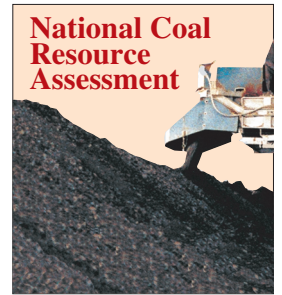


Chapter R

Coal Resources of the Henry Mountains Coal Field, Utah

By David E. Tabet¹



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Chapter R of

Geologic Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah

Edited by M.A. Kirschbaum, L.N.R. Roberts, and L.R.H. Biewick

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Abstract

A reappraisal of the coal resources within the Ferron Sandstone Member and the Muley Canyon Sandstone Member of the Upper Cretaceous Mancos Shale in the Henry Mountains coal field was made using recently obtained company drill-hole data in conjunction with older published drill-hole and measured-section data. Coal thickness and overburden thickness maps were prepared at a scale of 1:100,000 for both members. Coal-quality information was compiled and summarized in tabular form. The coals of the Henry Mountains coal field are subbituminous A to high-volatile bituminous C in rank. The coals of the Muley Canyon have the best quality, with generally lower ash and sulfur content.

The in-place coal resources of both the Ferron and Muley Canyon Sandstone Members were calculated for 4-ft thickness intervals ranging from 2 to 6 ft, 6 to 10 ft, and greater than 10 ft. The coal resources were also separated into overburden categories: 0 to 100 ft, 100 to 1,000 ft, and 1,000 to 2,000 ft. No coal resources in the Ferron or Muley Canyon Members are deeper than 2,000 ft. The coal resources were also subdivided by township tier and county. The majority of the coal resources for both units occurs in Garfield County, Utah. The Muley Canyon coal zone contains resources that are the thickest and of the best quality, and they comprise about 69 percent of the 2.2 billion short tons of coal resources in the Henry Mountains coal field.

Introduction

Location and Setting

The principal Cretaceous coal-bearing strata of the Henry Mountains coal field cover parts of central Wayne and Garfield Counties, Utah (fig. 1). Cretaceous strata are preserved in a structural basin, the Henry Mountains syncline, that is bounded on the west by the monocline of the Waterpocket fold, and on the east by the Monument upwarp. This north-south-elongated basin extends about 50 mi along its axis and is 2 to 18 mi wide.

Elevations in the area of the Henry Mountains coal field range from about 4,600 ft at the far northern end of the field to more than 11,000 ft at Mt. Ellen in the central Henry Mountains. The topography varies from steep, rugged terrain in the Henry Mountains in the east, to a series of dissected mesas and buttes in the central part of the coal field, and to cuestas and hogback ridges along the western margin of the coal field (fig. 2).

The Henry Mountains coal field is in a remote area of Utah with few paved roads and no railroads. State Highway 24 crosses the northern part of the coal field and is the only paved road in the area. State Routes 95 and 276 (fig. 3), which parallel the east margin of the coal field, are 10 mi to the east. Access to most parts of the coal field is limited to dirt roads. The nearest rail line is the Union Pacific line at Green River, Utah, about 60 mi to the north.

The remote Henry Mountains coal field is an area of scenic beauty. The striking Waterpocket fold to the west has been set aside, in part, as the Capitol Reef National Park; to the south and southeast are parts of the Glen Canyon National Recreation Area. The majority of the coal-bearing lands (fig. 4) are administered by the U.S. Bureau of Land Management (BLM). The remote, relatively roadless nature of the Henry Mountains coal field area led the BLM in 1990 to delineate three proposed Wilderness Areas covering parts of the coal field. However, BLM's proposals, which involved portions of the Mt. Ellen–Blue Hills, Mt. Pennell, and Mt. Hillers Wilderness Study Areas (WSA's) would not, for the most part, constrain potential development of the coal resources. Only a few sections of land in the central narrows portion of the Mt. Ellen–Blue Hills WSA under Oak Creek Bench and a few sections on the western edge of the Mt. Pennell WSA along Bullfrog Creek overlie potentially minable coal deposits. However, the BLM (1999) has since conducted a reinventory of Utah lands for wilderness that has substantially increased the areas in the Henry Mountains coal field being considered to have wilderness potential.

Minor coal occurs in the Dakota Sandstone, and minable quantities occur in the Ferron Sandstone and Muley Canyon Sandstone Members of the Mancos Shale (fig. 5). The coal-bearing Dakota Sandstone is thin and discontinuous, does not contain minable amounts of coal, and thus is considered to be an insignificant resource. The coals of the Ferron are

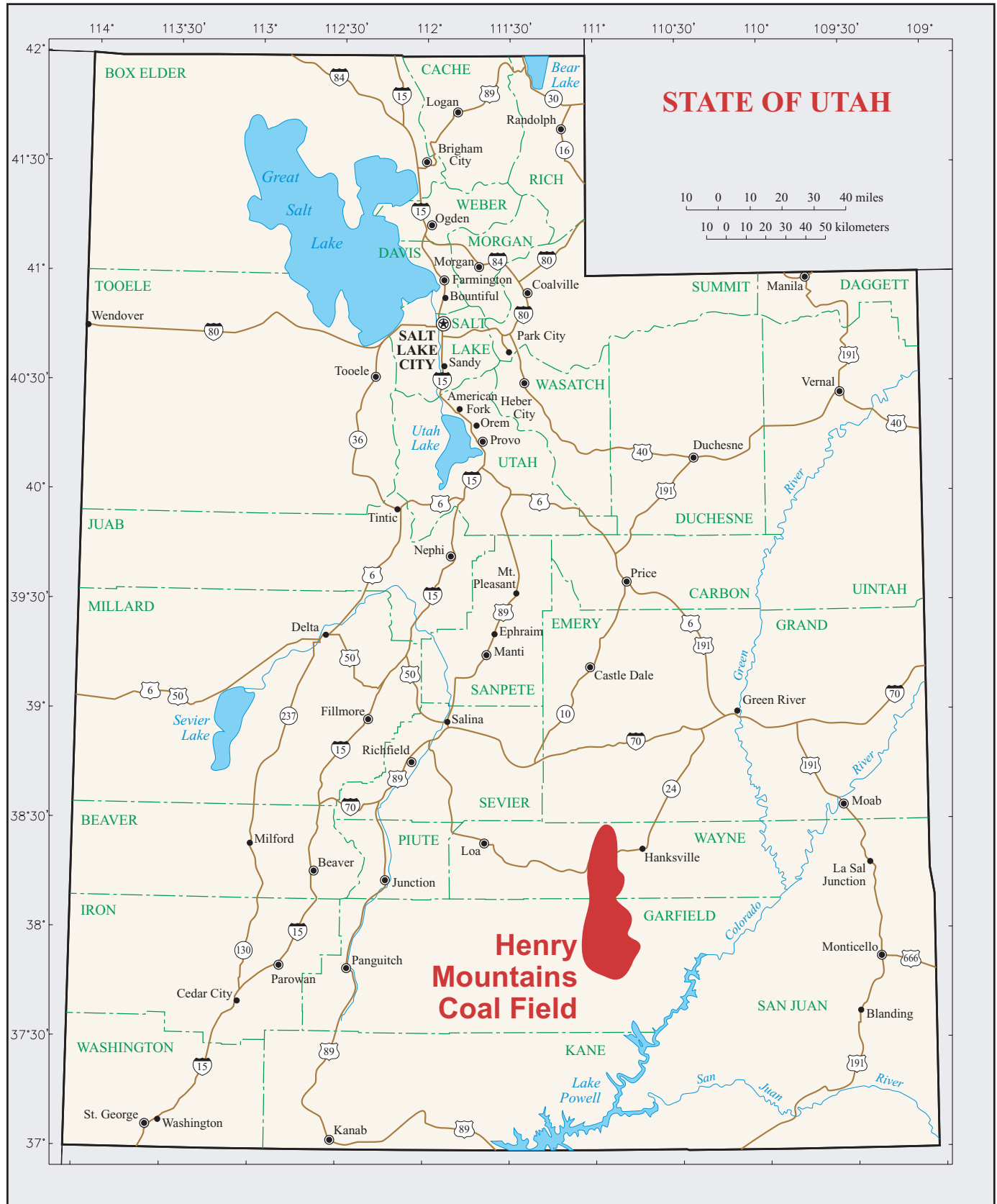


Figure 1. Map showing location of Henry Mountains coal field.



Figure 2. Photograph looking northeast across Henry Mountains coal field showing steeply dipping Jurassic strata along the Waterpocket fold in the foreground, relatively flat-lying mesas of Upper Cretaceous strata in the basin center, and intrusive-cored Henry Mountains on the east side of the coal field along the southern horizon. Photo by Mark A. Kirschbaum, U.S. Geological Survey.

locally thick, but also discontinuous, and have limited minable resources. Muley Canyon coals are the thickest, most continuous, and have the greatest amount of potentially minable resources (Doelling, 1972).

Coal in the Henry Mountains coal field has been mined in the past on a limited scale from both the Ferron and Muley Canyon Sandstone Members. This coal was used locally to supply ranchers and residents of nearby towns (Doelling, 1972).

Ferron coal, first developed at the south end of the coal field at the Stanton mine in section 36, T. 34 S., R. 10 E., was mined intermittently between 1888 and 1900 to supply gold dredges on the Colorado River to the south (Doelling, 1972). Small-scale mining of Ferron coal took place on a longer term basis at the far northern end of the field near Factory Butte. Mining in this area began in 1908 and continued to produce coal for local use through the 1950's. Renewed mining for electric power generation was attempted in the late 1970's by the Atlas-Dirty Devil Mining Company, who opened a surface mine in June 1978, trucked the coal to Green River, Utah, and sent test shipments by rail to the power plant at Moapa, Nev. (Uresk, 1979). Problems with coal quality prevented this operation from achieving full production.

The Muley Canyon coals were first developed around 1914 by tunneling into outcrops at the northern extent of this stratigraphic unit. W.D. Hendrickson started several small

mines along Sweetwater Creek in section 30, T. 31 S., R. 9 E. and Dugout Creek in section 7, T. 31 S., R. 9 E. to supply coal for local use (Hunt and others, 1953). Hunt and others (1953) reported that this coal was also later used to fuel a rig drilling two test wells in the Green River Desert. The last known activity at these mines was in the 1940's (Doelling, 1972).

Exploration on Federal and State lands over most of the Muley Canyon coal area was carried out by AMAX Coal Company, Cayman Corporation, Consolidation Coal Company, Gulf Mineral Resources Company, and the Federal Government in the mid-1970's. Primary interest at the time was evaluating surface-minable coal deposits, but environmental concerns and limitations eventually caused all prospecting areas to be dropped. The availability of the exploration data from the combined efforts of all the parties active in the 1970's has allowed the delineation of large amounts of deep Muley Canyon coal resources that could be mined with less surface disturbance than the originally anticipated surface mines.

