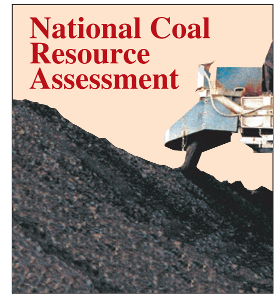
Chapter S

Geology and Coal Resources of the Blackhawk Formation in the Southern Wasatch Plateau, Central Utah



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Chapter S *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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Geology and Coal Resources of the Blackhawk Formation in the Southern Wasatch Plateau, Central Utah

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Abstract

This report on the coal resources of the southern Wasatch Plateau in central Utah is a contribution to the U.S. Geological Survey (USGS) project on the National Coal Resource Assessment (NCRA), a 5-year effort to identify and characterize the coal beds and coal zones that will potentially provide the fuel for the Nation's coal-derived energy during the 21st century. For the NCRA, the country is divided into five regions that contain the majority of the significant coal deposits of the United States: (1) the Appalachian Basin, (2) the Illinois Basin, (3) the Gulf of Mexico Coastal Plain, (4) The Powder River Basin and Northern Rocky Mountains, and (5) the Rocky Mountains and Colorado Plateau. Twelve areas within the Rocky Mountains and Colorado Plateau region have been designated high priority because they contain significant coal resources that are either currently being mined or that have high potential for being mined in the near future. The southern Wasatch Plateau is one of these high-priority areas.

The southern Wasatch Plateau is located in central Utah to the west of the San Rafael Swell in parts of Emery, Sevier, and Sanpete Counties. Although some coals may be present at great depth in the study area—both in the Cretaceous Dakota Sandstone and in the Ferron and Emery Sandstone Members of the Cretaceous Mancos Shale—the majority of thick, continuous coal beds at depths down to 5,000 ft occur within the Cretaceous Blackhawk Formation. Thick, laterally continuous coal beds occur in the basal part of the Blackhawk within the lower Blackhawk coal zone, which extends about 150 ft above the underlying Star Point Sandstone. Several coal beds overlie and extend in a paleo-landward direction from marine-shoreface sandstone parasequence pinch-outs in the Star Point. The sequence stratigraphic stacking pattern of the shoreface parasequences dictated the stacking pattern, stratigraphic spacing, and geographic location of the coal beds in the overlying Blackhawk Formation.

The coal quantities reported for this study are entirely "resources" and represent, as accurately as possible, all the coal in the ground within the lower Blackhawk coal zone that are in beds greater than 1.2 ft thick. The resources are qualified and subdivided into categories of total coal thickness and of overburden categories (depth to the coal in the subsurface). The USGS has not attempted to estimate coal "reserves" for this region. Reserves are that subset of the resource that could be economically produced at the present time.

Coal beds in the southern Wasatch Plateau are laterally discontinuous relative to eastern coal-bearing regions of the United States, such as the Appalachian Basin. That is, they terminate more abruptly and are more likely to split into thinner beds over shorter lateral distances. Because of these characteristics, the publicly available data in this study derived from approximately 190 measured sections and 119 drill holes are not sufficient in number and distribution to determine what proportion of the coal resource is technologically available or economically recoverable at the present time; additionally, it was not the focus of the present coal assessment to evaluate coal reserves. The coal resources are differentiated into "identified" and "hypothetical" categories based on the standard coal classification scheme of Wood and others (1982, 1983; see also USBM and USGS, 1976). Identified resources are those within 3 mi of a known measured thickness value, and hypothetical resources are farther than 3 mi from a data point. Data distribution in the southern Wasatch Plateau is such that 62 percent original in-place coal resources are in the identified category. In the extreme northwest part of the study area, subsurface drill-hole data are lacking and outcrop measurements are sparse. Thus, the resources in that region are in the hypothetical category and comprise 38 percent of the total resources.

Within the southern Wasatch Plateau, the thick and laterally persistent coal beds all occur within the lower Blackhawk coal zone. The lower Blackhawk coal zone is defined as the interval of the Blackhawk Formation that lies about 150 ft directly

over the Star Point Sandstone. Coals in the upper part of the Blackhawk are thin and discontinuous. The lower Blackhawk coal zone contains seven major coal beds, two of which contain coal that is thicker than 10 ft throughout part of the southern Wasatch Plateau. Each of the seven coal beds can be traced to and correlated with a distinct marine shoreface sandstone within the Star Point Sandstone. The stacking pattern of the coal beds is directly related to the stacking pattern and landward pinch-outs of the shoreface sandstone parasequences within the Star Point.

The original in-place coal resource in the southern Wasatch Plateau is defined to include all coal beds greater than 1.2 ft in thickness in the lower Blackhawk coal zone. Although small quantities of coal in the southern Wasatch Plateau could hypothetically be removed by surface mining of shallow coal beds from exposures of the Blackhawk that are close to the outcrop, any significant recovery operation would require underground mining due to the generally steep terrain and the thick overburden; thus, none of the resource is considered surface minable. Within the study area, the SUFCO mine in northeastern Sevier County, Utah, is the only active operation at the present time, producing coal from a bed about 14 ft thick and under about 1,000 ft of overburden. Within the southern Wasatch Plateau, original in-place resources for the overburden category 0 to 500 ft and the net-coal thickness category of 7 to 14 ft, there are 160 million short tons of coal; for the overburden category 0 to 500 ft and the net-coal thickness category of greater than 14 ft, there are 140 million short tons of coal. For the overburden category 500 to 1,000 ft and net coal thickness category 7 to 14 ft, there are 420 million short tons of coal; for that overburden category and net-coal thickness category of greater than 14 ft, there are 460 million short tons of coal. For overburden category 1,000 to 2,000 ft and net-coal thickness category 7 to 14 ft, there are 310 million short tons of coal; for that overburden category and net-coal thickness category greater than 14 ft, there are 2,100 million short tons of coal. For the overburden category 2,000 to 3,000 ft and net-coal thickness category 7 to 14 ft, there are 1.4 million short tons of coal, and for net-coal thickness category greater than 14 ft, there are 1,800 million short tons of coal. For the overburden category greater than 3,000 ft, there are 1,200 million short tons of coal in the net-coal thickness category greater than 14 ft. Additional coal resources are in the thickness categories 1.2 to 2.3 ft, 2.3 to 3.5 ft, and 3.5 to 7 ft throughout the study area. The Southern Wasatch Plateau study area contains an original in-place resource of 6.8 billion short tons of coal. This total resource figure does not reflect geologic, technologic, land-use, and environmental restrictions that may affect the availability and recoverability of the coal.

Introduction

Purpose and Scope

This report provides data on and a discussion of geology, the horizontal and vertical distribution of coal deposits, and an assessment of coal resources in the southern Wasatch Plateau in central Utah (figs. 1*A*, 1*B*). The report provides a preliminary delineation of thick coals and an estimate of coal resources that can serve as a baseline for future efforts to assess the availability and recoverability of coal in the Wasatch Plateau. The assessment of coal resources in the southern Wasatch Plateau is part of the U.S. Geological Survey National Coal Resource Assessment project that was initiated in 1994 (USGS, 1996). A coal assessment of the northern Wasatch Plateau, which is adjacent to the northern boundary of the study area of this report, was conducted by the Utah Geological Survey (Tabet and others, 1999). The National Coal Resource Assessment will not attempt to estimate the total coal endowment of the United States but will instead identify and characterize the coal beds and coal zones that that will provide the bulk of the Nation's coal-derived energy for the 21st century. The southern Wasatch Plateau is one of 12 priority areas containing coal within the Rocky Mountains and Colorado Plateau region of the Western United States. The Rocky Mountains and Colorado Plateau contain significant coal resources, and together they form one of the five major regions of the United States that are being evaluated as part of the National Coal Resource Assessment (USGS, 1996; see also Kirschbaum, Executive Summary , this CD-ROM). Additional areas having less potential for significant coal production during the next several decades will be studied in future years of the project. For each coal-producing region, measurements from outcrops and well logs identify the most important coal beds or coal zones and map the extent and thickness of these coal beds. In addition, information about resource parameters such as coal quality is also reported. All data are stored in digital form, and all products such as text, tables, and maps are available in digital form (see table 1, and Appendix 1), thereby permitting geographic-information-system (GIS) technology to be used to manipulate, evaluate, and display the coal-resource information.

Location of Southern Wasatch Plateau Study Area

The southern Wasatch Plateau lies in central Utah (fig. 1) and is contiguous with the northern Wasatch Plateau. Together, the two areas form the Wasatch Plateau coal field of earlier reports (e.g., Spieker, 1931; Doelling, 1972a,, 1972b; Davis and Doelling, 1977). The coal field extends for about 90 mi NNE., from just south of I-70 at Last Chance Creek north to U.S. Highway 50-6 near Colton and Soldier Summit, Utah. The Wasatch Plateau coal field extends from Carbon County on the north, south through Emery County, and into eastern Sanpete and Sevier Counties (Spieker, 1931; Doelling and Smith, 1982). The southern Wasatch Plateau (figs. 2*A*, 2*B*) covers parts of Sevier, Sanpete, and Emery counties. The eastern edge of the coal field consists of cliff exposures of the

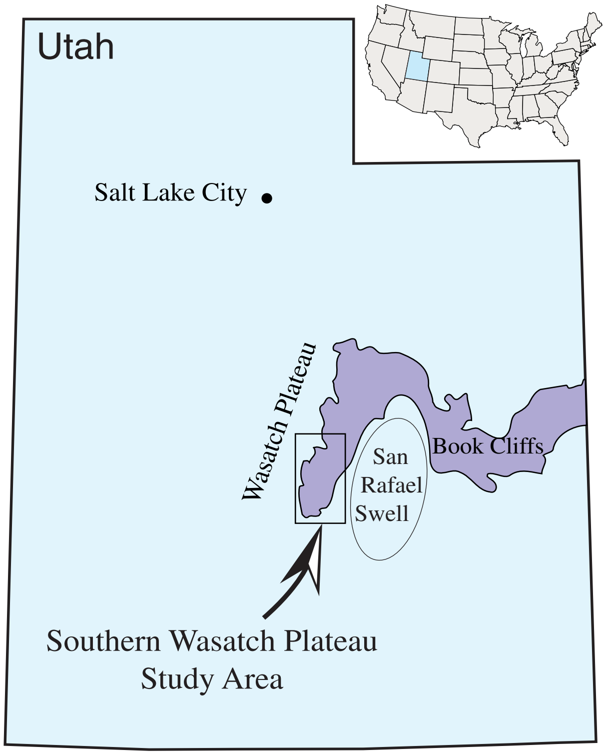


Figure 1*A*. Map of central Utah showing location of the Southern Wasatch Plateau study area, the Wasatch Plateau, the Book Cliffs, and the San Rafael Swell.

the extreme western part of Emery County, Utah. The southern Wasatch Plateau is bounded on the west by a series of north-south-trending normal faults (fig. 4). Coal in the study area occurs primarily in the Blackhawk Formation. Coal-bearing rocks of the Blackhawk Formation also exist along outcrops and in the subsurface farther west, particularly along I-70 and Ivie Creek in the Salina Canyon district; however, the rocks there are broken and shattered by numerous faults. The Blackhawk Formation and included coals in that area are discussed by Spieker (1931), but they are not considered in this evaluation of the coal resources of the southern Wasatch Plateau because the rocks are extensively faulted, making correlations of coal beds uncertain, and because the coals are thin and discontinuous (see Kirschbaum and Biewick, chap. B, this CD-ROM). At the southern boundary of the study area, coal-bearing rocks of the Blackhawk Formation are covered by volcanic rocks just south of Ivie Creek and I-70. On the maps of this report, the southern boundary of the study area is formed by the intersection of the outcrops of the Star Point Sandstone and Blackhawk Formation with the north-south-trending fault zone that forms the western margin of the study area. To the east of the study area, the coal-bearing Blackhawk Formation and the Star Point Sandstone form an erosional escarpment on the western flank of the San Rafael Swell. The eastern boundary of the study area corresponds with the contact between the Star Point Sandstone and the underlying Upper Cretaceous Star Point Sandstone and Blackhawk Formation along the west flank of the San Rafael Swell that are a continuation of the well-known Book Cliffs to the north (fig. 1*A*). To the west, the coal-bearing rocks continue to dip away from the San Rafael Swell into the subsurface at about 5° to 7°, where they are overlain by younger Cretaceous and Tertiary rocks and are displaced along major normal faults near the western margin of the Wasatch Plateau. To the north, coal-bearing Cretaceous rocks dip to the north into the Uinta Basin, and to the south they are covered by volcanic rocks of the Fish Lake Plateau. The width of the coal field varies from about a minimum of 6 mi at the southern end of the Wasatch Plateau to an average of about 22 mi at the northern end of the Wasatch Plateau. Coal resources in the northern part of the Wasatch Plateau were studied by the Utah Geological Survey (Tabet and others, 1999). The Utah Geological Survey is conducting both a coal resource study of Emery and Carbon Counties, Utah, and a coal-availability and recoverability study of quadrangles in those counties and in the area around North and South Horn Mountain in Emery County east of the Joes Valley graben system because those areas are geologically contiguous with rocks east of the Joes Valley graben to the north.

The southern Wasatch Plateau, referred to in this report as the "study area," covers about 550 mi^2 in parts of 15 7.5′ quadrangles (fig. 3) in eastern Sanpete and Sevier Counties and

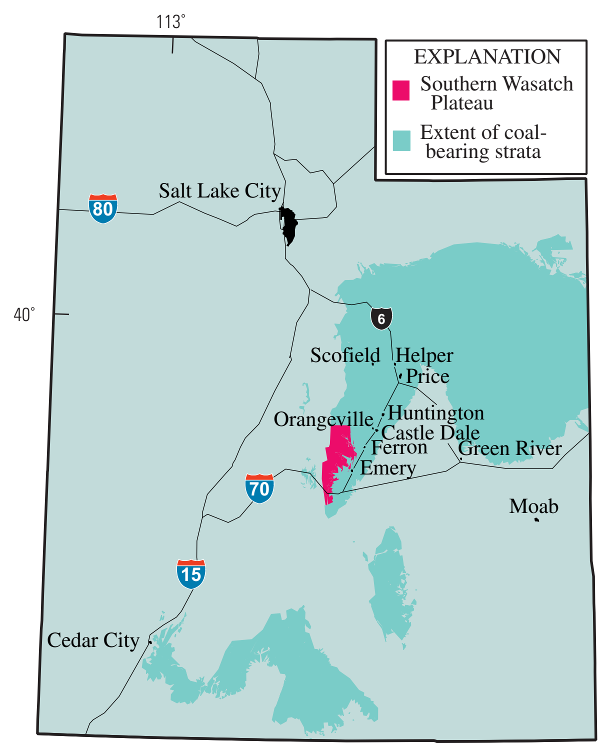


Figure 1*B*. Map showing the location of the southern Wasatch Plateau and the extent of coal-bearing strata in Utah in relation to towns and major roadways.

