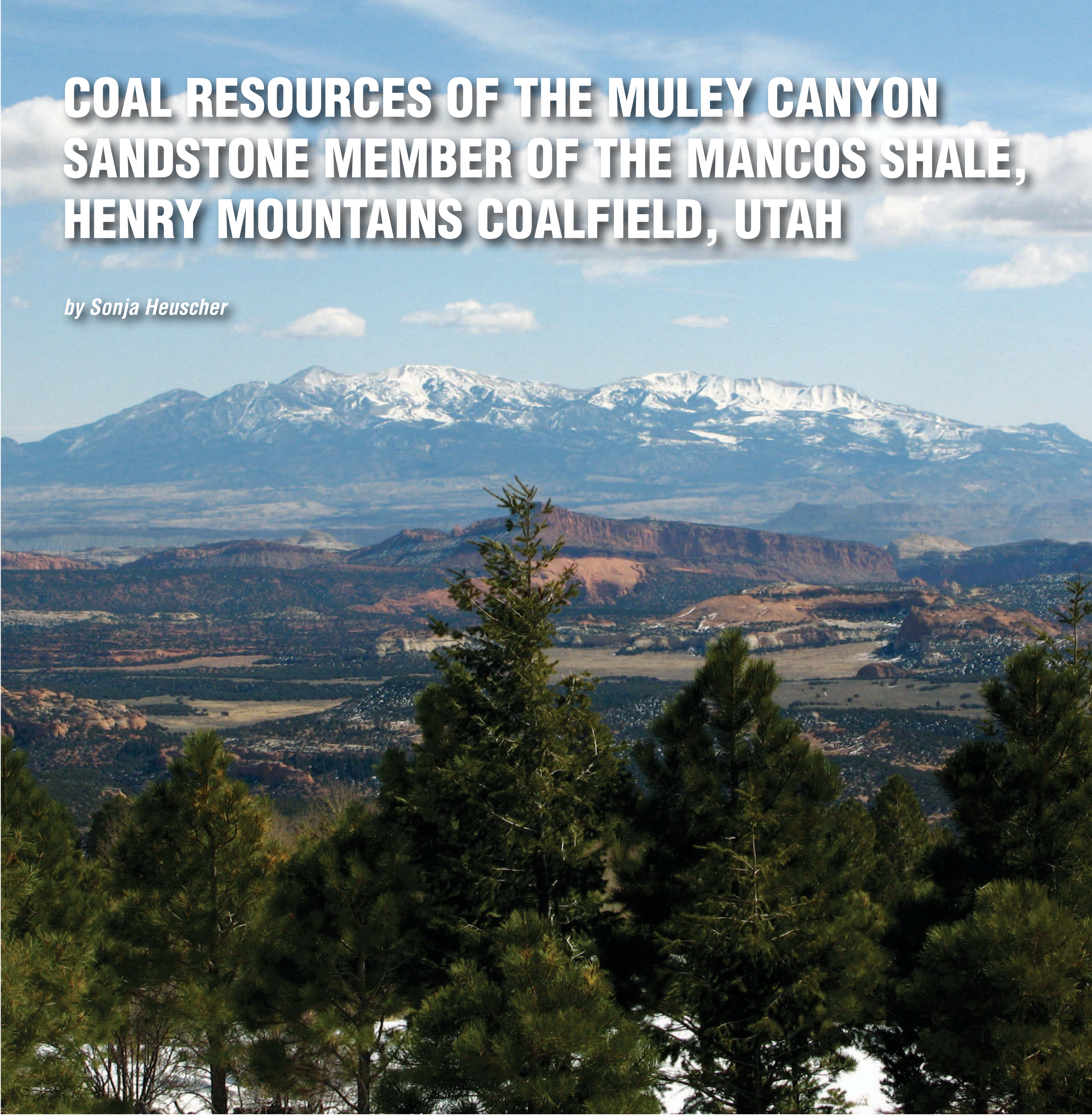
# COAL RESOURCES OF THE MULEY CANYON SANDSTONE MEMBER OF THE MANCOS SHALE, HENRY MOUNTAINS COALFIELD, UTAH

*by Sonja Heuscher*



**SPECIAL STUDY 138**
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*a division of*
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***Cover photo:*** *View to the east across the Henry Mountains Basin, Mt. Ellen and the Henry Mountains in the distance.*

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# Coal Resources of the Muley Canyon Sandstone Member of the Mancos Shale, Henry Mountains Coalfield, Utah

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## ABSTRACT

A re-evaluation of the underground minable coal resources in the Muley Canyon Sandstone Member of the Mancos Shale in the Henry Mountains coalfield was based on a compilation of existing geologic data from the Utah Geological Survey's coal files and published geologic reports. Previously uncalculated land-use and technical restrictions to the minable coal resource are included in this report. The Henry Mountains coalfield contains 875 million tons of potentially minable coal. Due to technical restrictions, 217 million tons of this coal are inaccessible to mining and 73 million tons cannot be mined due to land-use conflicts, leaving 585 million tons of coal available to mine. This report differs from previous evaluations in that it includes additional coal-bed thickness observations and accounts for common restrictions to the minable coal resource.

## INTRODUCTION

### Objectives

The purpose of this study is to evaluate the coal resource in the Muley Canyon Sandstone Member of the Mancos Shale. Although several previous studies of the coal resource have been conducted, this study differs from previous work by providing a detailed assessment of the effect of technical and land-use restrictions on mining the resource. New data are included in this study resulting in an up-to-date evaluation of the coal resource in the Muley Canyon Sandstone.

### Site Location and Description

The Henry Mountains coalfield is in central Wayne and Garfield Counties in a remote area of Utah with few paved roads. The Cretaceous outcrop shown on figure 1 defines the extent of the coalfield. State Highway 24 crosses the northern part of the coalfield, and State Highways 24, 95, and 276 parallel the eastern margin of the Henry Mountains (figure 1). The nearest rail line is about 60 miles northeast of the coalfield at Green River, Utah. Access to most of the coalfield is by a network of dirt roads. The southwestern margin of the coalfield lies within Capitol Reef National Park, and the Mt. Ellen–Blue Hills and Mt. Pennell Wilderness Study Areas (WSA) overlie significant parts of the north and south ends of the coalfield (figure 2).

### Geology

The Henry Mountains coalfield lies in a structural basin called the Henry Mountains syncline. The syncline is bounded on the west by the Waterpocket Fold, and on the east by the Henry Mountains and Monument upwarp (Doelling and Graham, 1972). This north-south elongated basin extends about 50 miles along its axis and is 2 to 18 miles wide (figure 1). The coalfield consists primarily of two coal-bearing units within the Cretaceous Mancos Shale: the Ferron Sandstone Member and the Muley Canyon Sandstone Member, which lies about 1000 feet above the Ferron Member. The outcrop of the Ferron Sandstone Member defines the extent of the coalfield. The Muley Canyon Sandstone Member is the focus of this study.

The stratigraphic nomenclature of Cretaceous units in the Henry Mountains Basin has changed three times, and a fourth change was proposed by Eaton (1990) (figure 3). Nomenclature proposed by Smith (1983) was used in this study. Peterson and others (1980) described the stratigraphy of the Upper Cretaceous units in the Henry Mountain syncline, and a detailed lithofacies description of the Muley Canyon Sandstone and Masuk Members was completed by Birgenheier and others (2009).

### Previous Work

The first descriptions of the geology and coal deposits of the Henry Mountains region were done by Gilbert (1877). In the 1930s, the first detailed study of the coal deposits of the Henry Mountains coalfield was conducted by the U.S. Geological Survey (USGS) (Hunt and others, 1953). Doelling and Graham (1972) provided a detailed evaluation of the coalfield resources as part of their comprehensive study of the coal deposits of Utah. Doelling (1975) and Doelling and Smith (1982) later revised these estimates to provide more details on the surface-minable resources of the field. Mckell and others (1978) compiled existing data on the coal deposits and evaluated post-mining reclamation strategies for the U.S. Bureau of Land Management (BLM). Law (1977, 1979a,b, 1980) reported results of USGS drilling and fieldwork in the coal zone of the Emery Sandstone Member of the Mancos Shale (called the Muley Canyon Sandstone in this report). Hatch and others (1977) and Tabet (1999) provided coal-quality data for the Ferron and Emery Sandstone (Muley Canyon Sandstone) Members. Muley Canyon coal rank ranges from subbituminous A to high volatile bituminous C (Tabet, 1999).