Previous Work

Early reconnaissance surveys included the first descriptions of the geology and coal deposits of the Henry Mountains region (Gilbert, 1877). The first detailed study of the coal

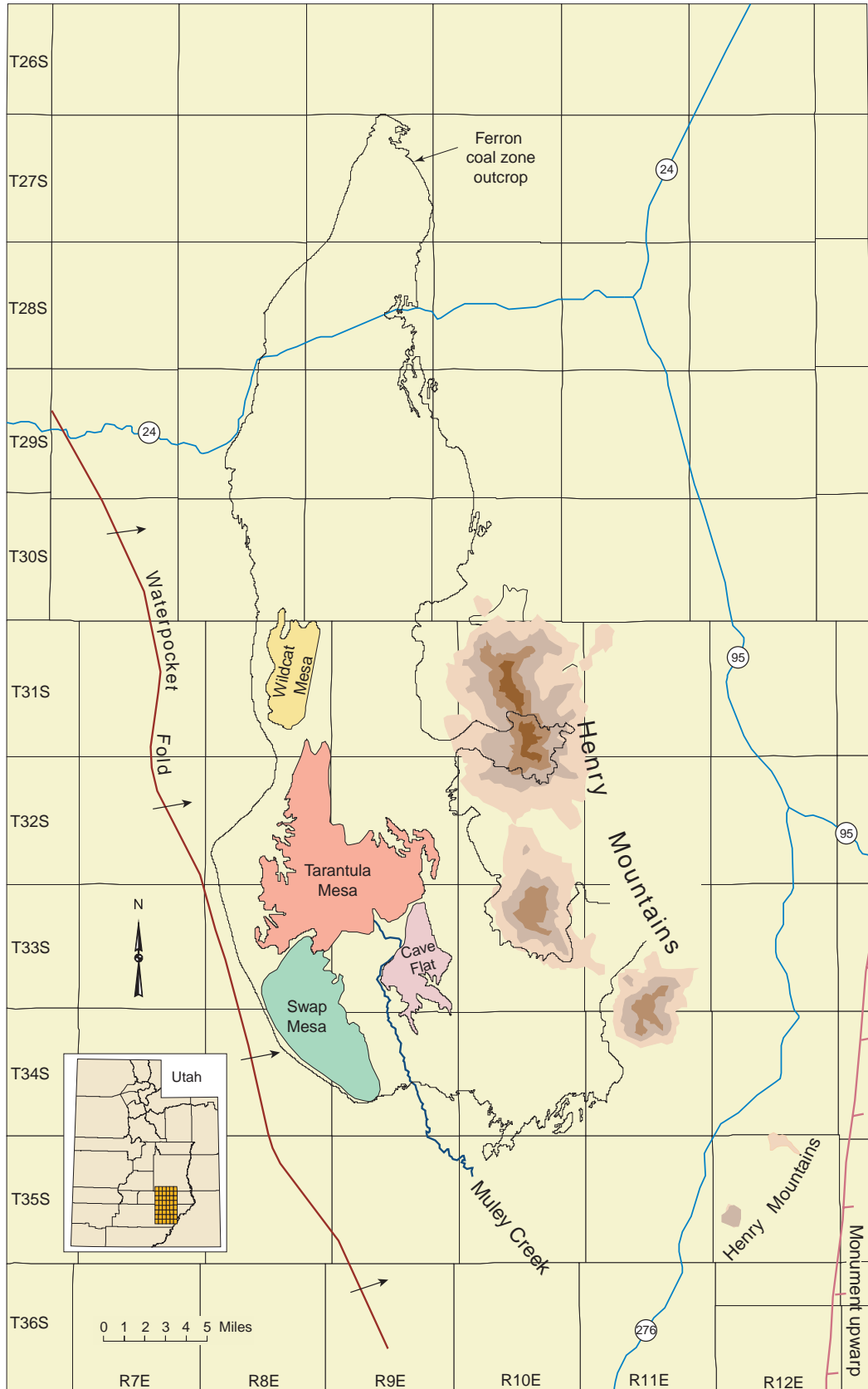


Figure 3. Roads and major physiographic features in the vicinity of the Henry Mountains coal field.

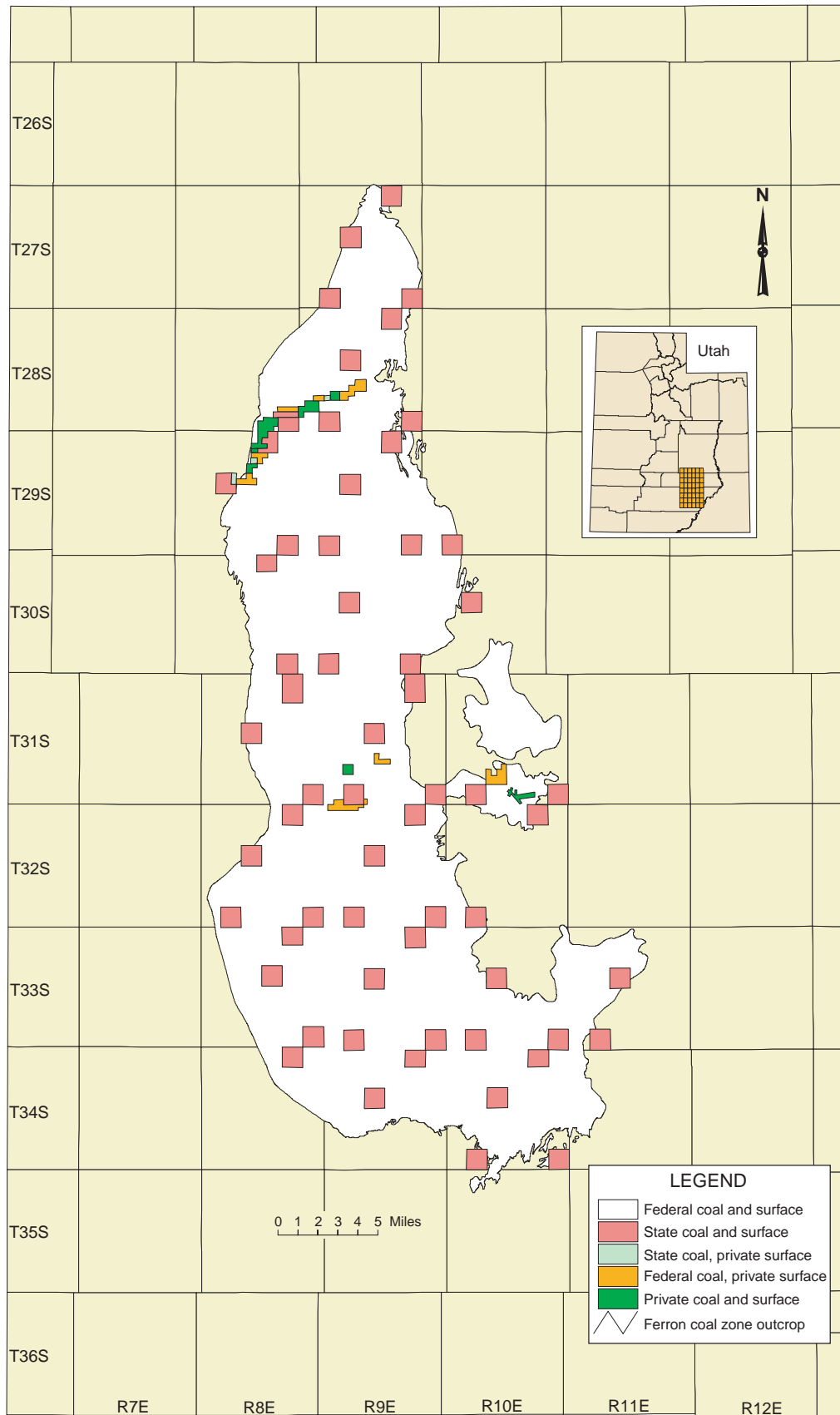


Figure 4. Map showing land ownership of Henry Mountains coal field.

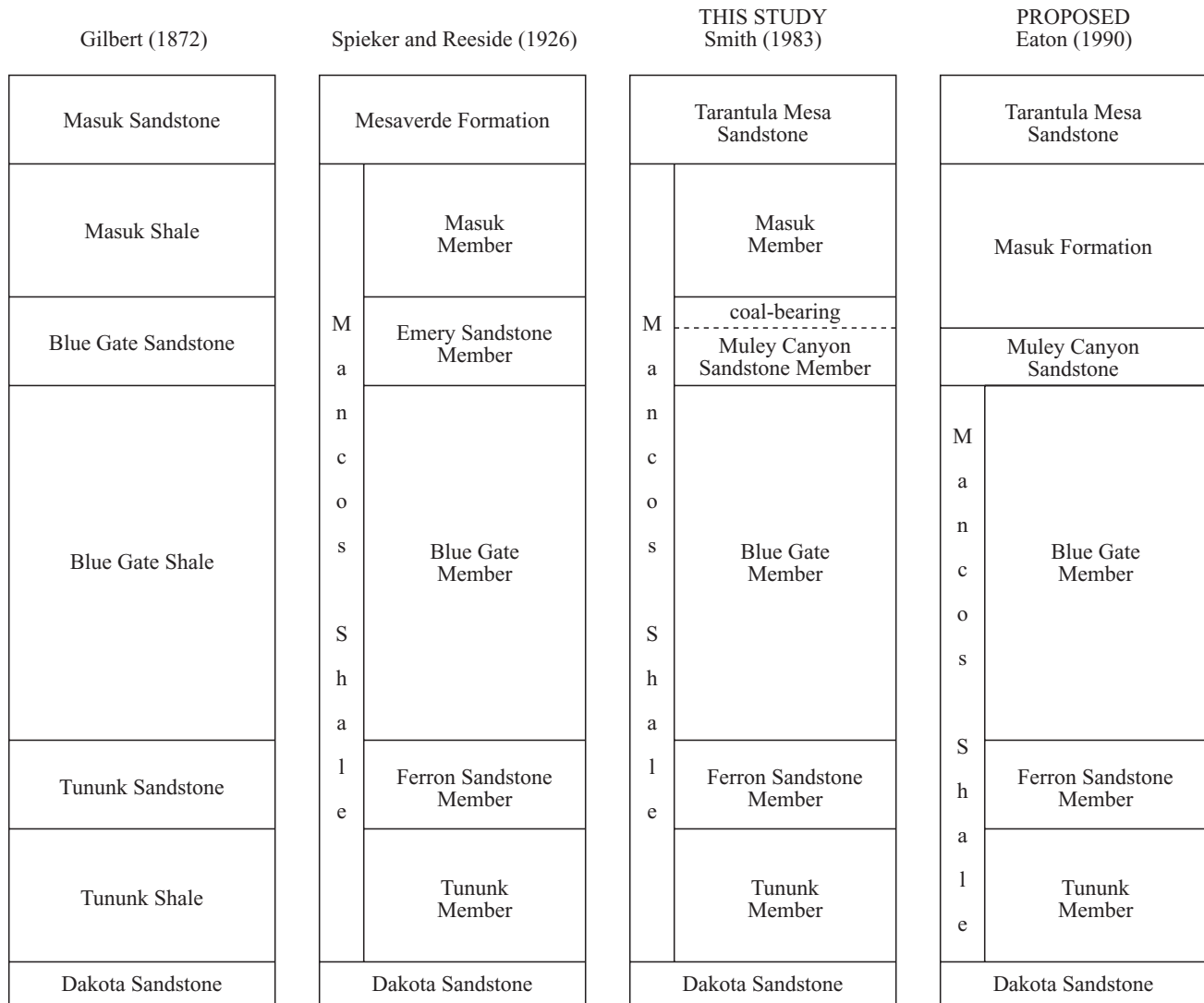


Figure 5. Chart showing evolution of Upper Cretaceous stratigraphic nomenclature of Henry Mountains Basin.

deposits of the Henry Mountains coal field was conducted from 1935 to 1939 by the U.S. Geological Survey (USGS) (Hunt and others, 1953). Interest in the coal deposits waned until the early 1970's when expanding fuel needs for electric generation sparked interest in domestic coal deposits. Doelling (1972) provided a detailed evaluation of the coal field resources as part of his comprehensive study of the coal deposits of Utah. New information prompted Doelling (1975) and Doelling and Smith (1982) to revise earlier coal resource estimates and to provide more details on the surface-minable resources of the field. McKell and others (1978) summarized the baseline data on the coal deposits and rehabilitation potential of coal lands in the coal field for the BLM. Law (1977, 1979a, 1979b, 1980) reported on the results of USGS drilling and field work in the coal zone of the Emery Sandstone Member of the Mancos Shale (herein called the Muley Canyon

Sandstone Member), and he concluded that tectonic and sedimentological controls caused the thickest coals in this unit to be deposited along the synclinal axis of the Henry Mountains Basin. Hatch and others (1979) presented coal-quality data for the Ferron and Emery Sandstone Members.