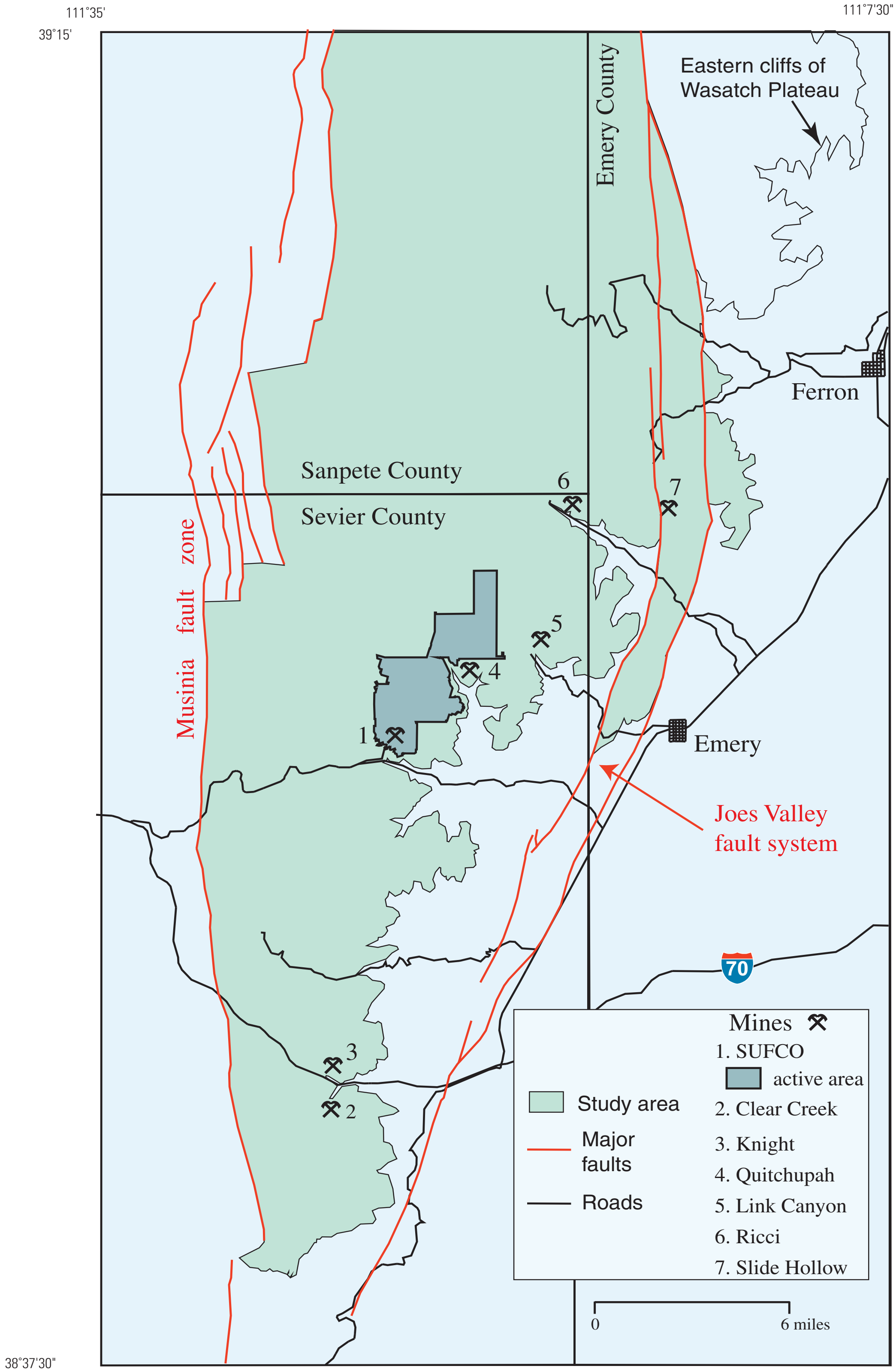


Figure 2*A*. Index map showing location of cultural features in and near the Southern Wasatch Plateau study area (green pattern). The eastern escarpment of the Wasatch Plateau is formed by cliffs of the Star Point Sandstone, and they essentially define the eastern boundary of the Southern Wasatch Plateau study area. Dark-green pattern shows underground extent of the SUFCO mine, the only active mine in the study area; numbered mine symbols show approximate location of former entryways of inactive mines.

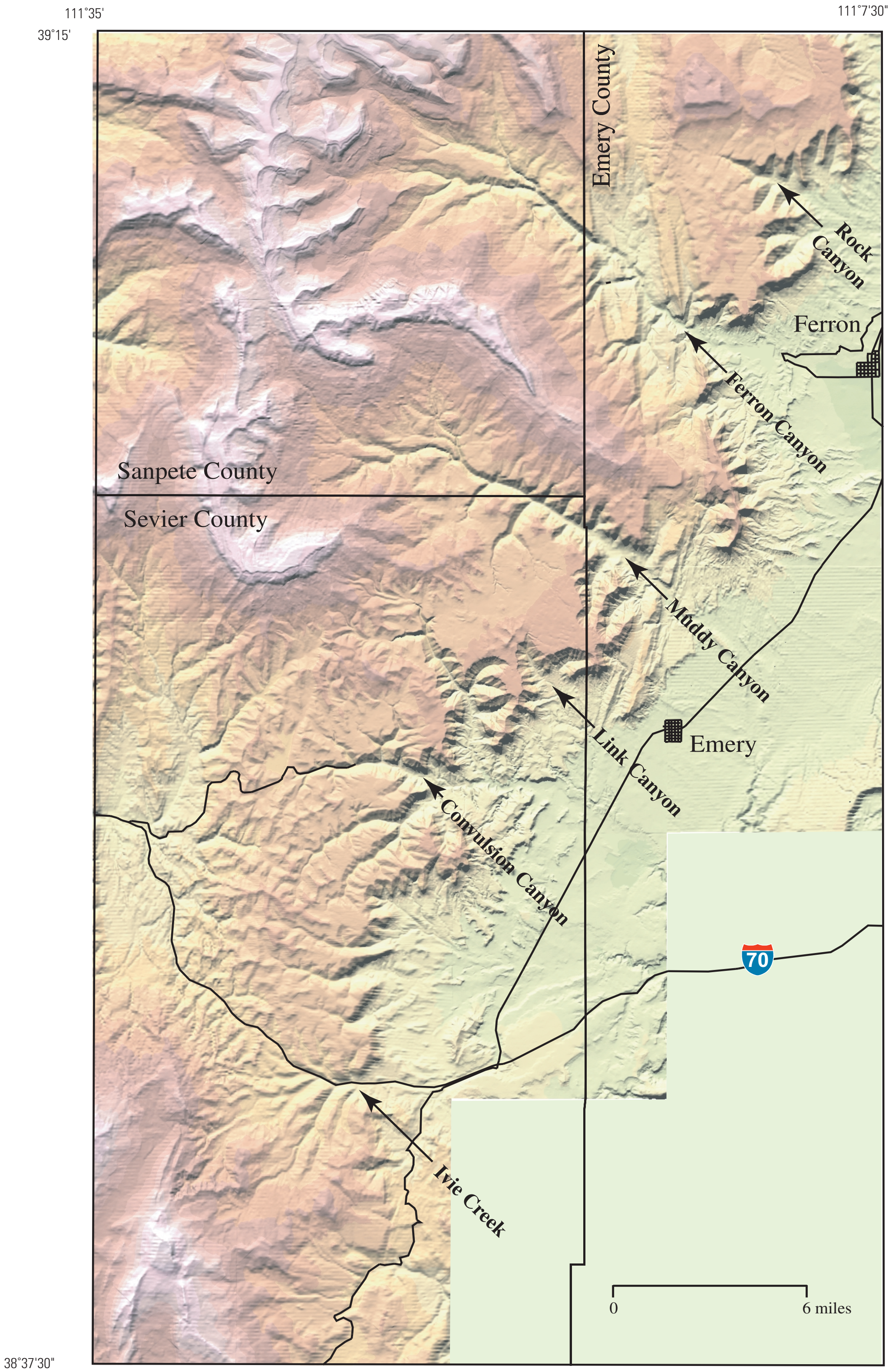


Figure 2*B*. Index map showing physiography from digital elevation models (DEM's) and physiographic features in and near the southern Wasatch Plateau that are referred to in the text.

Mancos Shale. The northern boundary of the study area is an east-west line at lat 39°15′N. that coincides with the southern boundary of part of the Northern Wasatch Plateau study area, which also includes The Cap quadrangle (fig. 3). The Cap quadrangle was included in the Northern Wasatch Plateau study area because rocks and coal in that area are east of the disrupted rocks of the Joes Valley fault system that lies near the eastern boundary of the southern Wasatch Plateau, and thus they are contiguous with strata included in the Northern Wasatch Plateau study area (Tabet and others, 1999).

The southern Wasatch Plateau, similar to the Wasatch Plateau in general, is an area of rugged topography (fig. 2*B*), with deep canyons cut on the eastern flank. The eastern plateau edge is a steep cliff formed by the Star Point Sandstone that is overlain by steep slopes of the Blackhawk Formation, with total relief on the eastern escarpment of about 1,000 ft. Elevations range from about 7,000 ft on the east to almost 10,000 ft near the central and western parts of the study area. Major drainages such as Rock Canyon Creek, Ferron Creek, Muddy Creek, Quitchupah Creek, and Ivie Creek (fig. 2*B*) have head-

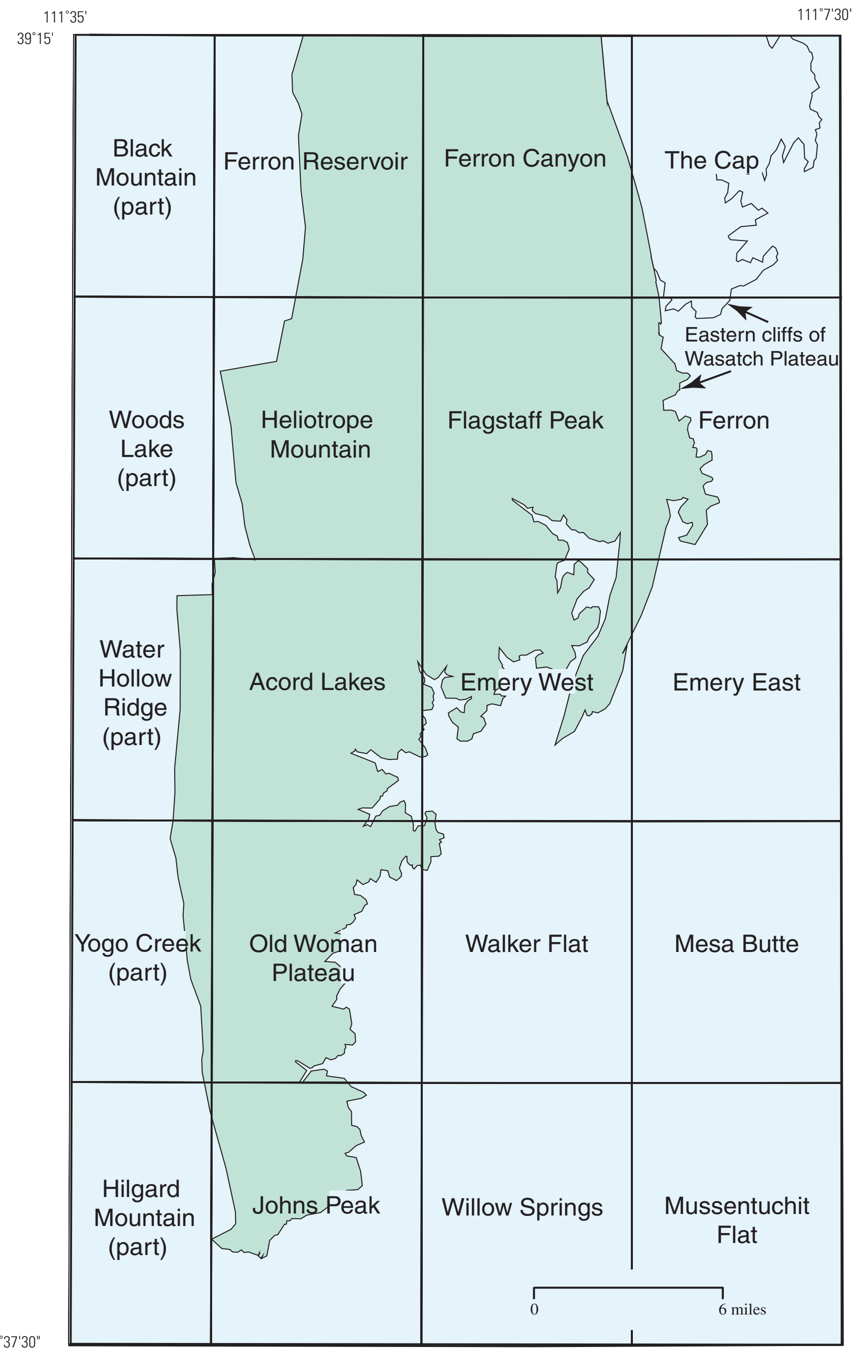


Figure 3. Index map showing location of 7.5′ quadrangles in and around the Southern Wasatch Plateau study area (green pattern).