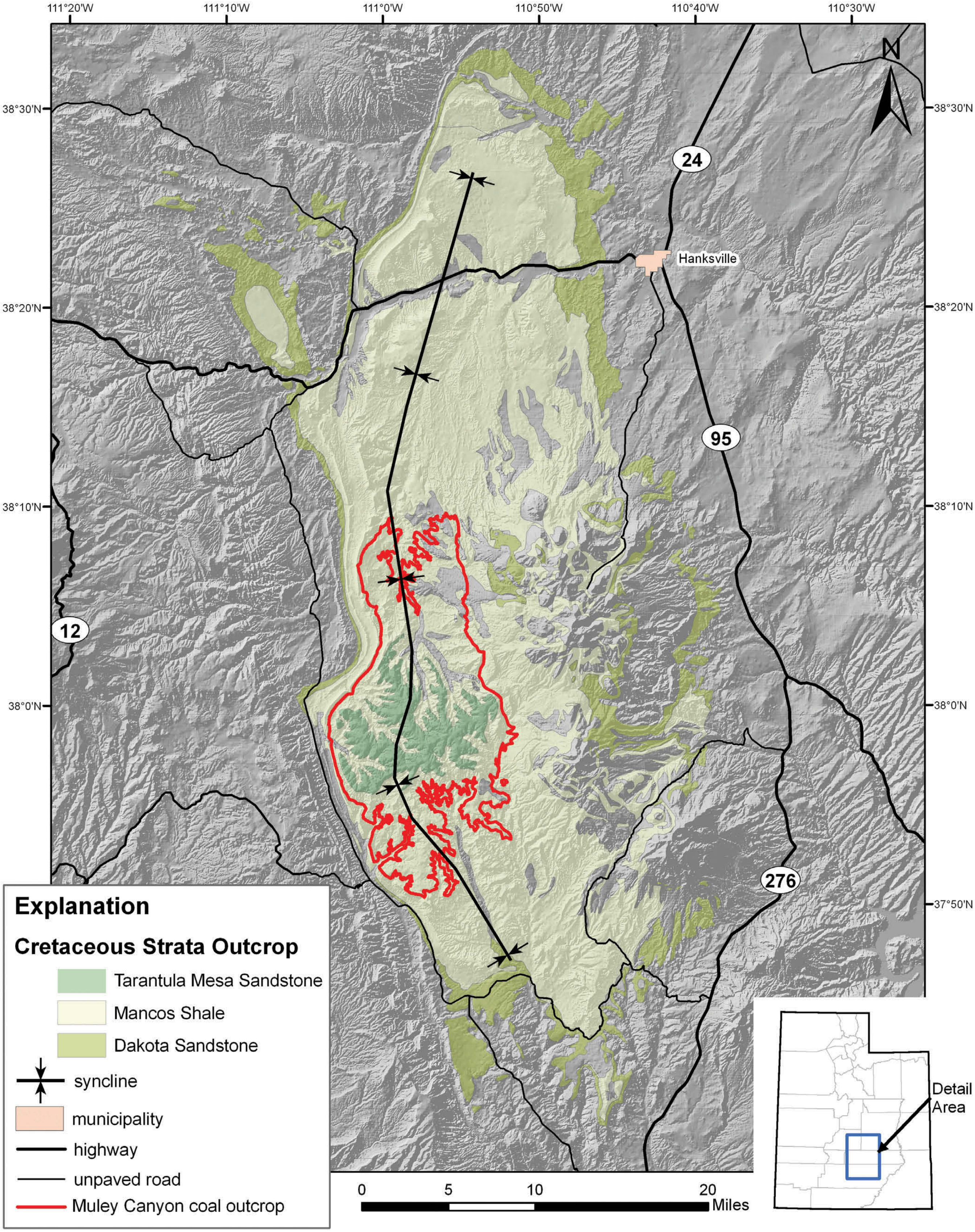


***Figure 1.*** *The Henry Mountains syncline, surrounding geologic units (Hunt and others, 1953), and Muley Canyon coal outcrop location. Coal-bearing units are in the Mancos Shale.*

