THE AVAILABLE COAL RESOURCE FOR EIGHT 7.5-MINUTE QUADRANGLES IN THE SOUTHERN EMERY COALFIELD, EMERY AND SEVIER COUNTIES, UTAH

by

Jeffrey C. Quick,
David E. Tabet,
Brigitte P. Hucka,
and
Sharon I. Wakefield

SPECIAL STUDY 112
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
2004

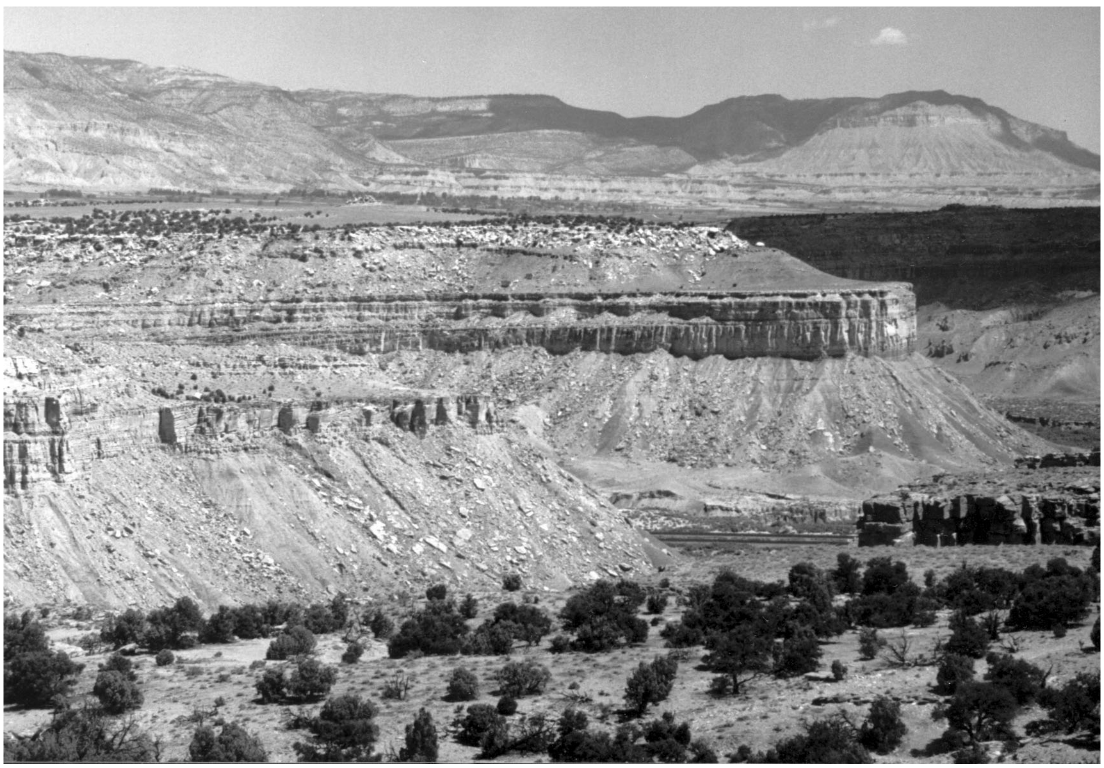
UTAH GEOLOGICAL SURVEY

Quick, Tabet, Hucka, Wakefield AVAILABLE COAL RESOURCE IN EIGHT 7.5-MINUTE QUADRANGLES IN SOUTHERN EMERY COALFIELD UGS Special Study SS 112

THE AVAILABLE COAL RESOURCE FOR EIGHT 7.5-MINUTE QUADRANGLES IN THE SOUTHERN EMERY COALFIELD, EMERY AND SEVIER COUNTIES, UTAH

by

Jeffrey C. Quick, David E. Tabet, Brigitte P. Hucka, and Sharon I. Wakefield



View looking northwest towards the coal-bearing Ferron Sandstone Member overlying talus-covered slopes of Tununk Member of Mancos Shale. Younger Cretaceous and Tertiary strata compose Wasatch Plateau in background.

Cover: close-up image of inclusions in coal.

ISBN 1-55791-705-1

SPECIAL STUDY 112
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
2004

UTAH GEOLOGICAL SURVEY

STATE OF UTAH
Olene S. Walker, Governor

DEPARTMENT OF NATURAL RESOURCES
Robert L. Morgan, Executive Director

UTAH GEOLOGICAL SURVEY
Richard G. Allis, Director

PUBLICATIONS
contact
Natural Resources Map/Bookstore
1594 W. North Temple
telephone: 801-537-3320
toll-free: 1-888-UTAH MAP
website: http://mapstore.utah.gov
email: geostore@utah.gov

THE UTAH GEOLOGICAL SURVEY
contact
1594 W. North Temple, Suite 3110
Salt Lake City, UT 84116
telephone: 801-537-3300
website: http://geology.utah.gov

TAKE Pride IN UTAH

Printed on recycled paper

1/04

CONTENTS

FIGURES

LIST OF TABLES

THE AVAILABLE COAL RESOURCE FOR EIGHT 7.5-MINUTE QUADRANGLES IN THE SOUTHERN EMERY COALFIELD, EMERY AND SEVIER COUNTIES, UTAH

by

Jeffrey C. Quick, David E. Tabet, Brigitte P. Hucka, and Sharon I. Wakefield

ABSTRACT

About 2.4 billion tons of coal are available for mining in the southern Emery coalfield, Utah. This includes about 200 million tons of surface-minable coal and 2.2 billion tons of underground-minable coal. Sixty percent of the available coal identified in this study is a demonstrated resource (within 0.75 miles of a measurement location) and the remainder is less reliably identified.

The available coal resource includes eight coalbeds, which are named (in ascending stratigraphic order) the A, CD, G, I, J, K, L, and M coalbeds. Maps and associated tables showing the distribution and quantity of the available coal are provided for each coalbed (appendix). Over 75 percent of the available coal is in three coalbeds: the A bed (30%), the CD bed (25%), and the I bed (22%). Coal rank varies from high-volatile B bituminous in the north, to subbituminous A in the south. Average sulfur content is above 2 pounds sulfur per million Btu (lbs S/10^6 Btu) in the upper coalbeds, but is markedly lower in the underlying, and economically more significant, A (1.1 lbs S/10^6 Btu), CD (0.9 lbs S/10^6 Btu), and I (0.8 lbs S/10^6 Btu) coalbeds. Available data show that the in-ground coal averages 11 pounds mercury per trillion Btu.

Considering coalbed thickness, distribution, and current mining practices, we estimate that about 500 million tons of the 2.4-billion-ton available coal resource might be recovered from the southern Emery coalfield. This tonnage is sufficient to satisfy Utah's current coal consumption for about 20 years.

INTRODUCTION

From the 1870s through 2002, Utah coal mines produced more than 830 million tons of coal, of which about nine million tons came from the southern Emery coalfield (UEO, 2003). Although the coalfield accounts for only 1 percent of Utah's cumulative coal production, its substantial in-ground coal resource and proximity to central Utah power plants suggest that production from the southern Emery coalfield will become increasingly important. This study provides an estimate of the amount and distribution of the available coal resource in the southern Emery coalfield.

We used a Geographic Information System (GIS) to identify and measure the available coal resource in the southern Emery coalfield. Table 1 provides conversion factors from the U.S. customary units used in this document to the International System of units. The words million, billion, and trillion used in this document equal 10^6, 10^9, and 10^{12}, respectively. Results of this study will be useful to government agencies, industry, landowners, academic workers, and environmental advocacy groups.

Table 1. Selected conversion factors between U.S. customary units used in this report and the International System of Units; modified from Hylland and Lund (2003), IEEE (1997), and ASTM (1990).

To convert from unit (abbreviation)	To unit (abbreviation)	Multiply by
inch (in.)	meter (m)	0.025 4 [a]
foot (ft)	meter (m)	0.3048 [a]
mile, statute (mi)	kilometer (km)	1.609
pound (lb)	kilogram (kg)	0.453 592 37 [a]
ton [b] ([c])	metric ton (t) [d]	0.907 2
British thermal unit per pound (Btu/lb)	megajoule per kilogram (MJ/kg)	0.002 326 [a]
square mile (mi^2)	square kilometer (km^2)	2 590.
acre-foot (acre-ft)	cubic meter (m^3)	1 233.5
cubic foot (ft^3)	cubic meter (m^3)	0.028 32
pound per million Btu (lbs/10^6 Btu)	microgram per joule (μg/J)	0.430 0
pound per trillion Btu (lbs/10^{12} Btu)	picogram per joule (pg/J)	0.430 0

[a] an exact conversion

[b] a short ton (2,000 lb)

[c] no abbreviation for this unit

[d] a commercial term (1,000 kg)

Location and General Geology

The study area (figure 1) covers 465 square miles and includes parts of Emery and Sevier Counties, Utah. The study area is defined by the eight, 7.5-minute quadrangles shown in figure 2, and encompasses the southern third of the Emery coalfield. The Emery coalfield extends north of the study area past the town of Price where it abruptly ends as the coal-bearing Ferron Sandstone Member of the Mancos Shale passes under the Book Cliffs coalfield. The southern Emery coalfield appears to overlap the Wasatch Plateau coalfield to the west, but Ferron coalbeds of the Emery coalfield occur several thousand feet stratigraphically below the coalbeds in the Wasatch Plateau and the Book Cliffs coalfields (figure 1).

State Highway 10 runs southwest through study area and Interstate Highway 70 crosses the central part of the study area (figure 1). No railroads serve the area, and the nearest rail loadout is at least 40 miles away, near the towns of Price and Green River.

The Emery coalfield lies along the gently dipping western flank of the San Rafael Swell. Dips of the coal-bearing strata are usually between two and four degrees over most of the study area. Dip directions are generally towards the west-northwest, except in the southern part of the study area where they change to north-northeast. The coalbeds in the Emery coalfield are in the 300- to 800-foot-thick Upper Cretaceous Ferron Sandstone Member of the Mancos Shale (Doelling, 1972). This unit is present over 60 percent of the study area (270 square miles). The Ferron Sandstone conformably overlies the 500- to 800-foot-thick Tununk Shale Member of the Mancos Shale that was deposited at the beginning of the North American Cretaceous marine incursion. The Ferron Sandstone crops out in the eastern side of the study area and forms an escarpment that marks the eastern edge of the coalfield. The escarpment is best developed in the southwest and disappears to the north where the coal-bearing sediments thin. The southern margin of the Emery coalfield is marked by Tertiary basalts and associated alluvium, which unconformably bury the Ferron Sandstone. The western edge of the Emery coalfield is defined where the coalbeds are more than 3,000 feet deep. Burial depths increase to the west as the overlying 1,500- to 2,000-foot-thick Lower Blue Gate Shale Member of the Mancos Shale thickens and is covered by increasing amounts of the 500- to 1,000-foot-thick Emery Sandstone Member of the Mancos Shale. The western boundary is near where the Emery Sandstone is covered by the approximately 500-foot-thick Upper Blue Gate Shale Member of the Mancos Shale and the cliff-forming Star Point Sandstone.

The northeast-trending Joes Valley graben (figure 2) is a significant structural feature within the southern Emery coalfield. The graben is about one mile wide in the northern part of the study area with over 1,000 feet of displacement and is roughly parallel to Highway 10 south of the town of Emery (figure 1). Coalbeds on the western side of the graben are generally more than a thousand feet deeper than those on the eastern side. The western coalbeds cannot be easily accessed by slope or drift mines appropriate for coalbeds on the east side of the graben.

For this study, eight coalbeds were mapped in the Ferron Sandstone (figure 3). In ascending order, these coalbeds are designated the A, CD, G, I, J, K, L, and M.

Mining History

Coal was first produced from the southern Emery coalfield in 1881 (Spieker, 1931) and continuous production occurred from 1930 to 1990. Production stopped in 1990 when Consolidation Coal Company suspended production from the Emery Deep mine because it could not secure sufficient sales to justify ongoing operations (Jahanbani, 1991). Limited production resumed in 2002 with the redevelopment of the Emery Deep mine (Utah Energy Office, 2003). Figure 2 shows the known locations of coal mines and prospects in the study area; nearly all of the coal production from the southern Emery coalfield has come from the Dog Valley, Browning, and Emery Deep coal mines in the I bed, with only small amounts produced from the other beds (figure 3, table 2).

COAL RANK, QUALITY, AND GAS CONTENT

Assay Data

Assay data for 4,450 coal samples from the southern Emery coalfield were used to evaluate the rank, quality, and gas content of coal in the coalfield. The data are from Doelling (1972), Affolter and others (1979), Doelling and others (1979), Crowley and others (1989), Bragg and others (1997), Lamarre (2003), Quick and Tabet (2003), as well as the U.S. Bureau of Land Management (BLM) and Utah Geological Survey (UGS) files.

Coal Rank

Evaluation of coal assay data collected by different agencies using different collection protocols is challenging (Hower and others, 1989). Utah's arid climate and low humidity promote the unrecognized loss of moisture from coal specimens (Kohler and others, 1997). Both of these problems hinder evaluation of coal rank.

The assay data used in this report are from different agencies. To minimize inconsistencies associated with variation of sampling and analysis protocol, we ignored data corresponding to size fractions, gravity fractions, surface samples, cuttings, weathered samples, or samples having more than 33 percent dry ash, as well as data records that lack sulfur, ash, and Btu values (which are required for calculation of ASTM coal rank). The 33 percent maximum ash limit is arbitrary but is similar to the 30 percent ash restriction used by Bragg and others (1997) to reduce calculation error related to conversion of data to different reporting bases. We also ignored a few records with unlikely, or anomalous values on cross-plots. Ultimately, we selected 1,609 data records to evaluate the rank of coal in the southern Emery coalfield.

To avoid complications due to unrecognized moisture loss, we adjusted the moist-basis Btu, ash, and sulfur values to a dry reporting basis. Next, we used the relationship shown in figure 4 to calculate moisture values for each sample. Then, the calculated moisture values were used to adjust

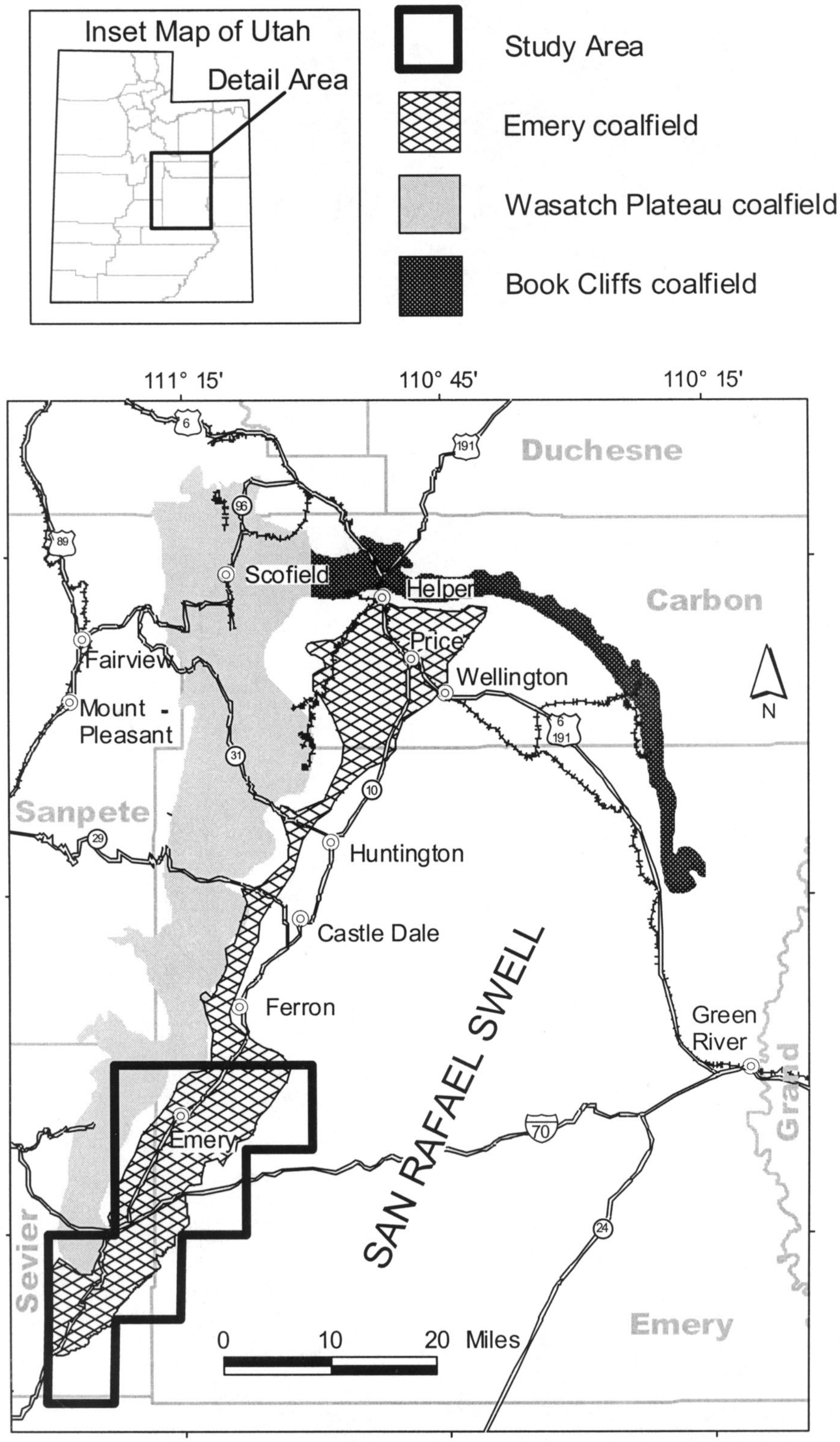


Figure 1. Location of the southern Emery coalfield study area, and other central Utah coalfields.