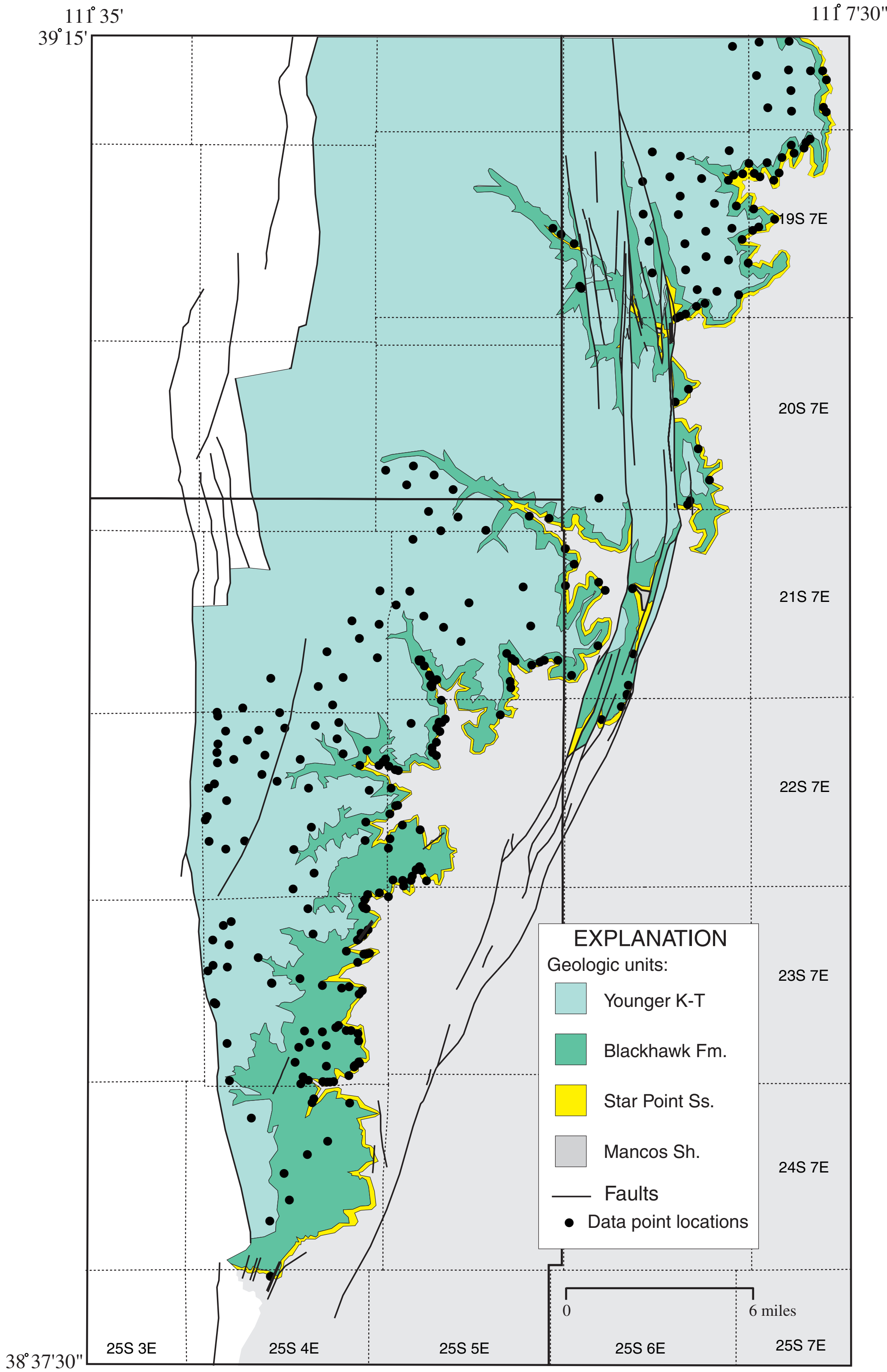


Figure 4. Index map of southern Wasatch Plateau showing location of data points, geologic units, and townships and ranges. Geology of the study area shows stratigraphic units and major faults. Geologic units are, in ascending order: Upper Cretaceous Mancos Shale and older rocks; Upper Cretaceous Star Point Sandstone; Upper Cretaceous Blackhawk Formation; undifferentiated younger Cretaceous and Tertiary rocks (includes the Cretaceous and Tertiary North Horn Formation (Maastrichtian to Eocene), and the Tertiary Flagstaff Limestone (Paleocene and Eocene), Colton Formation (Eocene), and Green River Formation (Eocene)).

waters at higher elevations on the Wasatch Plateau and flow southeast toward the Colorado River. The Federal Government owns the majority of surface and mineral rights in the study area, whereas State and private interests hold small tracts throughout the study area (figs. 5*A*, 5*B*).

Previous Geologic Studies

Spieker and Baker (1927) reported on the coal resources of the Salina Canyon district, a small area 6 mi wide and 14 mi long along Salina Creek west of the Southern Wasatch Plateau study area. The Salina Canyon district contains rocks and coal beds in the Blackhawk Formation similar to those that occur in the southern Wasatch Plateau, but coal resources are limited chiefly by the small size of the areas found between major north-south-trending faults. A summary of the coal resources in the Salina Canyon district can be found in Kirschbaum and Biewick (chap. B, this CD-ROM).

Clark (1928) reported on the economic geology, including the coal geology, of the Castlegate, Wellington, and Sunnyside quadrangles in the Book Cliffs east of the Southern Wasatch Plateau study area. He (Clark, 1928) also reported that Taff (1906) made a preliminary survey of the Wasatch Plateau coal

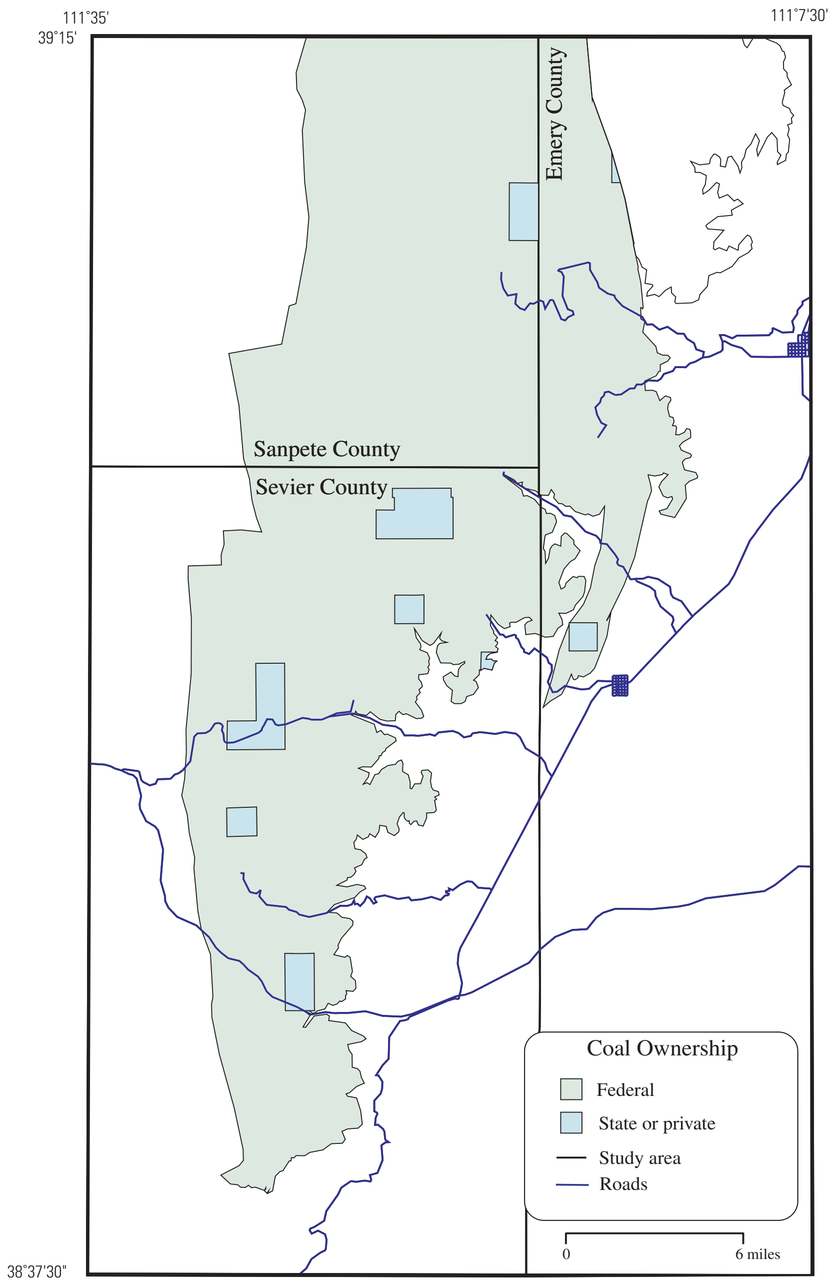


Figure 5*A*. Map showing coal ownership in the southern Wasatch Plateau.

field. Clark (1928) mapped the geology, traced coal beds, and named and discussed the stratigraphic relations of the Panther, Storrs, and Spring Canyon Tongues of the Star Point Sandstone and the Aberdeen Member of the Blackhawk Formation. Each of these units extends west and south into the Wasatch Plateau and into the Southern Wasatch Plateau study area. Clark (1928) provided much of the original basis for subsequent work on the intertonguing of the sandstone members of the Blackhawk Formation with the Mancos Shale to the east.

Spieker (1931, p. 6–7) summarized earlier work on the geology of the region, stating that the Wasatch Plateau coal field was first mentioned by Forrester (1893) and Storrs (1902) in their accounts of the coal fields of Utah. Spieker (1931) noted that Taff (1906) conducted the first significant study of the geology of the area, which was followed by a more detailed study of the northern part of the coal field (Taff, 1907). Spieker and Reeside (1925) described the stratigraphy of the Wasatch Plateau, defining various Cretaceous to Tertiary stratigraphic units that were applied throughout the Wasatch Plateau and Book Cliffs region. Spieker (1925) published a short account of the Wasatch Plateau coal field. Spieker (1931) presented the first detailed study of the geology, stratigraphy, and coal in the Wasatch Plateau, including both the Southern Wasatch Plateau study area of this report and the northern

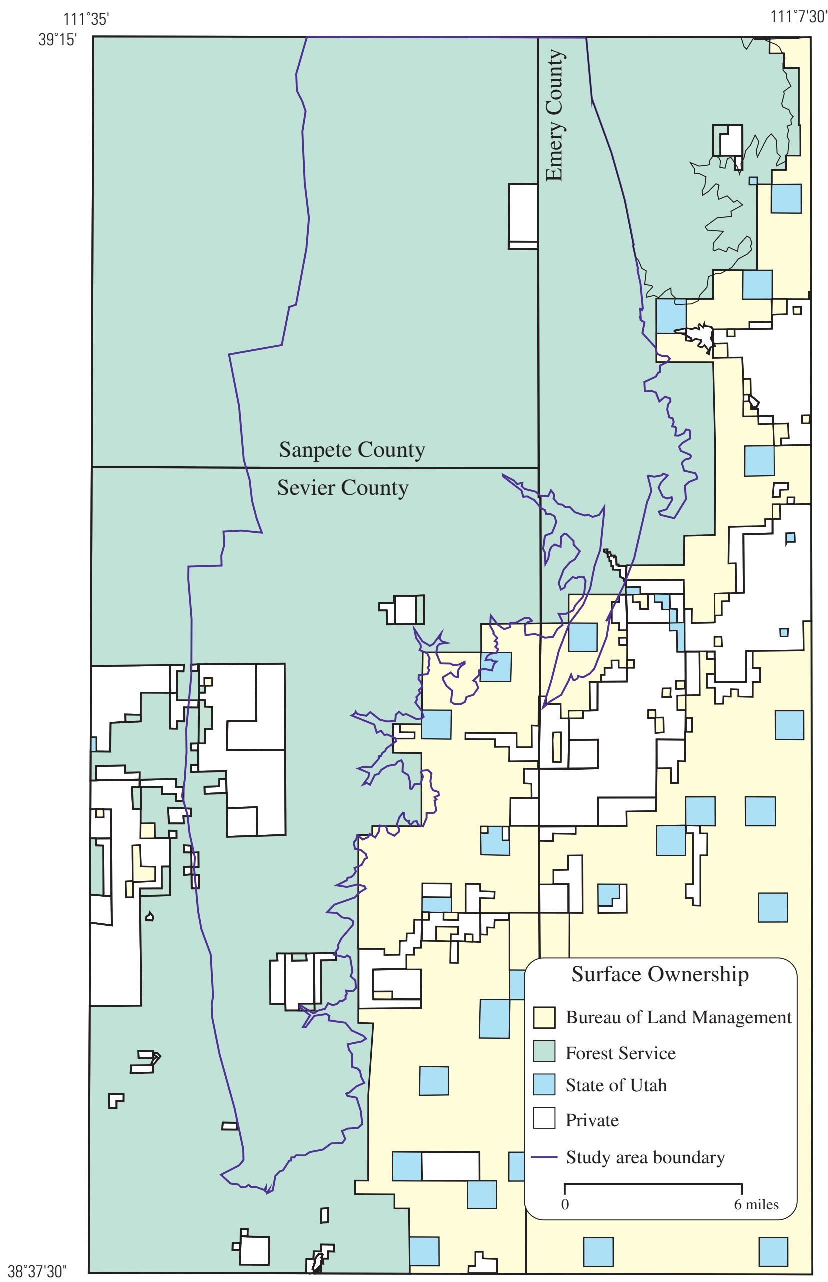


Figure 5*B*. Map showing surface ownership in and adjacent to the southern Wasatch Plateau.

Wasatch Plateau (Tabet and others, 1999).

Fisher (1936) described the geology and coal resources of the Book Cliffs in Emery and Grand Counties, Utah, east of the area covered by Clark (1928). Fisher's (1936) study area is considerably east of the Wasatch Plateau, but the general stratigraphy, geology, and coal occurrences parallel those found in the Southern Wasatch Plateau study area. Reports by Clark (1928), Fisher (1936), and others (e.g., Erdmann, 1934, covering the Book Cliffs in Garfield and Mesa Counties, Colorado) also provided the basis for subsequent ground-breaking studies of the marine shoreface sandstones by Young (1955) and other studies discussed below that continue to be a prime focus of sedimentologic research in the Book Cliffs to this day.