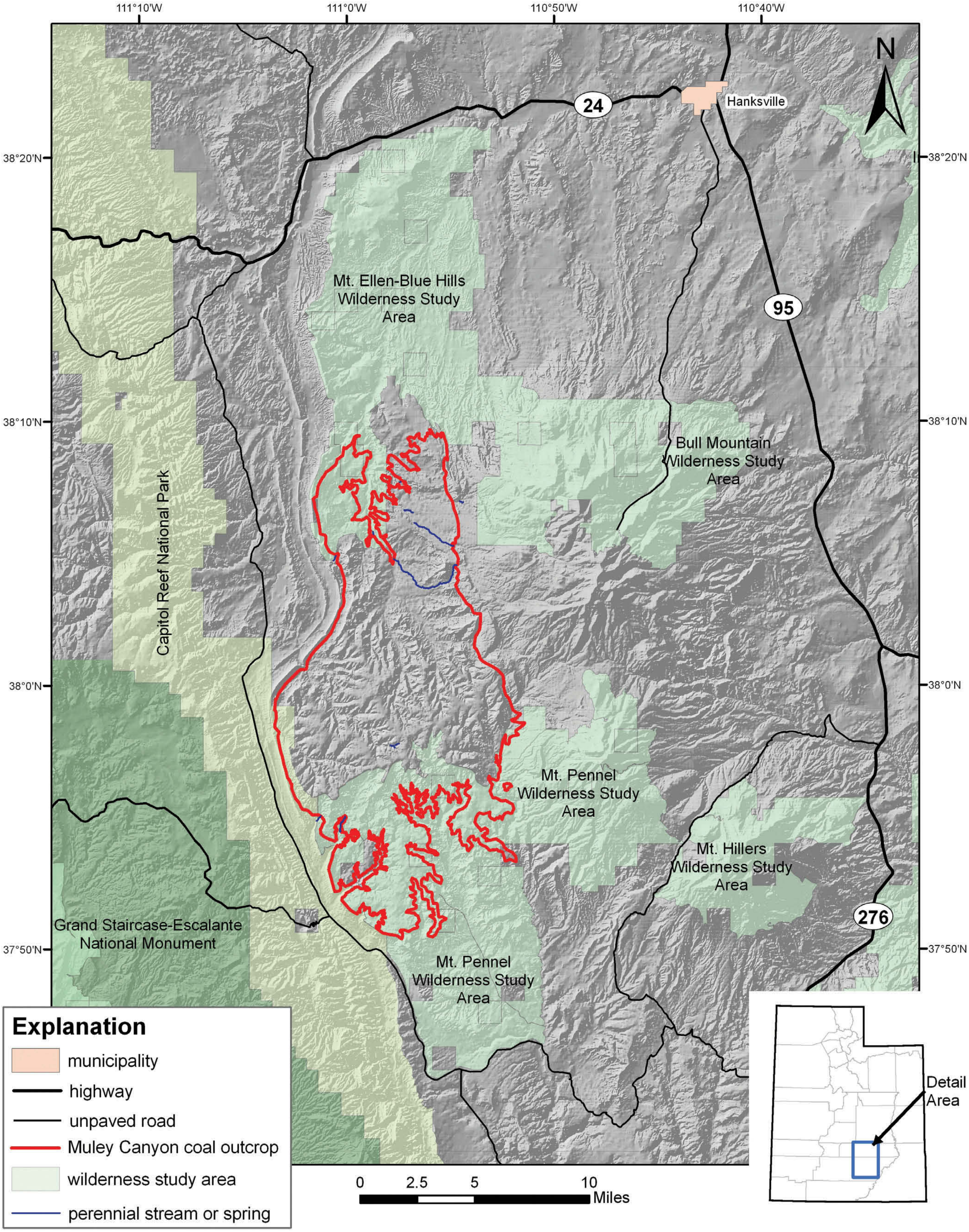


***Figure 2.*** *Wilderness study area and national park locations, and major access roads.*

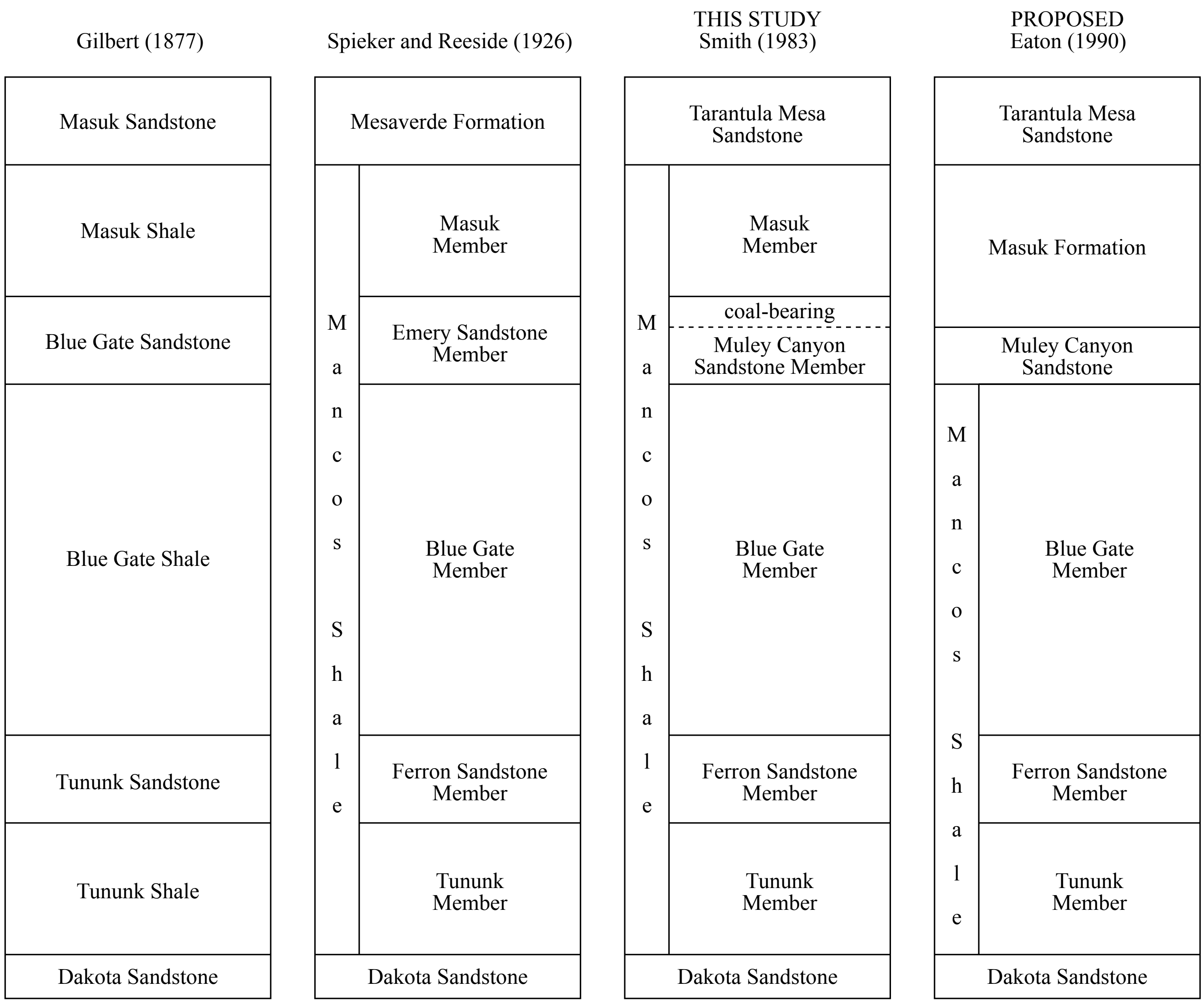


***Figure 3.*** *Evolution of Upper Cretaceous stratigraphic nomenclature of the Henry Mountains Basin (Tabet, 2000).*

The Muley Canyon coal's mean ash content is 11.74%, and its average sulfur content is 0.9%. The heat content of Muley Canyon coals ranges from 7710 to 12491 Btu per pound and averages 10086 Btu per pound (Tabet, 1999). Tabet (1999, 2000) also provided an updated coal resource assessment and a generalized geologic map of the Henry Mountains coalfield based on parts of four regional maps by various authors. Bon (2005) evaluated coal resources of state-owned lands in the Muley Canyon Sandstone. Birgenheier and others (2009) recently finished a sequence stratigraphic assessment of the Muley Canyon Sandstone and Masuk Formation, and their measured section data were included in this study.

## Mining History

Four coal mines have operated in the Henry Mountains coalfield but are now closed and abandoned. Two of these mines, the Dugout Creek mine and the Sweetwater Creek mine, produced coal from the Muley Canyon Sandstone (figure 4). Coal exploration occurred in the area from the late 1960s through early 1980s. Several companies were active in the Henry Mountains coalfield and most of the data used in this evaluation were acquired during that time. Exploration on federal and state-owned lands in the Muley Canyon coal zone was carried out by AMAX Coal Company, Cayman Corporation, Consolidation Coal Company, Gulf Mineral Resources Company, and the USGS. The primary interest at the time was evaluating surface-minable coal deposits, but environmental and economic concerns halted exploration (Tabet, 2000).

# METHODS

## Resource Evaluation

Wood and others (1983) define 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, I did not consider coal-production costs, the percent of the coal that can be recovered, or other factors required to estimate the coal reserve. Instead, I identified the in-place coal resource in the study area, which excludes coal in thin riders and sub-beds. From this in-place resource, I identified a subset called the available coal resource. The available coal resource is that part of the in-place coal that could be mined by conventional methods.

## Spatial Data used to Calculate Coal Resource Tonnage

Geographic and stratigraphic spatial data were used to calculate the coal resource in the Muley Canyon Sandstone Member of the Mancos Shale in the Henry Mountains coalfield. These data were used to create new maps showing the thickness, extent, and depth of coal beds, and to evaluate the impact of geologic, geographic, and land-use features on future coal mining. Data used to evaluate the amount of available coal in the study area are from Utah Geological Survey (UGS) files, the Utah Division of Oil, Gas, and Mining (DOGM, 2009), Environmental Systems Research Institute (ESRI, 2009), the Utah Automated Geographic Reference Center (AGRC, 2009), and the U.S. Department of Transportation (DOT, 2008).

Coal exploration drill hole data are electronic files compiled by the UGS for the National Coal Resources Data System. Data from 107 drill holes and 27 measured sections (figure 4) were used in this study. Before any maps were created, the geophysical logs from the drill holes were interpreted and the associated data entered into a spreadsheet. These data include the drill hole American Petroleum Institute (API) number, surface elevation, and Universal Transverse Mercator (UTM) coordinates, as well as the depth and thickness of the coal bed. The wide spacing of the limited number of drill holes in most of the study area makes correlation of coal beds over long distances difficult. For this reason, results identify areas having potentially minable coal, but more detailed drilling is needed to precisely define specific tracts of coal reserves. A structure contour map (figure 5) of the top of the Muley Canyon coal zone was created from the drill hole and stratigraphic data. The synclinal nature of the basin is apparent in this map.

## Method Used to Calculate Coal Resource Tonnage

Calculation of the in-ground coal tonnage requires knowing the areal extent, thickness, and density of each coal bed. For each bed, values for the areal extent for incremental thickness categories were calculated in ArcMap and entered into a spreadsheet where the coal tonnage was calculated using a coal density of 1800 tons per acre-foot of coal (Wood and others, 1983). The midpoint thickness for each thickness category was used in the tonnage calculation. For example, GIS analysis revealed 3075 acres where the available underground-minable coal in the Muley Canyon coal zone is between 4 and 4.25 feet thick (midpoint equals 4.13 feet). The spreadsheet calculation,

$$3075 \text{ acres} \times 4.13 \text{ feet coal} \times 1800 \frac{\text{tons coal}}{\text{acre-foot}} = 22.9 \text{ million tons coal},$$

shows that about 22.9 million tons of 4 to 4.25 foot-thick coal in the Muley Canyon coal zone are available for underground mining. Small coal thickness categories (0.25 foot) were used for an accurate estimate of the tonnage.

## Creating Maps

Maps created in this study are similar to those from previous UGS coal-resource studies except that they are based on more recent and comprehensive outcrop and drill-hole data. All maps were created using the Spatial Analyst extension for ArcGIS 9.3 software. Calculations in Spatial Analyst were based on identically registered, 10-meter grid cells (0.0247 acre) using zone 12, NAD83, UTM coordinates. A coal-bed thickness map was made using a second-order, six nearest neighbor, inverse-distance, mapping function. A coal-bed structure contour map was made using a tension, six nearest neighbor, spline, mapping function; this map was made for a single contiguous coal-bearing area. Coal-bed outcrop lines digitized from Doelling and Graham (1972) defined the edge of the study area. However, the intersection of the modeled coal-bed elevation and surface elevation in some locations did not match the outcrop mapped by Doelling and Graham (1972), due to the rapid change in dip along either side of the Henry Mountain syncline.

### Coal-Bed Thickness Map

Coal oxidation near the outcrop often reduces the thickness of coal beds in Utah. Oxidation can also cause slumping of overlying sediments, which further reduces the apparent coal-bed thickness at the outcrop (Doelling, 1968). Thus, outcrop observations in Utah are rarely representative of the amount of coal buried behind the outcrop. Because I had limited information from drill holes near the outcrop (figure 4), I also used some less-reliable outcrop thickness observations.