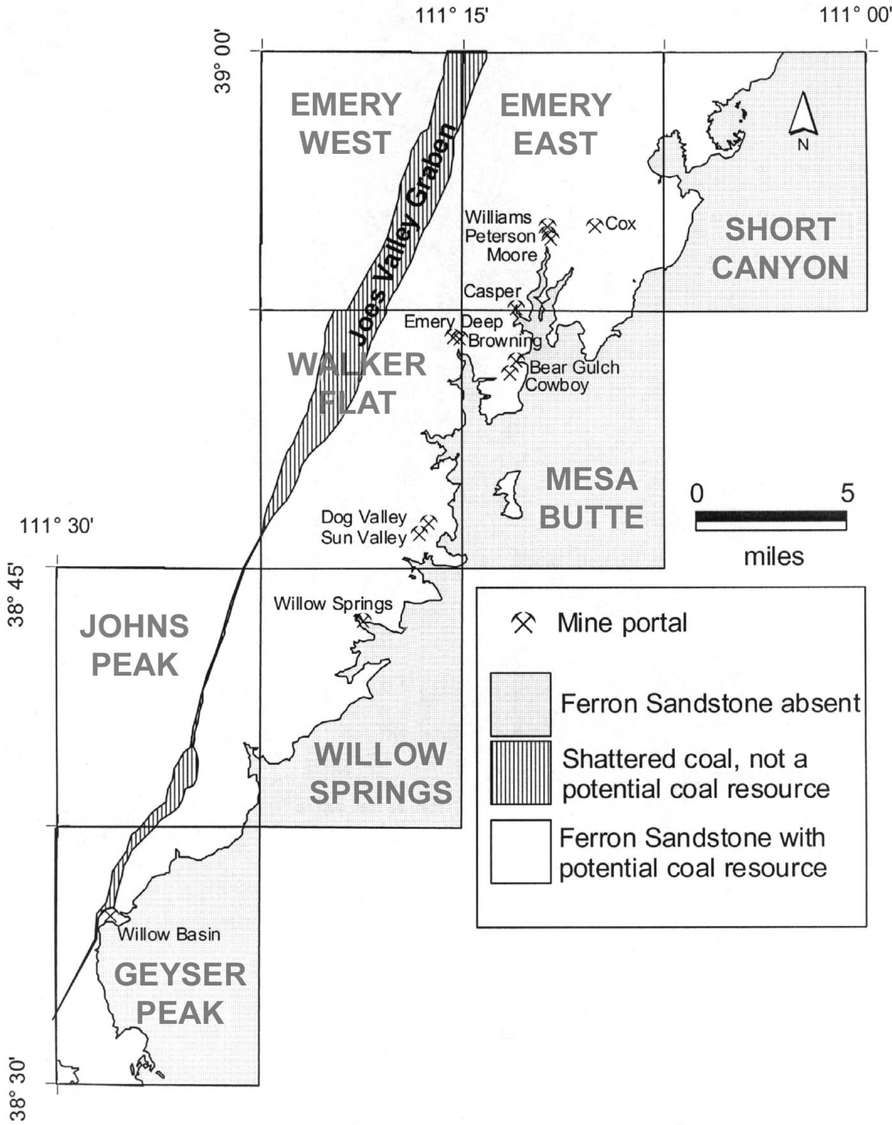


Figure 2. Index showing the eight 7.5-minute-quadrangle study area, the locations of active and abandoned coal mine portals, the extent of the coal-bearing Ferron Sandstone, and the location of shattered coal within Joes Valley graben, southern Emery coalfield, Utah.

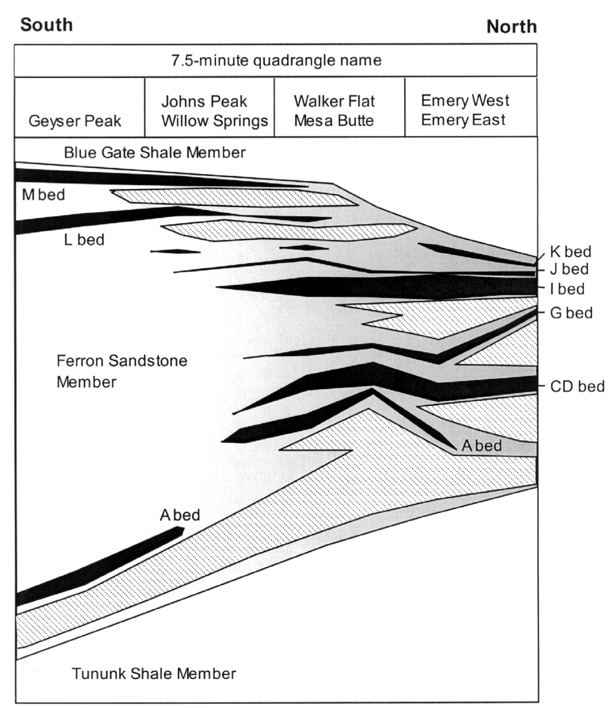


Figure 3. Idealized stratigraphic cross section showing eight coalbeds in the Ferron Sandstone Member of the Mancos Shale, southern Emery coalfield, Emery and Sevier Counties, Utah. The thickness and distribution of the coalbeds are based on drill data from the 7.5-minute quadrangles listed at the top of the figure. The thickness and distribution of associated sandstones (striped pattern) are qualititive and modified from Ryer (1981).

Table 2. Location, activity, and cumulative production (tons) for coal mines in the southern Emery coalfield, Emery and Sevier Counties, Utah.

Mine Name	UTM N 1	UTM E 1	Coalbed	Years of Activity	Cumulative Production to 2000
Emery Deep	4,301,250	477,880	I	1970 to 1990 re-opened: 2002	7,146,475
Browning	4,301,150	478,180	I	intermittent: 1881 to 1936 continuous: 1937 to 1970	1,318,000
Dog Valley	4,291,220	476,500	I	1930 to 1990	649,000
Sun Valley	4,290,650	476,000	I	1970 to 1973	76,800
Casper	4,302,800	481,260	CD	before: 1916	1,500
Cox	4,307,200	485,500	I or J	before: 1916	15
Moore	4,306,450	438,080	I or J	near: 1905	1,500
Williams	4,307,180	482,990	I or J	before: 1916	700
Peterson	4,306,760	482,930	I or J	1935 to 1938	4,000
Willow Springs	4,285,940	472,920	A	1932 to 1946	+16,000
Willow Basin	4,270,200	459,410	A	before: 1910	?
Bear Gulch	4,299,920	481,280	CD	1897 to 1916	?
Cowboy	4,299,300	480,890	I	1900 to 1920	1,000

[1] zone 12, NAD27, Universal Transverse Mercator northing (UTM N) and Easting (UTM E) coordinates (meters). Data are from Lupton (1916), Doelling (1972), Jahanbani (2001), Utah Energy Office (2003), and U.S. Bureau of Land Management files.

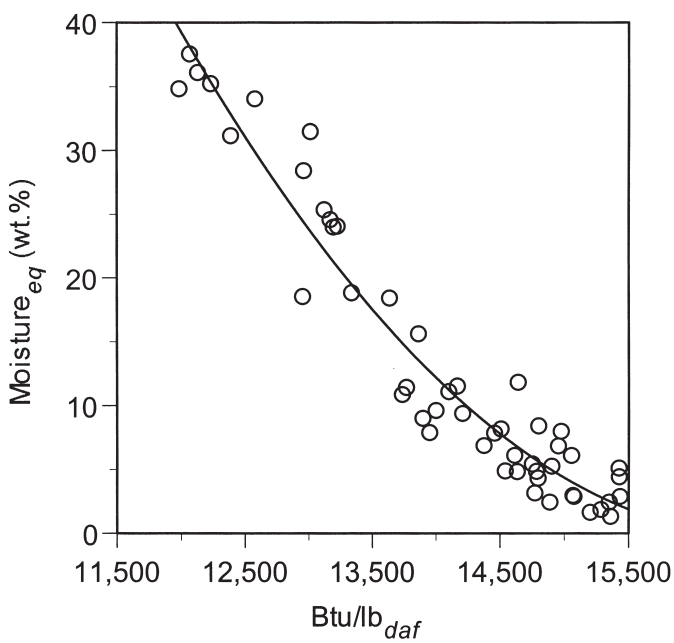


Figure 4. Relationship between the heating value on a dry, ash-free basis (Btu/lb_{daf}) and the equilibruim moisture (Moisture_{eq}) for 50, high-volatile A bituminous and lower rank, U.S. coals. The best-fit line corresponds to the equation: $\text{Moisture}_{eq} = 522.6 - 0.06318 \times \text{Btu/lb}_{daf} + 1.909^{-6} \times \text{Btu/lb}^2_{daf}$, which has an adjusted r^2 of 0.93, and a standard error of 2.9 percent moisture (data from Quick and Glick, 1999).

the Btu, ash, and sulfur values back to a moist basis. Finally, these adjusted, moist-basis values were used to calculate the moist, mineral-matter free Btu parameter (Btu $m,_{mmf}$) that is specified by ASTM (1990) to determine coal rank.

Figure 5 shows the spatial variation of coal rank in the southern Emery coalfield, which corresponds to the equation:

$$Btu_{m,mmf} = 11.071 \text{ x } UTM_{north} - 1.2812^{-6} \text{ x } UTM_{north}^{2} - 2.3903^{+7}$$

where: $Btu_{m,mmf}$ is the ASTM (1990) rank parameter, and UTM_{north} is the North American 1927 datum, zone 12 north, Universal Transverse Mercator northing coordinate (meters). This equation provides a satisfactory fit to the selected data (adjusted $r^2 = 0.45$, standard error = 300 Btu). Examination of figure 5 shows that coal rank decreases from high-volatile B bituminous in the north to subbituminous B in the south.

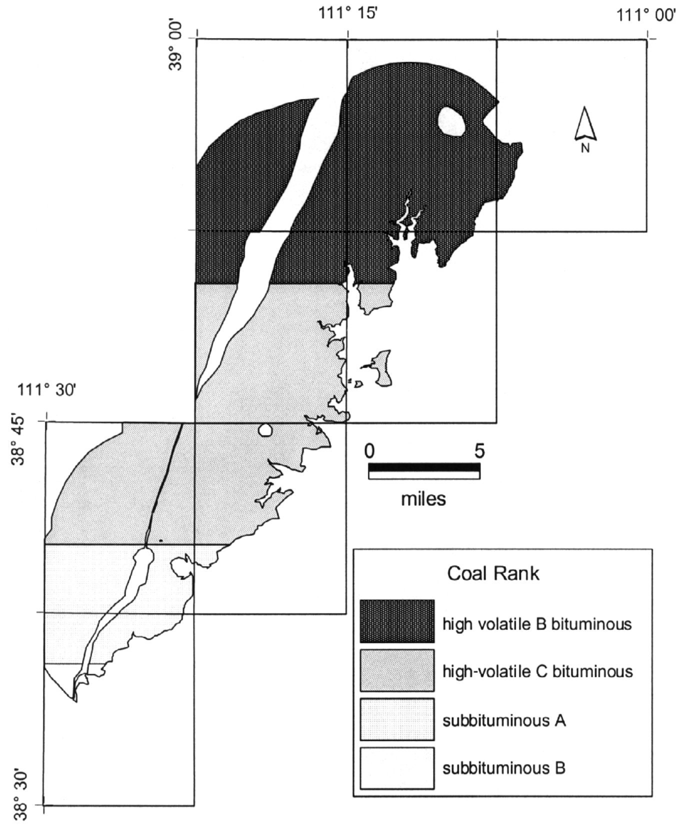


Figure 5. Geographic variation of ASTM (1990) coal rank classes for coal in the Ferron Sandstone, southern Emery coalfield, Utah. Rank classes are not shown beyond five miles of a coal assay location.

Coal Quality

Figure 6 shows that sulfur and ash values vary within and between the coalbeds. The upper coalbeds (J, K, L, and M) contain more sulfur than the lower coalbeds (A, CD, G, and I). The relatively high ash values observed for the CD bed might be partly due to volcanic ash parting material included in analysis specimens (Crowley and others, 1989).

Mercury emissions from electric utilities may be regulated by 2008 (U.S. Environmental Protection Agency, 2000). Accordingly, table 3 summarizes the mercury content of coalbeds in the southern Emery coalfield. Although the average mercury content of in-ground coal in the southern Emery coalfield is slightly less than the U.S. average of 13 lbs $Hg/10^{12}$ Btu, it is markedly higher than the average 3.7 lbs $Hg/10^{12}$ Btu observed for in-ground coal from the nearby Wasatch Plateau and Book Cliffs coalfields (Quick and others, 2003).

Hucka and others (1997) report petrographic data for 38 coal samples from selected coalbeds (A, CD, G, I, and J) in the Emery East and Walker Flat quadrangles of the southern Emery coalfield. The coals contain an average 75 percent vitrinite, 6 percent liptinite, and 19 percent inertinite. The average 0.62 percent vitrinite reflectance is consistent with the high-volatile B bituminous rank in this area (figure 5) according to a correlation between vitrinite reflectance and ASTM rank by Davis (1984).

Coalbed Methane

The southern Emery coalfield is in the southern part of the 80-mile-long Ferron coalbed methane trend (figure 7). North of the study area, in the Drunkards Wash coalbed methane field (figure 7), Ferron coals have produced more than 200 billion cubic feet of coalbed methane from 470 wells (Lamarre, 2003). No coalbed methane production has been recorded in the southern Emery coalfield.

Doelling and others (1979) tested six core samples from three locations within the southern Emery coalfield for gas content; four samples yielded no gas, and the others produced 3 and 20 cubic feet of gas per ton coal (cf/ton). They suggest that the low gas contents may relate to the close proximity of the sample locations to the outcrop (where any gas presumably leaked to the atmosphere). Montgomery and others (2001) note that the gas content of Ferron coal is 200 to 500 cf/ton north of southern Emery coalfield, and 0 to 150 cf/ton in areas within and adjacent to the southern Emery coalfield. Although available data suggest limited coalbed methane potential for coals in the southern Emery coalfield, additional drilling may show otherwise. Doelling and others (1979) note early reports of gassy conditions in the Emery Deep mine. In a study to determine the potentiometric surface of aquifers in the Ferron Sandstone, Lines and Morrissey (1981) were unable to determine the shut-in pressure of some artesian wells in the southern Emery coalfield because of gas accumulations in affected wells.

SPATIAL DATA USED TO CALCULATE COAL RESOURCE TONNAGE

Two kinds of spatial data were used to calculate the coal resource of the southern Emery coalfield. Geographic data are typically electronic or paper maps compiled by various agencies. We used these maps to evaluate the impact of geologic, geographic, and land-use features on coal mining. Stratigraphic data are numeric data sets that list coalbed thickness and depth values together with drill hole location coordinates; we used these data to create new maps showing the thickness, extent, and depth of coalbeds.

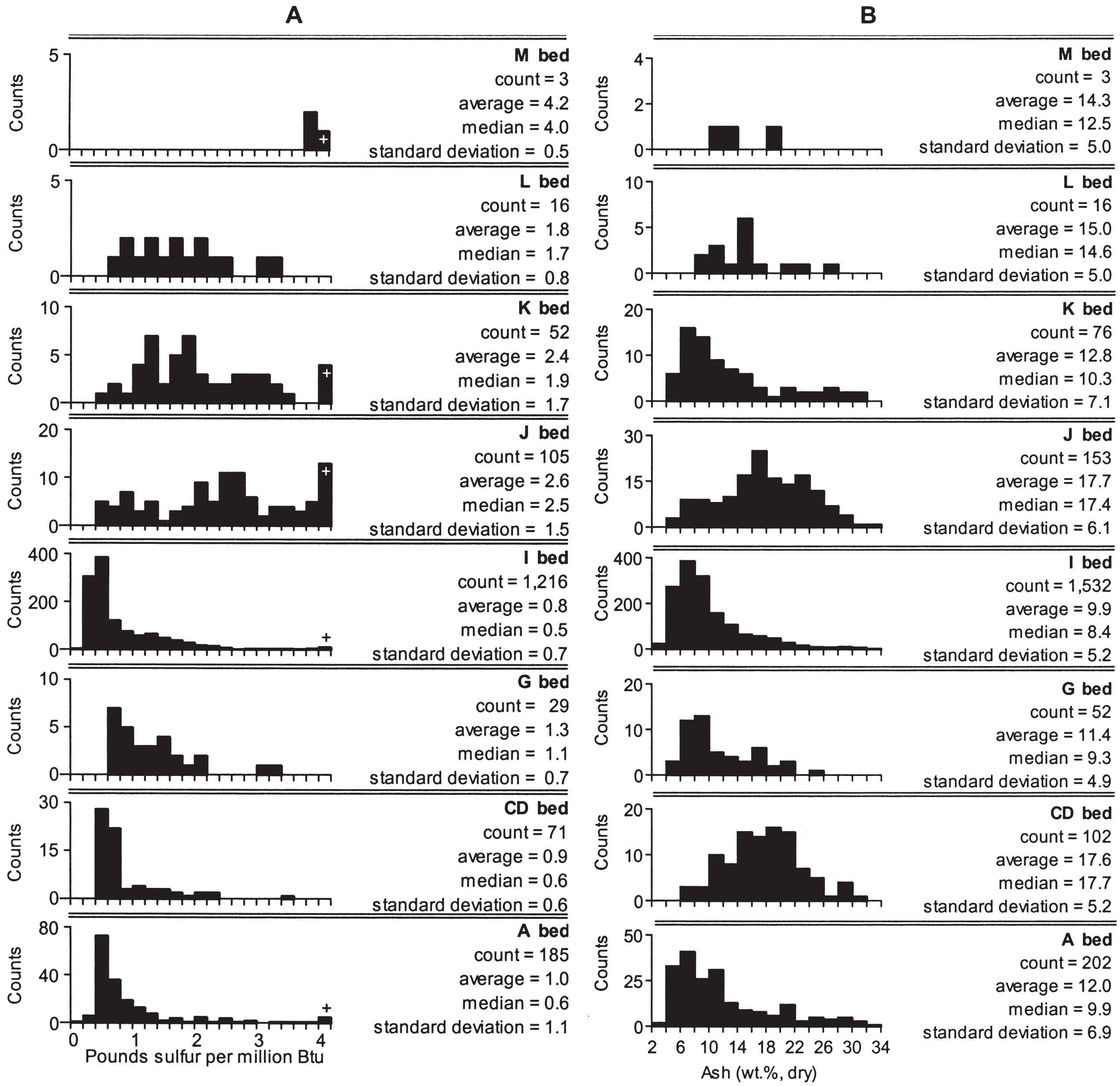


Figure 6. Frequency histograms and summary statistics showing sulfur (A) and ash (B) values for eight coalbeds in the southern Emery coalfield, Emery and Sevier Counties Utah. The histograms show the absolute frequency distribution of data records (one data record equals one count). Data are from Doelling (1972), Affolter and others (1979), Doelling and others (1979), Crowley and others (1989), Bragg and others (1997), BLM files and UGS files.