In a landmark work, Young (1955) described the sedimentary facies and intricate vertical and lateral intertonguing of marine and nonmarine rocks in the Upper Cretaceous Star Point Sandstone, Blackhawk Formation, and Price River Formation of the Book Cliffs in an area extending from just west of the town of Helper, Utah, eastward to just east of Grand Junction, Colo. That study discussed the progradation of marine shoreface sandstones within the Upper Cretaceous section and their relation to sedimentation and subsidence in the basin. Although the research focused on the Book Cliffs to the east of the present Southern Wasatch Plateau study area, it is relevant to the present report because similar facies and intertonguing relations exist in the shoreface sandstones of the Star Point Sandstone and the Blackhawk Formation in the Wasatch Plateau to the south of the Book Cliffs.

Maberry (1971) reported on the sedimentary features and trace fossils in the Aberdeen, Kenilworth, and Sunnyside Members of the Blackhawk Formation in the Sunnyside coal mining district and their relation to facies and engineering geology in the coal mines.

Doelling (1972a, p. 59–243) provided a comprehensive review of the Wasatch Plateau region, discussing stratigraphy, coal geology, measured sections, and coal mining and production. Doelling (1972b) prepared a summary of the Wales, Sterling, Salina Canyon, Mt. Pleasant, and Wasatch Plateau coal fields for a field conference, discussing coal occurrences, coal quality, and historical production. Davis and Doelling (1977) reported on coal drilling in both the northern and the southern parts of the Wasatch Plateau.

In the late 1970's, through the 1980's and into the 1990's, renewed interest in the low-sulfur coal deposits of the Blackhawk Formation of the Wasatch Plateau for the generation of electric power both locally and throughout the United States resulted in numerous mapping and drilling projects that produced a variety of reports on the stratigraphy, geology and cross sections, depositional environments, and coal occurrences and resources of the southern Wasatch Plateau (Blanchard and others, 1977; Davis and Doelling, 1977; Marley and Flores, 1977; Johnson, 1978; Marley, 1978; Abbay, 1979a, 1979b, 1979c; Flores and others, 1980; Hayes and Sanchez, 1979; Sanchez and Hayes, 1979; Albee 1980; Ellis, 1980; Marley and others, 1979; Muldoon, 1980; Blanchard, 1981; Ellis, 1981a, 1981b; Flores and others, 1982; Mercier and others, 1982; Sanchez and Brown, 1983; Sanchez and others, 1983a, 1983b; Flores and others, 1984; Sanchez and Brown, 1986, 1987; Brown and others, 1987; Sanchez, 1990; Sanchez and Ellis, 1990). Rather than describe the focus of each of those reports, they are referenced in the body of this report where they are relevant to discussions of geology, facies, or coal distribution. A similar body of literature exists specifically for coal drilling, mining, and geology of the northern Wasatch Plateau, and that data can be referenced in reports such as Doelling (1972a) and the report by Tabet and others (1999). All of these reports provide a plethora of data, observations, and interpretations on mapping, drill holes, and core descriptions from a variety of areas within or relevant to the southern Wasatch Plateau. They also provide information on coal beds and coal resources, along with coal correlations and chemical coal-quality analyses. Specific references to southern Wasatch Plateau coal-quality data that are discussed later in this report in the section on Coal Quality can be found in Doelling (1972a), Davis and Doelling (1977), and Smith (1981b).

While studies of the coal geology proceeded in the Book Cliffs and Wasatch Plateau, sedimentologic field research investigated the intertonguing stratigraphic relations between shoreface sandstones and marine shales that would subsequently be incorporated in sequence-stratigraphic studies related primarily to oil and gas exploration and development. Balsley and Horne (1980), building on the work of Young (1955), produced for field trips a comprehensive analysis of depositional facies and deposystems that included marine-shoreface, marginal-marine, and coastal-plain rocks along the Book Cliffs eastward from the town of Helper toward Green River, Utah. Since their work, numerous studies have elaborated on and clarified the relations of marine-shoreface sandstone intertonguing and stacking patterns, especially in members of the Blackhawk Formation in the Book Cliffs (e.g., Van Wagoner and others, 1988; Haq and others, 1988; Van Wagoner and others, 1990; Van Wagoner and others, 1991; Kamola and Van Wagoner, 1995; Van Wagoner, 1995; O'Byrne and Flint, 1995; Taylor and Lovell, 1995). These studies in the Book Cliffs have formed the backbone of much of the oil and gas industry's understanding of sequence stratigraphy in marine-shoreface and deltaic successions. However, most of those works utilize sequence stratigraphy in answering problems facing the hydrocarbon extraction industry, and only a few studies have applied sequence stratigraphic concepts to coastal-plain or terrestrial facies that contain coal (e.g., Cross, 1988; Hettinger and others, 1993; Shanley and McCabe, 1995; Bohacs and Suter, 1997).

The body of literature on coal geology, facies, stratigraphic relations, and depositional models for Cretaceous rocks is too voluminous to reference in this report. Specific studies related to the geology and coal occurrences of the southern Wasatch Plateau have been cited above, or they are referenced in the following body of the report as they pertain to specific issues or topics under discussion. Summary papers that may be investigated further by the reader for general concepts and coal references are provided by McCabe (1984, 1991), Rahmani and Flores (1984), Diessel (1992), Cobb and Cecil (1993), and references therein.

Mining Activity

Coal was discovered in the Wasatch Plateau in 1874, and mining started in 1875 in Huntington Canyon (see Spieker, 1931, for a more detailed summary of historical mining in the Wasatch Plateau). In 1876, coal was being mined from several mines in Coal Canyon and Huntington Canyon, in large part due to their proximity to the Salt Lake City market, and all of the early coal mining was in the northern part of the Wasatch Plateau. The first large mine was opened in 1878 along Pleasant Valley Creek about 3 mi south of Scofield, Utah. It was temporarily abandoned because mining entered a zone of faults, but the mine was reopened in 1922. In 1884 the Winters Quarter mine was opened in Winters Quarter Canyon, and the Union Pacific No. 1 mine was opened near Scofield. The Clear Creek mine at the head of Pleasant Valley was opened in 1899. From 1899 to 1909, only extensions of preexisting mines were opened, and Pleasant Valley produced all of the coal from the field. The first larger mines on the eastern front of the Wasatch Plateau were opened by United States Fuel Company at the sites of old wagon mines in Miller and Cedar Creek Canyons in 1909 and 1910. In 1909, the railroad was built from Price south to Hiawatha, Utah, and Consolidated Fuel Company opened the Hiawatha mines. In 1910, the Castle Valley Fuel Company opened the Mohrland mine and extended the railroad into Cedar Creek Canyon. Blackhawk Fuel Company opened the Blackhawk mine in 1911. In 1925, the Blackhawk and Mohrland mines were renamed the King No. 1 and King No. 2. In 1917, the Lion Coal Company opened a mine at Wattis on the Wattis bed and in 1924 opened a second mine on a lower bed. In 1924, the Sweet Coal Company began work on the North Fork of Gordon Creek. According to Doelling (1972a), between 1910 and 1920, coal production increased steadily as mechanical mining methods gradually replaced the pick-and-shovel methods of the early years.

Mines were developed gradually in the Wasatch Plateau coal field as demand increased, and the larger mines were concentrated in the northern Wasatch Plateau because of the presence of the railroad and the closer proximity to markets. The production for the Wasatch Plateau gradually increased until 1920, followed by a lag until the end of World War II, when Utah coal production peaked, followed by another decline in 1957. During the 1960's, renewed interest in coal for coal-powered power plants resulted in an increase in lease activity on the Wasatch Plateau. Through 1969, after 95 years of mining, almost 100 million short tons of coal had been removed from the Wasatch Plateau (Doelling, 1972a).

Doelling (1972a, table 3, p. 87–91) summarized the known mines and prospects from the Wasatch Plateau coal field, documenting the extensive mining activity that proliferated from the late 1920's until 1972. Active and former mines in the Southern Wasatch Plateau study area are shown on figure 2*A* and in Appendix 2. Semborski (1991) summarized the history of coal mining in Carbon and Emery Counties, Utah. Because the present report focuses on the southern Wasatch Plateau, only those mines in the study area are included in the following discussion (mine locations shown on fig. 2*A*; tabulated data for exact mine locations can be found in Doelling, 1972a). The mines and prospects are discussed by alphabetical order of their 7.5′ quadrangle (quadrangle locations shown on fig. 3). In the Acord Lakes quadrangle, the Quitchupah Creek mine (also spelled Queatch-up-pah or Queatchappel) at the head of the North Fork of Quitchupah Canyon was intermittently active from 1901 to 1920. Also in the Acord Lakes quadrangle, the SUFCO mine (historically also called the New Salina mine, Convulsion Canyon mine, and Hanson mine) is located in a small reentrant (East Spring Canyon) at the northwest end of Convulsion Canyon. The mine has been active from 1941 to the present time, and currently it is the only active mine in the southern Wasatch Plateau. In the Emery West quadrangle, the Link Canyon mine was active from 1940 to 1952. In the Flagstaff Peak quadrangle, the Ricci mine (also called the Muddy Creek mine) was active from 1941 to 1951. According to a map provided by the Utah Geological Survey (David Tabet, written commun., September 1998), adjacent to the Ricci mine the portal for the Crawford mine connected to the Ricci mining area and was active from 1942 to 1945. The Slide Hollow mine is reported by Doelling (1972a) only as being old and abandoned. In the Johns Peak quadrangle, Doelling (1972a) shows the Clear Creek mine along Clear Creek on a map but states in the text that its exact location is not known. In the Old Woman Plateau quadrangle, the Knight mine (also known as the Ivie Creek mine), was open in 1923. Doelling (1972a) does not list when the mine closed, but it was active in the 1970's, and at the present time the area has been reclaimed and is no longer active. In The Cap quadrangle, the Axel Anderson mine (also referred to as the Rock Canyon mine, Clawson mine, and Peterson mine) was active from 1906 to 1932. Spieker and Baker (1927) described several small wagon mines and tunnels in the Blackhawk Formation in the Salina Canyon district west of the Southern Wasatch Plateau study area (now along I-70), all of which were closed by 1923.

Acknowledgments

Numerous people have contributed data, discussions, and their expertise toward our understanding of geology and coal resources in the southern Wasatch Plateau. David Tabet (Utah Geological Survey) was instrumental in providing access to the original NCRDS data set that was modified and used in the present study, and he provided continual support and information on geology and coal resources of the southern Wasatch Plateau. Jim Kohler (BLM) provided discussions on coal and the availability of well-log data for the southern Wasatch Plateau. Debbie Carter (USGS) provided access to and downloaded files of the NCRDS data system used in this report. Tim Gognat, Marin Popov, and John Haacke (USGS contract employees) were indispensable in providing training for, modification of, and manipulation of the StratiFact (GRG Corporation, 1996) database, along with assisting in stratigraphic evaluations and drafting. Chris Kravits, mine geologist at SUFCO, was extremely helpful by providing discussions of geology and local coal-bed correlation. We thank students Ben Scheich, Dan Grunwald, Bill Everham, and Ray Colley for assistance with digitizing well logs, geology, and various GIS coverages used in this report. Dorsey Blake (USGS) and Dave Taylor (USGS) provided assistance with computer manipulation and conversion of digital well-log files into formats used in this study. Laura Biewick (USGS) provided essential organization of the digital library for GIS coverages used in this report. Jackie Huntoon (Michigan Technological University) provided insightful sequence-stratigraphic excursions to outcrops in the Wasatch Plateau, and Peter McCabe (USGS) engaged in thought-provoking discussions on sedimentologic concepts.

Methods Employed in the Assessment

NCRDS-StratiFact Database

This assessment of coal resources of the southern Wasatch Plateau is based on data from geologic mapping, outcrop measurements of stratigraphic sections of the coal-bearing units, drilling that has been conducted in the region primarily in the late 1970's and early 1980's, and recent sedimentologic research on the coals and associated shoreface sandstones in the Wasatch Plateau and the adjacent Book Cliffs to the north. The coal assessment and its inherent calculations are based primarily on a data set that was originally derived from the National Coal Resource Data System (NCRDS). The data set was significantly modified and updated as a StratiFact (GRG Corp., 1996) database during the present study for the purposes of this coal resource assessment. Data within NCRDS that pertain to the State of Utah and its coal resources have been entered into NCRDS by the State of Utah, the Utah Geological Survey, and various contractors and other entities over the last several years. Data used in this study are summarized in table 1, and they are available in Appendix 1.

The National Coal Resources Data System (NCRDS) is a publicly available, electronic coal database (for information on NCRDS see the Website at: http://energy.er.usgs.gov/projects/ncrds_proj_desc.htm). Started 20 years ago, the database contains coal-quality analyses of more than 14,000 coal samples and some 170,000 stratigraphic records. At least 136 parameters are determined, including detailed location information and a wide range of physical and chemical properties. The stratigraphic database contains more than 30 parameters describing the collected samples, including specific georeferenced information. The data have been used for many purposes, including locating coal deposits having desirable characteristics and assessing the environmental impact, coal reserves, and technological properties of coal from specific areas and beds. There are approximately 22 cooperating State geological survey agencies involved in a major effort to collect, verify, and correlate NCRDS-maintained data. A subset of the NCRDS contains coal-quality and quantity data for coal from other countries.

Data on stratigraphy and coal occurrences within the southern Wasatch Plateau in the NCRDS data set were originally derived and entered into the NCRDS by the Utah Geological Survey and its affiliates. The original data (table 1; Appendix 1) were collected from a variety of sources, including: (1) measured stratigraphic sections in published reports, some of which date back to the early 1900's, and others in more recent Master's theses and Ph.D. dissertations; (2) coal test holes and cores drilled by the U.S. Geological Survey (USGS), the Utah Geological Survey (formerly the Utah Geological and Mineral Survey (UGMS)), and private contractors (includes Coal Resource Occurrence–Coal Development Potential reports (CRO-CDP) by the former USGS Conservation Division), along with the geologic, geographic, and geophysical information from their associated reports); (3) field studies on the stratigraphy, sedimentology, and coal occurrences in central Utah conducted over the last few decades; and (4) proprietary data from drill holes belonging to companies operating coal mines and leases in the area. Although proprietary data within the NCRDS database were examined for this study and were used to correlate coal beds and confirm coal-bed thicknesses and resource calculations, no map locations or stratigraphic data from proprietary company data points are presented in any part of this report or the accompanying database (Appendix 1).