The proximity of national parks and wilderness study areas will likely preclude mining by surface (open-pit) methods in this area (figure 2). Because of this, the available coal resource was determined only for underground-minable coal. A coal-bed thickness map was constructed to include only those parts of the bed that might be recovered using underground

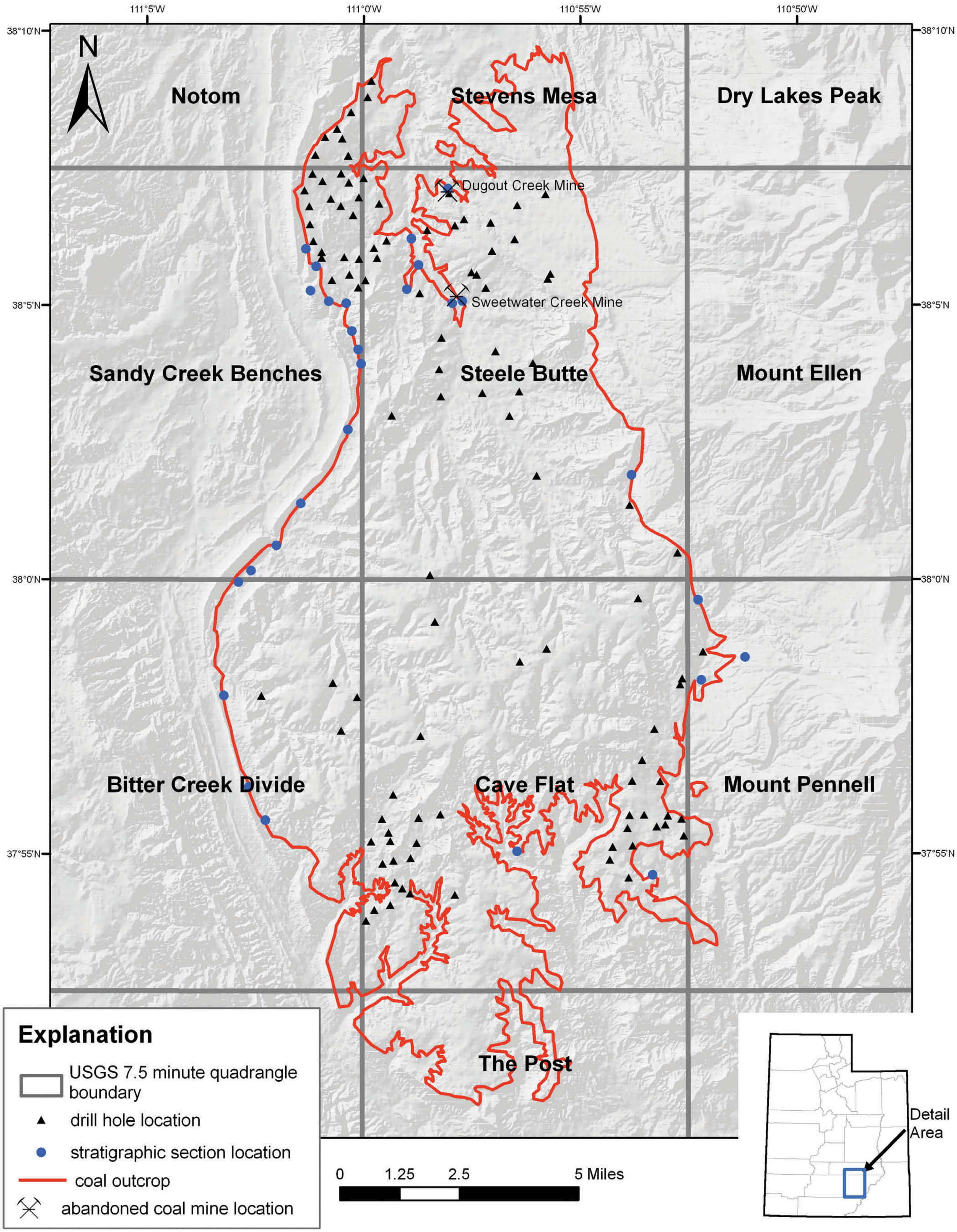


***Figure 4.*** *Drill hole and stratigraphic section data points used in this study.*

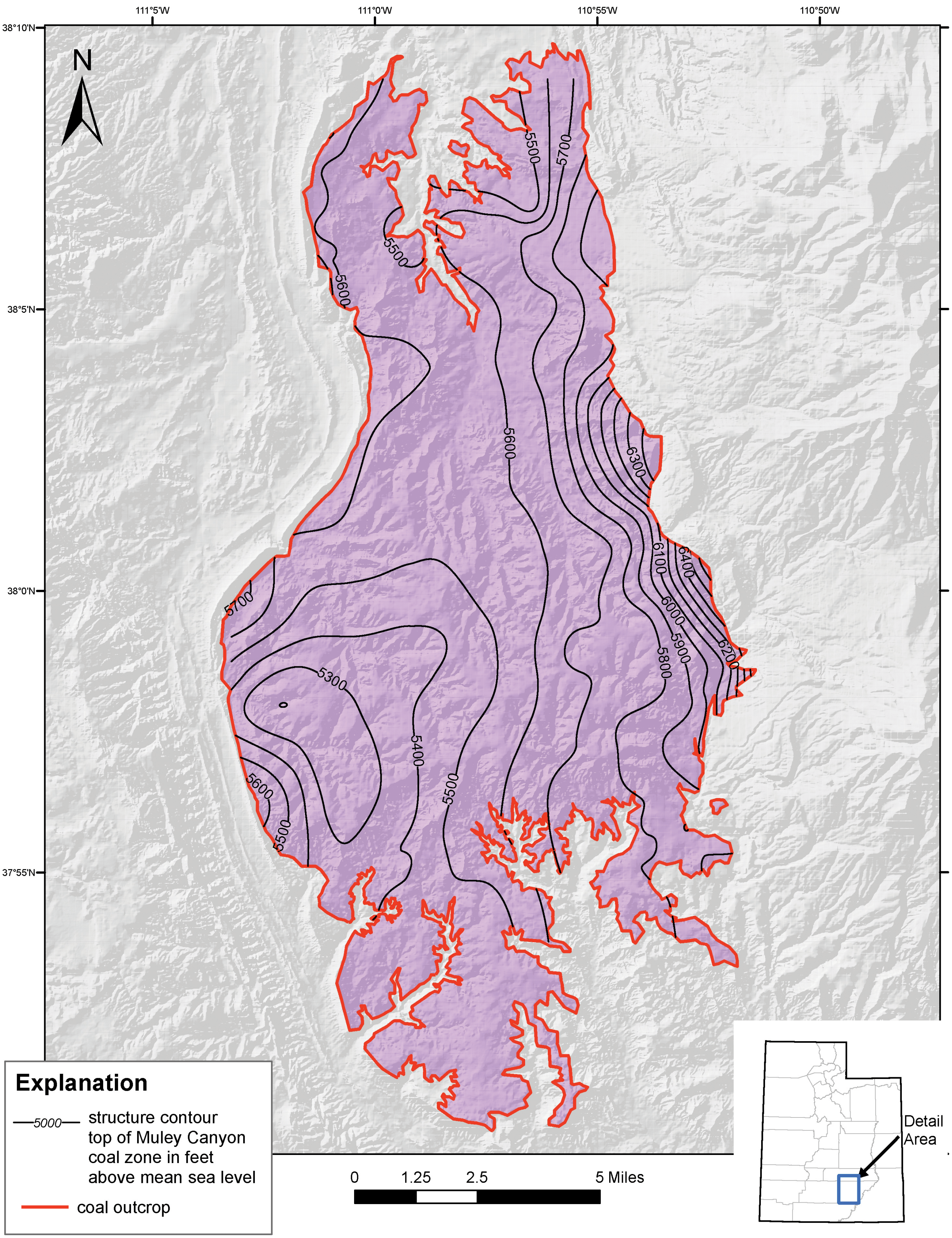


***Figure 5.*** *Structure map of the top of the Muley Canyon Sandstone coal.*

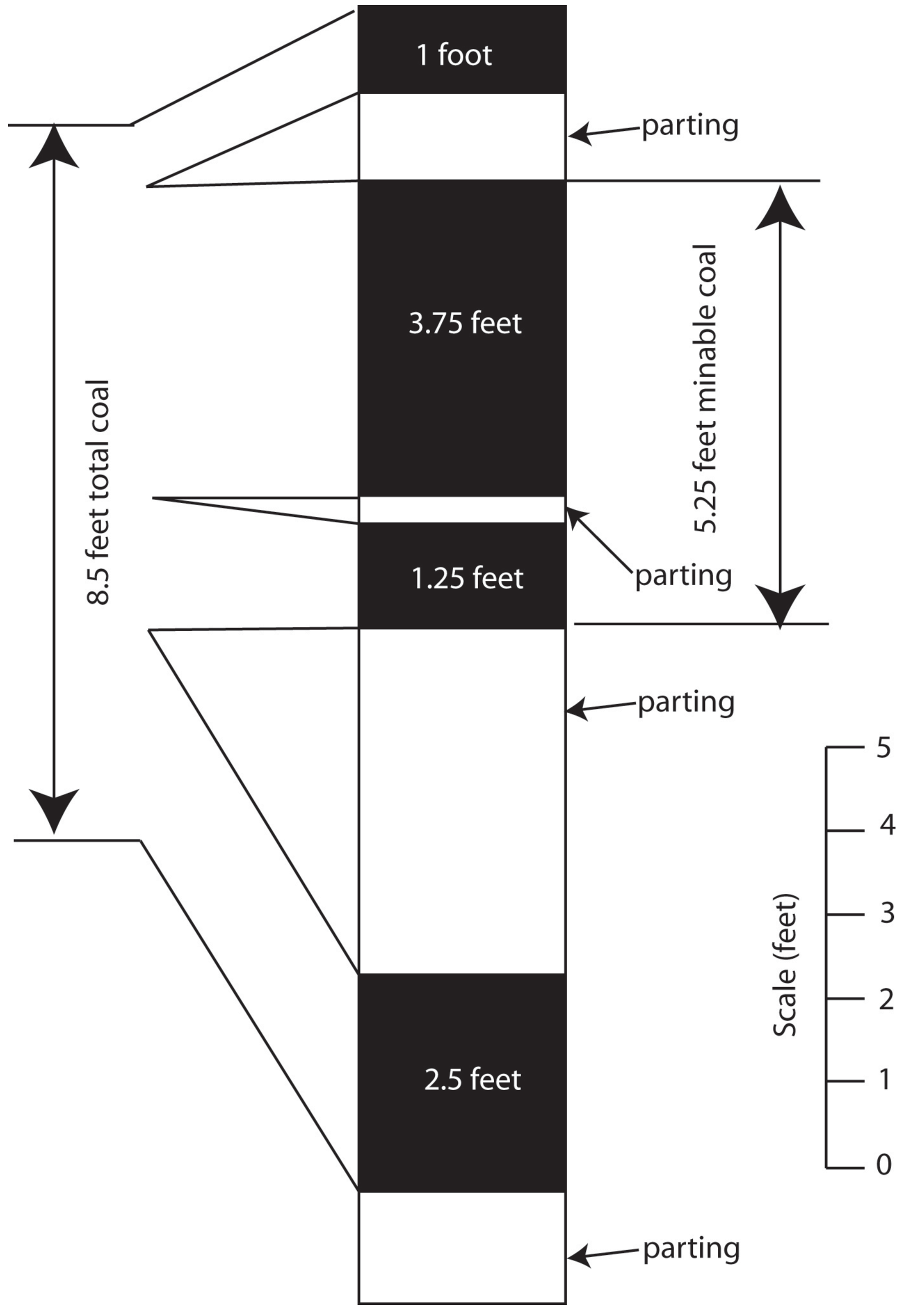


***Figure 6.*** *An example of a stratigraphic section or drill hole showing the underground-minable coal thickness and total coal thickness.*

mining methods; this map excludes coal in thinner splits, riders, and sub-beds that are separated from the thickest bed by more than one foot of rock. Identifying the underground-minable part of a coal bed is sometimes difficult where numerous partings, splits, riders, and sub-beds occur. Accordingly, some arbitrary but consistent rules were used to distinguish the underground-minable part of a coal bed. The underground-minable coal thickness in a given drill hole or stratigraphic section is the contiguous part of the coal bed that excludes partings, with the exception that partings less than 1 foot thick are included if two conditions are met: (a) both the coal above and below a parting are at least twice the thickness of the included parting, and (b) the included partings account for less than 20% of the minable coal thickness. Figure 6 illustrates how these rules are applied to a stratigraphic section or drill hole to determine underground-minable coal thickness.

## Coal-Bed Overburden Map

An overburden thickness map was made for the top of the minable coal bed encountered in the 107 drill holes shown on figure 4. The depth of the coal bed (overburden thickness) was calculated by subtracting the newly created structure contour map of the top of the bed from surface elevations obtained from the AGRC digital elevation model. Due to the scarcity of uniformly spaced drill hole observations, some error may occur in projecting structural trends into areas with little or no drill hole control.

## Coal-Bed Interburden

The thickness of rock between adjacent coal beds (the interburden) is significant because two beds with less than 40 feet of interburden cannot both be mined safely by underground mining methods. The interburden between the minable portions of the coal beds in the study area is everywhere less than 40 feet, and therefore this restriction applied to all beds. Generally, the thicker and more persistent bed was retained as the minable bed, while the thinner and less persistent bed was deemed unminable in resource calculations.

## 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 precluded because of technical or land-use restrictions. 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 damage human infrastructure or environmental assets. Table 1 lists the technical and land-use restrictions that are used in this study, together with their associated buffers and restriction factors. Figure 2 shows the location of the land-use restrictions.

## Restrictions for Underground-Minable Coal

In 2010, all active Utah coal mines were underground mines. Most of these mines used 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 coal beds. In the eastern U.S., underground coal mines sometimes work beds as thin as 2 or 3 feet (Tabet and others, 2009). However, this is done only where some special circumstance or use of the coal justifies a premium price. Moreover, underground mining of thinner coal beds in the eastern U.S. is possible because these Carboniferous-age coal beds typically maintain uniform thickness over large areas, which allows sufficient production to recover the cost of thin-coal mining equipment (Tabet and others, 2009). Cretaceous-age coal beds 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 coal beds can be economically mined under current market conditions. Furthermore, even if a premium price were offered for Utah coal, mining these thinner coal beds would be challenging because they are not uniformly thick over large areas (Tabet and others, 2009). Given these circumstances, a 4-foot minimum thickness restriction was used in this study to identify the underground-minable coal resource.