Table 3. Mercury content of coalbeds in the southern Emery coalfield, Emery and Sevier Counties, Utah (mercury content is pounds of mercury per trillion Btu). Data are from Doelling and others (1979), Bragg and others (1997), and UGS files.

Coalbed:	A	CD	G	I	J	K	L	M	All Beds
Average mercury content:	2.4	11.7	15.9	7.7	46.5	25.2	—	—	10.8
Median mercury content:	2.1	13.0	—	3.1	—	—	—	—	4.9
Number of data records:	7	26	2	35	2	1	—	—	78 [1]

[1] The 78 data records include a few records where the coalbed name is uncertain. Consequently, this value is greater than the sum of the records for the individual beds. Dash (—) indicates no data or insufficient data.

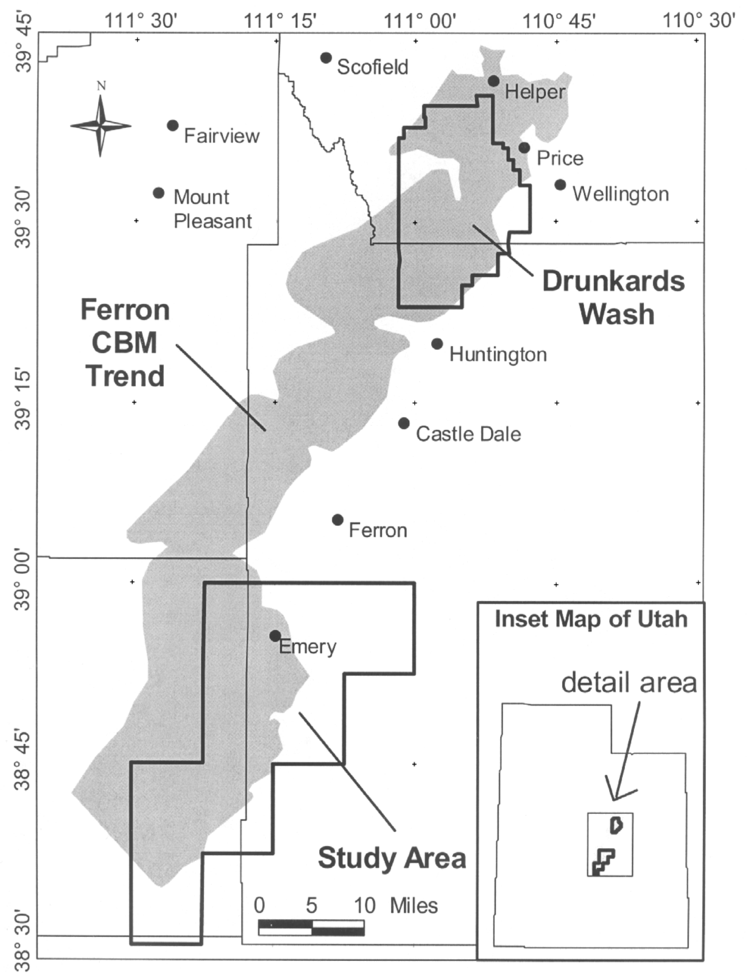


Figure 7. The study area is part of the Ferron coalbed methane (CBM) trend. The boundaries of the Ferron CBM trend and the Drunkards Wash lease area are modified from Tabet and others (1995), and from UDOGM (2003).

Geographic Data

Our study used digital maps of perennial streams, lakes, railroads, roads, pipelines, power lines, and municipalities from the Utah Automated Geographic Reference Center (UAGRC, 2003), as well as U.S. Geological Survey (USGS) 30-meter, digital elevation models. Mine maps for the Emery Deep, Browning, Dog Valley, Peterson, and Willow Springs mines are from UGS and BLM files. Data for oil and gas wells and are from the Utah Division of Oil, Gas and Mining (UDOGM, 2003). Faults were directly digitized from 1:24,000 scale, USGS Coal Investigations Maps (Hayes and Sanchez, 1979; Blanchard, 1980; Sanchez and others, 1983a, 1983b; Sanchez and Brown, 1983, 1987).

Stratigraphic Data

Coal exploration drill hole data listing the thickness and depth of coalbeds are from various sources; many of the data records are from electronic files provided by the BLM; additional records are from Edson and Barnosky (1977), Blanchard (1978), Edson (1978), Affolter and others (1979), and UGS files. Data for 530 drill holes (figure 8) were used in this study.

METHOD USED TO CALCULATE COAL RESOURCE TONNAGE

Calculation of the in-ground coal tonnage requires knowing the areal extent, thickness, and density of each coalbed. Values for the areal extent and thickness for each coalbed were entered into a spreadsheet where the coal tonnage was calculated using a coal density value of 1,800 tons per acre-foot of coal (Wood and others, 1983). For example, GIS analysis revealed 24,000 acres where the available, underground-minable coal in the A coalbed is between 4 and 6 feet thick. The spreadsheet calculation,

$$24{,}000 \text{ acres x 5 feet coal x } \frac{1{,}800 \text{ tons coal}}{\text{acre-feet}} = 216{,}000{,}000 \text{ tons coal,}$$

showed that there are 216 million tons of 4- to 6-foot-thick coal in the A coalbed that are available for underground mining.

Creating Maps Using ArcView©

As noted earlier, many of the maps used in this study were previously complied by various agencies. However, some were newly created. This section describes how these latter maps were made.

We created maps showing coalbed thickness, depth, and interburden thickness from data for drill holes using the Spatial Analyst (v.1.1) extension for ArcView (v.3.2) software. The calculations are based on identically registered, 30-meter grid cells (0.2224 acres), and zone 12, NAD27, UTM coordinates (meters). Coalbed thickness and interburden maps were made using a fourth-order, six-nearest-neighbor, inverse-distance, mapping function. Coalbed depth and elevation maps were made using a tension, six-nearest-neighbor, spline, mapping function. The intersection of the coalbed elevation and surface elevation defined the coalbed outcrop, which we verified by comparison to digitized outcrop lines from Doelling and others (1972).

Coalbed Thickness Maps

Coal oxidation and burning near the outcrop often reduces the thickness of coalbeds in Utah. Burning can also cause slumping of overlying sediments, which further reduces the apparent coalbed thickness at the outcrop Doelling (1968). Thus, outcrop observations in Utah are rarely representative of the amount of coal buried behind the outcrop. Because we have information from numerous drill holes (figure 8), we ignored outcrop thickness observations.

Sometimes, coalbeds in the southern Emery coalfield consist of several adjacent beds separated by one or more feet of rock parting. If such coalbeds can be mined by surface (open-pit) methods the adjacent beds can be successively exposed and recovered. However, if the coal is buried deeply, underground mining methods are required and only one of the adjacent beds can be recovered. Consequently, the available coal resource depends on the mining method. To account for the effect of the mining method on the available coal resource, coal thickness maps were constructed in two different ways. Coalbed thickness maps for surface-minable coal were constructed to include all coalbeds more than one foot thick; these maps include coal in adjacent splits, riders,

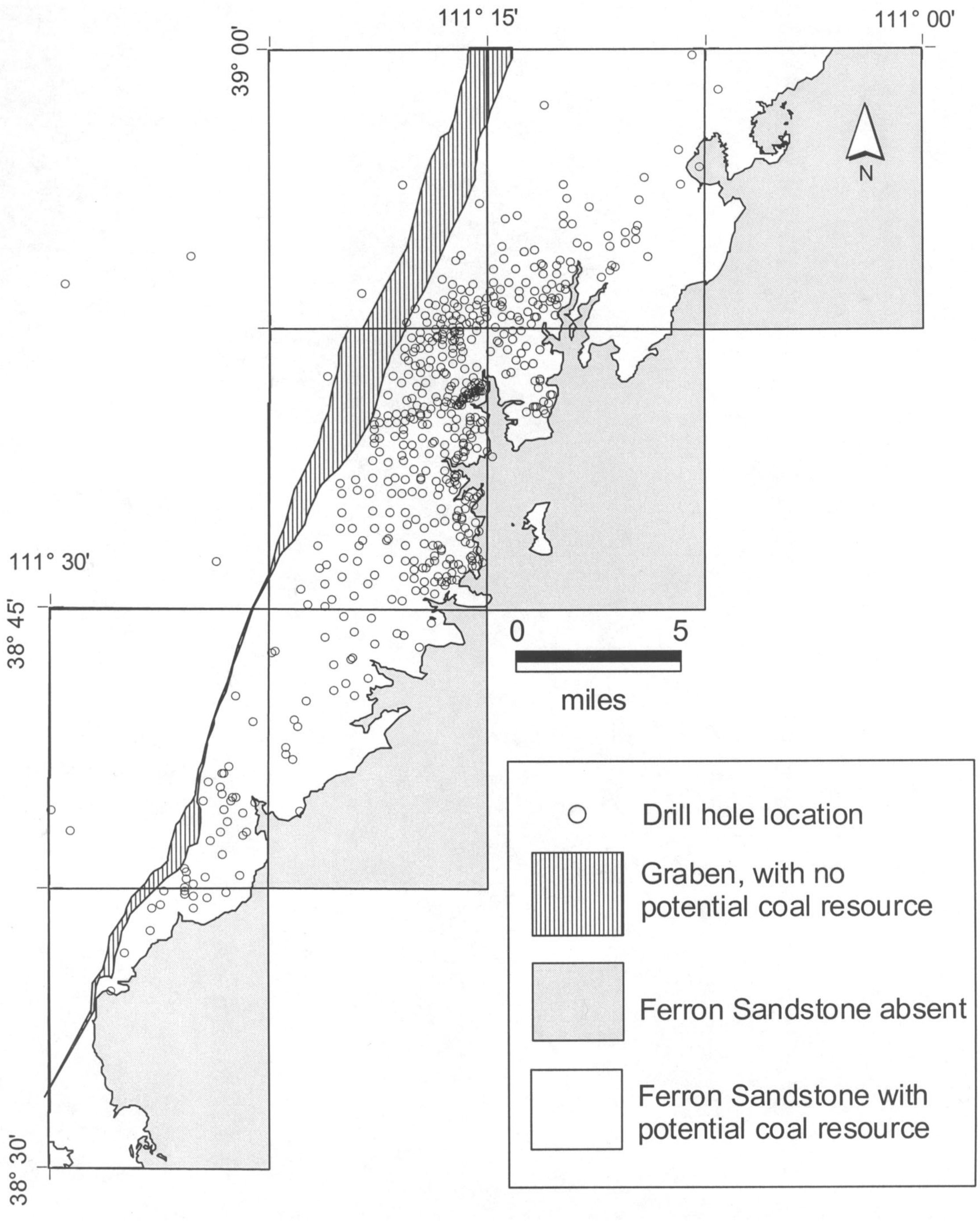


Figure 8. The location of 530 drill holes in (and adjacent to) the study area. Data for each drill hole include the depth and thickness of one or more coalbeds. Drill holes that are adjacent to the study area are included to improve the reliability of derived maps near the edge of the study area.

and subbeds. Coalbed-thickness maps for underground-minable coal were constructed to include only those parts of the bed that might be recovered using underground mining methods; these maps exclude coal in thinner splits, riders, and subbeds that are separated from the thickest bed by more than one foot of rock.

Identifying the underground-minable part of a coalbed is not simple where numerous partings, splits, riders, and subbeds occur. Accordingly, we used some arbitrary but consistent rules to distinguish the underground-minable part of a coalbed. For our maps of the underground-minable coal resource, the thickness of the coalbed was truncated at partings that are more than 1 foot thick. This convention generally excluded coal in riders and subbeds. Note that an underground-minable interval sometimes included rock partings that are less than 1 foot thick if: (a) the coal above or below a parting was at least twice the thickness of the included parting, and (b) the included partings accounted for less than 20 percent of the minable coal thickness.

Although thickness values for surface-minable and underground-minable coal were obtained using different tabulation methods, maps of both surface- and underground-minable coal were made using the same inverse-distance, mapping function. To avoid double counting coal tonnage, we excluded areas having surface-minable coal from subsequent mapping of the underground-minable coal.

Coalbed Depth Maps

Depth maps were made for tops of coalbeds encountered in the 530 drill holes shown on figure 8; areas on the east side and west side of the graben were mapped independently because of fault displacement. Subtraction of the newly created depth map from surface elevations obtained from the USGS digital elevation model allowed us to construct an elevation (structure) map for each coalbed (not included with this report).

Coalbed Interburden Maps

The thickness of sediment between adjacent coalbeds (the interburden) is significant because two beds with less than 40 feet of interburden cannot both be mined safely by underground mining methods. Although interburden maps made by subtracting the elevation surfaces of adjacent coalbeds did show trends of interburden variation, these maps sometimes showed adjacent coalbeds intersecting in areas without point-data observations. We attribute these erroneous intersections to the sometimes close proximity of adjacent coalbeds, the limited precision of the elevation data (about ±10 feet), and the trend-dependent extrapolations in the spline, mapping function used to create the coalbed elevation maps. To avoid this problem, interburden values observed for adjacent coalbeds encountered in drill holes were used to construct the coalbed interburden maps.

Resource Classification

The USGS (Wood and others, 1983) narrowly defines a coal reserve as coal that can be economically produced at the time of determination, whereas a coal resource is broadly defined to include coal for which economic extraction is potentially feasible. In this study, we did not rigorously consider coal-production costs, the percent of the in-ground coal that can be recovered, or other factors required to estimate the coal reserve. Instead, we identified a subset of the in-ground coal resource, which we call the available coal resource.

The Available Coal Resource

The available coal resource is that part of the total coal resource remaining after subtraction of coal in areas affected by past mining, or where mining is prohibited because of technical or land-use restrictions. These restrictions vary from place to place (Eggleston and others, 1990).

Restrictions to mining are considered in two groups. Technical restrictions limit mining to areas where the coal can be safely recovered using current technology. Land-use restrictions limit mining to areas where mining will not harm human infrastructure or environmental assets. Table 4 lists

Table 4. Restrictions to mining in the southern Emery coalfield, Emery and Sevier Counties, Utah (modified from Rohrbacher and others, 1993).

Land-use restrictions [1]	Buffer or Factor
Power lines	100 feet on either side
Highways	100 feet on either side
Perennial streams	100 feet on either side
Lakes or reservoirs	100 feet around margin
Towns or residences	300-foot radius
Oil and gas wells	100-foot radius
Escarpment protection	50:1 minimum area:circumference ratio (surface-minable coal)
Technical restrictions	**Buffer or Factor**
Maximum rock:coal stripping ratio	8:1 (surface-minable coal)
Minimum bed thickness	1 foot (surface-minable coal) 4 feet (underground-minable coal)
Minimum overburden	100 feet (underground-minable coal) 50 feet (surface-minable coal)
Maximum bed thickness	14 feet (underground-minable coal)
Maximum overburden	3,000 feet (underground-minable coal)
Minimum interburden	40 feet (underground-minable coal)
Faults	50 feet on either side (underground-minable coal)
Barrier for abandoned mines (Included with mined-out coal)	50 feet around margin

[1] No railroads, radio towers, or pipelines are present in the coal-bearing parts of the study area.

the land-use and technical restrictions that are used in this study, together with their associated buffers and restriction factors. Some of the restrictions are specific to surface-minable coal, some are specific to underground-minable coal, and some apply to both.

Restrictions for Underground-Minable Coal

All active Utah coal mines are underground mines that use continuous mining machines to develop mains and entries, and longwall mining machines for bulk production. Longwall machines used in Utah are usually designed for 6- to 14-feet-thick coalbeds. In eastern U.S. states, underground coal mines sometimes work beds as thin as 2 or 3 feet thick. However, this is done only where some special circumstance or use of the coal justifies a premium price. Moreover, underground mining of thinner coalbeds in the eastern U.S. is also possible because these Carboniferous-age coalbeds typically show uniform thickness over large areas, which allows sufficient production to recover the cost of thin-coal mining equipment. Cretaceous-age coalbeds in Utah show more thickness variation. Because Utah coal is sold to power plants, rather than to more lucrative specialty markets, it seems unlikely that thin Utah coalbeds can be economically mined. Furthermore, even if a premium price is offered for Utah coal, mining these thinner coalbeds will be challenging because they are not uniformly thick over large areas. Given these circumstances, we used a 4-foot minimum thickness restriction to identify the underground-minable coal resource.

Although coalbeds greater than 14 feet thick are actively mined in Utah, current underground mining methods can recover only a maximum 14-foot-thick segment of the coalbed; the remaining coal is lost in the gob pile behind the longwall mining machine. Accordingly, we used a maximum 14-foot thickness restriction to identify the underground-minable coal resource.