Data were originally entered into NCRDS by the Utah Geological Survey and their contractors from sources with varying reliability, including historical maps and surveys, more modern reports on Utah's coal geology, and ongoing studies. For the present report, the dataset from NCRDS was downloaded and entered into a database in StratiFact (GRG Corp., 1996), where data were checked, verified, and manipulated for the purposes of lithology and coal identification, stratigraphic and coal correlation, and coal thickness evaluation. In many instances, data originally entered into NCRDS were never rechecked or verified against the primary data source, so potential errors were never identified or corrected against the primary source of the data. Checking the data from NCRDS, verifying or correcting errant and missing attributes in the StratiFact database, and entering new data germane to this study were all a primary focus prior to utilizing the StratiFact database in an evaluation of the coal resources of the southern Wasatch Plateau. For instance, adding latitude or longitude information were simple cases of correcting data or adding missing data. Picking stratigraphic thicknesses of coal and other lithologic units from geophysical logs, and checking them against the original entry in the database identified other typographical or geologically incorrect stratigraphic data. Other errors were more subtle and required significant time to identify and correct. For example, many stratigraphic sections measured prior to about 1970 and even in the early 1980's were recorded as text paragraphs describing the stratigraphic units rather than being recorded in graphic vertical columns as many sedimentologists do today. When recorded in text, they are written with unit 1 at the top of the page, and unit 2 in the second paragraph, etc., down the page, even though the first unit measured in the field is generally at the stratigraphic bottom of the rock outcrop. When these text sections were originally entered into NCRDS, the compiler entered unit 1 at the top of the lithologic graphic column as NCRDS records them and then entered unit 2 below it as it was read down the text page, rather than putting unit 1 at the bottom according to its proper stratigraphic position on the outcrop. Consequently, in approximately 100 of the measured stratigraphic sections recorded in the database, the stratigraphic units, including the coals, were displayed in "upside down" stratigraphic order. These errors in the database were corrected by comparing the original measured stratigraphic text sections to the entries in the database and "turning them right side up" as necessary. Every measured stratigraphic section had to be verified in this manner before being used in the database.

The database utilized in this study is stored digitally (see Appendix 1) and was manipulated in a geographic information system (GIS) to calculate coal resources within a variety of spatial parameters that are useful for energy and land-use planning. The GIS coverages and ArcView project are also accessible on this 2-CD-ROM set (see Biewick and Mercier, chap., D, this CD-ROM, for explanation on accessing these coverages).

Lithologic and Stratigraphic Data

The data and attributes utilized in this coal assessment include geology, stratigraphy, and coal distribution from geologic mapping of the region, from measured stratigraphic sections, and from coal drill holes and cores and the corresponding geophysical logs of the bored holes. The stratigraphic occurrence, measured thickness, and geographic distribution of coal in the southern Wasatch Plateau have been analyzed and interpreted primarily from entries in the StratiFact database that were modified from the original NCRDS data set. The NCRDS data set contained stratigraphic or lithologic logs that indicated geologic units; lithologic units such as sandstone, shale, and coal, and their associated thickness; header information and reference data such as data point location, publication, or other source of the data; literature reference; and source and date of the entry. Other stratigraphic information that was discovered in a variety of literature sources and other available well logs was entered into the StratiFact database; it included similar lithologic, source, and location information as the other entries.

Each measured outcrop stratigraphic section and each well-log record for subsurface data points were checked against the original source of the data, wherever possible, or against other reports that reported and published the original data. Data from both measured sections and drill holes, and their included coal beds, apparently had been entered into the NCRDS by a variety of workers and at various times—many of the records were duplicate entries for unique data points. This was particularly evident for the measured outcrop sections, where several points plotted geographically at the same apparent map position. Duplicate entries such as these were eliminated from the database.

In the StratiFact database, the "Comment 2" field was designated with an integer value from 1 to 3 to reflect the confidence level in the reliability of the data. Points were labeled "1" where the data could be checked, verified and (or) corrected against the original source or publication. A "2" was used for data that were felt to be correct, but which had some uncertainty due to lack of an original reference, or some other uncertainty, such as a measured section being of limited thickness and recording a single coal bed. In this latter example, although the thickness of the rocks and the coal would be correct and verifiable, a short measured section that did not extend high enough into the Blackhawk Formation to record all of the coals in the coal zone being evaluated would result in a minimum value for total coal at that data point when used in assessment calculations. Because this inclusion would skew the calculation, points labeled "2" were used for coal-bed correlations, but they were not used in the coal assessment calculations. These points are retained in the database because they contain potentially useful information for coal correlation or for individual coal-bed evaluations. A "3" was assigned to points that were considered unreliable, had data missing, or for which no primary or secondary source could be found to verify the coal thickness or stratigraphic interval, despite being referenced in the literature. Points with a "3" designation were excluded from the final working copy of the database.

The original NCRDS data set consisted of about 800 data points, including both outcrop measured stratigraphic sections and subsurface drill hole or core localities. Of these, 119 of the subsurface points and 189 of the measured outcrop sections were retained in the modified database for the coal assessment for a total of 308 data points. Table 1 originally listed a total of 309 points, but point 202 was found to be a duplicate entry and was deleted from the final data set and table.

For each subsurface record in the database, a geophysical well log was obtained from publicly available logs on file and on microfiche in the well-log library of the USGS, Central Energy Team, Denver, Colo., or, alternatively, from available publications or from the original reference. On each well log, the coal-bed thickness and stratigraphic interval was determined, verified against the coal-bearing intervals in the database, and corrected where necessary.

Text continues on p. 22

Table 1. Data used in the assessment of coal resources in the southern Wasatch Plateau.

[Note: There is no entry for data point 202 because that point was found to be a replicate of another point]

Map no.	Point ID	Source	Longitude	Latitude	Sec	Township	Range	Total depth (ft)	Type	Surface elevation (ft)	Total coal (ft)	# beds	Top of Star Point Ss (ft)
1	C94B-USGS-19	Tabet\N.Horn Mtn	-111.16314	39.24703	20	18S	7E	982	206 geophysical	8,560	18.5	5	7,579
2	C94B-NH9/UGMS9	Tabet\N.Horn Mtn	-111.18122	39.24657	19	18S	7E	1,086	206 geophysical	8,360	12.9	4	7,274
3	C94B-NH8/UGMS8	Tabet\N.Horn Mtn	-111.19722	39.24455	24	18S	6E	1,236	206 geophysical	8,100	10.2	4	6,864
4	C94B-USGS-20	Tabet\N.Horn Mtn	-111.16354	39.23354	29	18S	7E	967	206 geophysical	8,550	32.7	6	7,583
5	C94B-M10	Sanchez/Muldoon	-111.14296	39.23318	28	18S	7E	203	102 outcrop	7,843	12.0	1	7,640
6	C94B-USGS-18	Tabet\N.Horn Mtn	-111.15028	39.23301	28	18S	7E	957	206 geophysical	8,640	27.0	4	7,684
7	C94B-57/UGMS7	Tabet\N.Horn Mtn	-111.18281	39.23089	30	18S	7E	1,113	206 geophysical	8,260	30.1	8	7,147
8	C94B-M54	Sanchez/Muldoon	-111.14076	39.22879	28	18S	7E	217	102 outcrop	7,856	16.3	2	7,640
9	C94B-NH6/UGMS6	Tabet\N.Horn Mtn	-111.16206	39.22397	29	18S	7E	1,205	206 geophysical	8,600	33.1	5	7,395
10	C94B-E110	Sanchez/Ellis	-111.14258	39.21605	33	18S	7E	84	102 outcrop	7,764	12.3	1	7,680
11	C94B-NH5/UGMS5	Tabet\N.Horn Mtn	-111.17605	39.21595	31	18S	7E	1,764	206 geophysical	9,060	38.5	3	7,296
12	C94B-NH4/UGMS4	Tabet\N.Horn Mtn	-111.16178	39.21430	32	18S	7E	1,096	206 geophysical	8,565	37.0	4	7,469
13	C94B-J5	Sanchez/Johnson	-111.14085	39.21386	33	18S	7E	203	102 outcrop	7,883	24.0	2	7,680
14	C94B-M52	Sanchez/Muldoon	-111.15061	39.20120	5	19S	7E	202	102 outcrop	7,701	11.8	2	7,499
15	C94B-E90	Sanchez/Ellis	-111.15311	39.19951	5	19S	7E	96	102 outcrop	7,605	26.3	2	7,510
16	C94B-S346	Sanchez/Speiker	-111.16190	39.19847	5	19S	7E	203	102 outcrop	7,722	27.9	4	7,520
17	C94B-S337	Sanchez/Spieker	-111.15427	39.19698	5	19S	7E	202	102 outcrop	7,701	11.7	2	7,500
18	C94B-USGS-17	Tabet\N.Horn Mtn	-111.19927	39.19582	1	19S	6E	1,124	206 geophysical	8,400	9.5	2	7,276
19	C94B-NH2/UGMS2	Tabet\N.Horn Mtn	-111.24545	39.19516	4	19S	6E	1,558	206 geophysical	8,310	14.5	1	6,752
20	C94B-S342	Sanchez/Spieker	-111.16021	39.19450	5	19S	7E	96	102 outcrop	7,580	20.3	2	7,484
21	C94B-NH3/UGMS3	Tabet\N.Horn Mtn	-111.22863	39.19316	3	19S	6E	1,192	206 geophysical	8,104	10.8	3	6,912
22	C94B-M51	Sanchez/Muldoon	-111.16755	39.19265	5	19S	7E	203	102 outcrop	7,662	19.1	5	7,460
23	C94B-M49	Sanchez/Muldoon	-111.17643	39.19012	6	19S	7E	203	102 outcrop	7,682	14.0	2	7,479
24	C94B-M47	Sanchez/Muldoon	-111.18738	39.18973	7	19S	7E	202	102 outcrop	7,692	14.7	5	7,514
25	C94B-M50	Sanchez/Muldoon	-111.16922	39.18537	7	19S	7E	202	102 outcrop	7,702	14.3	4	7,500
26	C94B-M46	Sanchez/Muldoon	-111.18423	39.18509	7	19S	7E	202	102 outcrop	7,601	17.9	6	7,424
27	C94B-M45	Sanchez/Muldoon	-111.19118	39.18497	12	19S	6E	203	102 outcrop	7,622	0.0	0	7,420
28	C94B-M44	Sanchez/Muldoon	-111.19656	39.18433	12	19S	6E	202	102 outcrop	7,622	5.0	1	7,420
29	C94B-J7	Sanchez/Johnson	-111.18075	39.18363	7	19S	7E	200	102 outcrop	7,670	9.2	1	7,470
30	C94B-NH1/UGMS1	Tabet\N.Horn Mtn	-111.23492	39.18360	10	19S	6E	1,326	206 geophysical	8,310	13.8	3	6,984
31	C94B-USGS-16	Tabet\N.Horn Mtn	-111.21584	39.18288	11	19S	6E	1,105	206 geophysical	8,360	8.0	4	7,256
32	C94B-M43	Sanchez/Muldoon	-111.19976	39.18196	12	19S	6E	199	102 outcrop	7,600	6.7	3	7,401
33	C94B-M48	Sanchez/Muldoon	-111.17240	39.18191	7	19S	7E	201	102 outcrop	7,700	17.5	4	7,499
34	C94B-USGS-15	Tabet\N.Horn Mtn	-111.25127	39.18133	9	19S	6E	1,252	206 geophysical	7,980	13.0	1	6,728
35	C94B-USGS-14	Tabet\N.Horn Mtn	-111.22869	39.17451	15	19S	6E	1,315	206 geophysical	8,500	13.9	4	7,185
36	C94B-USGS-13	Tabet\N.Horn Mtn	-111.20809	39.17108	14	19S	6E	1,039	206 geophysical	8,420	10.9	4	7,382
37	C94B-M40	Sanchez/Muldoon	-111.19492	39.16997	13	19S	6E	201	102 outcrop	7,630	9.6	4	7,430
38	C94B-M29	Sanchez/Muldoon	-111.18456	39.16860	29	19S	7E	201	102 outcrop	7,701	17.5	5	7,500
39	C94B-USGS-9	USGS-Slb-3,Pi Log	-111.25097	39.16622	16	19S	6E	1,216	206 geophysical	8,000	11.8	2	6,785

Table 1. Data used in the assessment of coal resources in the southern Wasatch Plateau—*Continued*.