Peterson and others (1975, 1980) reevaluated the stratigraphy and regional relations of the Cretaceous System in the Henry Mountains region and found that the Emery of the Henry Mountains did not correlate with the type section in the Wasatch Plateau area; consequently, they recommended not using the term in the Henry Mountains region. Examination of the Ferron exposures in two parts of the coal field led Uresk (1979) and Hill (1982) to conclude that the Ferron was deposited by a generally eastward prograding fluvial-dominated deltaic complex. Smith (1983), Morton (1984, 1986), and Whitlock (1984) studied the geology and coal resources of three

7.5-minute quadrangles in Garfield County. Following the suggestion of Peterson and others (1975,1980), Smith (1983) proposed changing the name of the Emery to the Muley Canyon Sandstone Member of the Mancos Shale and designated a type section in the southwest quarter of section 16, T. 33 S., R. 9 E., at the head of Muley Creek canyon. Eaton (1990) proposed revising the stratigraphy of the Campanian portion of the Upper Cretaceous section in the Henry Mountains Basin. He recommended (1) elevating the Muley Canyon to formational rank, as the Muley Canyon Sandstone, but restricting its usage to the lower cliff-forming marine sandstone portion of the unit; (2) renaming the Masuk Member of the Mancos Shale as the Masuk Formation because its predominant lithology is not shale and it is coastal plain in origin; (3) including the underlying coal-bearing portion of the Muley Canyon (formerly Emery) with his Masuk Formation because they are both coastal plain in origin; and (4) following Smith's (1983) suggestion to rename the Mesaverde Formation of previous workers as the Tarantula Mesa Sandstone. Eaton's (1990) nomenclature revisions would make the newly defined Muley Canyon Sandstone, Masuk Formation, and Tarantula Mesa Sandstone correlative, respectively, with to the Star Point Sandstone, Blackhawk Formation, and Castlegate Sandstone of the Wasatch Plateau area to the north of the Henry Mountains Basin.

As part of an updated coal resource assessment, a simplified geologic map was compiled by Tabet (1999) for the Henry Mountains coal field from parts of four regional maps by various workers. The geology of the western part the Henry Mountains coal field was taken from a geologic map of Capitol Reef National Park by Billingsley and others (1987). The geology of the eastern part of the coal field was taken from two geologic maps of Wilderness Study Areas (Larson and others, 1985; Patterson and others, 1985). The geology of a small, northern part of the Henry Mountains Basin was modified from Thompson (1967).

Methodology

This study builds on the work of previous investigators and includes new data from outcrop studies carried out by the Utah Geological Survey (UGS) during the late 1980's as well as recently released coal company drilling and coal-quality data. The coal outcrops, as mapped by the UGS on 1:24,000-scale (7.5 minute) quadrangles, were digitized and then recompiled at a 1:100,000 scale. Coal-thickness measurements from outcrops were plotted on the maps only when they appeared to fully represent the complete coal section for each coal zone. Published and newly released coal exploration drilling data were plotted with the outcrop data to produce field-wide total coal-zone-thickness and depth-to-coal maps for the Ferron and Muley Canyon coal zones. These two coal zones are defined as the upper coal-bearing parts of the Ferron and Muley Canyon Sandstone Members, which average 110–120 ft in thickness. Finally, coal resources were calculated using

the demonstrated, inferred, and hypothetical data-spacing reliability categories developed by the USGS (Wood and others, 1983). Demonstrated resources lie within 0.75 mi from a thickness-measurement point, inferred resources are between 0.75 and 3 mi from a thickness-measurement point, and hypothetical resources lie more than 3 mi from a thickness-measurement point. The resources were also classified using the following depth categories: less than 100 ft, 100 to 1,000 ft, and 1,000 to 2,000 ft. No coal resources in the Ferron and Muley Canyon are known to lie at depths below 2,000 ft.

Acknowledgments

Funding for this project was provided to the Utah Geological Survey by the USGS under cooperative agreements 1408-0001-A-0164 and 1434-92-A-0954. Drilling data used in the study were kindly provided by AMAX Coal West, Incorporated (now RAG International Mining), the Pittsburg and Midway Coal Company, and Consolidation Coal Company. The author wishes to thank Russell Dubiel, Ed Johnson, and Tom Judkins of the U.S. Geological Survey for their helpful reviews of this paper. Finally, the author wishes to thank Brigitte Hucka, Robert Gloyn, Alex Keith, Steven Sommer, Sharon Wakefield, and various former UGS personnel who helped compile data for this study.

Upper Cretaceous Stratigraphy

Dakota Sandstone

The Upper Cretaceous Dakota Sandstone (fig. 5) is the basal Upper Cretaceous unit, and it lies unconformably on older rocks (Peterson and others, 1980). It consists of a lower continental part of conglomeratic sandstone interbedded with carbonaceous mudstone and local thin beds of coal, and an upper marine part of fossiliferous, thin-bedded sandstone. Hunt and others (1953) reported a maximum Dakota thickness of 92 ft. Peterson and others (1980) report an average thickness of 35 ft. The formation is thickest in the southwestern part of the Henry Mountains coal field and is thin and locally missing in the northern part. Coal beds in the Dakota are discontinuous and rarely exceed 2 ft thick. Because of the thin nature of this unit, and its minor coal resources, Tabet (1999) combined it with the overlying Tununk Member of the Mancos Shale on his geologic map of the area.

Mancos Shale

The nomenclature of the Upper Cretaceous Mancos Shale in the Henry Mountains Basin is problematic, and numerous revisions have been suggested (see Previous Work section).

The presently available maps of the area depict the Mancos Shale as composed of five members. In ascending order they are the Tununk, Ferron Sandstone, Blue Gate, Muley Canyon Sandstone, and Masuk Members (Smith, 1983) (see fig. 5). Descriptions of these units are taken primarily from regional work of Peterson and others (1980), who consider each of these units “a distinct, mappable entity that probably should be considered a separate formation.”

Tununk Member

The Tununk Member conformably overlies the Dakota Sandstone and has a measured thickness from outcrop and drill holes ranging from 532 to 717 ft. The Tununk generally thickens toward the north. Lithologically, this unit is composed primarily of gray bentonitic, calcareous shale, but near the base and top it is yellowish-gray to greenish-gray mudstone, siltstone, and very fine grained sandstone.

Ferron Sandstone Member

This unit was first named the Tununk Sandstone (Gilbert, 1877), but was subsequently correlated by Spieker and Reeside (1926) with the type Ferron Member in the Castle Valley area, about 35 mi to the north of the Henry Mountains coal field. It conformably overlies the Tununk and is comprised of 205–395 ft of interbedded sandstone, shale, mudstone, and coal. Peterson and others (1980) have recommended dividing the Ferron into lower and upper parts based on distinctive lithologies and depositional environments.

According to Peterson and others (1980), the lower part of the Ferron consists of thin-bedded sandstone and shale at the base that grade upward to thick, cliff-forming sandstone at the top. This part of the Ferron averages 197 ft thick and ranges from 130 to 305 ft thick. The very fine to medium-grained sandstones of the lower part grade from laminated and ripple cross-laminated at the base to trough cross-stratified in the middle, and to low-angle cross-stratified at the top. This vertical sequence of beds is interpreted as being deposited in a regressive coastal barrier-island environment (Peterson and others, 1980). They infer a northwest-trending shoreline during deposition of the lower Ferron based on sedimentary structure and sand-body-geometry orientations in this unit. The lower part of the Ferron interfingers with the Tununk and rises stratigraphically to the northeast.

The upper part of the Ferron is described by Peterson and others (1980) as a 15- to 205-ft-thick (average 110 ft) unit of interbedded lenticular sandstone, carbonaceous mudstone, and coal. The sandstones are lenticular, channel-shaped bodies that are generally less than 40 ft thick. Sedimentary structures indicate a southeasterly paleoflow in the southwestern part of the basin (Hill, 1982), whereas those in the northeastern part of the basin have a northeasterly paleoflow (Uresk, 1979). These channel sandstones are characterized by unidirectional

cross-stratification, fining-upward cycles, and lateral interfingering with mudstones. The interbedded carbonaceous mudstones occur in a variety of gray, brown, and black tones. As many as five coal beds, some of minable thickness, can be found in the upper part of the Ferron. The depositional environment of the upper part was a system of meandering distributary channels and associated overbank flood-plain deposits (Peterson and others, 1980).

Blue Gate Member

The Blue Gate Member unconformably overlies the Ferron. The name Blue Gate Shale was first proposed by Gilbert (1877) as a formation, but was reduced to a member of the Mancos Shale by Hunt and Miller (1946) and Hunt and others (1953). Although lithologically similar to the Tununk, the Blue Gate is much thicker, averaging 1,280 ft (Peterson and others, 1980). Range in thickness is 1,093 to 1,500 ft, and the member thickens northward. The upper 250-ft transition zone with the overlying Muley Canyon Member consists of interbedded yellowish- or greenish-gray mudstone, siltstone, and very fine grained sandstone.

Muley Canyon Sandstone Member

Sandstones overlying the Blue Gate were first named the Blue Gate Sandstone by Gilbert (1877). Confusion over whether these strata correlated with the Ferron, Emery, or Mesaverde of the Wasatch Plateau caused Spieker and Reeside (1926) to erroneously name them Emery in the Henry Mountains region. Based on further work, Peterson and others (1980) determined that the proper correlation was with the Mesaverde Formation and suggested dropping the name Emery in the Henry Mountains region. Peterson and others (1980) subdivided the 298- to 446-ft-thick Muley Canyon strata into a lower and upper part. The lower, predominantly sandstone part forms prominent cliffs or cuestas, whereas the upper interbedded shale and sandstone unit forms a series of short slopes and small ledges. Subsequently, Smith (1983) proposed the name Muley Canyon Sandstone Member of the Mancos Shale for the strata between the Blue Gate and Masuk Members of the Mancos Shale.

Eaton (1990) recommended removing the Muley Canyon as a member of the Mancos and elevating it to formational status. He also restricted the term Muley Canyon Sandstone to the lower cliff-forming marine part of the originally defined unit. Eaton's proposal for future mapping in the area has much merit because it matches the scheme used for the type Mesaverde section of southwestern Colorado, where the distinct marine and nonmarine lithostratigraphic units have been separated as mappable units. The currently available geologic maps of the Henry Mountains coal field area predate Eaton's ideas, and these do not reflect his stratigraphic scheme. Because the scope of the present study did not include remap-

ping of the Cretaceous coal-bearing and associated units, this report follows the terminology of Smith (1983) because it can easily be applied to the mapping of earlier workers. The name Muley Canyon Sandstone Member of the Mancos Shale is used herein to avoid confusion with the Emery Sandstone Member elsewhere, and the Muley Canyon here includes the upper coal-bearing strata as mapped by previous workers.

The lower part of the Muley Canyon is a massive sandstone ranging in thickness from 131 to 307 ft and consists of very fine to medium-grained sandstone that is laminated to thin-bedded or cross-stratified. The top of this lower part is commonly a clean, white, low-angle, cross-laminated sandstone (a "white cap"). Locally, in the vicinity of Wildcat Mesa, tidal channel sandstones scoured into the top of the lower part of the Muley Canyon have been identified (Law, 1980). This unit was deposited in a regressive nearshore and shoreline marine environment.