Other technological restrictions to underground mining were also considered. To avoid unstable roof conditions and possible water infusions, most mines leave a 50-foot barrier near faults. Burned or oxidized coal behind the outcrop commonly causes operators to leave coal near the outcrop. Weathering near the outcrop sometimes extends to several hundred feet of burial. We chose a minimum 100-foot burial depth restriction to exclude weathered coal. In areas where there are multiple coabeds, 40 feet of interburden is required to allow for stable roof and floor conditions if both of the coalbeds are mined. Accordingly, we used a 40-foot interburden restriction to exclude the thinner of the two adjacent coalbeds; if both coalbeds are more than 4 feet thick, the more deeply buried coalbed was excluded. The maximum amount of overburden routinely planned for at most Utah coal mines is 2,500 feet. However, some operators are considering mining to depths of 3,000 feet, so a 3,000-foot maximum burial depth restriction was used in this study. Regulations require coal operators to leave a 50-foot barrier between abandoned and active coal mine workings to avoid potential ventilation or water infusion problems. Accordingly, we applied a 50-foot buffer restriction to the perimeter of abandoned coal mines.

Land-use restrictions for underground mining are intended to protect surface features from damage that might result from surface subsidence above underground mines. Protected surface features in the study area include power lines, highways, oil and gas wells, perennial streams, lakes, reservoirs, buildings, and municipalities. Land-use restrictions that prohibit mining under railroads, radio towers, and pipelines were not considered because these features do not occur in the study area.

Restrictions for Surface-Minable Coal

Preliminary examination of the Emery coalfield showed areas with surface-minable coal. With one minor exception, the steep topography of Utah's coalfields has generally dictated that no modern surface mines have produced coal in Utah. Consequently, restrictions appropriate to surface coal mines in Utah are not well established. Nonetheless, restrictions to surface mining listed in table 4 were applied. Note that the 8:1 rock:coal ratio was used to delineate areas with surface-minable coal. This calculation revealed numerous small isolated blocks, which we consider too small for economic resource recovery. Accordingly, we used a minimum 10-acre block size restriction to eliminate these small blocks from the surface-minable coal resource. The 50-foot overburden restriction excludes coal near the outcrop, where the coal is often burned or oxidized. Because surface-minable coal is more easily recovered than underground-minable coal, a one-foot minimum coalbed thickness restriction was used to identify surface-minable coal.

Using an 8:1, rock:coal stripping ratio, we observed long, narrow bands of potentially strippable coal along the Coal Cliffs escarpment. We believe that this coal is unlikely to be mined because such mining operations would alter the prominent cliff-face. Therefore, we applied a minimum 50:1 area:circumference restriction to preclude contour mining along the Coal Cliffs escarpment.

Thickness Categories

Coalbed thickness categories used in this study are similar to those recommended by the USGS (Wood and others, 1983). We deviated slightly from the USGS classification to account for current Utah mining practice, which preferentially selects coalbeds that are more than 6 feet thick. Table 5 compares the coalbed thickness categories used in this report to those recommended by the USGS.

Table 5. Coalbed thickness categories used in this report compared to those used in the Coal Resource Classification System of the USGS (Wood and others, 1983).

This Report		USGS	
feet	inches	feet	inches
1 to 2	12 to 24	1.2 to 2.3	14 to 28
2 to 4	24 to 48	2.3 to 3.5	28 to 42
4 to 6	48 to 72	3.5 to 7.0	42 to 84
6 to 10	72 to 120	7 to 14	84 to 168
10 to 14	120 to 168		
+ 14	+ 168	+ 14	+ 168

Overburden Categories

Table 6 compares the overburden categories used in this report to those recommended by the USGS (Wood and others, 1983). To identify shallow coal that is probably weathered or burned, we used a 0- to 100-foot-overburden category for underground-minable coal, and a slightly more inclusive 0- to 50-foot restriction for surface-minable coal. The USGS recommends a 0- to 500-foot-overburden category to identify coal that can be mined by open-pit methods. As discussed above, we identified surface-minable coal using a maximum 8:1 rock:coal stripping ratio.

Table 6. Overburden categories used in this report compared to those used in the Coal Resource Classification System of the USGS (Wood and others, 1983).

This Report (feet)	USGS (feet)
< 100 [1]	0 to 500
100 to 1,000	500 to 1,000
1,000 to 2,000	1,000 to 2,000
2,000 to 3,000	2,000 to 3,000
3,000 to 4,000	3,000 to 6,000
4,000 to 5,000	
+ 5,000	

[1] A zero to 50-foot restriction is applied to this category to calculate the surface-minable fraction of the available coal resource, whereas all of this coal is excluded from the underground-minable, available coal resource.

Reliability Categories

Three reliability categories (Wood and others, 1983) were used in this study. The demonstrated coal resource must be within 0.75 miles of a measured thickness location. The inferred coal resource is between 0.75 and 3 miles of a measured thickness location, while the hypothetical coal resource covers coal found more than 3 miles from a measured thickness location.

RESOURCE CALCULATION RESULTS

The Original Coal Resource

The original coal resource is the tonnage of minable coal that existed in the study area before mining, and without consideration of land-use or technical restrictions. Two factors are important when considering the original coal resource. The thickness of the individual coalbeds has obvious significance; coal in thin beds has little economic potential whereas coal in thick beds is potentially minable. The depth of the original coal resource is also important. Deeply buried coalbeds have little economic significance whereas coal at shallow to modest depths is more economically attractive.

Thickness of the Original Coal Resource

Table 7 shows tonnage values according to thickness categories for eight coalbeds in the southern Emery coalfield. Five percent of the original coal resource (217 million tons) is surface-minable and 95 percent (4,506 million tons) is underground-minable. About 70 percent the underground-minable coal is in beds that are more than 4 feet thick; most of this thicker coal is in the A, CD, and I coalbeds.

Depth of the Underground-Minable, Original Coal Resource

Table 8 shows the distribution of the underground-minable, original coal resource by burial depth, for coalbeds that are more than 4 feet thick. About 2.4 billion tons of this coal is at depths suitable for underground mining (between 100 and 3,000 feet deep).

Calculation of the Available Coal Resource

The available coal resource includes that part of the original coal resource that remains after subtraction of coal in areas affected by past mining and subtraction of coal that cannot be mined due to technical or land-use restrictions. Table 9 shows the effect of technical and land-use restrictions on the available coal resource. Note that the available coal tonnage is greater than the value obtained by sequentially subtracting the individual tonnage restrictions. This is because coal in areas subject to more than one restriction is only subtracted once.

Coal Lost to Technical Restrictions

Almost 30 percent (1.3 billion tons) of the original coal resource is in beds that are too thin for underground mining (less than 4 feet thick). About 20 percent (919 million tons) is in beds that are too deep to mine. About four percent (195 million tons) is too shallow and presumably burned. Other technical restrictions (table 9) are less significant.

Coal Lost to Land-Use Restrictions

Land-use restrictions individually exclude 127 million tons of coal (table 9), which is about 3 percent of the original coal resource in the study area. About 47 million tons is lost because of rules that prohibit mining under lakes and perennial streams, and 45 million tons is lost where the coal is under improved roads. The direct effect of other land-use restrictions is less significant although 18 million tons is lost where the coal is under buildings and municipalities (mostly attributable to the CD coalbed under the town of Emery).

THE AVAILABLE COAL RESOURCE

Table 9 shows that three coalbeds (A, CD, and I) account for over 75 percent of the 2.4-billion-ton available coal resource in the southern Emery coalfield. Over 90 percent (2.2 billion tons) of the coal is underground-minable, and over 200 million tons is surface-minable.

The 2.4-billion-ton available coal resource that we calculated for the southern Emery coalfield (table 9) is an estimate. In the following sections we use two approaches to evaluate the reliability of this estimate. First, we consider

Table 7. Original coal resource tonnage for eight coalbeds by coalbed thickness and mining method, Emery and Sevier Counties, Utah (million tons).

Coalbed mining method	COALBED THICKNESS (feet)								TOTAL			
	1-2	2-4	4-6	6-8	8-10	10-12	12-14	+ 14	surface	under-ground	sum	%
M surface	—	—	3	3	—	—	—	—	6	—	295	6
underground	29	84	91	84	—	—	—	—	—	289		
L surface	0	—	1	1	1	—	—	—	3	—	395	8
underground	72	220	66	28	4	2	—	—	—	392		
K surface	1	1	1	—	—	—	—	—	3	—	103	2
underground	29	39	15	17	1	—	—	—	—	100		
J surface	1	4	4	1	0	—	—	—	10	—	191	4
underground	26	66	65	21	3	—	—	—	—	181		
I surface		0	1	10	10	5	8	29	62	—	1,066	23
underground	46	147	132	241	205	104	19	110	—	1,004		
G surface	0	1	4	0	—	—	—	—	15	—	472	10
underground	54	115	223	54	9	1	1	—	—	457		
CD surface	—	0	0	1	5	11	20	48	85	—	997	21
underground	29	155	305	238	73	45	26	40	—	912		
A surface	0	2	5	9	12	3	—	—	32	—	1,205	26
underground	24	196	319	213	154	171	71	25	—	1,172		
TOTAL	313	1,029	1,236	922	476	342	143	252	217	4,506	4,723	100
PERCENT	7	22	26	20	10	7	3	5	95	5		

TOTAL may differ from results obtained by summing rows or columns due to rounding.

Zeros indicate rounded values less than 0.5 million tons.

Dashes (—) indicate null (true zero) values.

Table 8. Original coal resource tonnage for underground-minable coal in eight coalbeds by burial depth, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).

COALBED	DEPTH (feet)					TOTAL	TOTAL	PERCENT
	0 to 100	100 to 1,000	1,000 to 2,000	2,000 to 3,000	3,000 to 6,000	All depths	100 to 3,000 feet deep	100 to 3,000 feet deep
M	10	45	40	63	17	175	148	6
L	8	53	34	5	—	100	92	4
K	2	29	2	—	—	32	31	1
J	13	67	8	—	—	89	75	3
I	38	325	103	134	210	810	562	23
G	3	144	30	31	79	287	205	9
CD	18	313	187	67	142	727	567	24
A	36	438	113	165	200	952	717	30
TOTAL	128	1,415	517	465	648	3,173	2,397	76
PERCENT	4	45	16	15	20			

TOTALS may differ from results obtained by summing rows or columns due to rounding.

Dashes (—) indicate null (true zero) values.

Values exclude coal in coalbeds that are less than 4 feet thick.

Table 9. Coal tonnage lost to technical and land-use restrictions, and tabulation of the net available coal resource for eight coalbeds in the southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).

	ORIGINAL COAL RESOURCE		TECHNICAL RESTRICTIONS							LAND-USE RESTRICTIONS				AVAILABLE COAL RESOURCE		
COALBED	*Surface*	*Underground*	*Thin*	*Shallow*	*Deep*	*Mined*	*Faulted*	*Bed conflict*	*Thick*	*Wells*	*Water*	*Roads*	*Buildings*	*Electric*	*Surface*	*Underground*	TOTAL
M	6	289	114	15	25	—	3	—	—	0	3	2	0	0	6	144	150
L	3	392	292	19	83	0	3	7	—	0	3	4	0	0	3	88	91
K	3	100	68	7	0	4	0	5	—	0	2	2	1	1	2	25	28
J	10	181	92	24	14	4	1	7	—	0	2	2	2	1	10	72	81
I	62	1,004	194	50	239	47	4	7	26	0	15	12	4	4	50	489	539
G	15	457	170	10	121	2	1	1	—	0	3	3	1	3	13	198	211
CD	85	912	184	32	160	4	1	13	5	0	9	12	10	6	81	531	612
A	32	1,172	220	38	278	0	8	18	2	0	10	8	1	2	32	686	718
TOTAL	217	4,506	1,333	195	919	61	22	58	33	1	47	45	18	17	197	2,233	2,430
Percent	5	95	28	4	19	1	0	1	1	0	1	1	0	0	4	47	51

ORIGINAL COAL RESOURCE

Surface is surface-minable coal in beds more than 1 foot thick where the net stripping ratio is less than 8:1 and the block size is more than 10 acres, excluding contour-minable coal (where the area-circumference ratio is less than 50).

Underground is underground-minable coal in beds more than 1 foot thick, (generally excluding riders, splits, and sub-beds) that does not occur in areas designated as surface-minable.

RESTRICTIONS are individually tabulated for:

- *Thin* underground-minable coal in beds less than 4 feet thick.
- *Shallow* underground-minable coal less than 100 feet deep.
- *Deep* underground-minable coal more than 3,000 feet deep.
- *Mined* coal previous mined, or undermined (including a 50-foot buffer).
- *Faulted* underground-minable coal within 50 feet of a fault.
- *Bed conflict* underground-minable coal within 40 feet of a thicker or better coalbed.
- *Thick* underground-minable coal in parts of a bed more than 14 feet thick.
- *Wells* coal within 100 feet of an oil or gas well.
- *Water* coal under a perennial stream or water body (100-foot buffer).
- *Roads* coal under an improved road (100-foot buffer).
- *Buildings* coal under buildings or municipalities (300-foot buffer).
- *Electric* coal under electric power lines (100-foot buffer).

AVAILABLE COAL RESOURCE is the net total coal remaining after subtraction of restricted coal; coal in areas subject to multiple restrictions is only subtracted once.

TOTAL values may differ from results obtained by summing columns due to rounding.

Percent is percentage of total original coal tonnage (*Surface* + *Underground* = 4,723 million tons).

Zeros indicate rounded values less than 0.5 million tons.

Dashes (—) indicate null (true zero) values.

the spatial distribution of drill hole observations used to calculate the available coal resource. Second, we compare the results from this study with results from a previous study.

The reliability of the available coal resource estimate is evaluated using a classification from Wood and others (1983). About 60 percent of the available coal resource identified in this report is demonstrated (less than 0.75 miles from a thickness location), 36 percent is inferred (0.75 to 3 miles from a thickness location), and less than 4 percent is hypothetical (more than 3 miles from a thickness location). Table 10 shows the reliability of the available coal resource by coalbed.

Table 10. The available coal resource tonnage for eight coalbeds by reliability category, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).

	Reliability Category			
COALBED	Demonstrated	Inferred	Hypothetical	TOTAL
M	40	78	31	150
L	52	39	0	91
K	27	0	0	28
J	53	28	0	81
I	350	185	4	539
G	139	72	0	211
CD	394	214	4	612
A	415	266	38	718
TOTALS	1,470	883	77	2,430

Reliability Category(s) from Wood and others (1983).

Demonstrated is coal within 0.75 miles of an observation location.

Inferred is coal between 0.75 and 3 miles of an observation location.

Hypothetical is coal more than 3 miles from an observation location.

TOTAL may differ from results obtained by summing rows or columns due to rounding.

Table 11 compares the available coal resource estimate from this study to a similar estimate reported by Doelling (1972). Doelling's resource estimate is for coalbeds that are more than 4 feet thick, and less than 3,000 feet deep. Although we also tabulate the coal resource for coalbeds that are more than 4 feet thick and less than 3,000 feet deep, the comparison shown in table 11 is approximate rather than exact. For example, coal in the Emery West quadrangle is not included in Doelling's study but is included in our study. Furthermore, our available coal resource estimate excludes restricted coal (table 9) whereas Doelling's estimate includes this coal. Finally, different reliability categories are used in the two studies. To provide a more equitable comparison, the sum of the demonstrated and the inferred coal resource shown in table 10 is listed as the identified coal resource in table 11. Doelling's Class I, II, and III coal resource estimates are similarly combined and listed in table 11, and his Class IV coal resource estimate is directly compared to our hypothetical coal resource estimate.

We observe about 28 percent more coal in the southern Emery coalfield than reported in Doelling's monograph. Given the different calculation method and the slightly larger area examined in the present study, a 28 percent increase of the coal resource is not remarkable. More significant is the improved reliability. Doelling (1972) found that 33 percent of the coal is a Class IV resource ("potential coal... based on geographic and geologic position with little supporting data") whereas our study shows that only 5 percent of the coal is not reliably known (hypothetical coal, more than 3 miles from a thickness observation).

Table 11. Coal resource tonnage and reliability estimates from an earlier study compared to results from this study, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).

	Identified [3]	Hypothetical	Total
Doelling (1972) [1]	1,264	635	1,899
This study [2]	2,353	77	2,430

[1] excludes coal in the Emery West quadrangle and the northwestern corner of the Geyser Peak quadrangle.

[2] the available coal resource

[3] similar or equal to the demonstrated plus inferred coal resource.

DISCUSSION

The significance of the 2.4 billion ton available coal resource estimate depends on how much of this coal is produced in the near future. Predicting future production is clearly less certain than estimating the available coal resource. Nonetheless, we estimate the coal production potential of the southern Emery coalfield by considering the thickness and distribution of the available coal resource, as well as local mining practice.

Table 12 shows that 38 percent (852 million tons) of the underground-minable, available coal resource is in coalbeds that are less than 6 feet thick. Such relatively thin coal is rarely mined in Utah. About 1.6 billion tons of the available coal resource is in beds that are more than 6 feet thick. However, about 400 million tons of this thick coal is deeply buried on the west side of the graben that divides the study area. This coal in the graben is also unlikely to be mined because expensive slopes or shafts are required in this area rather than the ubiquitous, more economical, horizontal entries of existing Utah coal mines.

Coal mines in the nearby Wasatch Plateau coalfield typically recover about 35 percent of the available coal resource (Rohrbacher and others, 2001). Recovery from southern Emery coalfield will probably be less than 35 percent, because coalbeds in the southern Emery coalfield are more lenticular and less continuous than those in the Wasatch Plateau (Doelling 1972). Table 9 shows that 61 million tons of the original coal resource in the southern Emery coalfield has been removed from future mining consideration, either directly by mining or by undermining, while table 1 shows that the disturbed coal has accounted for only 9.5 million tons of production. The ratio of coal produced (9.5) to the amount of coal resource restricted by past mining disturbance (61) allows a 16 percent recovery factor from past mining to be calculated. This relatively low recovery is at least partly due to production from exceptionally thick

Table 12. The underground-minable, available coal resource tonnage for eight coalbeds by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).