Map no.	Point ID	Source	Longitude	Latitude	Sec	Township	Range	Total depth (ft)	Type	Surface elevation (ft)	Total coal (ft)	# beds	Top of Star Point Ss (ft)
40	C94B-USGS-10	USGS-Clb-1,Pi-Log	-111.22979	39.16594	15	19S	6E	1,199	206 geophysical	8,490	6.4	2	7,292
41	C94B-M26	Sanchez/Muldoon	-111.17194	39.16377	18	19S	7E	185	102 outcrop	7,690	11.3	3	7,506
42	FNC-M26	USGS OFR-81-319 Ellis	-111.30933	39.16117	24	19S	5E	46	102 outcrop	6,960			6,917
43	FNC-M25	USGS OFR-81-319 Ellis	-111.30603	39.16022	24	19S	5E	39	102 outcrop	6,960			6,924
44	C94B-M21	Sanchez/Muldoon	-111.18145	39.16004	19	19S	7E	219	102 outcrop	7,694	14.1	6	7,475
45	C94B-USGS-12	Tabet\N.Horn Mtn	-111.19763	39.15959	24	19S	6E	1,019	106 multiple sections	8,480	12.0	4	7,462
46	FNC-M44	USGS OFR-81-1026 Muldoon	-111.30528	39.15958	34	19S	5E	341	106 multiple sections	7,222	15.1	3	6,919
47	C94B-M20	Sanchez/Muldoon	-111.18514	39.15858	17	19S	7E	201	102 outcrop	7,670	13.0	5	7,470
48	FNC-M27	USGS OFR-81-319 Ellis	-111.30531	39.15831	24	19S	5E	31	102 outcrop	6,867			6,840
49	C94B-USGS-11	Tabet\N.Horn Mtn	-111.21330	39.15803	23	19S	6E	1,148	106 multiple sections	8,560	8.7	4	7,413
50	FNC-M24	USGS OFR-81-319 Ellis	-111.30200	39.15747	24	19S	5E	49	102 outcrop	6,943			6,900
51	FNC-M23	USGS OFR-81-319 Ellis	-111.30083	39.15689	24	19S	5E	61	102 outcrop	6,896			6,839
52	FNC-M45	USGS OFR-81-1026 Muldoon	-111.30033	39.15663	24	19S	5E	199	106 multiple sections	6,998	7.3	2	6,840
53	FNC-M28	USGS OFR-81-319 Ellis	-111.30219	39.15581	24	19S	5E	64	102 outcrop	7,000			6,943
54	FNC-M4	Spieker-USGS Bull 819	-111.29847	39.15574	19	19S	6E	52	102 outcrop	6,850			6,800
55	FNC-M22	USGS OFR-81-319 Ellis	-111.29771	39.15535	19	19S	6E	73	102 outcrop	6,861			6,800
56	C94B-M18	Sanchez/Muldoon	-111.19151	39.15422	24	19S	6E	202	102 outcrop	7,602	18.3	6	7,400
57	C94B-USGS-8	USGS-Slb-9,Pi-Log	-111.24747	39.15347	21	19S	6E	1,113	106 multiple sections	8,030	8.5	2	6,917
58	FNC-M21	USGS OFR-81-319 Ellis	-111.29453	39.15299	19	19S	6E	47	206 geophysical	6,843			6,800
59	C94B-USGS-7	USGS Dh	-111.22588	39.15239	22	19S	6E	1,005	206 geophysical	8,410	9.6	3	7,406
60	FNC-M43	USGS OFR-81-1026 Muldoon	-111.29247	39.15238	19	19S	6E	293	106 multiple sections	7,053	8.2	2	6,800
61	FNC-M20	USGS OFR-81-319 Ellis	-111.29089	39.15229	19	19S	6E	48	102 outcrop	6,845			6,800
62	FNC-M30	USGS OFR-81-319 Ellis	-111.29627	39.15225	19	19S	6E	42	102 outcrop	6,839			6,800
63	FNC-M31	USGS OFR-81-319 Ellis	-111.29631	39.15084	19	19S	6E	62	102 outcrop	6,860			6,801
64	FNC-M33	USGS OFR-81-319 Ellis	-111.29043	39.15025	19	19S	6E	12	102 outcrop	6,940			6,931
65	C94B-S406	Sanchez/Spieker	-111.16631	39.14906	20	19S	7E	34	102 outcrop	7,594			7,560
66	C94B-USGS-5	USGS Dh	-111.21317	39.14619	26	19S	6E	1,122	206 geophysical	8,570	11.3	5	7,449
67	C94B-USGS-6	USGS-Slb-2a,Pi-Log	-111.19973	39.14461	25	19S	6E	974	106 multiple sections	8,450	12.0	5	7,476
68	C94B-M15	Sanchez/Muldoon	-111.18788	39.14334	25	19S	6E	201	102 outcrop	7,720	12.8	6	7,520
69	C94B-E23	Sanchez/Ellis	-111.16787	39.14014	29	19S	7E	23	102 outcrop	7,723			7,700
70	FNC-M13	Spieker-USGS Bull 819	-111.28875	39.14005	30	19S	6E	37	102 outcrop	6,976			6,940
71	C94B-USGS-4	USGS Dh	-111.22543	39.14000	27	19S	6E	1,084	206 geophysical	8,560	8.0	3	7,476
72	C94B-USGS-1	USGS Dh	-111.24551	39.13862	28	19S	6E	1,060	201 core	8,010	20.5	6	6,950
73	FNC-M35	USGS OFR-81-319 Ellis	-111.28912	39.13243	30	19S	6E	74	106 multiple sections	7,171	8.3	3	7,100
74	C94B-M11	Sanchez/Muldoon	-111.28815	39.13138	31	19S	6E	161	102 outcrop	7,262	9.5	4	7,101
75	FNC-M39	USGS OFR-81-319 Ellis	-111.28900	39.13124	31	19S	6E	46	102 outcrop	7,163			7,120
76	C94B-USGS-2	USGS-Clb-2,Pi-Log	-111.21851	39.13088	35	19S	6E	959	106 multiple sections	8,480	11.6	4	7,522
77	C94B-USGS-3	USGS-Clb-3a,Pi-Log	-111.20664	39.13007	35	19S	6E	956	106 multiple sections	8,490	14.3	4	7,534
78	C94B-M13	Sanchez/Muldoon	-111.19363	39.12846	36	19S	6E	199	102 outcrop	7,840	10.3	3	7,641
79	FRN-M96	USGS OFR-81-1026 Muldoon	-111.21391	39.12432	35	19S	6E	218	106 multiple sections	7,720	15.2	7	7,519
80	FRN-M98	USGS OFR-81-1026 Muldoon	-111.21897	39.12295	35	19S	6E	225	106 multiple sections	7,724	13.9	4	7,520

Table 1. Data used in the assessment of coal resources in the southern Wasatch Plateau—*Continued.*

Map no.	Point ID	Source	Longitude	Latitude	Sec	Township	Range	Total depth (ft)	Type	Surface elevation (ft)	Total coal (ft)	# beds	Top of Star Point Ss (ft)
81	FRN-M99	USGS OFR-81-1026 Muldoon	-111.22544	39.11936	34	19S	6E	206	106 multiple sections	7,723	11.1	3	7,518
82	FRN-M106	Mine Map520-USGS-Bull819	-111.22867	39.11842	34	19S	6E	861	106 multiple sections	8,371	7.4	3	7,511
83	FRN-M100	USGS OFR-81-1026 Muldoon	-111.23079	39.11758	3	20S	6E	133	106 multiple sections	7,625	14.6	2	7,502
84	FRN-M91	USGS OFR-81-1026 Muldoon	-111.22376	39.08423	15	20S	6E	302	106 multiple sections	7,920	11.2	2	7,638
85	FRN-M90	USGS OFR-81-1026 Muldoon	-111.23175	39.07828	15	20S	6E	315	102 outcrop	7,979	19.5	5	7,760
86	FRN-M103	USGS OFR-81-1026 Muldoon	-111.21790	39.05635	26	20S	6E	329	106 multiple sections	8,273	18.1	8	8,000
87	HLT-C6	UGMS Special Studies 55	-111.38886	39.04828	20	20S	5E	1,686	204 w/e log	8,477	32.0	4	6,800
88	HLT-C4	UGMS Special Studies 55	-111.40544	39.04633	30	20S	5E	1,810	204 w/e log	8,423	25.3	5	6,671
89	HLT-C2	UGMS Special Studies 55	-111.37639	39.04403	29	20S	5E	1,171	204 w/e log	8,049	29.7	5	6,927
90	FRN-M105	USGS OFR-81-1026 Muldoon	-111.21118	39.04172	35	20S	6E	332	106 multiple sections	8,316	15.4	4	8,039
91	HLT-C3	UGMS Special Studies 55	-111.39283	39.03947	30	20S	5E	1,384	204 w/e log	8,147	19.4	4	6,817
92	FGP-C59	UGMS Special Studies 55	-111.36497	39.03719	28	20S	5E	1,141	204 w/e log	8,155	17.8	3	7,068
93	FGP-C14	Sanchez C94-A	-111.27750	39.03330	32	20S	6E	996	206 w/e log	8,600	22.0	2	
94	FRN-M101	USGS OFR-81-1026 Muldoon	-111.22288	39.03204	35	20S	6E	292	106 multiple sections	8,255	12.0	4	8,000
95	FRN-M89	USGS OFR-81-1026 Muldoon	-111.22432	39.03030	34	20S	6E	103	106 multiple sections	8,102	8.0	2	8,000
96	HLT-C1	UGMS Special Studies 55	-111.37972	39.02700	32	20S	5E	1,166	204 w/e log	8,152	20.5	3	7,039
97	FGP-M32	Spieker-USGS Bull819pl28	-111.28883	39.02575	6	21S	6E	36	102 outcrop	7,680			7,645
98	FGP-M55	OFR-77-833 Marley Flores	-111.31928	39.02489	35	20S	5E	222	106 multiple sections	7,661	21.6	5	7,440
99	FGP-C58	UGMS Special Studies 55	-111.36206	39.02453	33	20S	5E	1,126	204 w/e log	8,224	11.7	5	7,157
100	FGP-M4	Spieker-USGS Bull819pl28	-111.30733	39.02397	36	20S	5E	89	106 multiple sections	7,680	17.6	6	7,592
101	FGP-M31	Spieker-USGS Bull819pl28	-111.28528	39.02128	6	21S	6E	19	102 outcrop	7,650			7,632
102	FGP-C57	UGMS Special Studies 55	-111.34533	39.01822	34	20S	5E	1,075	204 drillers log	8,319	19.7	5	7,286
103	FGP-C60	UGMS Special Studies 55	-111.37236	39.01811	33	20S	5E	1,160	204 w/e log	8,244	18.4	5	7,143
104	HLT-C5	UGMS Special Studies 55	-111.38903	39.01394	5	21S	5E	1,344	204 w/e log	8,310	29.8	3	7,025
105	FGP-M47	OFR-77-833 Marley Flores	-111.29772	39.00967	12	21S	6E	301	106 multiple sections	7,940	9.0	4	7,640
106	FGP-M45	OFR-77-833 Marley Flores	-111.29239	39.00239	7	21S	6E	264	106 multiple sections	7,885	6.9	3	7,621
107	EMW-M137	OFR-77-833 Marley Flores	-111.27773	38.99403	17	21S	6E	124	106 multiple sections	8,003	7.0	2	7,880
108	EMW-M140	OFR-77-833 Marley Flores	-111.29758	38.99247	13	21S	5E	279	106 multiple sections	8,038	9.0	3	7,760
109	EW10	Blanchard,Ellis&Rob,1977	-111.32291	38.99173	14	21S	5E	1,080	216 w/e log	8,465	17.5	2	7,520
110	EMW-M152	OFR-77-833 Marley Flores	-111.25737	38.99107	16	21S	6E	219	106 multiple sections	6,878	6.0	2	6,660
111	EMW-M133	OFR-77-833 Marley Flores	-111.27379	38.99029	17	21S	6E	118	106 multiple sections	8,037	9.5	2	7,920
112	ACL-C110	UGMS Special Studies 55	-111.40881	38.98994	13	21S	4E	1,425	204 drillers log	8,380	19.8	4	7,042
113	ACL-C111	UGMS Special Studies 55	-111.39089	38.98964	18	21S	5E	1,280	204 drillers log	8,410	21.0	3	7,155
114	EW8	Blanchard,Ellis&Rob,1977	-111.35542	38.98436	16	21S	5E	1,027	216 coal test	8,350	20.0	2	7,353
115	ACL-C97	UGMS Special Studies 55	-111.39908	38.98336	18	21S	5E	1,196	204 w/e log	8,253	20.0	3	7,116
116	AL1	Blanchard,Ellis&Rob,1977	-111.38249	38.97810	20	21S	5E	1,120	216 w/e log	8,300	20.0	3	
117	ACL-C112	UGMS Special Studies 55	-111.42550	38.97575	23	21S	4E	1,516	204 w/e log	8,454	23.0	4	6,989
118	ACL-C98	UGMS Special Studies 55	-111.40922	38.97414	24	21S	4E	1,260	204 drillers log	8,317	24.6	4	7,108
119	EW9	Blanchard,Ellis&Rob,1977	-111.31835	38.97361	23	21S	5E	1,054	216 coal test	8,650	19.5	4	7,620
120	BCR3\USGS3A	Sanchez USGS-C-93-B?	-111.37060	38.97285	21	21S	5E	1,193	e-log	8,530	22.0	3	7,493
121	ACL-C99	UGMS Special Studies 55	-111.42108	38.96764	24	21S	4E	1,195	204 drillers log	8,271	29.5	2	7,082

Table 1. Data used in the assessment of coal resources in the southern Wasatch Plateau—*Continued*.

