8.1	2	2.5
NE56	Lower Zone	3.0	4.5	2	2.0
NE57	Lower Zone	3.7	3.7	1	3.7

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
NE58	Lower Zone	2.5	2.5	1	2.5
NE59	Lower Zone	3.6	12.1	3	1.8
NE60	Lower Zone	7.0	14.3	2	4.7
NE61	Lower Zone	2.0	7.0	2	1.5
NE62	Lower Zone	2.5	3.7	2	1.8
NE63	Lower Zone	4.0	4.4	2	2.0
NE64	Lower Zone	3.0	3.4	2	1.9
NE65	Lower Zone	4.1	9.4	2	3.8
NE66	Lower Zone	5.9	6.4	2	3.0
NE67	Alvey	4.2	6.2	2	3.8
NS2A	Smoky Hollow	2.0	2.0	1	2.0
NS3A	Smoky Hollow	1.8	1.8	1	1.8
NS4A	Smoky Hollow	2.3	2.3	1	2.3
NS5A	Smoky Hollow	3.6	3.6	1	3.6
NS6A	Smoky Hollow	5.2	5.2	1	5.2
NS7A	Smoky Hollow	3.8	3.8	1	3.8
NS8A	Smoky Hollow	5.3	5.3	1	5.3
NS9A	Smoky Hollow	5.2	5.2	1	5.2
NS10A	Smoky Hollow	4.7	4.7	1	4.7
NS11A	Smoky Hollow	3.1	3.1	1	3.1
NS12A	Smoky Hollow	2.6	8.8	2	1.6
NS1B	Lower Zone	1.0	1.0	1	1.0
NS2B	Lower Zone	3.3	59.4	3	1.3
NS3B	Lower Zone	4.7	32.2	2	3.7
NS4B	Lower Zone	3.7	41.2	3	1.4
NS5B	Lower Zone	9.4	46.4	6	2.3
NS6B	Lower Zone	7.0	31.7	2	5.2
NS7B	Lower Zone	7.3	42.5	4	3.3
NS8B	Lower Zone	6.6	17.8	3	4.6
NS9B	Lower Zone	2.0	41.0	2	1.0
NS10B	Lower Zone	4.5	39.3	3	1.7
NS11B	Lower Zone	1.0	1.0	1	1.0
NS12B	Lower Zone	1.8	1.8	1	1.8
NS1C	Christensen	2.0	52.0	2	1.0
NS2C	Christensen	1.0	1.0	1	1.0
NS4C	Christensen	7.7	42.4	5	3.7
NS5C	Christensen	12.4	79.7	8	4.6
NS6C	Christensen	3.7	61.7	3	1.7
NS7C	Christensen	13.5	153.2	6	4.7
NS8C	Christensen	16.2	168.1	10	3.4
NS9C	Christensen	7.4	171.3	4	3.3
NS10C	Christensen	2.5	97.0	2	1.5
NS11C	Christensen	3.1	44.1	2	2.1
NS12C	Christensen	5.6	45.6	5	1.3
NW1	Christensen	2.6	9.6	2	1.4
NW1A	Lower Zone	0.0	6.0	0	0.0
PC1	Alvey	2.5	4.0	2	1.5
PC2	Alvey	9.8	16.5	2	8.8
PC3	Alvey	0.0	5.0	0	0.0
PC4	Alvey	13.0	18.0	2	7.5
PC5	Alvey	2.5	2.5	1	2.5
PC6	Alvey	4.0	36.0	3	1.5
PC7	Alvey	6.1	24.7	3	4.3
PC8	Alvey	5.3	5.3	1	5.3