	COALBED THICKNESS (feet)									TOTALS	
COALBED	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	> 20	All beds	+6 feet
M	76	68	—	—	—	—	—	—	—	144	68
L	58	26	3	1	—	—	—	—	—	88	31
K	11	14	1	—	—	—	—	—	—	25	15
J	53	16	2	—	—	—	—	—	—	72	18
I	99	140	118	71	12	14	16	11	8	489	390
G	138	50	9	1	1	—	—	—	—	198	60
CD	201	174	57	41	24	18	14	—	—	531	330
A	216	160	92	131	66	17	5	1		686	470
TOTALS	852	649	282	244	103	49	35	11	8	2,233	1,382

TOTALS may differ from results obtained by summing rows or columns due to rounding.
Dash (—) indicates a null (true zero) value.

coalbeds. Figure 9 shows that the available coal in the I coalbed is typically 6 to 8 feet thick, whereas coal mines have preferentially targeted areas where the I coalbed is more than 20 feet thick. Recovery of coal from such exceptionally thick coalbeds is difficult. Indeed, current underground mining methods used in Utah can only recover coal from parts of the bed up to 14 feet thick; coal in parts of the bed that is more than 14 feet thick is not recovered. However, past mining in the southern Emery coalfield has been by less-efficient room and pillar methods, while future mining will likely entail the more-efficient longwall mining method. Thus, an estimated future coal mining recovery rate of 35 percent for the southern Emery coalfield, similar to that of the other central Utah coalfields, is not unreasonable if longwall methods are employed at future mining operations.

Excluding the coal on the west side of the graben and the relatively thin, 4- to 6-foot-thick coal, and optimistically assuming 35 percent recovery from underground mines and 80 percent recovery from surface mines, we anticipate that up to 500 million tons of coal might be produced from the southern Emery coalfield. Two caveats bear on this estimate. First, more coal could be produced if higher coal prices or technological advances enable economic mining of thinner coal and increase the recovery factor. Second, less coal might be produced if the sometimes high sulfur and mercury content of coals in the southern Emery coalfield limit their marketability, or if mining is restricted due to changing environmental valuations.

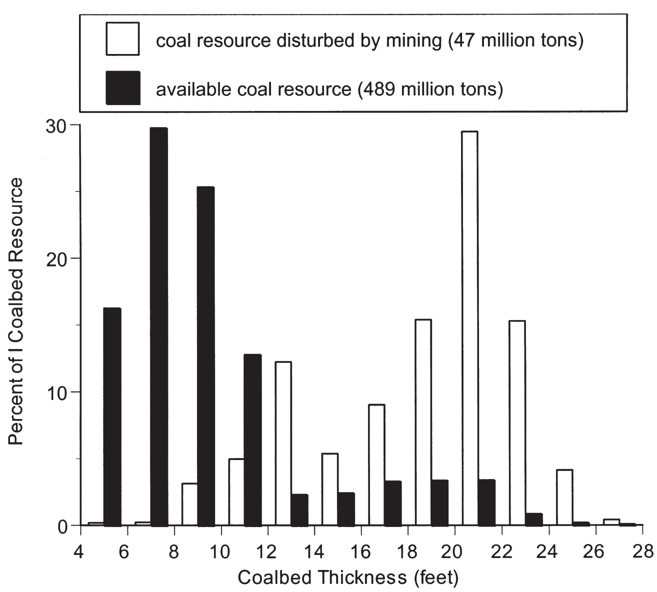


Figure 9. Relative frequency histogram showing that the thicker parts of the I coalbed have been preferentially mined. Black bars show the thickness distribution of the 489 million tons of available coal in the I coalbed. White bars show the thickness distribution of the 47 million tons of coal in parts of the I coalbed that have been mined (this includes 9 million tons of produced coal and 38 million tons of unrecovered coal in areas disturbed by mining). The I coalbed is in the southern Emery coalfield, Emery and Sevier Counties, Utah.

SUMMARY

Maps showing the thickness and distribution of the available coal resource for eight coalbeds in the southern Emery coalfield are provided in the Appendix. Of the 4.7 billion ton original coal resource, only 2.4 billion tons is part of the available coal resource. Nearly 2.3 billion tons of the original coal resource is in coalbeds that are too thin (less than 4 feet thick) or too deep (more than 3,000 feet) for mining. Smaller amounts of coal (200 million tons) are near surface and presumably burned. Past mining has disturbed very little of the original coal resource (61 million tons) and only 125 million tons is subject to land-use restrictions. Other findings include:

- 60 percent of the available coal resource identified in this study is demonstrated (within 0.75 miles of a measurement location).
- Over 75 percent of the available coal resource is in three coalbeds: the A bed (30%), the CD bed (25%), and the I bed (22%).
- Coal rank varies from high-volatile B bituminous in the north, to subbituminous A in the south.

- Average sulfur content is above 2 pounds sulfur per million Btu (lbs S/10^6 Btu) in the J, K, L, and M coalbeds, but is markedly lower in the underlying, and economically more significant, A (1.1 lbs S/10^6 Btu), CD (0.9 lbs S/10^6 Btu), and I (0.8 lbs S/10^6 Btu) coalbeds.
- Dry basis ash values are typically near 10 percent except for the CD and J coalbeds (both near 17 percent).
- Available data show that the in-ground coal in the study area averages 11 pounds mercury per trillion Btu (lbs Hg/10^{12} Btu), which is three times higher than the average mercury content of coal in the nearby Wasatch Plateau and Book Cliffs coalfields but slightly less than the U.S. average of 13 lbs Hg/10^{12} Btu.

Nearly 40 percent (852 million tons) of the underground-minable, available coal resource occurs in beds that are less than 6 feet thick. Because Utah's underground coal mines rarely produce from beds that are less than 6 feet thick, this coal is unlikely to be mined soon. Furthermore, about 400 million tons of the underground-minable coal that is more than 6 feet thick is buried on the west side of the graben that divides the study area. This coal is also unlikely to be mined. Excluding the coal on the west side of the graben and the relatively thin, 4- to 6-foot-thick coal, and assuming 35 percent recovery from underground mines and 80 percent recovery from surface mines, about 500 million tons of coal might still be produced from the southern Emery coalfield. This potential production is sufficient to satisfy Utah's current coal consumption for about 20 years.

ACKNOWLEDGMENTS

We acknowledge funding from the U.S. Geological Survey under cooperative agreement number 02ERAG0043. We thank M. Devereux Carter of the U.S. Geological Survey and James Kohler of the U.S. Bureau of the Bureau of Land Management for their helpful reviews and discussions. The Utah State Office of the U.S. Bureau of Land Management provided recent drill hole information. The personnel of the Utah Division of Oil, Gas and Mining public room provided access to annual reports from active coal mines, data on the location of active oil and gas wells, and guidance on land-use restrictions. The Utah Automated Geographic Reference Center provided digital land grid, topographic, road, stream, and power-line coverages for the study area. Reviews by Kimm Harty of the Utah Geological Survey improved the manuscript.

REFERENCES

Affolter, R.H., Hatch, J.R., and Ryer, T.A., 1979, Chemical analyses of coal and shale from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah: U.S. Geological Survey Open-File Report 79-858, 35 p.

American Society for Testing and Materials, 1990, D 388-90, Standard classification of coals by rank: West Conshohocken, Pennsylvania, v. 05.05, p. 193-196.

Blanchard, L.F., 1978, Geophysical and lithologic logs of holes drilled in the Wasatch Plateau and Emery coal fields, Johns Peak and Old Woman Plateau quadrangles, Sevier County, Utah: U.S. Geological Survey Open-File Report 78-363, 56 p.

—1980, Geologic map and coal sections of Johns Peak Quadrangle, Sevier County, Utah: U.S. Geological Survey Open-File Report 80-491, 2 sheets, scale 1:250,000.

Bragg, L.J., Oman, J.K., Tewalt, S.J., Oman, C.L., Rega, N.H., Washington, P.M., and Finkelman, R.B., 1997, U.S. Geological Survey coal quality (COALQUAL) database- version 2.0: U.S. Geological Survey Open-File Report 97-134, CD-ROM.

Crowley, S.S., Stanton, R.W., and Ryer, T.A., 1989, The effects of volcanic ash on the maceral and chemical composition of the C coal bed, Emery coal field, Utah: Organic Geochemistry, v. 14, p. 315-331.

Davis, A., 1984, Chapter 3, Coal petrology and petrographic analysis, in Ward, C.R., editor, Coal geology and coal technology: Melbourne, Blackwell Scientific, p. 74-112.

Doelling, H.H., 1968, Carcass Canyon coal area, Kaiparowits Plateau, Garfield and Kane Counties, Utah: Utah Geological and Mineralogical Survey Special Study 25, 23 p.

—1972, Central Utah coal fields - Sevier-Sanpete, Wasatch Plateau, Book Cliffs, and Emery: Utah Geological and Mineralogical Survey Monograph Series no. 3, 571 p.

Doelling, H.H., Smith, A.D., and Davis, F.D., 1979, Methane content of Utah coals, in Smith, M., editor, Coal studies: Utah Geological and Mineral Survey Special Study 49, p. 1-60.

Edson, G.M., 1978, Core drilling in 1978- Willow Springs quadrangle, Emery and Sevier Counties, Utah: U.S. Geological Survey Open-File Report 78-1049, 21 p.

Edson, G.M., and Barnosky, C.T., 1977, Lithologic and geophysical logs of holes drilled in the Willow Springs quadrangle, Emery and Sevier Counties, Utah: U.S. Geological Survey Open-File Report 77B866, 31 p.

Eggleston, J.R., Carter, M.D., and Cobb, J.C., 1990, Coal resources available for development – a methodology and pilot study: U.S. Geological Survey Circular 1055, 15 p.

Hayes, P.T., and Sanchez, J.D., 1979, Geologic map and coal resources of the Emery West quadrangle, Emery and Sevier Counties, Utah: U. S. Geological Survey Coal Investigations Map C-82, 2 plates, scale 1:24,000.

Hower, J.C., Griswold, T.B., and Pollock, J.D., 1989, Caveats on the use of published coal quality data: Journal of Coal Quality, v. 8, p. 49-51.

Hucka, B.P., Sommer, S.N., and Tabet, D.E., 1997, Petrographic and physical characteristics of Utah coals: Utah Geological Survey Circular 94, 80 p.

Hylland, M.D., and Lund, W.R., 2003, Guide for the preparation of reports for the Utah Geological Survey, second edition: Utah Geological Survey Miscellaneous Publication 03-7, 68 p.

Institute of Electrical and Electronics Engineers, 1997, Standard for the use of the International System of Units (SI) – The modern metric system: New York, New York, IEEE Inc. and West Conshohocken, Pennsylvania, American Society for Testing and Materials, IEEE/ASTM SI 10-1997, 66 p.

Jahanbani, F.R., 2001, 2000 annual review and forecast of Utah coal production and distribution: Utah Office of Energy and Resource Planning, 30 p.

Jahanbani, F.R., 1991, 1990 annual review and forecast of Utah coal production and distribution: Utah Department of Natural Resources, Division of Energy, 30 p.

Kohler, J.F., Quick, J.C., and Tabet, D.E., 1997, Variation in the chemistry of Upper Cretaceous, Straight Cliffs Formation coals, in Hill, L.M., editor, Learning from the land: Grand Staircase-Escalante National Monument Science Symposium Proceedings, Cedar City, Utah: Salt Lake City, Utah, U.S. Bureau of Land Management, p. 307-318.

Lamarre, R.A., 2003, Hydrodynamic and stratigraphic controls for a large coalbed methane accumulation in Ferron coals of east-central Utah: International Journal of Coal Geology, v. 56, p. 97-110.

Lines, G.C., and Morrissey, D.J., 1981, Hydrology of the Ferron Sandstone aquifer and effects of proposed surface-coal mining in the Castle Valley, Utah: U.S. Geological Survey Open-File Report 81-535, 106 p.

Lupton, C.T., 1916, Geology and coal resources of Castle Valley: U.S. Geological Survey Bulletin 628, 88 p.

Montgomery, S.L., Barker, C.E., and Tabet, D.E., 2001, Upper Cretaceous Ferron Sandstone – major coalbed methane play in central Utah: American Association of Petroleum Geologists Bulletin, v. 85, p. 199-219.

Quick, J.C., Brill, T.C., and Tabet, D.E., 2003, Mercury in US coal – observations using the COALQUAL and ICR data sets: Environmental Geology, v. 43, p. 247-259.

Quick, J.C., and Glick, D.C., 1999, Carbon dioxide from coal combustion – variation with rank of US coal: Fuel, v. 79, p. 803-812.

Quick, J.C., and Tabet, D.E., 2003, Suppressed reflectance vitrinite in the Ferron coalbed gas fairway, central Utah: International Journal of Coal Geology, v. 56, p. 49-67.

Rohrbacher, T.J., Teeters, D.D., Sullivan, G.L., and Osmonson, L.M., 1993, Coal resource recoverability, a methodology: U.S. Bureau of Mines Information Circular 9368, 48 p.

Rohrbacher, T.J., Molnia, C.L., Osmonson, L.M., Carter, M.D., Eakins, W., Hoffman, G.K., Tabet, D.E., Schultz, J.E., Scott, D.C., Teeters, D.D., Jones, G.E., Quick, J.C., Hucka, B.P., and Hanson, J.A., 2001, Chapter F, coal availability, recoverability, and economic evaluations of coal resources in the Colorado Plateau, Colorado, New Mexico, and Utah, in Kirschbaum, M.A., Roberts, L.N.R., and Biewick, L.R.H, editors, Geologic assessment of coal in the Colorado Plateau – Arizona, Colorado, New Mexico, and Utah: U.S. Geological Survey Professional Paper 1625BB, Online, <energy.cr.usgs.gov/coal/coalar/index.htm>, accessed March 2004.

Ryer, T.A., 1981, Deltaic coals of Ferron Sandstone Member of the Mancos Shale – predictive model for Cretaceous coal-bearing strata of Western Interior: American Association of Petroleum Geologists Bulletin, v. 65, p. 2323-2340.

Sanchez, J.D., Blanchard, L.F., and August, L.L., 1983a, Stratigraphic framework and coal resources of the Upper Cretaceous Blackhawk Formation in the Johns Peak and Old

Woman Plateau areas of the Wasatch Plateau coal field, Salina 30' x 60' quadrangle, Sevier County, Utah: U.S. Geological Survey Coal Investigations Map C 93-A, 2 sheets, scale 1:24,000.

—1983b, Stratigraphic framework and coal resources of the Upper Cretaceous Blackhawk Formation in the Convulsion Canyon and Wash Rock Canyon areas of the Wasatch Plateau coal field, Salina 30′ x 60′ quadrangle, Sevier and Emery Counties, Utah: U.S. Geological Survey Coal Investigations Map C 93-B, 3 sheets, scale 1:24,000.

Sanchez, J.D., and Brown, T.L., 1983, Stratigraphic framework and coal resources of the Upper Cretaceous Blackhawk Formation in the Muddy Creek and Nelson Mountain areas of the Wasatch Plateau coal field, Manti 30′ x 60′ quadrangle, Emery, Sevier, and Sanpete Counties, Utah: U.S. Geological Survey Coal Investigations Map C 94-A, 2 sheets, scale 1:24,000.

—1987, Stratigraphic framework and coal resources of the Upper Cretaceous Blackhawk Formation in the Ferron Canyon and Rock Canyon areas of the Wasatch Plateau coal field, Manti 30' x 60' quadrangle, Emery and Sanpete Counties, Utah: U.S. Geological Survey Coal Investigations Map C 94-B, 3 sheets, scale 1:24,000.

Spieker, E.M., 1931, The Wasatch Plateau coal field, Utah: U.S. Geological Survey Bulletin 819, 210 p.

Tabet, D.E., Hucka, B.P., Sommer, S.N., 1995, Maps of the total Ferron coal, depth to the top, and vitrinite reflectance for the Ferron Sandstone Member of the Mancos Shale, central Utah: Utah Geological Survey Open-File Report 329, 3 plates, scale 1:250,000.

Tabet, D.E., Quick, J.C., Hucka, B.P., and Hanson, J.A., 1999, The available coal resources for nine 7.5-minute quadrangles in the northern Wasatch Plateau coalfield, Carbon and Emery Counties, Utah: Utah Geological Survey Circular 100, 46 p.

U.S. Environmental Protection Agency, 2000, Regulatory finding on the emissions of hazardous air pollutants from electric utility steam generating units: U.S. Federal Register, v. 65, no. 245, p. 79825-79831.

Utah Automated Geographic Reference Center, 2003, Utah's statewide geographic information database: Online, <agrc.utah.gov/agrc_sgid/sgidintro.html>, accessed 2003.

Utah Energy Office, 2003, Annual review and forecast of Utah coal production and distribution, 2002: Online, <energy.utah.gov/edis.htm#coal>, accessed March 2004.

Utah Division of Oil, Gas and Mining, 2003, Utah oil and gas information center: Online, <ogm.utah.gov/oilgas/default.htm>, accessed June 2003.

Wood, G.H., Jr., Kehn, T.M., Carter, M.D., and Culberston, W.C., 1983, Coal Resource Classification System of the U.S. Geological Survey: U.S. Geological Survey Circular 891, 65 p.

APPENDIX

Tabulations of the Available Coal Resource with Associated Maps, for Eight Coalbeds in the Southern Emery Coalfield, Emery and Sevier Counties, Utah

Notes to tables:

The coalbed thickness includes rock partings less than 1 foot thick.