The upper part of the Muley Canyon Sandstone Member is more heterogeneous lithologically than the lower part and consists of lenticular sandstones and interbedded carbonaceous mudstone and coal. This part ranges in thickness from 92 to 209 ft and contains three to ten coal beds in an interval as much as 120 ft thick. This coal zone contains the thickest and most persistent coal beds in the Henry Mountains coal field. The upper part of the Muley Canyon was deposited in fluvial and tidal coastal-plain environments (Law, 1980).

Masuk Member

The Masuk Member conformably overlies the Muley Canyon Sandstone Member. Peterson and others (1980) report that the gradational transition between the two members has made it difficult to pick a consistent marker horizon for the contact. Most workers have tried to pick some continuous sandstone above the coals to be the uppermost unit of the Muley Canyon, but most of the sandstones above the coals are discontinuous fluvial channel deposits that do not create a persistent, easily mappable contact. To alleviate the problem, Eaton (1990) recommended that the coal-bearing portion of the Muley Canyon be included with the nonmarine Masuk and that the name Muley Canyon be restricted to the lower cliff-forming marine portion of that unit. However, the geologic maps of the area (Billingsley and others, 1987; Larson and others, 1985; Patterson and others, 1985; Thompson, 1967) predate this recommendation.

The 600-plus feet of Masuk strata (Peterson and others, 1980) consists of two-thirds light-green mudstone with thin discontinuous lenses of carbonaceous mudstone or gray limestone, and one-third thin-bedded, ripple- or cross-laminated sandstone. The sandstones in the Masuk tend to have scoured bases and consist of fining-upward cycles. These mudstones and sandstones are typical of well-drained, flood-plain and meandering-stream deposits. Fossils recovered from the Masuk support the interpretation of a freshwater, continental environment (Peterson and others, 1980).

Tarantula Mesa Sandstone

Gilbert (1877) originally named the sandstones above his Masuk Shale the Masuk Sandstone. Subsequent workers (Spieker and Reeside, 1925; Hunt and Miller, 1946) assigned the sandstones to the Mesaverde Formation. The term Mesaverde was considered inappropriate by Peterson and others (1980), and they enclosed the term in quotes. Smith (1983) renamed the mesa-capping sandstones the Tarantula Mesa Sandstone, and Eaton (1990) also adopted this terminology.

The Tarantula Mesa Sandstone has a gradational contact with the underlying Masuk Member of the Mancos Shale. It is a gray or brown cliff-forming sandstone that is preserved only in the central portions of the Henry Mountains Basin on the top of Tarantula Mesa and on a few isolated surrounding mesas. Only a few sections of these strata have been measured with thicknesses ranging from 300 to 400 ft (Peterson and others, 1980). The Tarantula Mesa Sandstone is composed of seemingly continuous sandstones formed from laterally migrated, discrete channel bodies. According to Peterson and others (1980), these continuous-appearing sandstones contain very light gray or brown, fine-grained sandstone with local pebbles of chert, quartzite, and petrified wood. The individual sandstone beds have tabular-planar to scoured contacts and exhibit cross-stratification and fining-upward cycles. Cross-laminae in the lower part indicate transport to the south-east. A few thin lenses of gray mudstone are interbedded with the sandstones in the lower part of the formation.

The upper part of the Tarantula Mesa Sandstone is more conglomeratic and exhibits less planar bedding surfaces and more scouring between beds. Higher depositional energy is also indicated by the lack of interbedded mudstone in the upper half, and cross lamination in this part of the unit indicates an east-northeast transport direction. The lithology and sedimentary structures of the Tarantula Mesa Sandstone point to a highly meandering or braided fluvial environment of deposition (Peterson and others, 1980).

Younger Beds on Tarantula Mesa

Erosional remnants of younger Cretaceous strata are locally preserved on the top of Tarantula Mesa. Fossils reported by Eaton (1990) indicate a Campanian age. Only 36 to 100 ft of these beds are preserved, with the thickest deposits located on the western part of the mesa (Peterson and others, 1980). These strata are not well exposed because they are commonly capped by a veneer of Quaternary gravel and wind-blown sand. Where exposed, they consist of 75 percent yellowish- to greenish-gray mudstone with several carbonaceous lenses containing fossil plant fragments and 25 percent light- to dark-brown, very fine to fine-grained sandstone. The sandstones commonly have scoured bases and internally are planar bedded to cross-stratified. This unit is interpreted to have been deposited in a flood-plain environment (Peterson and others, 1980).

Coal Geology

Thickness and Geometry of Ferron Coal

The coals in the Ferron Sandstone Member of the Mancos Shale occur in the upper 110 ft of the nonmarine part of the unit. The coal beds are generally in a 50-ft-thick zone immediately above the lower marine part of the Ferron. The coal interval contains one to five beds that have an aggregate thickness of coal as much as 16.5 ft. Individual coal beds seldom exceed 4 ft in thickness and commonly average 1–3 ft thick.

The areal distribution of coal is patchy, with isolated east-west-elongated pods present at scattered locations across the Henry Mountains Basin (fig. 6). The pods are approximately 1–5 mi wide and from 3 to 10 mi long. Although the coal-thickness data come primarily from the margins of the coal field, it appears that the coal is best developed in three widely separated areas in the northern, central, and southern parts of the field. The coal in the central area is more speculative than the other two because it relies heavily on data from only one deep oil and gas well.

Because the depositional environment for the Ferron in the Henry Mountains Basin has been interpreted as a fluvial-deltaic complex (Uresk, 1979; Hill, 1982), the east-west-elongate coal pods might reflect interfluvial swamps formed on eastward-prograding fluvial-delta lobes that formed in the northern, central, and southern parts of the basin. However, the original distribution of coal in the upper part of the Ferron might have been altered by the erosional nature of the upper

Ferron contact with the overlying Blue Gate Member, which resulted in a variable thickness of the coal-bearing unit.

Depth to Ferron Coal Zone

The coal in the Ferron Sandstone Member generally occurs in the upper part, but in many places throughout the field there is no coal. Therefore, it was easier to map the top of the Ferron to approximate the depth to the coal zone throughout the field (fig. 7). The top of the Ferron is exposed around the margins of the Henry Mountains Basin, and it reaches a maximum depth of slightly more than 2,000 ft in an area several square miles in extent that lies beneath the highest portions of Tarantula Mesa in the central part of the basin. Thus, all the Ferron coal deposits of the Henry Mountains coal field that are thick enough to mine occur at potentially minable depths.

Chemistry of Ferron Coal

Only four coal-sample analyses from the Ferron have been published for the Henry Mountains coal field (Doelling, 1972; Hatch and others, 1979). These coals have an apparent rank of high-volatile C bituminous. The four samples come from the northern (3 samples) and southern (1 sample) edges of the field. The mean analytical values indicate high ash (14.5 percent) and sulfur (2.5 percent) contents. Table 1 gives the proximate analyses of the four coal samples.

Table 1. Proximate analyses of Ferron coal samples (as-received basis).

Cadastral location	Moisture (percent)	Volatile matter (percent)	Fixed carbon (percent)	Ash (percent)	Sulfur (percent)	Btu per pound
02-27S-09E	8.3	34.1	43.8	13.8	1.6	10,650
11-27S-09E	4.9	33.5	48.7	12.9	2.6	10,920
11-27S-09E	5.5	33.6	44.9	16.0	2.5	10,840
36-34S-10E	4.6	38.1	42.2	15.1	3.2	11,743
Mean	5.8	34.8	44.9	14.5	2.5	11,038
Minimum	4.6	33.5	42.2	12.9	1.6	10,650
Maximum	8.3	38.1	48.7	16.0	3.2	11,743
Standard deviation	1.7	2.2	2.8	1.4	0.7	483

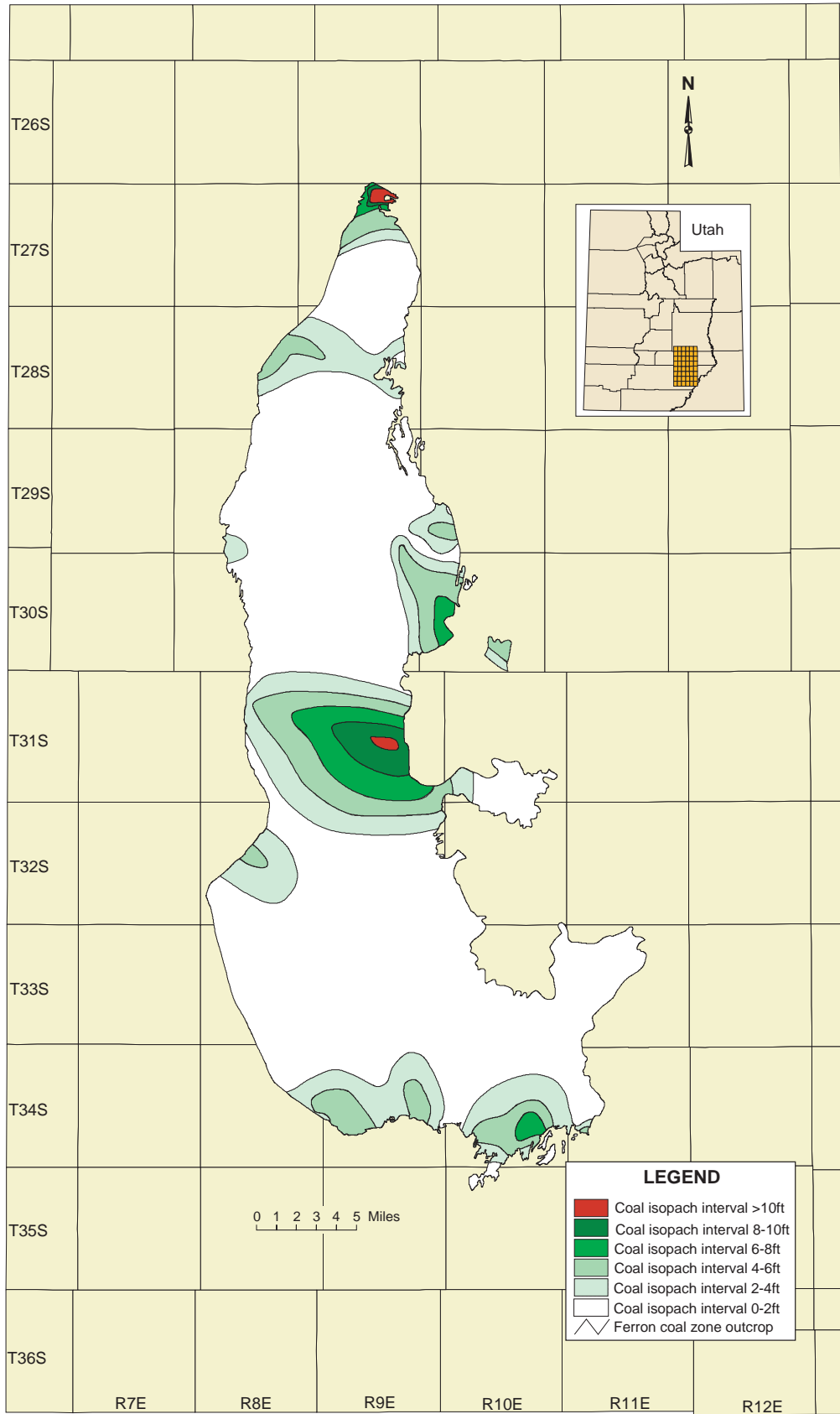


Figure 6. Isopach map of Ferron coal zone.