Location No.	Coal Zone Name	Total Coal (feet)	Total Interval (feet)	Number of Seams	Thickest Seam (feet)
PC9	Alvey	15.0	30.8	4	6.1
PC10	Alvey	10.8	12.6	3	5.6
PC11	Alvey	4.0	4.0	1	4.0
PC12	Alvey	6.6	6.6	1	6.6
PC13	Alvey	2.1	21.6	3	0.8
PC14	Alvey	3.8	9.3	2	2.8
PC15	Alvey	4.8	4.8	1	4.8
PC16	Alvey	5.0	5.0	1	5.0
PC17	Alvey	5.0	5.0	1	5.0
PC18	Alvey	6.5	6.5	1	6.5
PC19	Alvey	4.2	9.9	3	3.2
PC20	Rees	5.8	9.4	3	5.3
PC21	Rees	8.3	17.5	5	4.0
PC22	Rees	2.2	8.2	2	2.0
PN1	Dakota	1.0	1.0	1	1.0
PN2	Dakota	5.6	5.6	1	5.6
PN3	Dakota	2.0	2.0	1	2.0
PN4	Dakota	2.0	2.0	1	2.0
PN5	Dakota	1.5	1.5	1	1.5
SB1	Christensen	10.0	15.8	4	7.0
SB2	Christensen	1.3	1.3	1	1.3
SB3	Dakota	1.5	1.5	1	1.5
SB4	Dakota	0.3	0.3	1	0.3
SB5	Dakota	0.4	0.4	1	0.4
SB6	Dakota	1.2	1.2	1	1.2
SB7	Dakota	0.4	0.4	1	0.4
SF1	Christensen	8.0	8.0	1	8.0
SF2	Christensen	16.0	31.0	3	12.0
SF3	Dakota	2.2	2.6	2	1.4
SF4	Dakota	0.6	0.6	1	0.6
SF5	Dakota	3.1	7.6	3	2.5
SF6	Dakota	0.7	1.2	2	0.5
SF7	Dakota	1.0	1.0	1	1.0
SM1	Alvey	2.8	2.8	1	2.8

APPENDIX B:

Summary of coal drill-hole data for the Kaiparowits Plateau coal field.

Drill Hole Number	Total Depth (ft)	Number of Seams Total	Number of Seams > 4 ft	Thickness of Coal (ft) Total	Thickness of Coal (ft) > 4 ft	Thickest Seam (ft)
1	950	9	0	14.2	0.0	2.7
2	813	12	5	56.5	45.4	20.6
3	751	13	3	40.9	17.0	6.2
4	810	9	3	37.5	23.0	12.1
5	830	9	0	16.2	0.0	3.8
6	905	13	1	25.0	5.3	5.3
7	1,038	8	0	15.0	0.0	3.1
8	718	7	1	17.6	8.2	8.2
9	769	7	0	13.3	0.0	3.2
10	1,400	16	4	37.2	19.6	5.3
11	640	9	3	31.9	17.7	7.8
12	679	14	1	35.1	4.5	4.5
13	668	10	2	36.8	19.3	11.2
14	669	14	2	38.9	15.7	9.8
15	749	11	3	37.7	21.1	10.0
16	801	12	5	44.2	32.7	10.2
17	1,099	10	1	19.5	6.2	6.2
18	928	11	3	34.8	20.1	7.5
19	706	14	2	39.0	18.1	9.3
20	810	15	4	45.7	27.9	9.2
21	2,480	4	1	11.9	4.1	4.1
22	1,104	10	10	86.0	86.0	22.0
23	1,066	9	9	78.0	78.0	16.0
24	1,174	8	8	77.0	77.0	29.0
25	1,164	10	10	88.0	88.0	16.0
26	1,281	6	6	77.0	77.0	21.0
28	1,180	9	9	56.0	56.0	9.0
29	1,980	7	6	63.0	60.0	20.0
30	2,000	7	7	47.0	47.0	11.0
31	2,076	7	7	50.0	50.0	16.0
32	1,020	3	1	7.0	5.0	5.0
33	1,055	13	13	90.0	90.0	11.0
34	900	7	7	65.0	65.0	20.0
35	1,903	8	8	80.0	80.0	20.0
36	1,927	10	10	91.0	91.0	21.0
37	1,913	6	6	63.0	63.0	22.0
38	1,170	8	8	86.0	86.0	18.0
39	1,210	10	9	87.0	85.0	18.0
40	1,872	11	11	106.0	106.0	14.0
41	1,925	10	10	119.0	119.0	27.0
42	1,920	10	10	89.0	89.0	14.0
43	1,040	14	14	103.0	103.0	18.0
44	1,220	10	10	86.0	86.0	15.0
46	741	15	7	70.2	52.4	15.0
47	393	2	2	17.0	17.0	11.0
48	860	20	10	130.9	106.2	23.7
49	862	20	12	104.5	83.9	9.8
50	1,002	18	5	57.2	35.5	9.3
51	1,027	23	8	89.3	61.2	11.0
52	1,415	18	9	90.4	70.8	16.1
53	1,228	12	9	92.0	86.7	18.1
54	1,098	14	7	75.5	58.7	17.4
55	1,160	14	8	80.9	66.1	24.4
56	1,041	12	6	80.3	62.9	16.3