Map no.	Point ID	Source	Longitude	Latitude	Sec	Township	Range	Total depth (ft)	Type	Surface elevation (ft)	Total coal (ft)	# beds	Top of Star Point Ss (ft)
122	EW7	Blanchard,Ellis&Rob,1977	-111.36016	38.96624	28	21S	5E	1,193	216 coal test	8,480	18.0	3	7,475
123	EMW-M120	OFR-77-833 Marley Flores	-111.27815	38.96436	29	25S	6E	333	106 multiple sections	8,372	10.4	4	8,039
124	ACL-C95	USGS OFR-82-28 Albee	-111.44051	38.96127	26	21S	4E	1,960	206 geophysical	8,920	22.3	4	6,993
125	EMW-M85	OFR-77-833 Marley Flores	-111.33272	38.96072	26	21S	5E	322	106 multiple sections	7,961	5.0	3	7,645
126	EMW-M169	OFR-77-833 Marley Flores	-111.25692	38.96047	28	21S	6E	279	106 multiple sections	7,279	13.6	4	7,000
127	ACL-C100	UGMS Special Studies 55	-111.41025	38.95858	25	21S	4E	1,210	204 drillers log	8,342	16.5	2	7,243
128	EMW-M88	OFR-77-833 Marley Flores	-111.32964	38.95822	26	21S	5E	165	106 multiple sections	7,844	14.0	2	7,680
129	ACL-M86	USGS-C-93-B Sanchez	-111.38529	38.95764	29	21S	5E	46	106 multiple sections	7,460	15.2	2	7,415
130	ACL-M88	USGS-C-93-B Sanchez	-111.38422	38.95762	29	21S	5E	42	106 multiple sections	7,470	14.3	1	7,429
131	EMW-M101	OFR-77-833-Marley Flores	-111.31025	38.95756	25	21S	5E	298	106 multiple sections	8,097	15.5	5	7,800
132	EMW-M104	OFR-77-833-Marley Flores	-111.30208	38.95739	25	21S	5E	337	106 multiple sections	8,136	22.0	7	7,800
133	EMW-M89	OFR-77-833 Marley Flores	-111.32778	38.95714	26	21S	5E	567	106 multiple sections	8,206	0.0	0	7,640
134	ACL-M16	Spieker USGS-Bull819pl29	-111.38520	38.95701	29	21S	5E	38	106 multiple sections	7,460	23.0	2	7,423
135	EMW-M99	OFR-77-833-Marley Flores	-111.31283	38.95675	25	21S	5E	307	106 multiple sections	8,106	22.8	6	7,800
136	EMW-M97	OFR-77-833 Marley Flores	-111.31772	38.95528	26	21S	5E	271	106 multiple sections	8,000	23.4	4	7,729
137	ACL-M84	USGS-C-93-B Sanchez	-111.38204	38.95481	29	21S	5E	31	106 multiple sections	7,460	17.4	1	7,431
138	ACL-M31	USGS-C-93-B Sanchez	-111.37903	38.95067	32	21S	5E	49	106 multiple sections	7,470	21.4	2	7,422
139	EMW-M110	OFR-77-833 Marley Flores	-111.29383	38.95040	31	21S	6E	380	106 multiple sections	8,340	0.0	0	7,961
140	ACL-M19	Spieker-USGS-Bull819pl29	-111.37871	38.94998	32	21S	5E	41	106 multiple sections	7,480	19.2	2	7,300
141	ACL-C103	UGMS Special Studies 55	-111.43078	38.94928	26	21S	4E	1,460	204 w/e log	8,629	12.0	2	7,199
142	ACL-C94	USGS OFR-82-28 Albee	-111.47416	38.94889	28	21S	4E	1,258	206 geophysical	8,010	7.5	3	6,775
143	EMW-M204	USGS-C-93-B Sanchez	-111.37461	38.94850	32	21S	5E	42	106 multiple sections	7,480	22.0	2	7,439
144	EMW-M81	OFR-77-833 Marley Flores	-111.33067	38.94758	35	21S	5E	285	106 multiple sections	8,004	3.0	1	7,720
145	ACL-M22	USGS-C-93-B Sanchez	-111.37719	38.94678	32	21S	5E	34	106 multiple sections	7,436	13.7	2	7,403
146	ACL-M20	USGS-C-93-B Sanchez	-111.37752	38.94625	32	21S	5E	37	106 multiple sections	7,440	12.5	1	7,404
147	EMW-M170	OFR-77-833 Marley Flores	-111.25983	38.94578	33	21S	6E	300	106 multiple sections	7,259	28.1	5	6,959
148	ACL-M17	USGS-C-93-B Sanchez	-111.37819	38.94569	32	21S	5E	51	106 multiple sections	7,490	12.6	1	7,440
149	ACL-C101	UGMS Special Studies 55	-111.44567	38.94503	34	21S	4E	1,431	204 drillers log	8,438	14.0	5	7,022
150	ACL-M21	Spieker-USGS-Bull819pl29	-111.37761	38.94501	32	21S	5E	39	106 multiple sections	7,540	13.0	3	7,502
151	EMW-M80	OFR-77-833 Marley Flores	-111.33028	38.94464	35	21S	5E	194	106 multiple sections	7,960	6.5	3	7,766
152	EMW-M174	OFR-77-833 Marley Flores	-111.26064	38.94161	33	21S	6E	136	106 multiple sections	7,235	16.2	4	7,100
153	EMW-M176	OFR-77-833 Marley Flores	-111.26056	38.94097	33	21S	6E	63	106 multiple sections	7,162	10.0	1	7,100
154	EMW-M31	Spieker-USGS Bull819pl29	-111.37192	38.93883	5	22S	5E	36	106 multiple sections	7,560	14.8	1	7,525
155	ACL-C109	UGMS Special Studies 55	-111.43697	38.93644	35	21S	4E	1,225	204 drillers log	8,307	11.5	3	7,135
156	EMW-M69	OFR-77-833 Marley Flores	-111.26406	38.93589	5	22S	6E	332	106 multiple sections	7,531	4.5	1	7,199
157	ACL-C137	USGS C-93-B Sanchez	-111.49085	38.93495	32	21S	4E	1,187	204 drillers log	7,920	10.8	3	6,733
158	WRD-C19	USGS C-93-B Sanchez	-111.50629	38.93292	6	22S	4E	1,203	204 drillers log	7,900	20.7	5	6,698
159	ACL-C145	USGS C-93-B Sanchez	-111.46874	38.93288	4	22S	4E	1,466	204 drillers log	8,100	12.4	2	6,634
160	EMW-M1	Spieker-USGSbull819 Pl29	-111.33656	38.93204	3	22S	5E	101	106 multiple sections	7,880	17.1	4	7,780
161	WRD-C18	USGS C-93-B Sanchez	-111.50582	38.93109	6	22S	4E	1,196	204 drillers log	7,820	14.0	3	6,624
162	EMW-M199	USGS-C-93-B Sanchez	-111.36953	38.92994	4	22S	5E	39	106 multiple sections	7,680	14.6	2	7,642

Table 1. Data used in the assessment of coal resources in the southern Wasatch Plateau—*Continued.*

Map no.	Point ID	Source	Longitude	Latitude	Sec	Township	Range	Total depth (ft)	Type	Surface elevation (ft)	Total coal (ft)	# beds	Top of Star Point Ss (ft)
163	EMW-M189	USGS Map-C-82,Hayes	-111.27589	38.92986	5	22S	6E	143	106 multiple sections	7,342	9.6	2	7,200
164	EMW-M34	Spieker-USGS Bull819pl29	-111.37317	38.92858	5	22S	5E	70	106 multiple sections	7,500	18.7	2	7,431
165	EMW-M198	USGS-C-93-B Sanchez	-111.37158	38.92844	4	22S	5E	54	106 multiple sections	7,600	20.8	2	7,547
166	BCR4	UGMS Special Studies 55	-111.43333	38.92833	2	22S	4E	1,036	204 drillers log	8,290	20.5	2	7,380
167	ACL-C121	OFR-79-1009-Aaa-Eng&Draf	-111.39002	38.92788	5	22S	5E	1,005	204 drillers log	8,475	13.9	2	7,470
168	ACL-C102	UGMS Special Studies 55	-111.44736	38.92683	3	22S	4E	1,080	204 drillers log	8,186	11.5	2	7,227
169	EMW-M196	USGS-C-93-B Sanchez	-111.37467	38.92572	5	22S	5E	46	106 multiple sections	7,680	10.8	1	7,635
170	ACL-C144	USGS C-93-B Sanchez	-111.46566	38.92554	4	22S	4E	1,390	204 drillers log	8,069	10.8	2	6,679
171	ACL-C140	USGS C-93-B Sanchez	-111.48114	38.92458	5	22S	4E	1,455	204 drillers log	8,060	17.5	2	6,605
172	EMW-M36	Spieker-USGS Bull819pl29	-111.37278	38.92417	8	22S	5E	36	106 multiple sections	7,650	24.0	2	7,615
173	WRD-C17	USGS C-93-B Sanchez	-111.50105	38.92410	6	22S	4E	1,079	204 drillers log	7,840	17.4	3	6,761
174	ACL-C108	UGMS Special Studies 55	-111.43428	38.92072	2	22S	4E	1,160	204 drillers log	8,280	13.6	2	7,368
175	ACL-C139	USGS C-93-B Sanchez	-111.48807	38.91994	5	22S	4E	1,688	204 drillers log	8,585	19.4	4	6,898
176	EMW-M40	Mine Map520-USGS-Bull819	-111.37483	38.91917	8	22S	5E	835	106 multiple sections	8,540	7.2	2	7,706
177	WRD-C16	USGS C-93-B Sanchez	-111.50570	38.91814	7	22S	4E	1,091	204 drillers log	7,830	13.8	3	6,739
178	ACL-M13	USGS-C-93-B Sanchez	-111.37743	38.91647	8	22S	5E	75	106 multiple sections	7,720	9.0	2	7,646
179	ACL-M3	Spieker-USGS-Bull819pl29	-111.41638	38.91525	12	22S	4E	129	106 multiple sections	7,540	15.2	2	7,412
180	ACL-M12	USGS-C-93-B Sanchez	-111.37716	38.91421	8	22S	5E	66	106 multiple sections	7,740	7.0	2	7,675
181	WRD-C15	USGS C-93-B Sanchez	-111.50631	38.91402	7	22S	4E	1,081	204 drillers log	7,852	6.8	1	6,771
182	ACL-C106	UGMS Special Studies 55	-111.43067	38.91353	11	22S	4E	947	204 drillers log	8,280	17.5	2	7,430
183	EMW-M194	USGS-C-93-B Sanchez	-111.37481	38.91297	8	22S	5E	63	106 multiple sections	7,810	11.3	1	7,748
184	ACL-C143	USGS C-93-B Sanchez	-111.47751	38.91286	9	22S	4E	1,261	204 drillers log	8,002	19.0	2	6,742
185	ACL-M164	USGS C-93-B Sanchez	-111.40531	38.91116	12	22S	4E	77	106 multiple sections	7,490	19.6	3	7,414
186	ACL-C104	UGMS Special Studies 55	-111.45639	38.91106	10	22S	4E	1,020	204 drillers log	8,135	9.7	4	7,208
187	ACL-C138	USGS C-93-B Sanchez	-111.49620	38.91091	8	22S	4E	1,378	204 drillers log	8,290	16.0	3	6,912
188	ACL-M163	USGS C-93-B Sanchez	-111.40678	38.90979	12	22S	4E	85	106 multiple sections	7,544	18.4	2	7,460
189	WRD-C13	USGS C-93-B Sanchez	-111.50595	38.90932	7	22S	4E	1,355	204 drillers log	8,140	12.0	3	6,786
190	ACL-M4	Spieker-USGS-Bull819pl29	-111.42069	38.90828	12	22S	4E	99	106 multiple sections	7,500	14.3	3	7,402
191	ACL-M162	USGS C-93-B Sanchez	-111.40920	38.90817	12	22S	4E	62	106 multiple sections	7,500	10.0	2	7,439
192	ACL-M165	USGS C-93-B Sanchez	-111.40324	38.90781	18	22S	5E	70	106 multiple sections	7,520	10.8	3	7,451
193	ACL-M166	USGS C-93-B Sanchez	-111.39944	38.90630	18	22S	5E	95	106 multiple sections	7,560	9.2	2	7,466
194	ACL-M2	Spieker-USGS-Bull819pl29	-111.39753	38.90579	18	22S	5E	95	106 multiple sections	7,653	12.1	2	7,559
195	ACL-C142	USGS C-93-B Sanchez	-111.47929	38.90393	17	22S	4E	1,179	204 drillers log	7,984	16.0	2	6,805
196	ACL-C141	USGS C-93-B Sanchez	-111.47018	38.90067	16	22S	4E	902	204 drillers log	8,100	17.0	3	7,199
197	WRD-C11	USGS C-93-B Sanchez	-111.50765	38.89951	18	22S	4E	1,063	204 drillers log	7,830	5.0	2	6,767
198	ACL-M5	Spieker-USGS-Bull819pl29	-111.40192	38.89767	18	22S	5E	127	106 multiple sections	7,626	13.0	3	7,500
199	ACL-C107	UGMS Special Studies 55	-111.45133	38.89750	15	22S	4E	1,100	204 drillers log	8,240	13.5	4	7,257
200	WRD-C12	USGS C-93-B Sanchez	-111.51127	38.89748	18	22S	4E	985	204 drillers log	7,810	14.0	3	6,826
201	ACL-C105	UGMS Special Studies 55	-111.41497	38.89667	13	22S	4E	1,126	204 drillers log	8,398	14.0	3	
203	WRD-C10	USGS C-93-B Sanchez	-111.50035	38.89170	18	22S	4E	1,397	204 drillers log	8,295	8.0	2	6,898
204	ACL-M6	Spieker-USGS-Bull819pl29	-111.39794	38.88965	19	22S	5E	128	106 multiple sections	7,627	10.5	4	7,500

Table 1. Data used in the assessment of coal resources in the southern Wasatch Plateau—*Continued*.