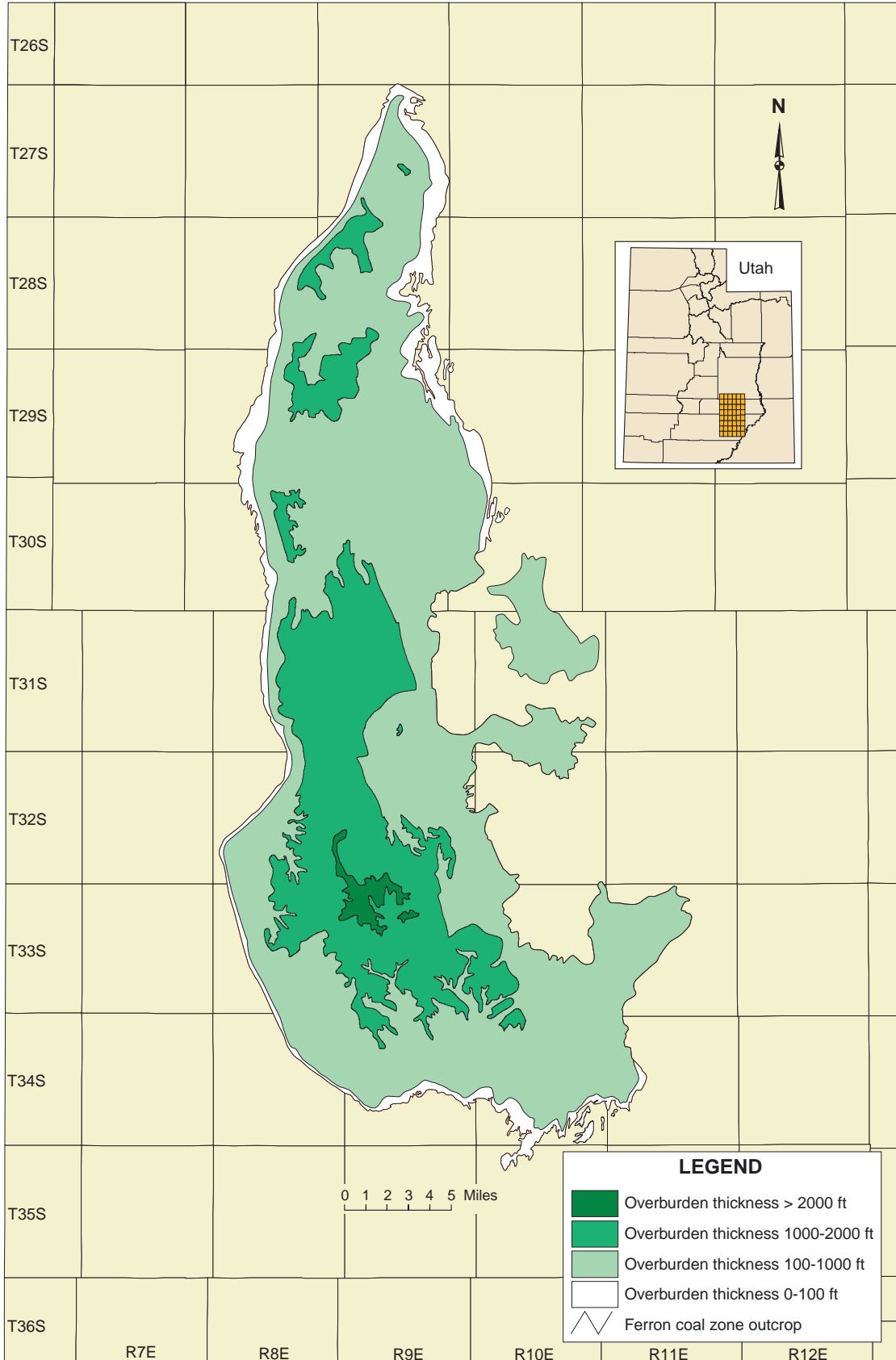


Figure 7. Overburden map of Ferron coal zone.

Coal Resources of the Ferron Sandstone Member

The Ferron contains an estimated 683.5 million short tons of in-place coal resources, of which about three-quarters lie in Garfield County. Because of limited exploration data, only 27 percent, or 187.3 million short tons, of the total resources falls in the demonstrated resource category (occurring within 0.75 mi of a thickness-measurement point). The bulk of the coal resource, 67 percent, fall in the inferred resource category (occurring at least 0.75 to 3 mi from a thickness-measurement point). Only a few percent of the resources lie more than 3 mi from a thickness-measurement point, or in the hypothetical category.

Overburden measurements show that 11 percent of the

Ferron resources, or 75.1 million short tons, lie at depths of 100 ft or less, and that nearly all of the remainder is less than 2,000 ft deep (fig. 7). As mentioned above, the total coal thickness in the Ferron is generally thin, and this is reflected by the fact that 68 percent of the resources falls in the 2- to 6-ft-thick resource category. Less than one-third of the coal resources have an aggregate thickness greater than 6 ft.

In summary, the majority of the Ferron coal resources are poorly defined by USGS reliability standards; they are primarily less than 6 ft thick, deeper than 100 ft, and lie within Garfield County. The in-place coal resources for the total Ferron zone are summarized by thickness, depth, reliability category, and county in tables 2, 3, and 4. Readers should note that the individual resource categories in these and other resource tables may not sum to totals at the bottoms of the tables due to independent rounding.

Table 2. Total Ferron coal zone resources by thickness and county.

[All coal beds greater than or equal to 1 ft thick; figures in millions of short tons. DEM, demonstrated; INF, inferred; HYP, hypothetical]

County	2–6 ft thick			6–10 ft thick			10+ ft thick		
	DEM	INF	HYP	DEM	INF	HYP	DEM	INF	HYP
Wayne	65.1	71.2	0.0	12.0	8.8	0.0	8.6	0.0	0.0
Garfield	74.8	224.6	28.8	19.1	153.0	9.8	7.7	0.0	0.0
TOTAL	139.9	295.8	28.8	31.1	161.8	9.8	16.3	0.0	0.0

Table 3. Total Ferron coal zone resources by thickness and depth of cover.

[All coal beds greater than or equal to 1 ft thick; figures in millions of short tons. DEM, demonstrated; INF, inferred; HYP, hypothetical]

Depth (ft)	2–6 ft thick			6–10 ft thick			10+ ft thick		
	DEM	INF	HYP	DEM	INF	HYP	DEM	INF	HYP
0–100	54.2	5.1	0.0	6.7	2.2	0.0	6.9	0.0	0.0
100–1,000	81.3	187.4	12.8	20.0	84.4	0.0	5.5	0.0	0.0
1,000–2,000	4.3	103.3	16.0	4.5	75.3	9.8	4.0	0.0	0.0
TOTAL	139.9	295.8	28.8	31.1	161.8	9.8	16.3	0.0	0.0

Table 4. Total Ferron coal zone resources by thickness and township tier.

[All coal beds greater than or equal to 1 ft thick; figures in millions of short tons. DEM, demonstrated; INF, inferred; HYP, hypothetical]

Tier	2–6 ft thick			6–10 ft thick			10+ ft thick		
	DEM	INF	HYP	DEM	INF	HYP	DEM	INF	HYP
T. 27 S.	13.3	4.4	0.0	7.6	0.0	0.0	8.6	0.0	0.0
T. 28 S.	19.8	28.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T. 29 S.	13.2	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T. 30 S.	18.8	35.0	0.0	4.4	8.8	0.0	0.0	0.0	0.0
T. 31 S.	13.8	102.4	15.4	12.4	149.1	9.8	7.7	0.0	0.0
T. 32 S.	11.2	44.8	13.5	0.0	0.0	0.0	0.0	0.0	0.0
T. 33 S.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T. 34 S.	49.8	77.3	0.0	6.7	3.9	0.0	0.0	0.0	0.0
TOTAL	139.9	295.8	28.8	31.1	161.8	9.8	16.3	0.0	0.0

Thickness and Geometry of Muley Canyon Coal

The upper part of the Muley Canyon Member is a nonmarine coal-bearing interval with thicknesses ranging from 92 to 209 ft thick and averaging about 150 ft. This stratigraphic interval, referred to as the Muley Canyon coal zone in this report, commonly contains three to four coal beds, but locally has as many as 10 beds. Individual coal beds range from 0 to 13.4 ft thick and are commonly 2–5 ft thick; aggregate thickness of coal is as much as 27.5 ft (fig. 8). Most of the area underlain by this zone has at least 5 ft of total coal, and about half of the area has 10 ft or more of total coal.

Unlike the Ferron coal, the Muley Canyon coal occurs throughout most the coal field (fig. 8). The Muley Canyon coal is thickest in elongate pods oriented in an east-west direction that tend to be thicker on the west side of the Henry Mountains Basin and thin gradually to the east. The largest thick pod of coal lies in the center of the basin, as was the case with the Ferron coals (fig. 6).

Depth to Muley Canyon Coal Zone

Broad expanses of the coal zone in the Muley Canyon at the northern and southern ends of this unit's exposures are less than 100 ft deep (see fig. 9). Thus, some of the thicker coal beds under parts of Wildcat Mesa, Cave Flat, and Swap Mesa are potentially surface-minable. The extensive, thick (>24 ft) Muley Canyon coal under Tarantula Mesa reaches a maximum depth of slightly more than 1,000 ft, and therefore it is at shallow to moderate depths for underground mining methods.

Chemistry of Muley Canyon Coal

The coal beds in the Muley Canyon coal zone have been more extensively sampled than those in the Ferron. The coals sampled come primarily from the northern and southern ends of the area underlain by the Muley Canyon coal zone where there is shallow cover and not from the deeper, central area. The Muley Canyon coal analyses, from seven outcrops and 30 drill cores, are listed in table 5.

The Muley Canyon coal has an apparent rank of sub-bituminous A to high-volatile bituminous C (Hatch and others, 1979; Law, 1980), a slightly lower rank than the Ferron coals that translates to a lower heat content and higher moisture content. The mean ash content of the Muley coals, 11.74 percent, is less than that of the Ferron coals; for comparison, the Utah coal produced from the Wasatch Plateau and Book

Cliffs coal fields typically has an average ash content of about 10 percent. Figure 10 shows the variation in the ash content of the Muley Canyon coals across the coal field. The ash content is highest in two, east-west-trending lobate areas—one each in the northern part and the southern part of the field.

The sulfur content of the Muley Canyon coals ranges as high as 3.2 percent (table 5), which is as high as the Ferron coals, but the mean sulfur content of the Muley Canyon samples is considerably less, at 0.9 percent. In comparison, the average sulfur content of coal presently produced from the Wasatch Plateau and Book Cliffs coal fields is 0.5 to 0.7 percent. The variation in sulfur content of the Muley Canyon coals across the coal field is shown in figure 11. One east-west-trending, high-sulfur area coincides with the northern high-ash area.

The heat content of Muley Canyon coals ranges from 7,710 to 12,491 Btu per pound and averages 10,086 Btu per pound (table 5). Figure 12 shows that the heat-content distribution across the coal field consists of east-west trends with low heat areas corresponding directly with areas having high ash content. In addition to this primary east-west trend, the heat content values of the Muley Canyon coals appear to be slightly higher on the east side of the field than on the west, suggesting that the eastern coals were possibly thermally upgraded by the intrusion of the Henry Mountains laccoliths.

The ash chemistry of some of the Muley Canyon coals has been studied by Hatch and others (1979). Chemical analyses of the major oxides in the Muley Canyon coal ash (table 6) can be used to predict coal utilization characteristics, such as boiler slagging and fouling characteristics. The physical and chemical transformations that the minerals in the coal ash undergo during combustion is a complex process. Vaninetti and Busch (1981) define slagging as the buildup of molten ash materials within the lower furnace section of a boiler and fouling as the accumulation of sintered ash in the convective passes section of a boiler. Both of these problems reduce boiler efficiency, increase operating costs, and shorten boiler life. Various indices can predict the combustion characteristics of coal ash, and two of them are presented in table 7. The first step in analyzing ash combustion properties is to determine the type of coal ash present. Coal ash is characterized as either lignitic or bituminous depending on the value determined by summing CaO and MgO and dividing by Fe₂O₃. Coal ash is termed lignitic when the value is greater than 1.0 and bituminous when the value is less than 1.0. Most of the Muley Canyon ash analyses fall in the lignitic ash category, although two ash samples fall in the bituminous ash category. Both of these bituminous ash analyses are from coal samples with high iron and sulfur content, indicating a high pyrite content.