Although coal beds greater than 14 feet thick are actively mined, current underground mining machines in Utah can recover only a 14-foot-thick portion of the coal bed; the remaining coal is lost. Thus, where the coal beds in the study area are very thick, a maximum 14-foot thickness restriction was used to identify the underground-minable coal resource.

Other technical restrictions to underground mining were also considered. To avoid unstable roof conditions and possible

***Table 1.*** *Restrictions to underground mining in the Henry Mountains coalfield, Utah.*

| Technical Restrictions | Buffer or Factor |
|---|---|
| Minimum bed thickness | 4 feet |
| Minimum overburden | 100 feet |
| Maximum bed thickness | 14 feet |
| Maximum overburden | 3000 feet |

| Land-Use Restrictions | Buffer or Factor |
|---|---|
| Perennial streams and springs | 100 feet on either side |
| National park | 100 feet around margin |
| Wilderness study area | 100 feet around margin |

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, so a minimum 100-foot burial depth restriction was chosen to exclude weathered coal. In areas with multiple coal beds, 40 feet of interburden is required to allow for stable roof and floor conditions if both of the coal beds are mined, but only one bed is designated as minable in the study area, so this restriction does not apply. The maximum amount of overburden routinely planned for at most Utah coal mines is 2500 feet. 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.

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 perennial streams and springs, Capitol Reef National Park, and two wilderness study areas (figure 1). Land-use restrictions that prohibit mining under power lines, railroads, improved roads, pipelines, radio towers, producing oil and gas wells, towns, lakes and reservoirs, and cemeteries were not considered because these features do not occur in the study area.

***Table 2.*** *Coal-bed thickness categories used in this report compared to those used in the Coal Resource Classication System of the USGS (Wood and others, 1983).*

| This Report (feet) | USGS (feet) |
|---|---|
| 1 to 2 | 1.2 to 2.3 |
| 2 to 4 | 2.3 to 3.5 |
| 4 to 6 | 3.5 to 7.0 |
| 6 to 10 | 7 to 14 |
| 10 to 14 | |
| over 14 | over 14 |

***Table 3.*** *Coal-bed 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) |
|---|---|
| 0 to 100 | 0 to 500 |
| 100 to 1000 | 500 to 1000 |
| 1000 to 2000 | 1000 to 2000 |

### Thickness and Overburden Categories

Coal-bed thickness categories reported in this study are similar to those recommended by the USGS (Wood and others, 1983), but in this study, thinner increments were used for the resource calculations. The Utah Geological Survey also deviates from the USGS classification to account for current Utah mining practice, which preferentially selects coal beds that are more than 6 feet thick. Table 2 compares the coal-bed thickness categories used in this report to those recommended by the USGS.

Table 3 compares the overburden categories used in this report to those recommended by the USGS (Wood and others, 1983). To identify shallow coal that is likely weathered or burned, a 0- to 100-foot depth restriction for underground-minable coal was used. Other overburden thicknesses were grouped into categories of 100 to 1000 feet and 1000 to 2000 feet.