Drill Hole Number	Total Depth (ft)	Number of Seams		Thickness of Coal (ft)		Thickest Seam (ft)
		Total	> 4 ft	Total	> 4 ft	
57	1,021	16	6	81.9	56.8	20.3
58	1,040	12	5	51.9	33.7	13.0
59	318	2	2	28.0	28.0	15.0
60	917	12	6	63.5	49.2	14.3
61	720	8	5	62.2	54.8	22.0
62	770	11	5	80.0	66.8	27.6
63	784	8	3	25.8	15.9	6.5
64	800	9	2	29.2	14.3	9.5
65	195	5	2	19.3	11.7	6.0
66	726	13	5	46.3	27.7	7.0
67	807	10	5	61.4	48.8	15.3
68	810	3	3	29.2	29.2	14.3
69	775	1	0	1.5	0.0	1.5
70	677	12	7	50.7	40.9	11.2
71	805	13	5	48.8	25.6	6.5
72	843	10	4	52.8	38.4	12.8
73	815	10	4	44.1	31.1	13.0
74	851	15	8	92.5	72.8	18.0
75	1,385	14	11	93.0	84.5	16.7
76	2,197	25	11	105.5	77.5	25.0
77	1,595	26	11	114.5	83.5	21.5
78	1,340	12	8	93.6	85.1	14.6
79	1,277	17	9	131.5	110.5	36.0
80	1,391	8	7	77.5	74.0	30.0
81	2,185	17	5	85.5	64.0	26.5
82	2,435	23	9	106.5	77.0	27.0
83	2,700	20	12	85.5	67.0	10.0
84	1,277	12	7	84.3	74.5	18.5
85	1,399	17	7	78.4	56.8	18.1
86	1,330	21	9	79.1	55.5	16.0
87	1,300	33	20	149.0	122.0	11.5
88	2,350	14	8	75.0	61.0	12.0
89	1,160	20	17	134.0	125.0	16.0
90	851	10	4	47.5	32.5	12.0
91	880	11	6	55.7	41.6	14.0
92	853	5	1	13.9	4.0	4.0
93	803	6	1	25.9	11.3	11.3
94	751	9	3	34.0	21.0	12.0
95	1,460	10	8	54.0	48.0	12.0
96	1,200	12	12	81.0	81.0	18.0
97	1,080	16	10	128.3	114.0	27.0
98	1,460	22	16	134.5	119.0	14.0
99	1,180	19	11	116.4	99.9	20.0
100	800	19	6	81.0	55.5	19.0
101	771	13	8	73.0	59.0	12.0
102	2,400	15	2	36.0	9.0	5.0
103	2,400	19	2	53.0	15.0	8.0
104	2,365	27	10	88.0	54.0	9.0
105	2,290	11	4	46.1	28.0	10.3
106	2,444	19	12	95.0	76.0	17.0
107	854	18	6	89.4	60.8	21.8
108	850	9	6	58.5	50.5	17.5
109	850	20	7	86.5	58.3	20.7
110	734	7	4	31.2	25.7	10.9