Table 5. Proximate analyses of Muley Canyon coal samples (as-received basis).

Cadastral location	Moisture (percent)	Volatile matter (percent)	Fixed carbon (percent)	Ash (percent)	Sulfur (percent)	Btu per pound
22-31S-8E	11.5	35.3	40.3	12.9	0.8	10,110
22-31S-8E	11.0	35.4	37.0	16.6	0.4	9,440
22-31S-8E	9.5	32.7	33.3	24.5	2.0	8,510
23-31S-8E	11.6	36.6	42.7	9.1	0.6	10,620
23-31S-8E	10.3	36.0	36.3	17.4	0.7	9,400
23-31S-8E	10.9	38.2	42.4	8.5	1.0	10,790
-31S-8E	14.28	33.47	41.97	10.64	0.66	9,986
36-31S-8E	13.51	31.99	35.69	18.81	0.53	9,015
36-31S-8E	13.87	34.37	41.33	10.43	1.0	10,204
07-31S-9E	6.36	39.52	44.14	9.98	0.67	9,698
07-31S-9E	13.1	34.0	45.1	7.8	0.7	10,210
07-31S-9E	9.5	35.0	45.8	9.7	0.7	10,480
17-31S-9E	13.0	35.0	37.7	14.3	0.7	9,670
18-31S-9E	12.5	33.6	35.7	18.2	0.7	9,300
18-31S-9E	12.7	32.2	32.0	23.1	3.2	8,520
19-31S-9E	12.5	34.6	39.3	13.6	0.5	9,990
19-31S-9E	13.7	36.5	42.7	7.1	0.6	10,600
20-31S-9E	11.6	35.4	36.3	16.7	2.8	9,610
20-31S-9E	12.1	37.1	41.4	9.4	0.4	10,660
27-31S-9E	6.9	38.0	49.1	6.0	0.7	11,130
30-31S-9E	9.3	37.2	46.7	6.8	0.8	10,900
30-31S-9E	11.5	38.5	40.8	7.7	1.5	12,491
-32S-9E	9.2	35.4	44.9	10.5	0.7	9,590
05-32S-9E	13.6	32.56	39.3	14.54	0.8	9,597
05-32S-9E	13.6	35.25	36.19	14.96	0.69	9,652
12-33S-8E	14.7	27.4	30.6	27.3	0.4	7,710
24-33S-8E	14.37	35.57	35.14	16.92	0.99	9,156
24-33S-8E	14.37	34.92	42.47	8.24	1.16	10,231
24-33S-8E	14.37	35.61	45.48	4.54	1.09	10,759
02-33S-9E	10.48	38.29	45.25	5.98	0.78	11,468
11-33S-9E	11.34	36.09	43.86	8.71	0.46	10,856
11-33S-9E	13.7	37.2	44.19	4.91	0.47	11,121
14-33S-9E	12.29	36.65	45.49	5.57	0.55	11,147
22-33S-9E	13.3	36.23	39.33	11.14	1.05	8,178
23-33S-9E	13.48	34.45	43.61	8.46	0.83	10,660
23-33S-9E	13.3	36.36	43.36	5.97	0.67	11,010
23-33S-9E	14.28	34.89	43.51	7.32	1.12	10,718
Mean	12.1	35.34	40.82	11.74	0.9	10,086
Minimum	6.36	27.4	30.6	4.54	0.4	7,710
Maximum	14.7	39.52	49.1	27.3	3.2	12,491
Standard deviation	2.04	2.2	4.38	5.6	0.6	970
Statistics for 34 samples with less than 20 percent ash						
Mean	12.08	35.74	41.60	10.57	0.8	10,248
Minimum	6.36	31.99	35.14	4.54	0.4	8,178
Maximum	14.37	39.52	49.10	18.81	2.8	12,491
Standard deviation	2.03	1.66	3.64	4.14	0.4	829

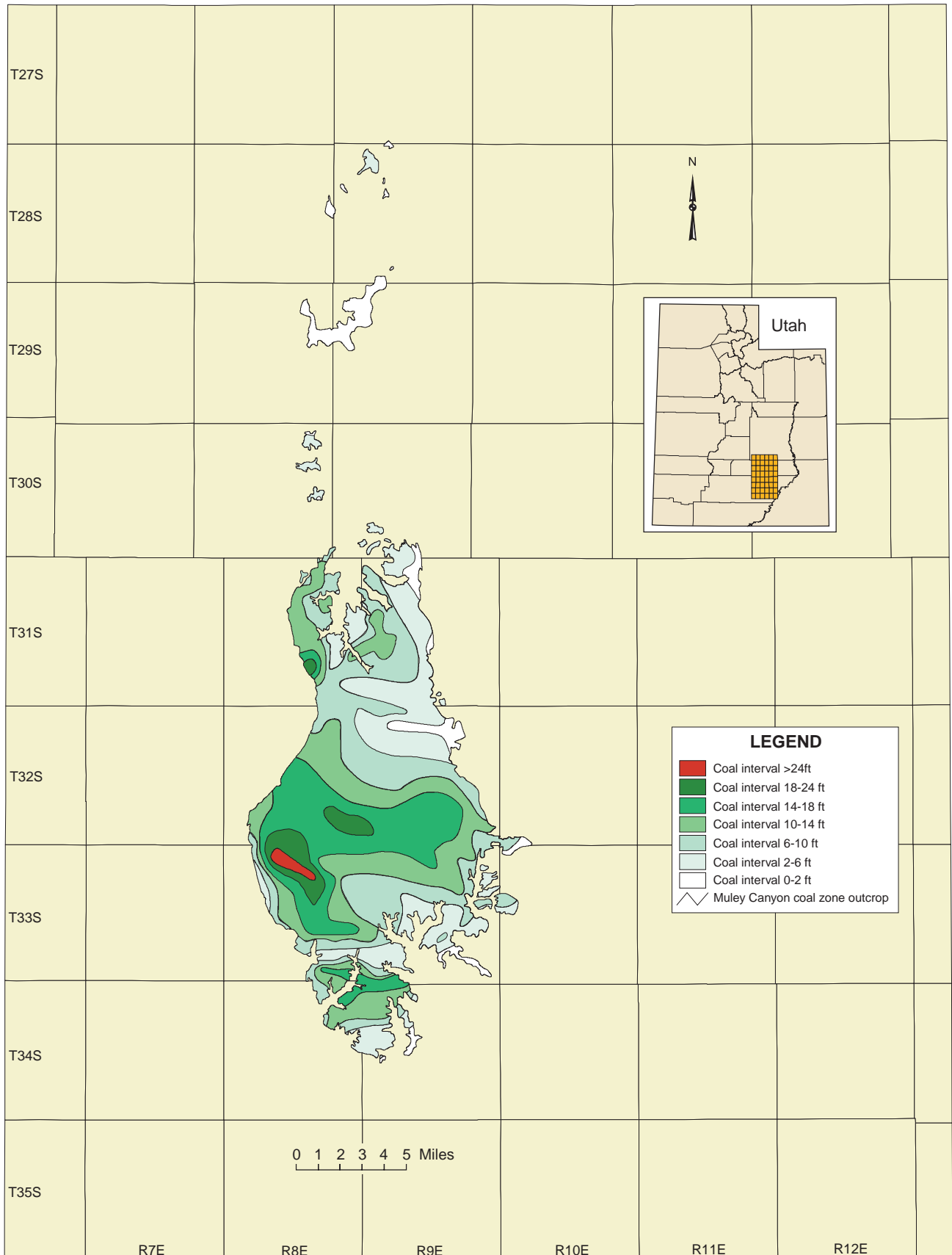


Figure 8. Isopach map of Muley Canyon coal zone.

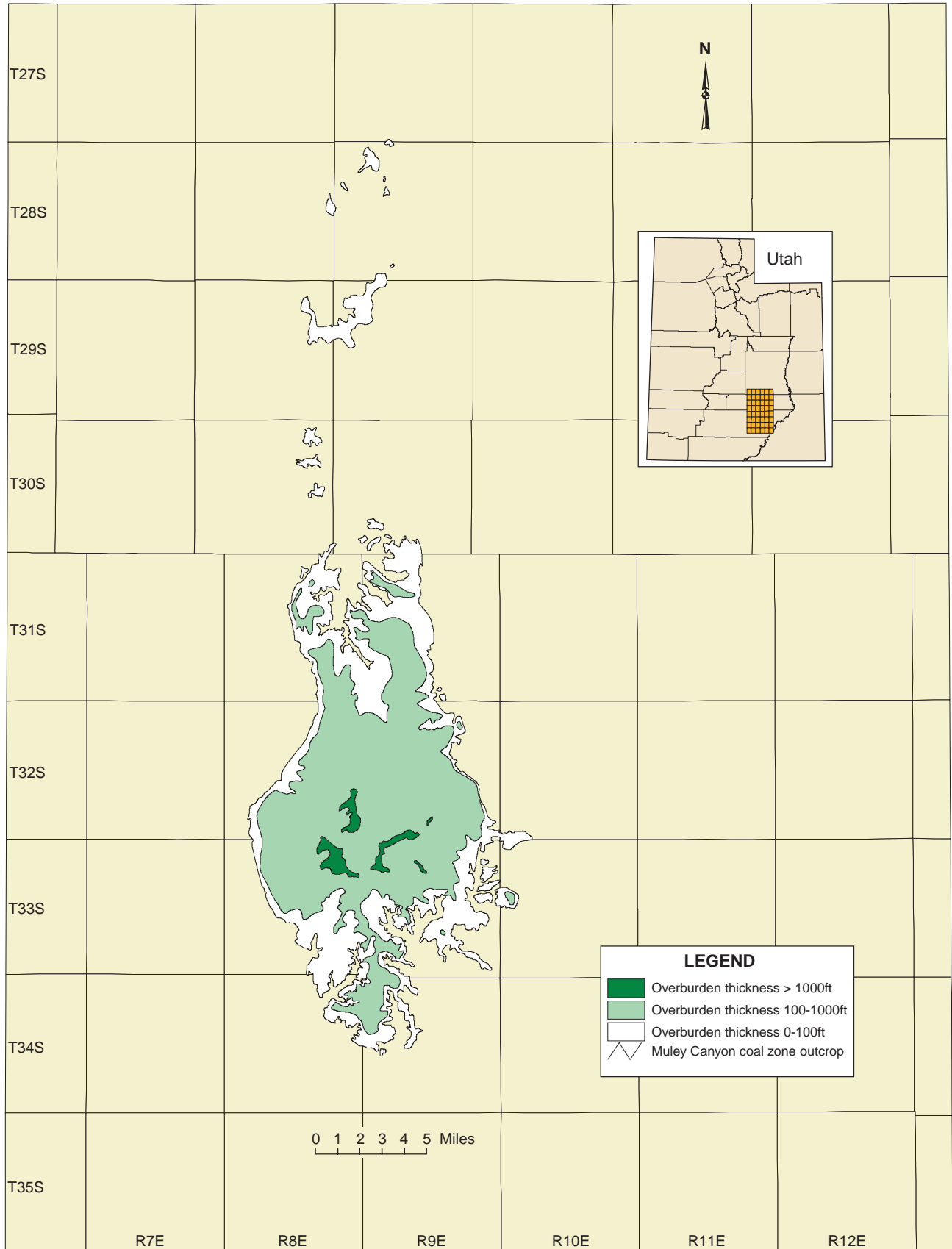


Figure 9. Overburden map of Muley Canyon coal zone.