### Reliability Categories

Three reliability categories (Wood and others, 1983) were used in this study. The first category is coal within 0.75 mile of a measured thickness location, called the demonstrated coal resource. The inferred coal resource is between 0.75 and 3 miles of a measured thickness location. The hypothetical coal resource is coal that is more than 3 miles from a measured thickness location.

The study area has relatively few drill hole or other coal measurements (107 drill holes, 27 measured sections), and most of those measurements are irregularly spaced across the study area. The non-uniform and sparse distribution of the drill holes and outcrop observations, and the possibly lenticular nature of coal beds, make correlation of the coal beds in this field problematic and the resource determination less reliable.

## RESULTS

### Thickness of the In-Place Coal Resource

The in-place coal resource is the tonnage of minable coal that exists in the study area without consideration of land-use or technical restrictions. Table 4 shows tonnage values according to thickness categories calculated in this study for the Muley Canyon Sandstone coal. Most of the coal (67%) is located in beds that are greater than 6 feet thick, and about 85% of the original minable coal is in beds that are more than 4 feet thick. Coal thickness apprears to be more variable in the northern part of the study area (figure 7). Coal under Tarantula Mesa is thicker and appears to be more consistent in thickness than the rest of the study area, but due to a lower data point density on the mesa, additional drilling would be necessary to verify this. The area designated as Tarantula Mesa on figure 7 is defined by the Tarantula Mesa Sandstone outcrop line on figure 1.

***Table 4.*** *Original coal resource for Muley Canyon Sandstone coal (greater than one foot thick) by thickness categories.*

| Thickness (feet) | Coal Tonnage (millions tons) | Percent (%) |
|---|---|---|
| 1–2 | 7 | 0.8 |
| 2–4 | 124 | 14 |
| 4–6 | 138 | 16 |
| 6–10 | 256 | 29 |
| 10–14 | 336 | 38 |
| greater than 14 | 14 | 1.6 |
| Total: | 875 | 100 |
| Total > 4 feet: | 744 | 85 |

*Note that totals may differ from sum of columns due to rounding.*

## Depth of the Underground-Minable, Original Coal Resource

Table 5 shows the tabulation of the underground-minable, original coal resource by overburden thickness, for all coal beds that are more than one foot thick. Table 6 shows the tabulation of overburden and thickness. Fourteen percent of coal in the study area is at depths less than 100 feet, which is too shallow for underground mining. All the remaining coal is less than 2000 feet deep, which is suitable for underground mining. Figure 8 shows the coal overburden distribution for Muley Canyon Sandstone coal. Coal under Tarantula Mesa is over 500 feet deep (figure 8) necessitating underground mining.

## Coal Lost to Technical Restrictions

Table 7 shows the amount of coal lost to technical restrictions in the study area. Most of the coal is moderately thick and could be fully mined by underground technology. However, a small portion of the coal (0.1%) is thicker than 14 feet and subject to a maximum thickness cutoff. About 15% (131 million tons) of the original coal resource is in beds that are too thin for underground mining (less than 4 feet thick). Fourteen percent of the original coal resource is in beds that are too shallow to underground mine. The combination of beds that are too thin, too thick, or too shallow to mine results in 25% of the original coal resource in the study area having mining restrictions. This leaves 658 million tons of technically minable coal. Multiple technical restrictions can occur in the same place in the study area resulting in the technical net restricted coal, not a simple sum of individual restrictions (table 7).

## Coal Lost to Land-Use Restrictions

Land-use restrictions exclude 73 million tons of coal (table 8, figure 2), which is about 11% of the technically minable coal resource in the study area. Sixty million tons is potentially lost where the coal is located in wilderness study areas. Thirteen million tons is located in Capitol Reef National Park. Only 0.3 million tons occur under or near streams and springs. No technically minable coal in the study area underlies railroads, municipalities, improved roads, power lines, pipelines, or producing oil and gas wells. Given all the technical and land-use restrictions, there is 585 million tons of available coal in the study area.

## The Available Coal Resource

Figure 9 shows the location of the available coal resource with the thickness categories discussed previously. Of the 658 million tons of technically minable coal, 585 million tons (89%) is available for underground mining (table 8). The reliability of this calculation was evaluated using the spatial distribution of drill hole observations using a resource classification scheme developed by the USGS (Wood and others, 1983). About 268 million tons (46%) of the available coal resource (table 9) is classified as a demonstrated resource (less than 0.75 mile from a thickness location), whereas 317 million tons (54%) is classified as an inferred resource (0.75 to 3 miles from a thickness location). None of the coal in the study area is a hypothetical resource (greater than 3 miles from a measurement point). Figure 10 shows the map extent of these reliability categories.