The surface minable, original coal resource includes coal in beds more than 1 foot thick and more than 50 feet deep, where the net stripping ratio is less than 8:1, the coal is in contiguous blocks more than 10 acres, and the block area/circumference ratio is less than 50. The surface minable coal includes coal in associated riders, splits, and subbeds.

The underground-minable, original coal resource includes coal in areas without surface-minable coal, and generally excludes coal in associated riders, splits, and subbeds).

Restricted coal cannot be mined due to land-use or technical restrictions. Land-use restrictions exclude coal under roads, power lines, buildings, municipalities, perennial streams, or water bodies. Technical restrictions exclude coal near mined-out areas and oil/gas wells, as well as underground-minable coal near faults, affected by interburden conflicts, less than 4 feet thick, in parts of a coalbed more than 14 feet thick, and coal more than 3,000 feet deep. A 100-foot minimum depth is applied to underground-minable coal to exclude burned coal. The net restricted coal shows the total amount of restricted coal where coal in areas subject to multiple restrictions is only counted once.

The available coal resource is that part of the original coal resource that is not restricted. Three reliability categories (Wood and others, 1983) are recognized: Demonstrated, includes the available coal resource within 0.75 miles of a measured thickness location, Inferred, includes the available coal resource between 0.75 and 3 miles of a measured thickness location, and Hypothetical, includes the available coal resource more than 3 miles from a measured thickness location.

Reporting conventions used in the tables include:

Numeric values show million tons coal, rounded to the nearest whole value.

Coal in beds less than 4 feet thick is not included in sums of the underground-minable available coal resource. Nonetheless, the reliability and amount of this thin coal is listed and enclosed in parentheses.

Zeros indicate rounded values less than 0.5 million tons.

Dash (B) indicates a null (true zero) value.

Table A1. *Tabulation of the surface-minable, available coal resource for all coalbeds by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions** mine	water	road	bldgs	well	**Net restricted coal**	**Reliability** demonstrated	inferred	hypothetical	**Available coal resource**
1-2	5	0	0	0	0	0	0	4	1	—	4
2-4	15	1	0	0	0	0	1	13	1	—	14
4-6	20	1	0	0	—	0	1	18	1	—	19
6-8	25	0	0	—	—	0	0	21	4	—	25
8-10	29	2	0	0	0	0	2	25	1	—	26
10-12	20	2	0	—	0	0	2	17	1	—	17
12-14	27	2	—	—	0	0	2	24	1	—	25
14-16	25	0	0	0	—	0	0	23	1	—	24
16-18	25	1	0	0	0	0	1	23	—	—	23
18-20	11	2	0	0	0	—	2	9	—	—	9
20-22	7	1	0	—	0	—	1	5	—	—	5
22-24	8	3	0	—	—	—	4	5	—	—	5
24-26	1	1	—	—	—	—	1	1	—	—	1
sum	217	18	1	1	0	0	20	187	10	—	197

Table A2. *Tabulation of the underground-minable, available coal resource for all coalbeds by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions** too deep	too shallow	mine	fault	water	road	bldgs	elec-tric	well	inter-burden	too thin	too thick	**Net restricted coal**	**Reliability** demon-strated	infer-red	hypo-thetical	**Available coal resource**
1-2	311	46	18	1	2	3	3	1	1	0		311	—	311	(112)	(127)	(29)	(238)
2-4	1,021	225	49	3	5	8	9	4	3	0	38	1,021	—	1,021	(317)	(318)	(83)	(689)
4-6	1,216	270	53	2	5	10	11	2	3	0	15	—	—	364	476	356	71	852
6-8	897	184	30	2	4	11	8	3	7	0	3	—	—	248	396	266	6	649
8-10	447	139	11	1	3	4	5	4	2	0	1	—	—	165	184	99	1	282
10-12	322	55	12	2	2	4	3	1	0	0	—	—	—	77	138	107	—	244
12-14	116	—	5	4	1	1	2	1	—	0	—	—	—	13	66	37	—	103
14-16	59	—	2	2	0	0	2	1	—	—	—	—	4	11	41	8	—	49
16-18	51	—	3	3	0	0	1	1	—	—	—	—	9	16	35	—	—	35
18-20	28	—	7	5	—	1	1	0	—	—	—	—	7	17	11	—	—	11
20-22	27	—	4	13	—	2	0	0	—	—	—	—	9	20	7	—	—	7
22-24	7	—	1	4	—	1	0	—	—	—	—	—	3	6	1	—	—	1
24-26	2	—	0	1	—	0	0	—	—	—	—	—	1	1	0	—	—	0
26-28	1	—	—	0	—	—	—	—	—	—	—	—	0	0	0	—	—	0
sum	4,506	919	195	43	22	46	44	18	17	1	58	1,333	33	2,273	1,355	873	77	2,233

See notes to tables at the beginning of the appendix for an explanation of table headings and reporting conventions.

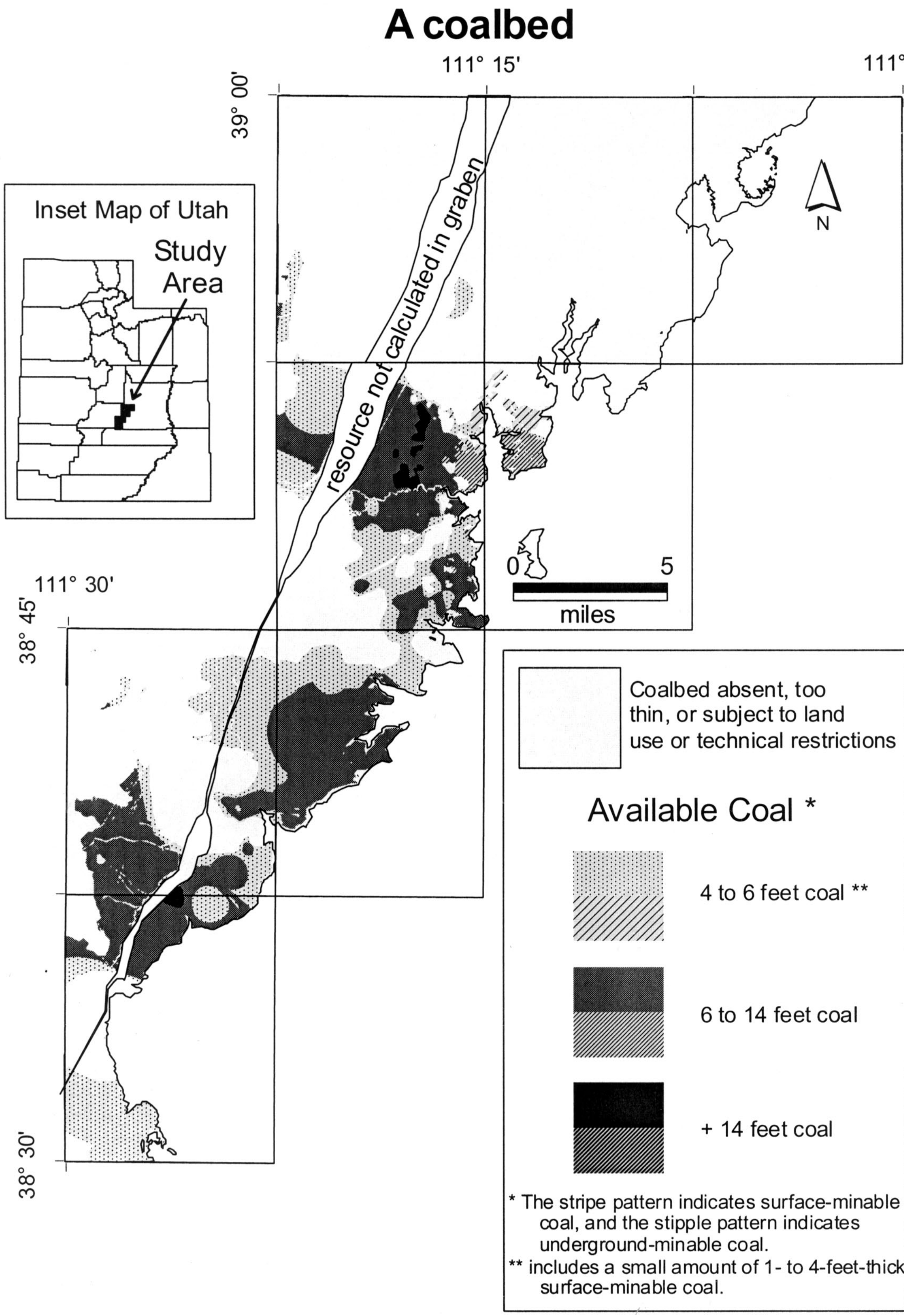


Figure A1. Location of the available coal resource for the A coalbed, southern Emery coalfield, Utah.

Table A3. *Tabulation of the surface-minable, available coal resource for the A coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions**					**Net restricted coal**	**Reliability**			**Available coal resource**
		mine	water	road	bldgs	well		demonstrated	inferred	hypothetical	
1-2	0	0	0	0	0	—	0	0	0	—	0
2-4	2	0	0	—	—	—	0	2	0	—	2
4-6	5	—	—	—	—	—	—	5	0	—	5
6-8	9	—	—	—	—	0	0	7	2	—	9
8-10	12	—	—	—	—	0	0	12	—	—	12
10-12	3	—	—	—	—	0	0	3	—	—	3
12-14	—	—	—	—	—	—	—	—	—	—	—
14-16	—	—	—	—	—	—	—	—	—	—	—
16-18	—	—	—	—	—	—	—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—
sum	32	0	0	0	0	0	0	30	3	—	32

Table A4. *Tabulation of the underground-minable, available coal resource for the A coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions**												**Net restricted coal**	**Reliability**			**Available coal resource**
		too deep	too shallow	mine	fault	water	road	bldgs	elec-tric	well	inter-burden	too thin	too thick		demon-strated	infer-red	hypo-thetical	
1-2	24	5	1	—	0	0	0	0	0	0	—	24	—	24	(11)	(7)	(1)	(18)
2-4	196	73	2	—	1	1	2	0	0	0	5	196	—	196	(49)	(57)	(6)	(112)
4-6	319	78	11	—	2	2	2	0	1	0	10	—	—	103	106	72	38	216
6-8	213	40	9	—	1	1	1	0	0	0	2	—	—	54	92	67	0	160
8-10	154	53	5	0	2	1	1	0	1	0	1	—	—	62	57	35	—	92
10-12	171	29	7	0	2	3	1		—	0	—	—	—	40	60	70	—	131
12-14	71	—	3	—	1	0	1	0	—	—	—	—	—	5	47	19	—	66
14-16	18	—	—	—	0	0	0	—	—	—	—	—	1	2	17	—	—	17
16-18	6	—	—	—	—	0	—	—	—	—	—	—	1	1	5	—	—	5
18-20	1	—	—	—	—	—	—	—	—	—	—	—	0	0	1	—	—	1
20-22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26-28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sum	1,172	278	38	0	8	10	8	1	2	0	18	220	2	486	385	263	38	686

See notes to tables at the beginning of the appendix for an explanation of table headings and reporting conventions.

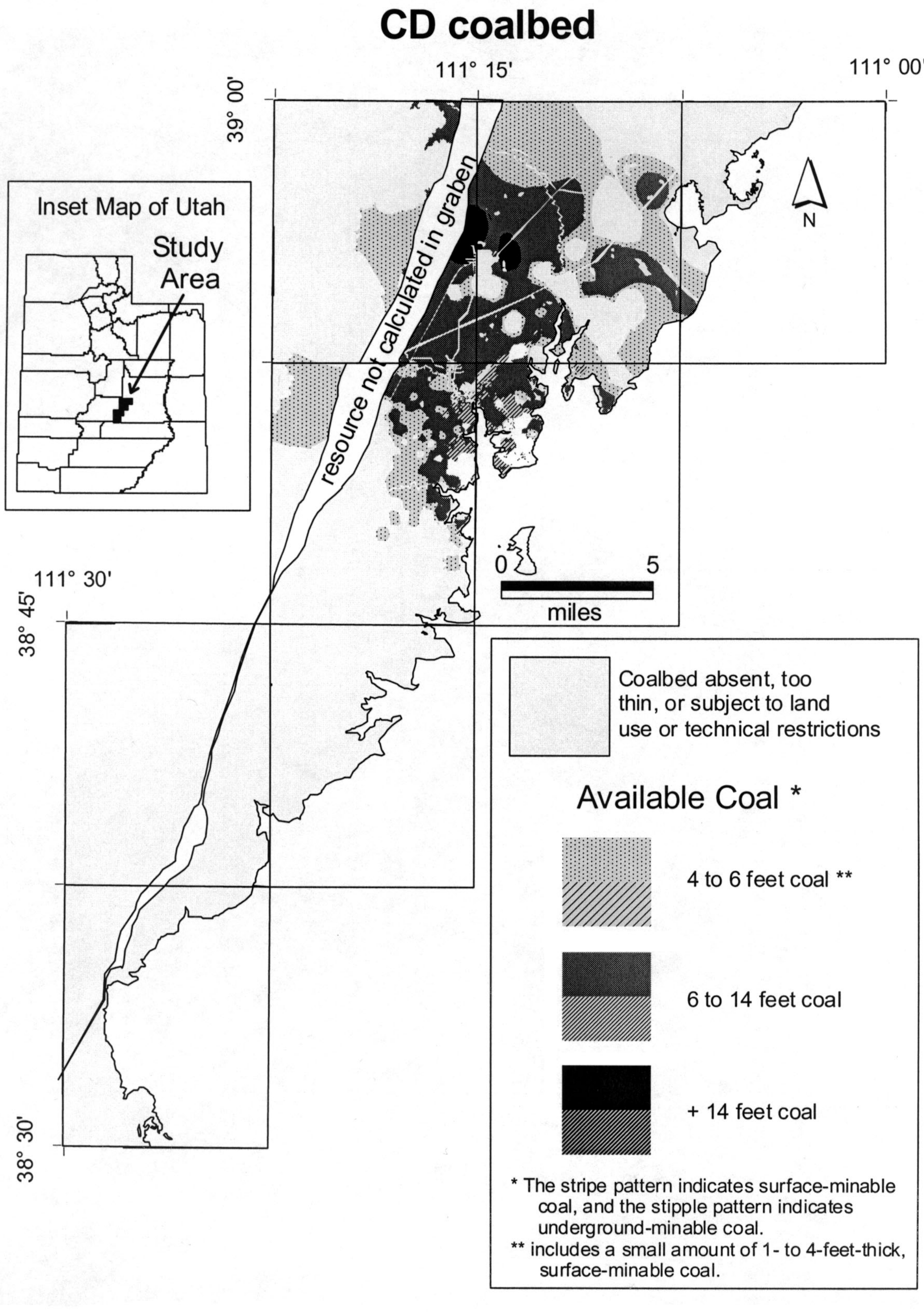


Figure A2. Location of the available coal resource for the CD coalbed, southern Emery coalfield, Utah.

Table A5. *Tabulation of the surface-minable, available coal resource for the CD coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	Original coal resource	Restrictions					Net restricted coal	Reliability			Available coal resource
		mine	water	road	bldgs	well		demonstrated	inferred	hypothetical	
1-2	—	—	—	—	—	—	—	—	—	—	—
2-4	0	0	—	—	—	—	0	0	—	—	0
4-6	0	—	—	—	—	—	—	0	—	—	0
6-8	1	0	0	—	—	—	0	0	1	—	1
8-10	5	2	0	0	0	—	2	3	0	—	3
10-12	11	2	0	—	—	—	2	9	1	—	9
12-14	20	0		—	—	0	0	18	1	—	19
14-16	21	—	0	—	—	0	0	20	1	—	21
16-18	21	—	0			0	0	21	—	—	21
18-20	4	—	—	—	—	—	—	4	—	—	4
20-22	1	—	—	—	—	—	—	1	—	—	1
22-24	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—
sum	85	4	0	0	0	0	4	77	4	—	81

Table A6. *Tabulation of the underground-minable, available coal resource for the CD coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	Original coal resource	Restrictions												Net restricted coal	Reliability			Available coal resource
		too deep	too shallow	mine	fault	water	road	bldgs	elec-tric	well	inter-burden	too thin	too thick		demon-strated	infer-red	hypo-thetical	
1-2	29	4	1	—	0	0	0	0	0	0	—	29	—	29	(13)	(10)	(1)	(24)
2-4	155	15	12	—	0	2	1	1	1	0	8	155	—	155	(45)	(70)	(2)	(117)
4-6	305	89	6	—	0	2	2	1	1	0	3	—	—	104	81	121	—	201
6-8	238	46	7	—	0	3	3	2	3	0	1	—	—	64	138	34	3	174
8-10	73	7	3	—	0	1	2	3	0	0	—	—	—	15	43	14	1	57
10-12	45	—	1	—	0	1	1	1	0	0	—	—	—	4	24	17	—	41
12-14	26	—	0	—	0	—	1	1	—	0	—	—	—	2	6	18	—	24
14-16	21	—	—	—	0	—	1	1	—	—	—	—	1	3	10	8	—	18
16-18	19	—	—	—	0	—	1	1	—	—	—	—	3	4	14	—	—	14
18-20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26-28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sum	912	160	32	—	1	9	12	10	6	0	13	184	5	381	317	210	4	531

See notes to tables at the beginning of the appendix for an explanation of table headings and reporting conventions.