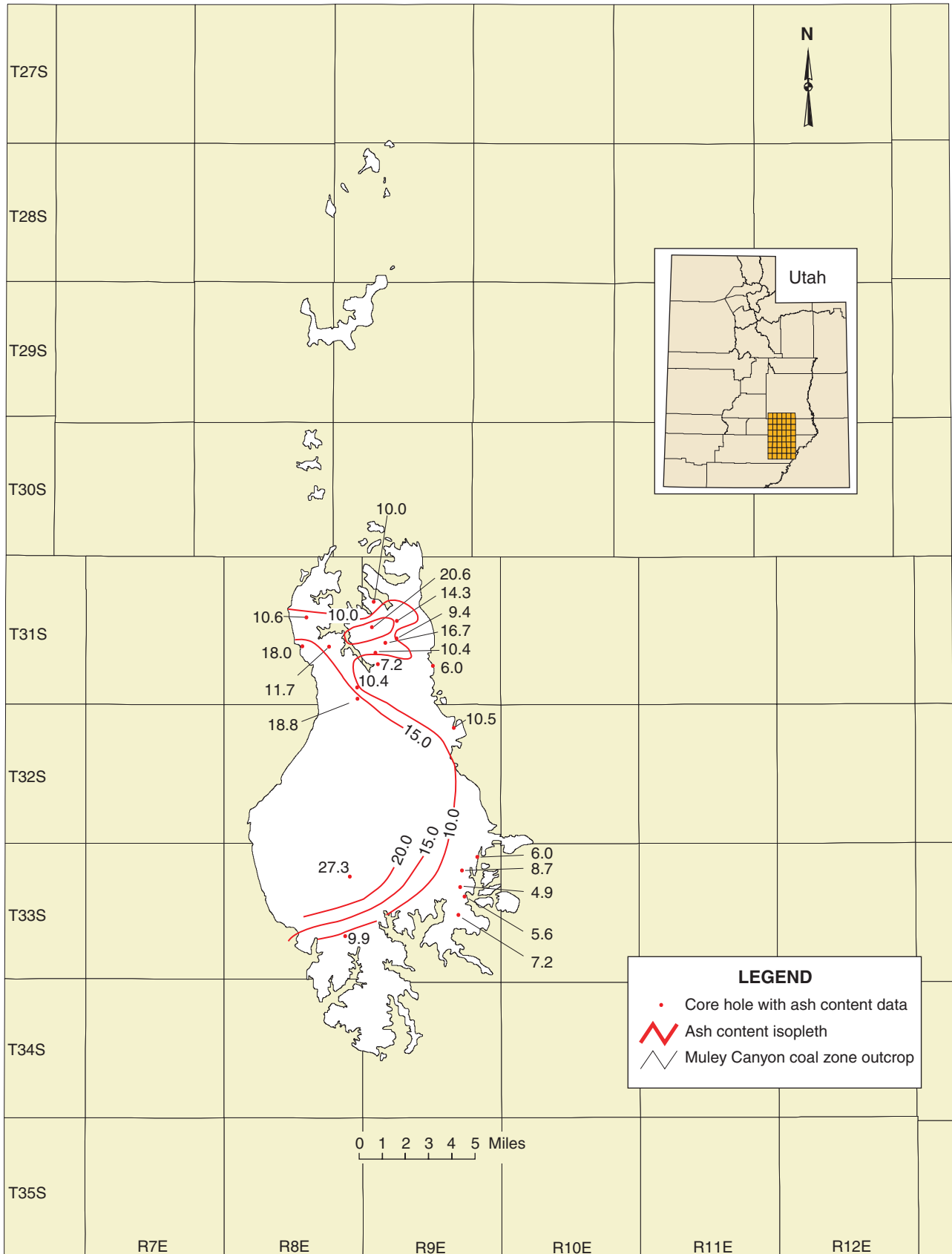


Figure 10. Map showing ash content of coal in Muley Canyon coal zone (as-received basis).

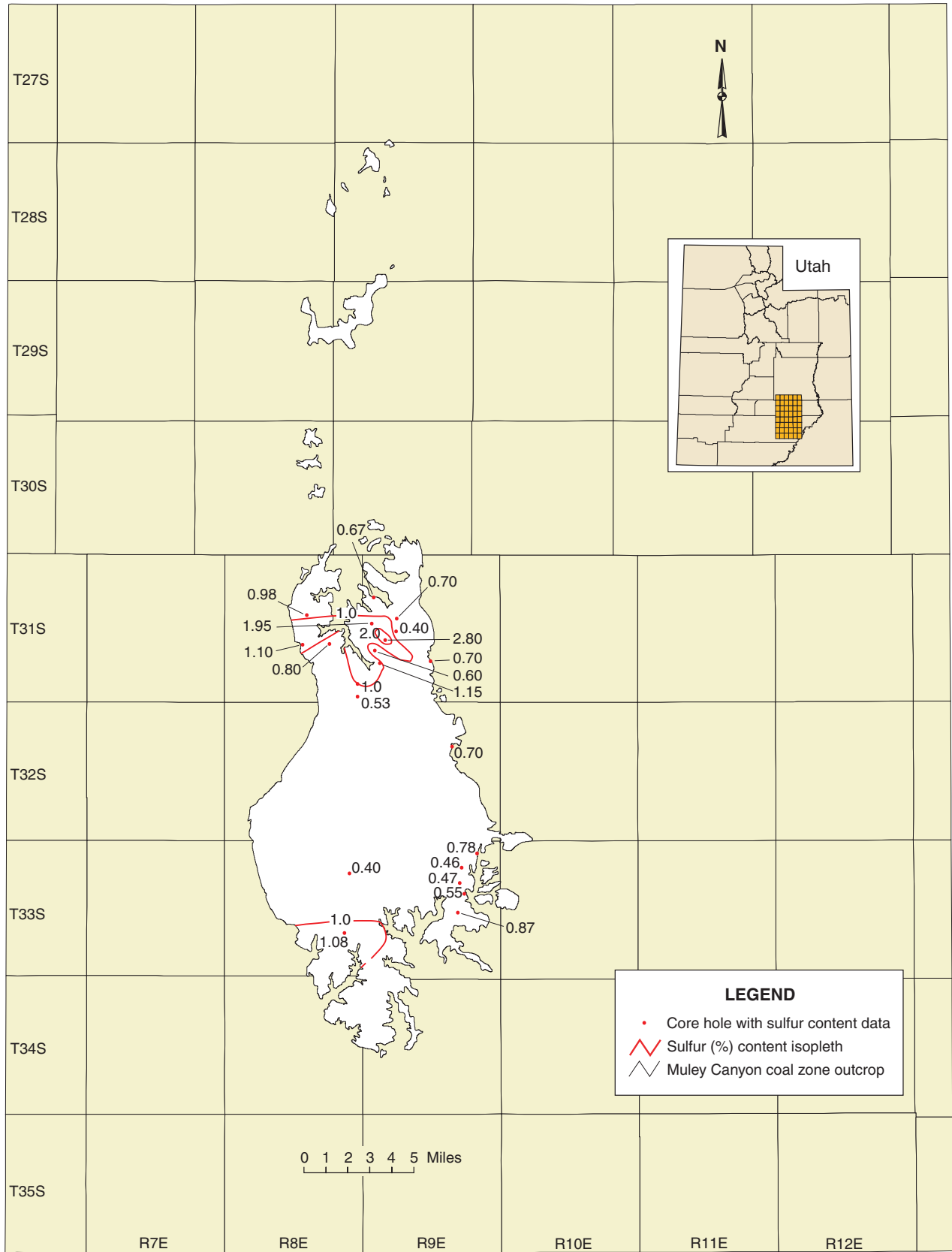


Figure 11. Map showing sulfur content of coal in Muley Canyon coal zone (as-received basis).

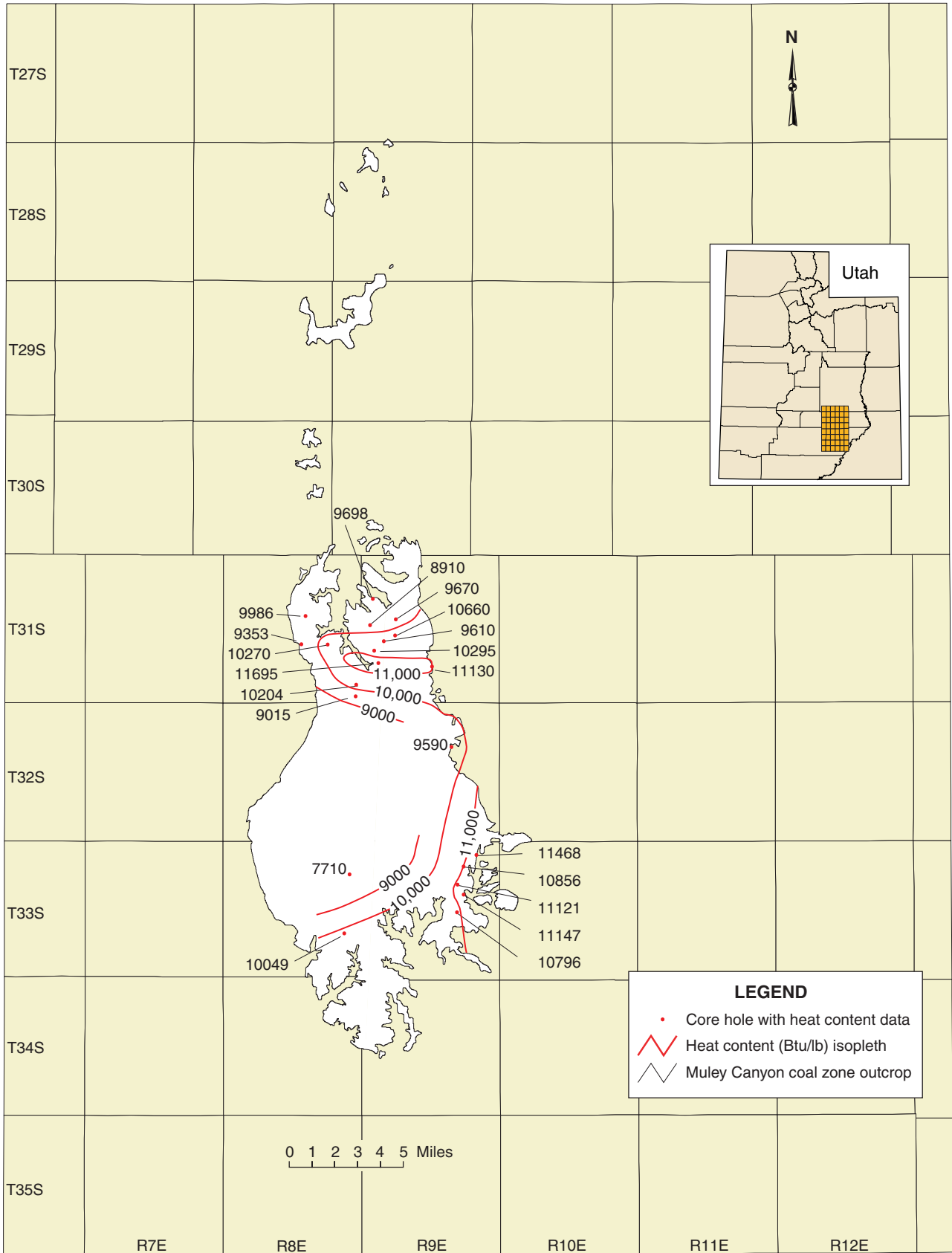


Figure 12. Map showing heat content of coal in Muley Canyon coal zone (as-received basis).