The largest area of available coal underlies Tarantula Mesa

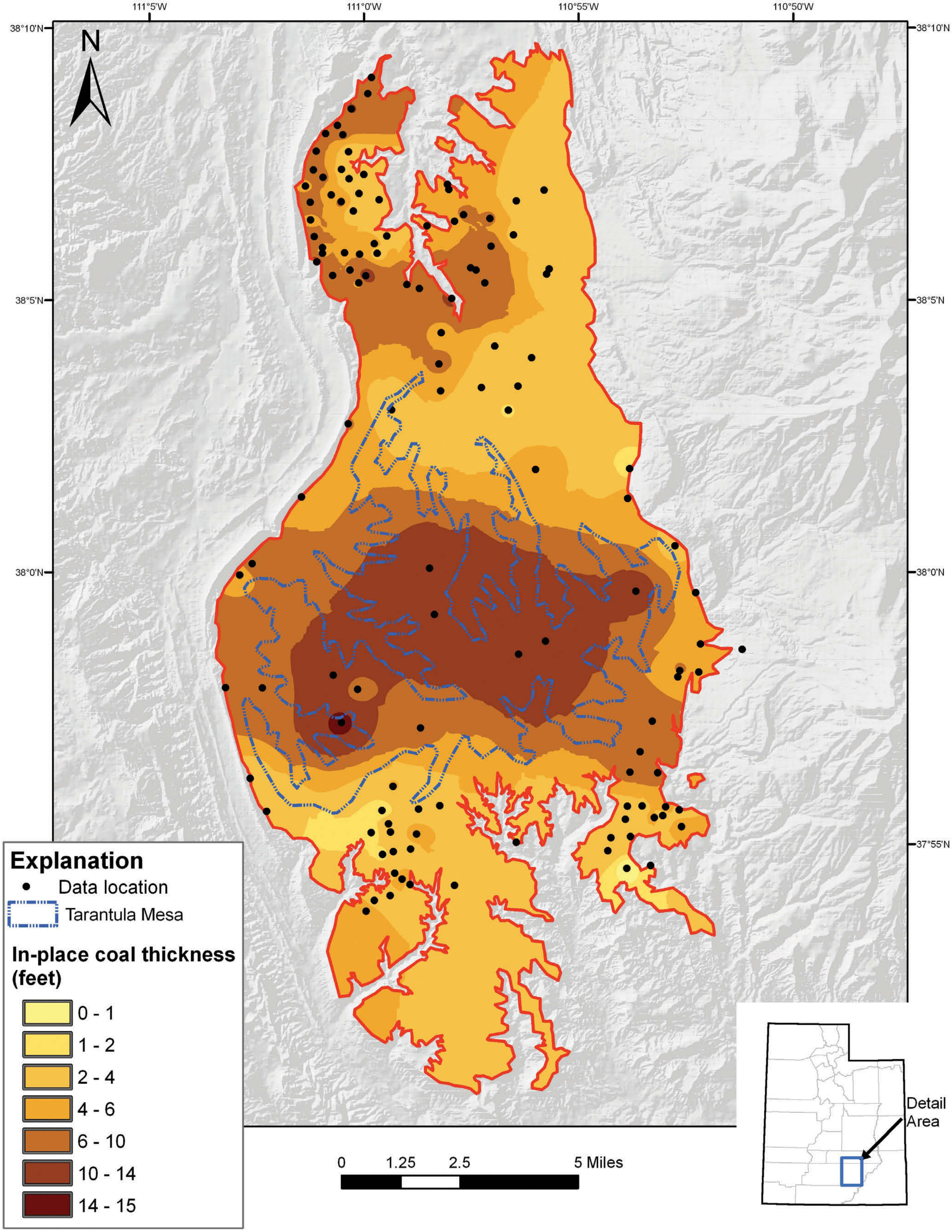


***Figure 7.*** *Original in-place coal resource for the Muley Canyon Sandstone coal, Henry Mountains coalfield, Utah.*

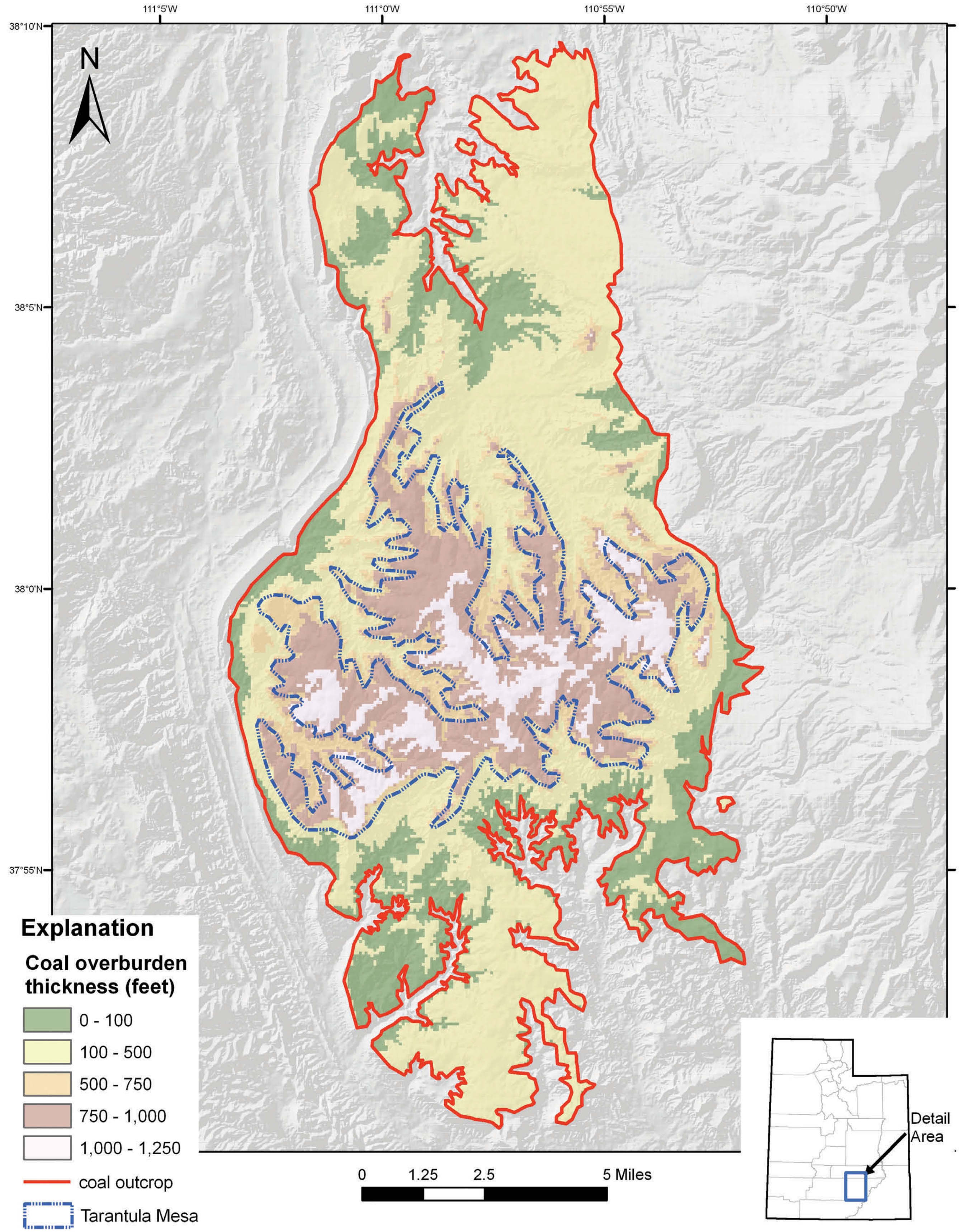


***Figure 8.*** *Overburden thickness for the Muley Canyon Sandstone coal, Henry Mountains coalfield, Utah.*

***Table 5.*** *Original coal resource for Muley Canyon Sandstone coal (greater than 1 foot thick) by overburden categories.*

| Thickness (feet) | Coal Tonnage (millions tons) | Percent (%) |
|---|---|---|
| 0–100 | 120 | 14 |
| 100–1000 | 643 | 74 |
| 1000–2000 | 111 | 13 |
| 2000–3000 | 0 | 0 |
| Total: | 875 | 100 |

*Note that totals may differ from sum of columns due to rounding.*

***Table 6.*** *Original coal resource (millions of tons) for Muley Canyon Sandstone coal by thickness and depth of cover for coal beds greater than 1 foot thick.*

| Thickness (feet) | 0–100 Feet Overburden | 100–1000 Feet Overburden | 1000–2000 Feet Overburden |
|---|---|---|---|
| 1–2 | 3 | 4 | 0 |
| 2–4 | 31 | 91 | 1 |
| 4–6 | 31 | 103 | 3 |
| 6–10 | 50 | 188 | 18 |
| 10–14 | 4 | 246 | 86 |
| greater than 14 | 0 | 10 | 4 |

(figure 9). Because the continuity and consistency of coal-bed thickness in this area seem the most attractive for underground mining, the available coal under just Tarantula Mesa was calculated (table 10). However, the density of drill holes on the mesa is low (figure 10), which reduces the amount of coal that could be classified in the most reliable demonstrated category.

## DISCUSSION AND CONCLUSIONS

Results from calculations of the amount of in-place and amount of available coal resource for the Muley Canyon Sandstone in the Henry Mountains coalfield are provided in tables 6 and 9. Maps showing the overburden, thickness of in-place resource, and thickness of the available coal resource in the Muley Canyon Sandstone are in figures 7, 8, and 9. About 875 million tons of minable coal occur in beds more than one foot thick. Of the original 875 million tons, 585 million tons is available for mining. Of the original coal resource, 131 million tons is in beds that are too thin (less than 4 feet thick) for mining, about 120 million tons is too shallow for underground mining, and 73 million tons is subject to land-use restrictions. The most significant potential land-use restriction is land classified as wilderness study areas, which removes 60 million tons.

About 46% of the available coal resource is demonstrated (within 0.75 mile of a measurement location), and the remaining 54% is inferred (between 0.75 and 3 miles of a measurement location). The area under Tarantula Mesa is the most favorable for underground mining, and it appears to have the most consistent coal-bed thickness. Considered in isolation, calculations show that 80% of the available coal resource (467 million tons) underlies Tarantula Mesa in beds that are between 6 and 14 feet thick. Nonetheless, more drilling is necessary in this area to more reliably determine the coal resource.

The calculations in this report (658 million tons technically minable coal) are slightly more than the deep-minable resource (646 million tons) reported in Bon (2005). The amount of coal calculated under Tarantula Mesa (467 million tons) matches fairly well with that calculated (450 million tons) in Tabet (1999).

Fourteen percent (84 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 in the near future. Excluding the relatively thin, 4- to 6-foot-thick coal, and assuming 65% recovery from underground longwall mines, about 325 million tons of coal might be produced from the Muley Canyon coal. This estimated resource is sufficient to support a single 4-million-ton-per-year underground mine for about 81 years. Assuming 65% recovery from the Tarantula Mesa area, about 303 million tons of coal could be produced, potentially supporting a 4-million-ton-per-year underground mine for 76 years.

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***Table 7.*** *Technical restrictions to minable coal.*

| Technical Restrictions | Coal Tonnage (millions tons) | Percent (%) |
|---|---|---|
| original coal | 875 | 100 |
| too deep | 0 | 0 |
| too thin | 131 | 15 |
| too thick | 0.7 | 0.1 |
| too shallow | 120 | 14 |
| interburden | N/A | N/A |
| Technical net restricted | 217 | 25 |
| Technically minable | 658 | 75 |

*Note: some coal occurs in both "too thin" and "too shallow" categories.*

***Table 8.*** *Land-use restrictions to minable coal.*

| Land-Use restriction | Coal Tonnage (millions tons) | Percent (%) |
|---|---|---|
| municipalities | 0 | 0 |
| oil and gas wells | 0 | 0 |
| wilderness study areas | 60 | 9 |
| national parks | 13 | 2 |
| power lines and pipelines | 0 | 0 |
| streams, springs, water bodies | 0.3 | 0.05 |
| Land use net restricted | 73 | 11 |
| Available coal | 585 | 89 |