Drill Hole Number	Total Depth (ft)	Number of Seams		Thickness of Coal (ft)		Thickest Seam (ft)
		Total	> 4 ft	Total	> 4 ft	
111	800	20	7	67.5	43.5	10.0
112	900	16	7	65.2	44.7	9.5
113	805	5	4	31.0	29.0	11.0
114	751	18	3	44.9	13.3	4.7
115	759	11	3	31.9	15.2	5.7
116	800	10	7	51.7	47.2	9.6
117	795	28	7	99.3	49.4	10.5
118	770	20	10	89.5	67.2	10.1
119	1,125	17	11	88.3	70.0	15.0
120	728	16	9	69.4	58.5	12.4
121	780	5	4	33.0	31.0	14.5
122	587	2	2	14.0	14.0	10.0
123	800	13	4	65.6	47.4	22.1
124	520	4	0	11.4	0.0	3.3
125	800	17	3	48.8	23.1	8.5
126	751	7	0	18.5	0.0	3.9
128	800	18	5	68.0	38.1	12.5
129	815	16	6	62.8	42.4	12.5
130	860	19	8	70.1	51.5	9.0
131	850	22	10	98.8	76.9	12.6
132	880	15	8	97.3	79.3	18.3
133	725	14	6	72.9	55.5	14.0
134	700	3	2	12.1	10.1	6.0
135	1,100	11	10	81.4	79.4	26.0
136	804	5	2	25.5	18.0	13.0
137	429	5	0	8.0	0.0	3.2
138	650	6	1	20.5	5.1	5.1
140	582	4	2	17.5	11.8	7.0
141	402	1	0	1.0	0.0	1.0
142	481	18	4	55.1	26.5	7.4
143	342	12	6	56.2	42.4	10.0
144	436	19	3	50.4	17.3	6.9
145	302	12	6	60.8	44.9	11.6
146	156	7	4	33.7	26.3	10.0
147	523	7	2	24.7	13.9	8.3
149	605	5	1	17.5	7.9	7.9
150	402	3	0	3.8	0.0	1.6
151	454	8	5	39.6	33.2	8.2
152	320	7	4	24.1	18.1	5.2
155	391	5	5	36.9	36.9	10.1
156	356	5	4	40.4	36.5	18.6
157	495	8	4	36.0	28.1	9.0
158	842	16	9	83.3	65.6	17.0
159	721	11	5	51.6	39.9	15.0
160	603	9	5	54.0	46.4	12.5
161	699	10	3	52.3	34.1	18.7
162	754	19	6	55.2	36.9	8.0
163	702	10	1	25.5	6.9	6.9
164	670	13	5	67.6	44.7	11.9
165	750	14	4	42.2	21.8	5.8
166	642	7	1	12.6	4.8	4.8
167	972	11	4	43.7	28.8	11.5
168	674	11	4	30.5	18.5	4.9
169	764	11	2	47.2	28.3	22.0

Drill Hole Number	Total Depth (ft)	Number of Seams Total	Number of Seams > 4 ft	Thickness of Coal (ft) Total	Thickness of Coal (ft) > 4 ft	Thickest Seam (ft)
170	741	13	9	73.6	64.3	16.7
171	714	18	3	47.0	20.7	8.9
172	523	4	2	14.8	9.4	5.0
174	1,000	10	0	18.0	0.0	2.5
175	722	12	6	58.5	48.2	11.8
176	404	3	0	7.7	0.0	3.5

PLATE 1. COAL IN THE STRAIGHT CLIFFS FORMATION OF THE SOUTHERN KAIPAROWITS PLATEAU REGION, KANE COUNTY, UTAH.

111°45′ 111°30′ 111°15′

37°30′ 37°15′

GARFIELD CO. KANE CO. SAN JUAN CO.

UPPER VALLEY CANAAN PEAK THE COCKSCOMB EAST KAIBAB MONOCLINE SMOKY MOUNTAIN NIPPLE BENCH FIFTYMILE MOUNTAIN

Ksj

Top of the John Henry Member

Base of the John Henry Member

900-meter (2,953 ft) overburden contour above the base of the Christensen (Henderson) coal zone-- after Hansen, 1978b

600-meter (1,969 ft) overburden contour above the base of the Christensen (Henderson) coal zone-- after Hansen, 1978b

Warm Creek test mine

Spencer No. 1 and No. 2 mines

John Henry prospect

EXPLANATION

- CA29 — Location of coal-outcrop measurement. Designation refers to summary in appendix A (from Doelling and Graham, 1972).
- 130 — Location of coal drill hole. Number refers to summary in appendix B.
- Ksj — Outcrop of the John Henry Member (Ksj) or equivalent unit within the Straight Cliffs Formation (from Doelling and Davis, 1989).
- 80 — Isopleth, in feet, of total coal within the John Henry Member of the Straight Cliffs Formation. Dashed where Ksj is eroded.
- 600-meter (1,969 ft) contour of overburden above the base of the Christensen (Henderson) coal zone (after Hansen, 1978b).
- 900-meter (2,953 ft) thickness contour of overburden above the base of the Christensen (Henderson) coal zone (after Hansen, 1978b).

N

0 5 mi

0 5 km

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