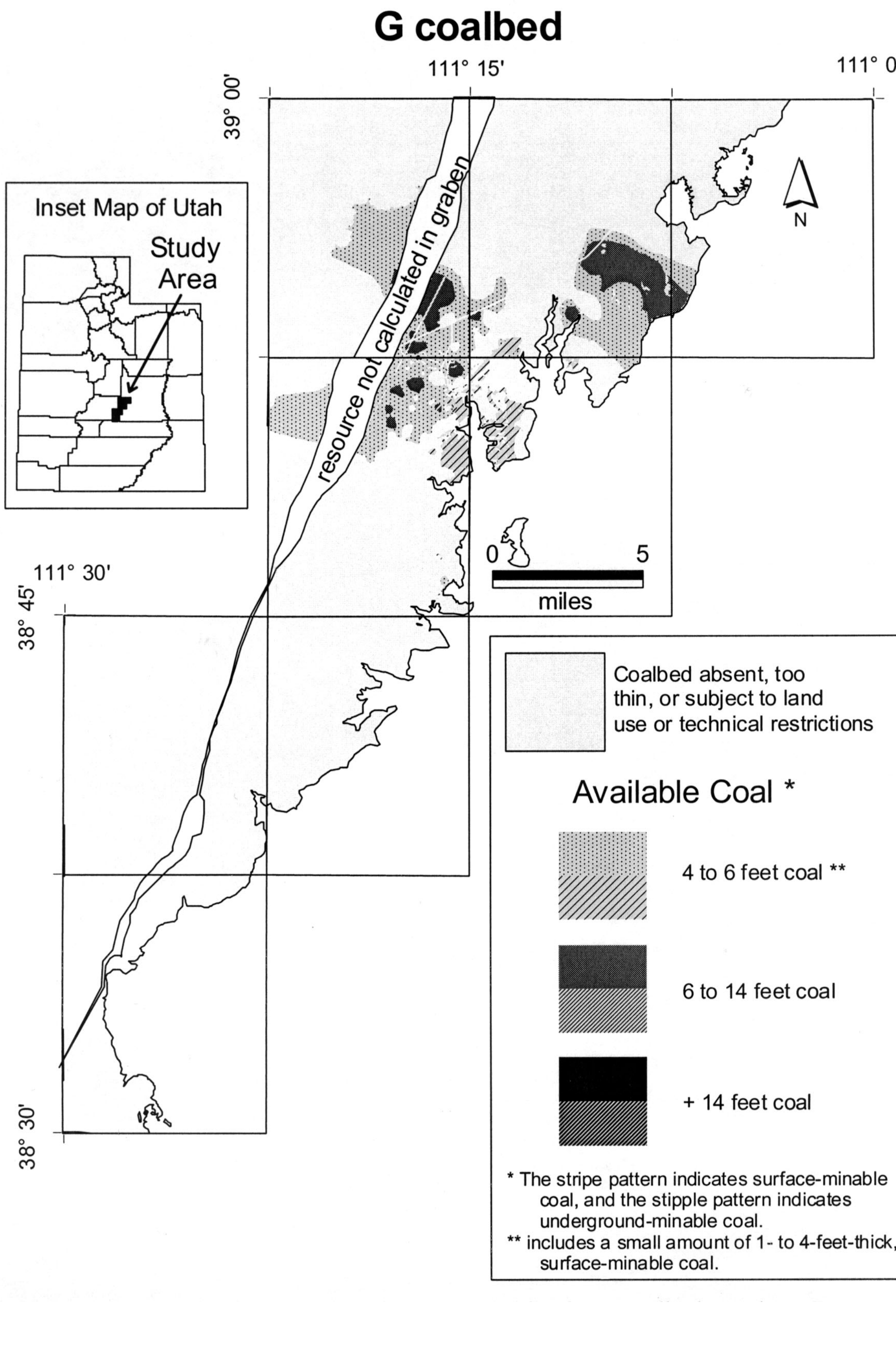


Figure A3. Location of the available coal resource for the G coalbed, southern Emery coalfield, Utah.

Table A7. *Tabulation of the surface-minable, available coal resource for the G coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	Original coal resource	Restrictions					Net restricted coal	Reliability			Available coal resource
		mine	water	road	bldgs	well		demonstrated	inferred	hypothetical	
1-2	0	—	0	—	—	0	0	2	0	—	2
2-4	1	1	0	0	0	0	1	7	0	—	8
4-6	4	1	0	0	—	—	1	3	—	—	3
6-8	0	0	—	—	—	—	0	0	—	—	0
8-10	—	—	—	—	—	—	—	—	—	—	—
10-12	—	—	—	—	—	—	—	—	—	—	—
12-14	—	—	—	—	—	—	—	—	—	—	—
14-16	—	—	—	—	—	—	—	—	—	—	—
16-18	—	—	—	—	—	—	—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—
sum	15	2	0	0	0	0	2	13	0	—	13

Table A8. *Tabulation of the underground-minable, available coal resource for the G coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	Original coal resource	Restrictions												Net restricted coal	Reliability categories			Available coal resource
		too deep	too shallow	mine	fault	water	road	bldgs	elec-tric	well	inter-burden	too thin	too thick		demon-strated	infer-red	hypo-thetical	
1-2	54	6	3	—	0	0	1	0	0	0	—	54	—	54	(44)	(26)	(5)	(44)
2-4	115	36	4	—	0	1	0	0	1	0	1	115	—	115	(74)	(28)	(1)	(74)
4-6	223	79	1	—	1	1	2	0	1	0	—	—	—	85	138	51	—	138
6-8	54	—	1	—	0	0	1	0	1	—	—	—	—	4	50	19	—	50
8-10	9	—	—	—	—	—	—	0	0	—	—	—	—	0	9	2	—	9
10-12	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
12-14	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
14-16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16-18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26-28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sum	457	121	10	—	1	3	3	1	3	0	1	170	—	259	198	72	—	198

See notes to tables at the beginning of the appendix for an explanation of table headings and reporting conventions.

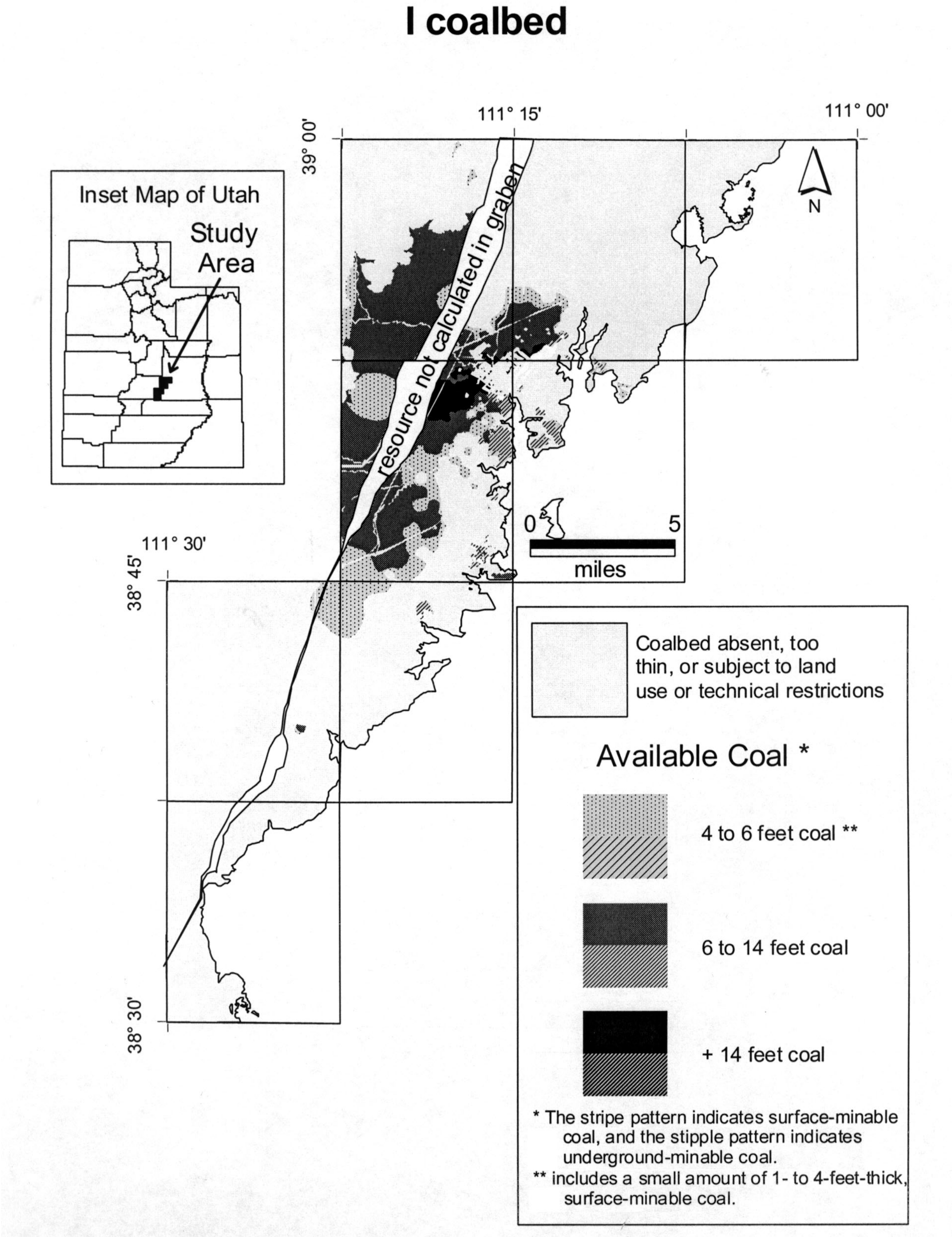


Figure A4. Location of the available coal resource for the I coalbed, southern Emery coalfield, Utah.

Table A9. *Tabulation of the surface-minable, available coal resource for the I coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions**					**Net restricted coal**	**Reliability**			**Available coal resource**
		mine	water	road	bldgs	well		demonstrated	inferred	hypothetical	
1-2	—	—	—	—	—	—	—	—	—	—	—
2-4	0	—	—	—	—	—	—	0	0	—	0
4-6	1	—	—	—	—	0	0	1	0	—	1
6-8	10	—	—	—	—	0	0	9	1	—	10
8-10	10	0	—	—	—	0	0	9	1	—	10
10-12	5	1	—	—	0	—	1	5	—	—	5
12-14	8	2	—	—	0	—	2	6	—	—	6
14-16	3	0	0	0	—	—	0	3	—	—	3
16-18	3	1	0	0	0	—	1	2	—	—	2
18-20	7	2	0	0	0	—	2	5	—	—	5
20-22	5	1	0	—	0	—	1	4	—	—	4
22-24	8	3	0	—	—	—	4	5	—	—	5
24-26	1	1	—	—	—	—	1	1	—	—	1
sum	62	11	1	0	0	0	12	48	2	—	50

Table A10. *Tabulation of the underground-minable, available coal resource for the I coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions**												**Net restricted coal**	**Reliability**			**Available coal resource**
		too deep	too shallow	mine	fault	water	road	bldgs	elec-tric	well	inter-burden	too thin	too thick		demon-strated	infer-red	hypo-thetical	
1-2	46	6	3	0	0	0	0	0	0	0	—	46	—	46	(11)	(20)	(5)	(36)
2-4	147	23	8	0	1	1	2	2	0	0	7	147	—	147	(58)	(31)	(18)	(107)
4-6	132	19	10	0	0	1	2	0	0	0	0	—	—	33	69	28	2	99
6-8	241	86	5	0	1	4	2	1	3	0	0	—	—	101	53	86	2	140
8-10	205	78	3	1	1	2	2	0	1	0	—	—	—	88	69	49	—	118
10-12	104	27	2	2	0	0	1	0	0	0	—	—	—	33	51	20	—	71
12-14	19	—	2	4	0	1	1	0	—	—	—	—	—	6	12	—	—	12
14-16	20	—	2	2	0	0	1	0	—	—	—	—	1	6	14	—	—	14
16-18	27	—	3	3	0	0	1	0	—	—	—	—	5	11	16	—	—	16
18-20	27	—	7	5	—	1	1	0	—	—	—	—	7	17	11	—	—	11
20-22	27	—	4	13	—	2	0	0	—	—	—	—	9	20	7	—	—	7
22-24	7	—	1	4	—	1	0	—	—	—	—	—	3	6	1	—	—	1
24-26	2	—	0	1	—	0	0	—	—	—	—	—	1	1	0	—	—	0
26-28	1	—	—	0	—	—	—	—	—	—	—	—	0	0	0	—	—	0
sum	1,004	239	50	36	4	14	11	4	4	0	7	194	26	515	302	183	4	489

See notes to tables at the beginning of the appendix for an explanation of table headings and reporting conventions.

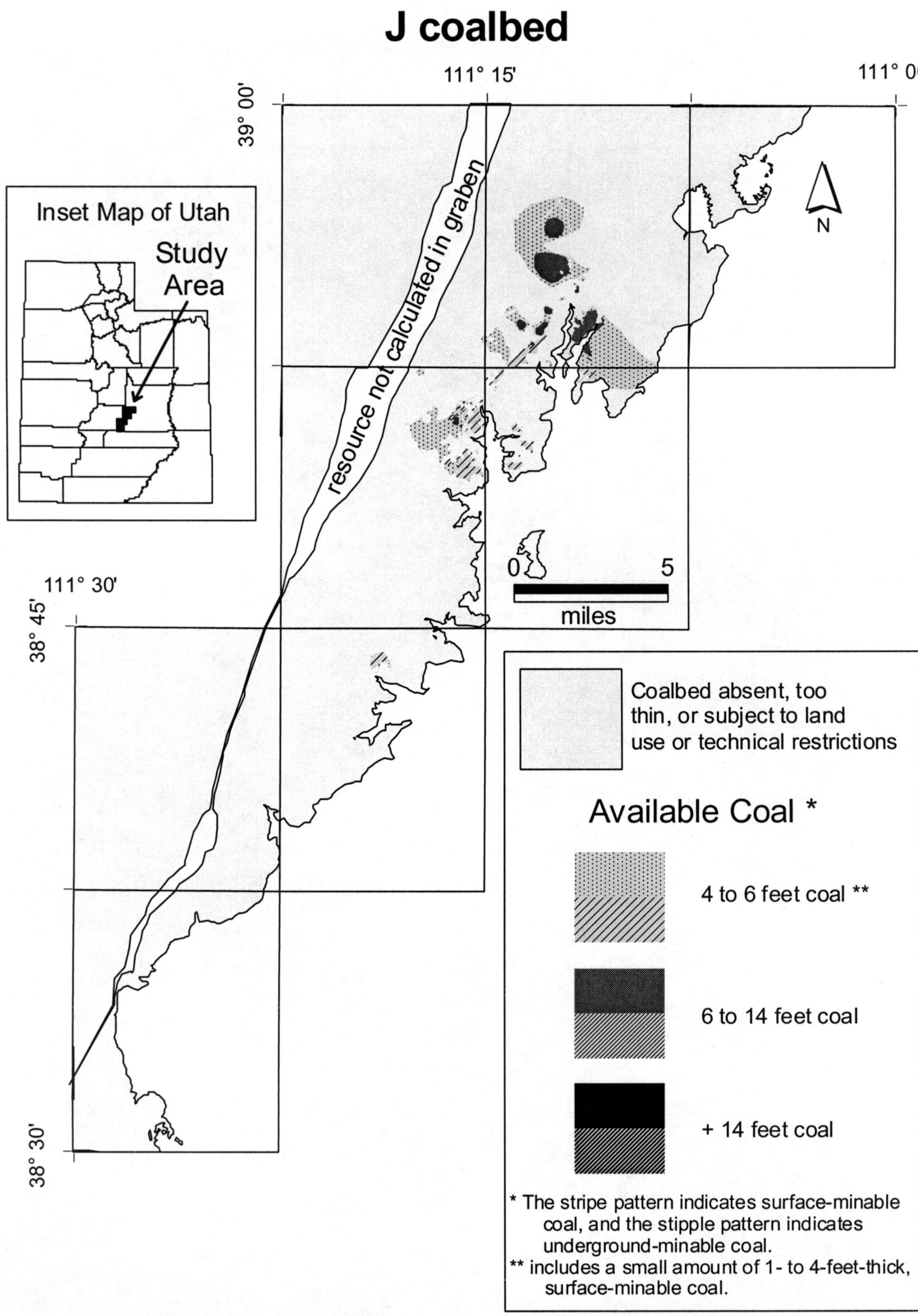


Figure A5. Location of the available coal resource for the J coalbed, southern Emery coalfield, Utah.

Table A11. *Tabulation of the surface-minable, available coal resource for the J coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions**					**Net restricted coal**	**Reliability**			**Available coal resource**
		mine	water	road	bldgs	well		demonstrated	inferred	hypothetical	
1-2	1	0	0	0	0	0	0	1	0	—	1
2-4	4	0	0	0	0	0	0	3	1	—	4
4-6	4	0	0	—	—	0	0	4	1	—	4
6-8	1	0	—	—	—	—	0	1	—	—	1
8-10	0	—	—	—	—	—	—	0	—	—	0
10-12	—	—	—	—	—	—	—	—	—	—	—
12-14	—	—	—	—	—	—	—	—	—	—	—
14-16	—	—	—	—	—	—	—	—	—	—	—
16-18	—	—	—	—	—	—	—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—
sum	10	1	0	0	0	0	1	9	1	—	10

Table A12. *Tabulation of the underground-minable, available coal resource for the J coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions**												**Net restricted coal**	**Reliability**			**Available coal resource**
		too deep	too shallow	mine	fault	water	road	bldgs	elec-tric	well	inter-burden	too thin	too thick		demon-strated	infer-red	hypo-thetical	
1-2	26	5	3	1	0	0	0	0	0	0	—	26	—	26	(3)	(10)	(3)	(16)
2-4	66	8	8	2	1	1	1	1	0	0	6	66	—	66	(18)	(22)	(0)	(40)
4-6	65	—	8	0		1	1	0	0	0	1		—	12	27	26	—	53
6-8	21	—	5	—	—	0		0		0	—	—	—	5	15	1	—	16
8-10	3	—	0	—	—	—	—	—	—	—	—	—	—	0	2		—	2
10-12	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12-14	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14-16	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16-18	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18-20	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20-22	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22-24	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24-26	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26-28	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sum	181	14	24	3	1	2	2	2	1	0	7	92	—	109	44	27	—	72

See notes to tables at the beginning of the appendix for an explanation of table headings and reporting conventions.