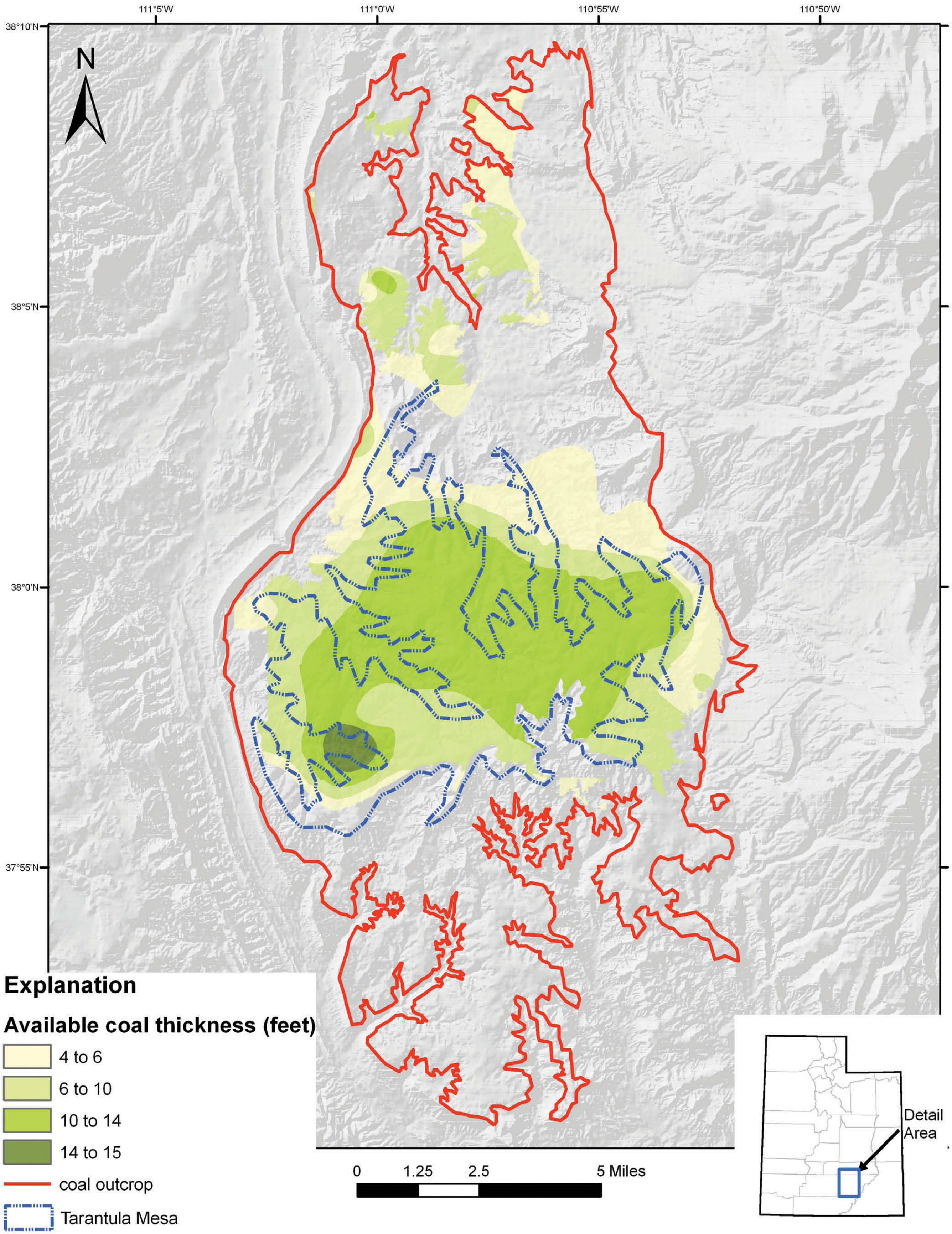


***Figure 9.*** *Available coal resource for the Muley Canyon Sandstone coal, Henry Mountains coalfield, Utah.*

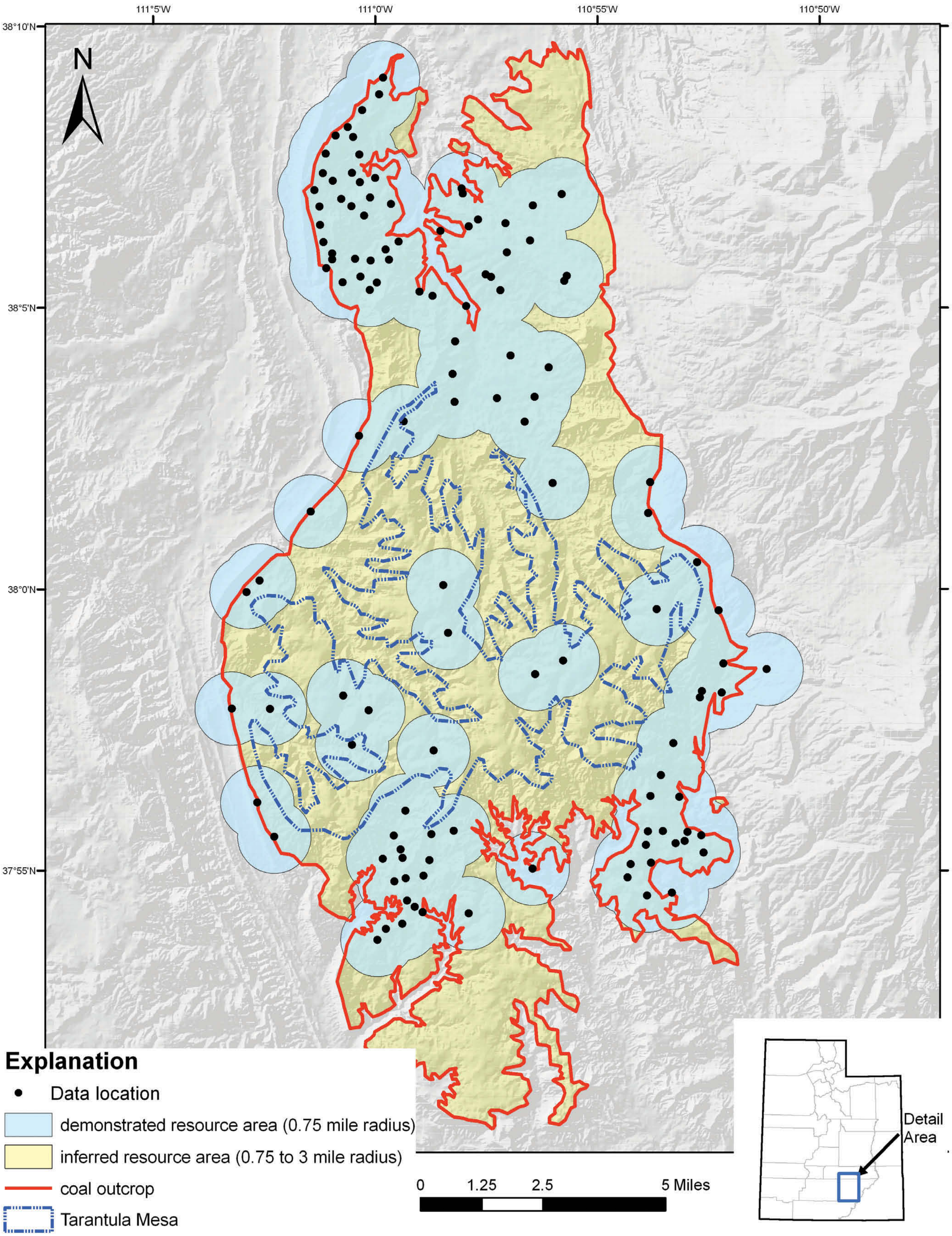


***Figure 10.*** *Demonstrated and inferred reliability category areas for the Muley Canyon Sandstone coal resource calculated in this study, Henry Mountains coalfield, Utah.*

logical Survey, and David Tabet, Roger Bon, Jeffery Quick, and Robert Ressetar of the Utah Geological Survey for helpful reviews of a draft of the manuscript. The Utah Division of Oil, Gas, and Mining provided data on the location of oil and gas wells, and the Utah Automated Geographic Reference Center provided several digital data sets that cover the study area.

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***Table 9.*** *The available coal resource for the study area by reliability category.*

| Reliability Category | Coal Tonnage (millions tons) | Percent (%) |
|---|---|---|
| *Demonstrated* | 268 | 46 |
| *Inferred* | 317 | 54 |
| *Hypothetical* | 0 | 0 |
| Total | 585 | 100 |

*Demonstrated* is coal within 0.75 mile of an observation location.
*Inferred* is coal between 0.75 and 3 miles of an observation location.
*Hypothetical* is coal beyond 3 miles of an observation location.

***Table 10.*** *Available coal resource for Muley Canyon Sandstone coal under Tarantula Mesa.*

| Thickness (feet) | Coal Tonnage (millions tons) | Percent of Available Coal (%) |
|---|---|---|
| 6 - 10 | 140 | 24 |
| 10 - 14 | 314 | 54 |
| greater than 14 | 13 | 2 |
| Total: | 467 | 80 |

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