Table 6. Major oxide composition (in percent) of ash from 13 Muley Canyon coal samples from the Henry Mountains coal field.

[Standard dev., standard deviation]

Cadastral location	Acidic oxides			Basic oxides				Ash	
	SiO ₂	Al ₂ O ₃	TiO ₂	CaO	MgO	Na ₂ O	K ₂ O		Fe ₂ O ₃
22-31S-8E	60.0	12.0	1.00	8.9	2.00	0.75	0.44	5.8	13.0
22-31S-8E	54.0	27.0	0.79	9.0	1.03	0.95	1.20	1.0	19.6
22-31S-8E	57.0	24.0	1.00	6.0	1.18	0.28	1.10	1.0	10.2
23-31S-8E	53.0	14.0	0.88	13.0	2.09	2.75	0.43	3.5	9.8
23-31S-8E	51.0	23.0	0.88	14.0	1.27	1.09	0.66	1.9	20.0
23-31S-8E	38.0	22.0	1.20	16.0	2.53	1.62	0.31	4.9	9.1
17-31S-9E	58.0	17.0	0.87	10.0	1.96	0.13	0.73	3.3	14.5
18-31S-9E	61.0	17.0	1.00	6.2	1.58	0.54	1.20	2.5	19.7
18-31S-9E	50.0	12.0	0.70	6.5	1.49	0.92	1.20	17.0	19.6
19-31S-9E	65.0	14.0	1.00	8.4	1.76	0.51	0.62	2.5	15.6
19-31S-9E	30.0	11.0	0.60	29.0	2.80	1.30	0.48	4.4	8.3
20-31S-9E	65.0	7.8	1.20	12.0	2.31	0.24	0.54	3.1	10.8
20-31S-9E	46.0	18.0	1.10	7.5	1.36	0.40	0.74	15.0	18.3
Mean	52.9	16.8	0.94	11.3	1.80	0.88	0.74	5.5	14.5
Minimum	30.0	7.8	0.60	6.0	1.03	0.13	0.31	1.0	8.3
Maximum	65.0	27.0	1.20	29.0	2.80	2.75	1.20	17.0	20.0
Standard dev.	10.2	5.8	0.18	6.2	0.54	0.71	0.32	4.9	4.6

Table 7. Ash type, fouling, and slagging evaluation of the oxide composition of Muley Canyon coal ash.

[Base/acid ratio = CaO+MgO+Na₂O+K₂O+Fe₂O₃/SiO₂+Al₂O₃+TiO₂; med, medium]

Cadastral location	Ash type (CaO+MgO/Fe ₂ O ₃)	Fouling severity (Percent Na ₂ O)	Slagging severity (Base/acid ratio)
22-31S-8E	1.88 (lignitic)	0.75 (low)	0.245 (low)
22-31S-8E	10.03 (lignitic)	0.95 (low)	0.161 (low)
22-31S-8E	1.14 (lignitic)	0.28 (low)	0.181 (low)
23-31S-8E	4.31 (lignitic)	2.75 (low)	0.320 (med-severe)
23-31S-8E	8.04 (lignitic)	1.09 (low)	0.253 (med-severe)
23-31S-8E	3.78 (lignitic)	1.62 (low)	0.414 (med-severe)
17-31S-9E	3.62 (lignitic)	0.13 (low)	0.212 (low)
18-31S-9E	3.11 (lignitic)	0.54 (low)	0.152 (low)
18-31S-9E	0.47 (bituminous)	0.92 (medium)	0.432 (low)
19-31S-9E	4.06 (lignitic)	0.51 (low)	0.172 (low)
19-31S-9E	7.23 (lignitic)	1.30 (low)	0.913 (low)
20-31S-9E	4.62 (lignitic)	0.24 (low)	0.246 (low)
20-31S-9E	0.59 (bituminous)	0.40 (low)	0.384 (low)
Mean	4.07 (lignitic)	0.88 (low)	0.314 (med-severe)

Sodium content in the ash is critical to various indices of ash-fouling potential, and the simplest indicator of fouling is the total sodium oxide content of the ash alone. Bituminous and lignitic ash coals respond differently to increased sodium oxide content, with coals in the bituminous category being much more sensitive to small increases in sodium oxide. The change in ash-fouling tendency with increasing sodium oxide content according to Vaninetti and Busch (1981) is as follows:

Fouling Tendency

Factor	Ash type	Low	Medium	High	Severe
Na ₂ O in ash (%)	bituminous	<0.5	0.5–1.0	1.0–2.5	>2.5
Na ₂ O in ash (%)	lignitic	<3.0	3.0–5.0		>5.0

When examining just the sodium content of the ash, all but one of the Muley Canyon coal ash samples fall in the low-fouling-potential range.

If coal from the Muley Canyon were mined, various quality-control strategies including blending, selective mining, or selective washing could probably produce a low-ash, low-sulfur coal similar to that presently produced in central Utah. The coal that could be produced is predicted to have low-slugging and low-fouling boiler combustion properties based on ash chemistry.

Coal Resources of the Muley Canyon Sandstone Member

The Muley Canyon contains 1,526.1 million short tons of in-place coal resources. All but half a percent of the coal resources lies in Garfield County. Because of extensive exploration data, 62 percent, or 945.6 million short tons, of the total coal resources falls in the demonstrated, or the most reliable, resource category. The remaining 38 percent, 580.5 million short tons, falls in the inferred resource category, (at least 0.75

to 3 mi from a thickness-measurement point). None of the coal resources is in the hypothetical category (more than 3 mi from a thickness-measurement point).

Measurement of depth of cover shows that 25.6 percent, or 391 million short tons, lies within 100 ft or less of the ground surface. The remainder are all less than 2,000 ft deep and most are under less than 1,000 ft of overburden (fig. 9).

A review of the coal resources by coal-thickness category shows that 91 percent has a total coal thickness of 6 ft or greater and that about 70 percent of the coal resources has a total coal thickness of more than 10 ft. In much of the area below Tarantula Mesa, the Muley Canyon coal zone consists of a single thick bed from 6 to 12 ft thick (Tabet, 1999). Only 9 percent of the coal resources has a thickness of less than 6 ft.

In summary, the Muley Canyon coal resources are, for the most part, well defined according to USGS reliability standards, greater than 6 ft thick, deeper than 100 ft, and within Garfield County. The in-place coal resources for the total Muley Canyon coal zone are summarized by thickness, depth, reliability, and county categories in tables 8, 9, and 10. Readers should again note that the individual resource categories in the tables may not sum to totals at the bottoms of the tables due to independent rounding.

Coal Development Potential

The coal resources of the Ferron Sandstone Member of the Mancos Shale offer limited development potential for mining, commonly being too thin and discontinuous to be of economic interest. The Ferron coals are further hampered by poor coal quality—both ash and sulfur content are high. Limited areas might be suitable for surface mining, but environmental constraints could possibly restrict development. The thick, shallow deposits at the north end of the coal field near Factory Butte offer the best development potential. This area contains about 20 million short tons of coal under less than 100 ft of cover that could be surface-mined if warranted by marketing conditions and if mining could be conducted in an environmentally acceptable manner.

Table 8. Total Muley Canyon coal zone resources by thickness and depth of cover.

[All coal beds greater than or equal to 1 ft thick; figures in millions of short tons. DEM, demonstrated; INF, inferred]

Depth (ft)	2–6 ft thick		6–10 ft thick		10+ ft thick		Total
	DEM	INF	DEM	INF	DEM	INF	
0-100	78.3	4.4	107.4	7.6	172.4	20.9	391.0
100-1,000	42.1	11.3	118.5	75.7	383.7	449.4	1,080.7
1,000-2,000	1.6	0.0	4.9	1.2	36.8	9.9	54.4
TOTAL	121.9	15.8	230.9	84.5	592.8	480.2	1,526.1

Table 9. Total Muley Canyon coal zone resources by thickness and county.

[All coal beds greater than or equal to 1 ft thick; figures in millions of short tons. DEM, demonstrated; INF, inferred]

County	2–6 ft thick		6–10 ft thick		10+ ft thick		Total
	DEM	INF	DEM	INF	DEM	INF	
Wayne	7.3	0.0	0.2	0.0	0.0	0.0	7.5
Garfield	114.6	15.8	230.7	84.5	592.8	480.2	1,518.6
TOTAL	121.9	15.8	230.9	84.5	592.8	480.2	1,526.1

Table 10. Total Muley Canyon coal zone resources by thickness and township tier.

[All coal beds greater than or equal to 1 ft thick; figures in millions of short tons. DEM, demonstrated; INF, inferred]

Tier	2–6 ft thick		6–10 ft thick		10+ ft thick		Total
	DEM	INF	DEM	INF	DEM	INF	
T. 30 S.	7.3	0.0	0.2	0.0	0.0	0.0	7.5
T. 31 S.	45.5	2.5	89.1	6.5	86.0	0.0	229.6
T. 32 S.	21.5	10.9	61.0	44.4	205.1	293.8	636.7
T. 33 S.	40.7	0.6	77.0	27.5	259.8	169.2	574.8
T. 34 S.	6.9	1.8	3.6	6.1	41.9	17.2	77.5
TOTAL	121.9	15.8	230.9	84.5	592.8	480.2	1,526.1

The coal resources of the Muley Canyon Member are generally thicker and more persistent in areal extent than the Ferron coal resources in the Henry Mountains coal field. Thick, sufficiently large concentrations of both surface- and underground-minable coal deposits exist in the Muley Canyon. During the 1970's, Amax Coal Company (now RAG International Mining) delineated approximately 120 million short tons of recoverable surface-minable coal divided among three tracts located at Wildcat Mesa, Swap Mesa, and Cave Flat. Prior to issuing coal leases to Amax, the BLM conducted a survey in 1982 to determine which lands were unsuitable for surface mining. As a result, the areas containing all 22 million short tons of coal in the vicinity of Cave Flat, 20 million of the 35 million short tons of coal in the Swap Mesa area, and 3 million of the 63 million short tons of coal in the Wildcat Mesa area were deemed unsuitable for surface mining. This ruling essentially precluded surface coal mining from southern end of the Muley Canyon coal area, but it allowed for the possibility that 60 million short tons of coal under Wildcat Mesa could be surface-mined.

The greatest coal development potential for the coal field lies in the large amounts of deep Muley Canyon coal under

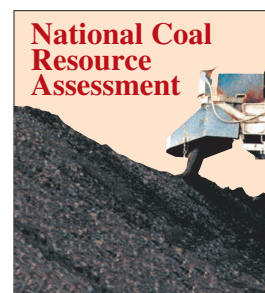
Tarantula Mesa. One of the coal beds is 6–15 ft thick, and it occurs under no more than 1,100 ft of overburden—favorable conditions for underground mining (Tabet, 1999). Access to the underground coal could be achieved through openings in exposures either on the east or west side of the field or, if necessary, via a shallow shaft. The area under Tarantula Mesa contains an estimated 450 million short tons of in-place, deep coal resources in one thick coal bed. Assuming roof and floor conditions are not adverse, these coal resources are large enough to support several deep mines producing as much as 2 to 3 million short tons of coal per year.

The Muley Canyon coal is of better quality than the Ferron coal, and thus probably could supply a suitable product for electric-power generation despite containing higher amounts of ash and sulfur in places. The coal is slightly inferior in quality to that typically produced from the Blackhawk Formation mines in the central Utah coal fields. Environmental, wilderness, and transportation issues are possible deterrents to future development of at least part of the Muley Canyon coal deposits, but the actual amount of these resources suitable for eventual mining awaits further and more detailed engineering, environmental, geologic, and marketing studies.

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