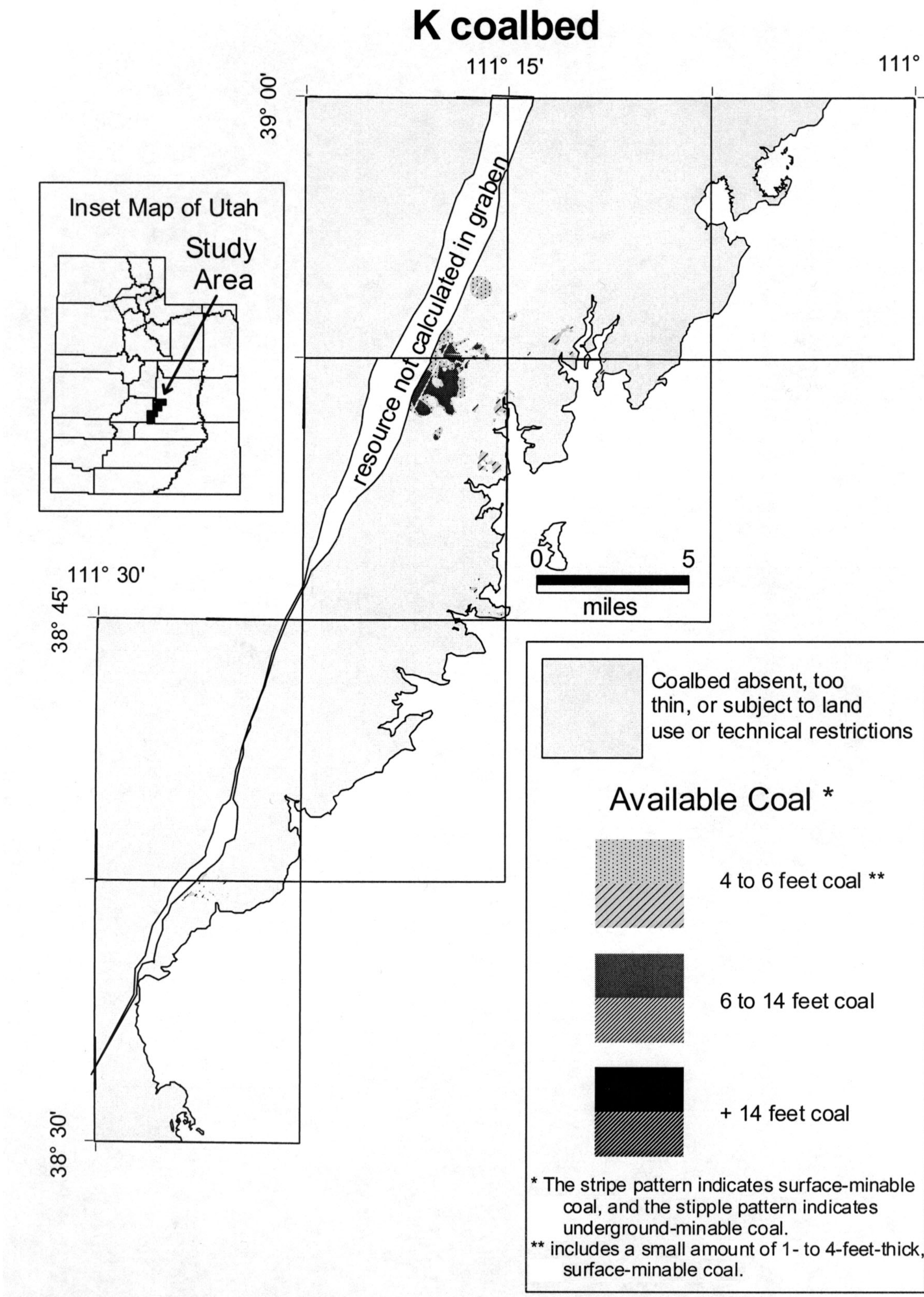


Figure A6. Location of the available coal resource for the K coalbed, southern Emery coalfield, Utah.

Table A13. *Tabulation of the surface-minable, available coal resource for the K coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions** mine	water	road	bldgs	well	**Net restricted coal**	**Reliability** demonstrated	inferred	hypothetical	**Available coal resource**
1-2	1	0	—	—	—	0	0	1	0	—	1
2-4	1	0	0	—	—	0	0	1	0	—	1
4-6	1	0	—	—	—	—	0	1			1
6-8	—	—	—	—	—	—	—	—	—	—	—
8-10	—	—	—	—	—	—	—	—	—	—	—
10-12	—	—	—	—	—	—	—	—	—	—	—
12-14	—	—	—	—	—	—	—	—	—	—	—
14-16	—	—	—	—	—	—	—	—	—	—	—
16-18	—	—	—	—	—	—	—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—
sum	3	0	0	—	—	0	0	2	0	—	2

Table A14. *Tabulation of the underground-minable, available coal resource for the K coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions** too deep	too shallow	mine	fault	water	road	bldgs	electric	well	interburden	too thin	too thick	**Net restricted coal**	**Reliability** demonstrated	inferred	hypothetical	**Available coal resource**
1-2	29	—	3	0	0	0	0	0	0	0	—	29	—	29	(12)	(12)	(1)	(25)
2-4	39	—	2	1	0	1	1	0	0	—	5	39	—	39	(21)	(9)	(0)	(29)
4-6	15	—	2	2	0	0	1	0	0	—	0		—	4	10	0	—	11
6-8	17	—	—	2	0	0	1	0	0	—	—	—	—	3	14	—	—	14
8-10	1	—	—	—	—	—	—	0	—	—	—	—	—	0	1	—	—	1
10-12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12-14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14-16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16-18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26-28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sum	100	—	7	4	0	2	2	1	1	0	5	68	—	75	25	0	—	25

See notes to tables at the beginning of the appendix for an explanation of table headings and reporting conventions.

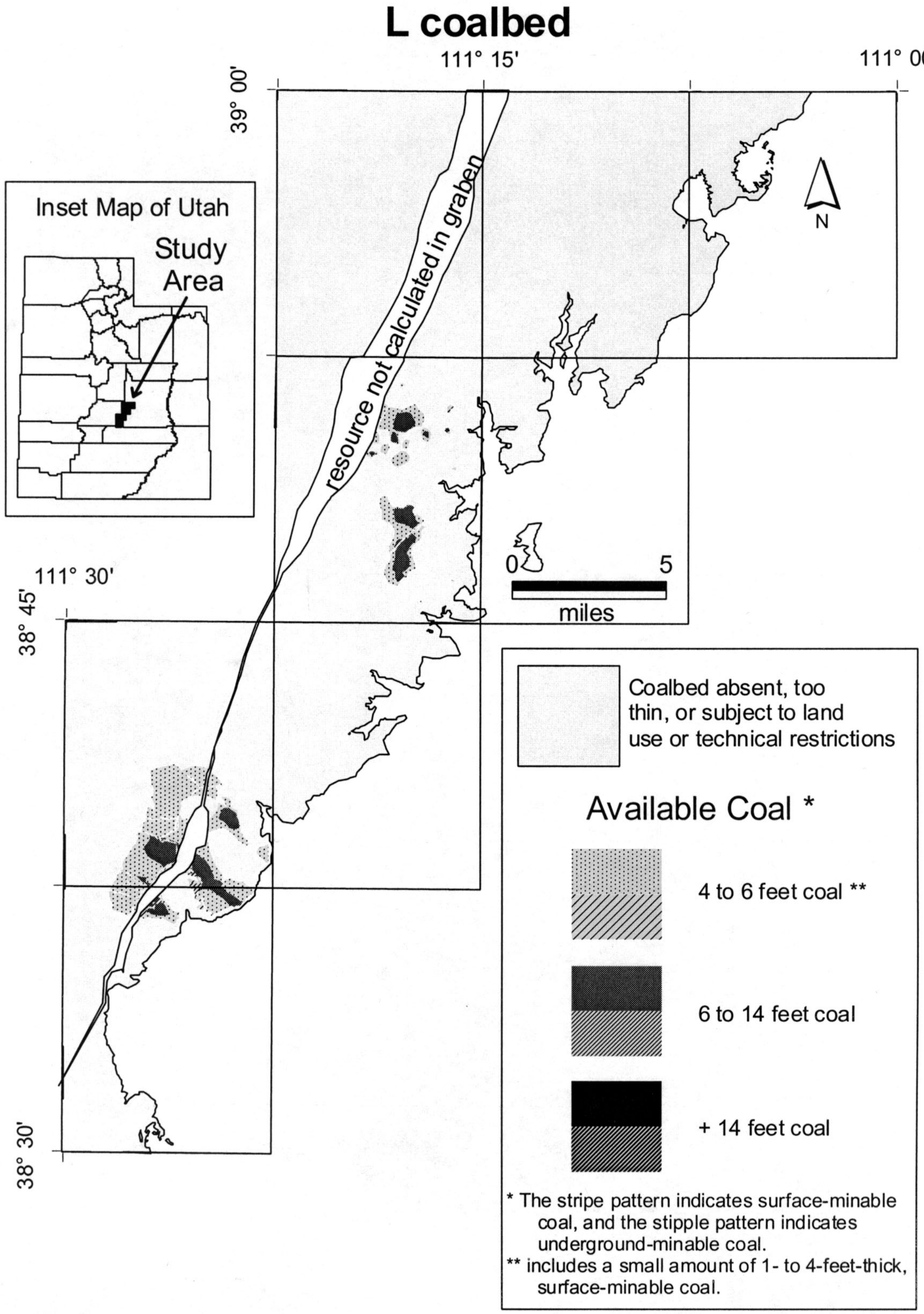


Figure A7. Location of the available coal resource for the L coalbed, southern Emery coalfield, Utah.

Table A15. *Tabulation of the surface-minable, available coal resource for the L coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions**					**Net restricted coal**	**Reliability**			**Available coal resource**
		mine	water	road	bldgs	well		demonstrated	inferred	hypothetical	
1-2	0	0	—	—	—	—	0	0	—	—	0
2-4	—	—	—	—	—	—	—	—	—	—	—
4-6	1	—	—	—	—	—	—	1	—	—	1
6-8	1	—	—	—	—	—	—	1	—	—	1
8-10	1	—	—	—	—	—	—	1	—	—	1
10-12	—	—	—	—	—	—	—	—	—	—	—
12-14	—	—	—	—	—	—	—	—	—	—	—
14-16	—	—	—	—	—	—	—	—	—	—	—
16-18	—	—	—	—	—	—	—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—
sum	3	0	—	—	—	—	0	3	—	—	3

Table A16. *Tabulation of the underground-minable, available coal resource for the L coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	**Original coal resource**	**Restrictions**													**Net restricted coal**	**Reliability**			**Available coal resource**
		too deep	too shallow	mine	fault	water	road	bldgs	elec-tric	well	inter-burden	too thin	too thick			demon-strated	infer-red	hypo-thetical	
1-2	72	17	2	0	1	1	1	0	0	0	—	72	—		72	(13)	(30)	(7)	(50)
2-4	220	65	9	0	1	1	1	0	0	0	7	220	—		220	(37)	(60)	(40)	(137)
4-6	66	—	6	0	0	1	1	0	—	—	0		—		9	26	32	—	58
6-8	28	—	1	—	0	0	1	—	—	—	—	—	—		2	19	8	—	26
8-10	4	—	0	—	—	—	—	—	—	—	—	—	—		0	3	—	—	3
10-12	2	—	1	—	—	—	—	—	—	—	—	—	—		1	1	—	—	1
12-14	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—
14-16	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—
16-18	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—
26-28	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—
sum	392	83	19	0	3	3	4	0	0	0	7	292	—		303	49	39	—	88

See notes to tables at the beginning of the appendix for an explanation of table headings and reporting conventions.

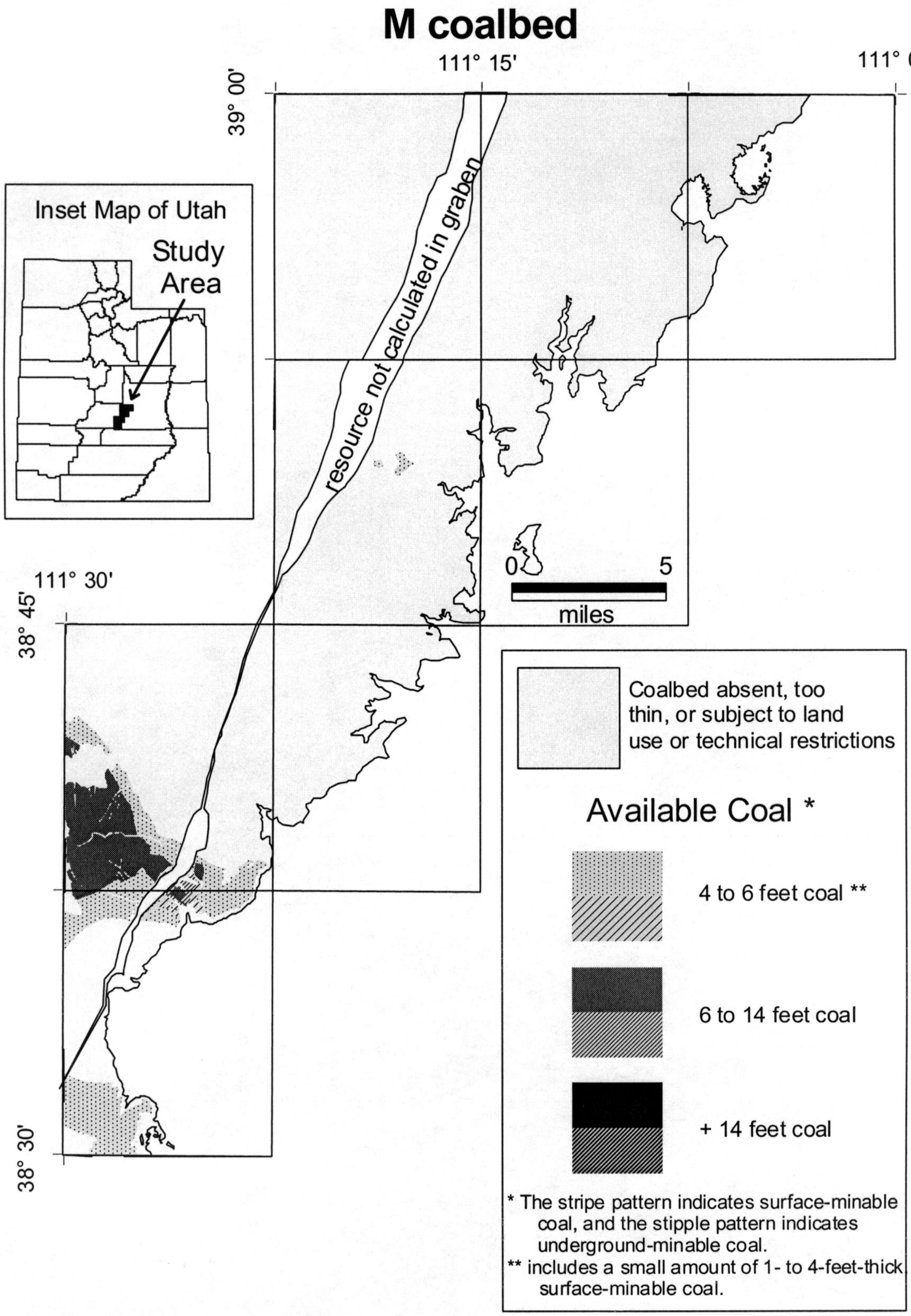


Figure A8. Location of the available coal resource for the M coalbed, southern Emery coalfield, Utah.

Table A17. *Tabulation of the surface-minable, available coal resource for the M coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	Original coal resource	Restrictions					Net restricted coal	Reliability			Available coal resource
		mine	water	road	bldgs	well		demonstrated	inferred	hypothetical	
1-2	—	—	—	—	—	—	—	—	—	—	—
2-4	—	—	—	—	—	—	—	—	—	—	—
4-6	3	—	—	—	—		—	3	0	—	3
6-8	3	—	—	—	—	—	—	3	0	—	3
8-10	—	—	—	—	—	—	—	—	—	—	—
10-12	—	—	—	—	—		—	—	—	—	—
12-14	—	—	—	—	—	—	—	—	—	—	—
14-16	—	—	—	—	—	—	—	—	—	—	—
16-18	—	—	—	—	—		—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—		—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—
sum	6	—	—	—	—	—	—	6	0	—	6

Table A18. *Tabulation of the underground-minable, available coal resource for the M coalbed by coalbed thickness, southern Emery coalfield, Emery and Sevier Counties, Utah (million tons).*

Coalbed thickness (feet)	Original coal resource	Restrictions												Net restricted coal	Reliability			Available coal resource
		too deep	too shallow	mine	fault	water	road	bldgs	elec-tric	well	inter-burden	too thin	too thick		demon-strated	infer-red	hypo-thetical	
1-2	29	3	1	—	0	0	0	—	0		—	29	—	29	(5)	(12)	(7)	(24)
2-4	84	5	4	—	0	1	1	0	—	0	—	84	—	84	(17)	(41)	(16)	(73)
4-6	91	4	9	—	1	1	1	0	—	0	—	—	—	15	19	26	31	76
6-8	84	13	1	—	2	1	0	—	—	0	—	—	—	16	15	52	1	68
8-10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10-12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12-14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14-16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16-18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18-20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20-22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22-24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24-26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26-28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sum	289	25	15	—	3	3	2	0	0	0	—	114	—	145	34	78	31	144

See notes to tables at the beginning of the appendix for an explanation of table headings and reporting conventions.