Map no.	Point ID	Source	Longitude	Latitude	Sec	Township	Range	Total depth (ft)	Type	Surface elevation (ft)	Total coal (ft)	# beds	Top of Star Point Ss (ft)
205	ACL-M160	USGS C-93-B Sanchez	-111.39924	38.88933	19	22S	5E	108	106 multiple sections	7,600	7.3	2	7,493
206	ACL-M158	USGS C-93-B Sanchez	-111.40263	38.88564	19	22S	5E	99	106 multiple sections	7,695	6.8	2	7,597
207	WRD-C9	USGS C-93-B Sanchez	-111.51196	38.88408	19	22S	4E	1,338	204 drillers log	8,150	9.0	4	6,812
208	WRD-C8	USGS C-93-B Sanchez	-111.51312	38.88252	19	22S	4E	1,293	204 drillers log	8,104	6.1	3	6,812
209	ACL-M7	Spieker-USGS-Bull819pl29	-111.41704	38.88174	24	22S	5E	118	106 multiple sections	7,617	9.4	2	7,383
210	ACL-M1	Spieker-USGS-Bull819pl29	-111.39508	38.88039	30	22S	5E	104	106 multiple sections	7,750	9.3	3	7,647
211	AL19	Blanchard,Ellis&Rob,1977	-111.44958	38.87926	22	22S	4E	1,085	216 w/e log	8,220	8.5	4	7,332
212	ACL-M150	USGS C-93-B Sanchez	-111.38453	38.87819	29	22S	5E	77	106 multiple sections	7,840	8.5	1	7,764
213	OWP-M10	Spieker-USGS-Bull819pl29	-111.40255	38.87404	30	22S	5E	118	106 multiple sections	7,600	10.3	1	7,484
214	OW55	USGS Dh	-111.41744	38.87314	25	22S	4E	900	216 w/ e log	8,365	11.5	3	7,555
215	OWP-C94	USGS-Map-C93A-Sanchez	-111.48957	38.87289	29	22S	4E	865	204 drillers log	7,840	6.8	2	6,975
216	YGC-C8	USGS-Map-C93A Sanchez	-111.51083	38.87259	30	22S	4E	602	204 drillers log	7,440	9.0	3	6,838
217	OWP-M9	Spieker-USGS-Bull819pl29	-111.40343	38.86945	25	22S	4E	85	106 multiple sections	7,600	9.0	1	7,516
218	YGC-C7	USGS-Map-C93A Sanchez	-111.50081	38.86892	30	22S	4E	1,030	204 drillers log	7,640	11.3	2	6,611
219	OWP-C95	USGS-Map-C93A-Sanchez	-111.46007	38.86885	28	22S	4E	887	204 drillers log	8,156	6.0	2	7,269
220	OWP-M144	USGS OFR-82-1093 Blanch	-111.38483	38.86089	32	22S	5E	76	106 multiple sections	7,865	11.2	2	7,790
221	OWP-M43	Spieker-USGS-Bull819pl30	-111.38671	38.85959	35	23S	4E	110	106 multiple sections	7,900	8.7	1	7,791
222	OWP-M143	USGS OFR-82-1093 Blanch	-111.38683	38.85956	32	22S	5E	67	106 multiple sections	7,860	9.9	2	7,794
223	OWP-M11	Spieker-USGS-Bull819pl30	-111.38366	38.85909	32	22S	5E	54	106 multiple sections	7,843	1.3	1	7,790
224	OWP-C235	USGS OFR-78-363 Blanch	-111.44789	38.85787	34	22S	4E	920	204 drillers log	8,310	12.5	4	7,418
225	OWP-M142	USGS OFR-82-1093 Blanch	-111.38919	38.85658	32	22S	5E	97	106 multiple sections	7,840	12.6	3	7,744
226	OWP-M13	Spieker-USGS-Bull819pl30	-111.40071	38.85474	31	22S	5E	91	106 multiple sections	7,750	8.7	2	7,660
227	OWP-M141	USGS OFR-82-1093 Blanch	-111.38994	38.85458	32	22S	5E	96	106 multiple sections	7,880	5.9	2	7,785
228	OWP-M137	USGS OFR-82-1093 Blanch	-111.39492	38.85450	31	22S	5E	113	106 multiple sections	7,723	10.2	2	7,646
229	OWP-M145	USGS OFR-82-1093 Blanch	-111.38064	38.85422	32	22S	5E	79	106 multiple sections	7,888	9.3	2	7,810
230	OWP-M138	USGS OFR-82-1093 Blanch	-111.39431	38.85397	31	22S	5E	111	106 multiple sections	7,716	10.0	2	7,640
231	OWP-M139	USGS OFR-82-1093 Blanch	-111.39428	38.85189	31	22S	5E	99	106 multiple sections	7,760	8.9	2	7,663
232	OWP-C100	USGS-Map-C93A-Sanchez	-111.46046	38.85039	33	22S	4E	950	204 drillers log	8,180	7.4	1	7,231
233	OWP-M2	Spieker-USGS-Bull819pl30	-111.40878	38.84873	36	22S	4E	188	106 multiple sections	7,650	9.4	3	7,463
234	OWP-M3	Spieker-USGS-Bull819pl30	-111.41585	38.84790	36	22S	4E	157	106 multiple sections	7,650	7.5	2	7,494
235	OWP-M1	Spieker-USGS-Bull819pl30	-111.40340	38.84679	6	23S	5E	174	106 multiple sections	7,650	12.6	4	7,477
236	OWP-M23	Spieker-USGS-Bull819pl30	-111.41752	38.84552	1	23S	4E	72	106 multiple sections	7,600	8.5	2	7,529
237	OWP-M159	USGS OFR-82-1093 Blanch	-111.41883	38.84267	1	23S	4E	61	106 multiple sections	7,640	11.2	1	7,580
238	OWP-M158	USGS OFR-82-1093 Blanch	-111.41800	38.84169	1	23S	4E	58	106 multiple sections	7,637	10.1	1	7,580
239	OWP-M26	Spieker-USGS-Bull819pl30	-111.41667	38.84117	1	23S	4E	81	106 multiple sections	7,580	5.7	2	7,500
240	OW58	USGS Dh	-111.45155	38.84107	3	23S	4E	1,070	216 w/ e log	8,351	8.5	2	7,426
241	OWP-C99	USGS-Map-C93A-Sanchez	-111.49742	38.83504	6	23S	4E	990	204 drillers log	8,000	5.0	2	7,010
242	YGC-C1	USGS-Map-C93A Sanchez	-111.50216	38.83321	6	23S	4E	1,026	204 drillers log	7,966	6.7	1	6,940
243	OWP-M27	Spieker-USGS-Bull819pl30	-111.41553	38.83139	1	23S	4E	117	106 multiple sections	7,600	12.8	3	7,484
244	OWP-M155	USGS OFR-82-1093 Blanch	-111.41975	38.82978	12	23S	4E	89	106 multiple sections	7,650	15.1	2	7,562
245	OWP-C148	USGS OFR-82-1093 Blanch	-111.44844	38.82939	10	23S	4E	891	204 drillers log	8,340	11.1	4	7,461

Table 1. Data used in the assessment of coal resources in the southern Wasatch Plateau—*Continued.*

Map no.	Point ID	Source	Longitude	Latitude	Sec	Township	Range	Total depth (ft)	Type	Surface elevation (ft)	Total coal (ft)	# beds	Top of Star Point Ss (ft)
246	OWP-M29	Spieker-USGS-Bull819pl30	-111.41863	38.82888	12	23S	4E	117	106 multiple sections	7,660	12.8	2	7,544
247	OWP-M30	Spieker-USGS-Bull819pl30	-111.42114	38.82706	12	23S	4E	125	106 multiple sections	7,600	12.5	3	7,476
248	OWP-M153	USGS OFR-82-1093 Blanch	-111.42194	38.82661	12	23S	4E	73	106 multiple sections	7,750	7.6	1	7,678
249	YGC-C2	USGS-Map-C93A Sanchez	-111.50846	38.82636	7	23S	4E	938	204 drillers log	7,897	20.6	4	6,960
250	OWP-C96	USGS-Map-C93A-Sanchez	-111.49866	38.82424	7	23S	4E	985	204 drillers log	7,990	9.0	1	7,006
251	OWP-M177	USGS OFR-82-1093 Blanch	-111.42852	38.82131	11	23S	4E	67	106 multiple sections	7,700	4.3	2	7,634
252	OWP-M173	USGS OFR-82-1093 Blanch	-111.41469	38.82033	12	23S	4E	71	106 multiple sections	7,800	7.5	1	7,731
253	OWP-M174	USGS OFR-82-1093 Blanch	-111.41583	38.82011	12	23S	4E	86	106 multiple sections	7,800	8.9	1	7,715
254	OWP-M175	USGS OFR-82-1093 Blanch	-111.41661	38.82000	12	23S	4E	70	106 multiple sections	7,800	6.1	1	7,731
255	OWP-M176	USGS OFR-82-1093 Blanch	-111.41808	38.81989	12	23S	4E	67	106 multiple sections	7,800	7.8	1	7,734
256	OWP-C239	USGS OFR-78-363 Blanch	-111.48121	38.81828	8	23S	4E	1,035	204 drillers log	8,115	5.0	1	7,175
257	OWP-M167	USGS OFR-82-1093 Blanch	-111.42169	38.81619	12	23S	4E	68	106 multiple sections	7,800	11.1	3	7,733
258	YGC-C4	USGS-Map-C93A Sanchez	-111.50826	38.81448	18	23S	4E	762	204 drillers log	7,748	11.0	2	6,986
259	OWP-C107	USGS-Map-C93A-Sanchez	-111.49966	38.81378	18	23S	4E	1,193	204 drillers log	8,180	11.5	4	6,987
260	YGC-C3	USGS-Map-C93A Sanchez	-111.51128	38.81188	18	23S	4E	800	204 drillers log	7,690	9.0	2	6,890
261	OWP-C162	USGS OFR-82-1093 Blanch	-111.45625	38.80847	15	23S	4E	485	204 drillers log	7,840	11.2	3	7,443
262	OW62	USGS Dh	-111.47320	38.80648	16	23S	4E	885	216 coal test	8,150	7.2	3	
263	OWP-C160	USGS OFR-82-1093 Blanch	-111.47297	38.80622	16	23S	4E	977	204 drillers log	8,140	5.5	2	7,236
264	OWP-M36	Spieker-USGS-Bull819pl30	-111.44281	38.80519	15	23S	4E	99	106 multiple sections	7,668	5.8	1	7,570
265	OWP-M200	USGS OFR-82-1093 Blanch	-111.42684	38.80475	14	23S	4E	69	106 multiple sections	7,760	7.3	1	7,692
266	OWP-M37	Spieker-USGS-Bull819pl30	-111.43129	38.80413	14	23S	4E	96	106 multiple sections	7,735	7.0	1	7,640
267	OWP-M198	USGS OFR-82-1093 Blanch	-111.41898	38.80282	13	23S	4E	83	106 multiple sections	7,840	10.8	1	7,759
268	OWP-M197	USGS OFR-82-1093 Blanch	-111.42086	38.80130	24	23S	4E	100	106 multiple sections	7,800	10.8	2	7,701
269	YGC-C6	USGS-Map-C93A Sanchez	-111.50744	38.79722	19	23S	4E	738	204 drillers log	7,560	6.0	3	6,822
270	YGC-C5	USGS-Map-C93A Sanchez	-111.50655	38.79660	19	23S	4E	606	204 drillers log	7,628	6.4	4	7,023
271	OWP-M38	Spieker-USGS-Bull819pl30	-111.43314	38.78656	26	23S	4E	101	106 multiple sections	7,680	6.8	1	7,580
272	OWP-M186	USGS OFR-82-1093 Blanch	-111.43477	38.78556	26	23S	4E	135	106 multiple sections	7,700	8.3	1	7,566
273	OWP-M181	USGS OFR-82-1093 Blanch	-111.42849	38.78424	26	23S	4E	138	106 multiple sections	7,800	10.6	2	7,663
274	OWP-M180	USGS OFR-82-1093 Blanch	-111.42563	38.78414	26	23S	4E	189	106 multiple sections	7,900	6.7	1	7,712
275	OW64	Blanchard,Ellis&Rob,1977	-111.45345	38.78396	27	23S	4E	740	216 w/ e log	8,080	11.1	4	7,422
276	OWP-C110	USGS-Map-C93A-Sanchez	-111.44276	38.78357	27	23S	4E	684	204 drillers log	8,250	19.3	6	
277	OWP-M178	USGS OFR-82-1093 Blanch	-111.42150	38.78292	25	23S	4E	191	106 multiple sections	7,880	7.1	1	7,690
278	OWP-M225	USGS OFR-82-1093 Blanch	-111.42102	38.77947	25	23S	4E	172	106 multiple sections	7,950	8.3	1	7,779
279	OWP-C109	USGS-Map-C93A-Sanchez	-111.45029	38.77852	27	23S	4E	669	204 drillers log	8,120	9.7	3	7,452
280	OWP-C102	USGS-Map-C93A-Sanchez	-111.49974	38.77804	30	23S	4E	837	204 drillers log	7,740	5.5	3	6,904
281	OWP-C111	USGS-Map-C93A-Sanchez	-111.44043	38.77714	26	23S	4E	651	204 drillers log	8,262	7.0	4	7,612
282	OWP-C108	USGS-Map-C93A-Sanchez	-111.45684	38.77644	27	23S	4E	698	204 drillers log	8,160	13.4	5	7,462
283	OWP-M223	USGS OFR-82-1093 Blanch	-111.42097	38.76950	36	23S	4E	176	106 multiple sections	7,960	0.0	0	7,785
284	OWP-C88	USGS-Map-C93A-Sanchez	-111.45900	38.76938	34	23S	4E	418	204 drillers log	7,860	10.2	5	7,443
285	OWP-M80	USGS-Map-C93A-Sanchez	-111.42050	38.76903	36	23S	4E	169	106 multiple sections	7,960	3.2	2	7,792
286	OWP-M79	USGS-Map-C93A-Sanchez	-111.42303	38.76798	35	23S	4E	171	106 multiple sections	7,800	7.4	2	7,630

Table 1. Data used in the assessment of coal resources in the southern Wasatch Plateau—*Continued*.

Map no.	Point ID	Source	Longitude	Latitude	Sec	Township	Range	Total depth (ft)	Type	Surface elevation (ft)	Total coal (ft)	# beds	Top of Star Point Ss (ft)
287	OWP-C91	USGS-Map-C93A-Sanchez	-111.44033	38.76755	35	23S	4E	590	204 drillers log	8,240	9.8	4	7,650
288	OWP-M41	Spieker USGS Bull819pl30	-111.42368	38.76749	35	23S	4E	130	106 multiple sections	7,880	5.3	2	7,751
289	OWP-M222	USGS OFR-82-1093 Blanch	-111.42365	38.76708	35	23S	4E	177	106 multiple sections	7,920	5.3	1	7,744
290	OWP-M220	USGS OFR-82-1093 Blanch	-111.42691	38.76314	35	23S	4E	165	106 multiple sections	7,900	8.1	1	7,736
291	OWP-M53	Spieker-USGS-Bull819pl30	-111.45420	38.76250	34	23S	4E	94	106 multiple sections	7,640	4.0	2	7,548
292	OWP-M205	USGS OFR-82-1093 Blanch	-111.45107	38.76083	34	23S	4E	100	106 multiple sections	7,580	7.4	1	7,481
293	OWP-C101	USGS-Map-C93A-Sanchez	-111.49819	38.76069	31	23S	4E	970	204 drillers log	7,860	5.5	3	6,890
294	OWP-M48	Spieker-USGS-Bull819pl30	-111.43592	38.76037	35	23S	4E	123	106 multiple sections	7,770	7.4	1	7,648
295	OWP-M210	USGS OFR-82-1093 Blanch	-111.44240	38.76036	34	23S	4E	144	106 multiple sections	7,720	5.8	1	7,577
296	OWP-M212	USGS OFR-82-1093 Blanch	-111.43818	38.76009	35	23S	4E	117	106 multiple sections	7,760	7.1	1	7,644
297	OWP-M211	USGS OFR-82-1093 Blanch	-111.43969	38.76005	35	23S	4E	147	106 multiple sections	7,760	7.3	2	7,614
298	OWP-M226	USGS OFR-82-1093 Blanch	-111.45562	38.75921	34	23S	4E	99	106 multiple sections	7,540	3.3	2	7,442
299	OWP-M231	USGS OFR-82-1093 Blanch	-111.44779	38.75226	3	24S	4E	113	106 multiple sections	7,680	9.5	1	7,568
300	OWP-M67	Spieker-USGS-Bull819pl29	-111.43023	38.75074	2	24S	4E	79	102 outcrop	7,820			7,742
301	OWP-M232	USGS OFR-82-1093 Blanch	-111.44881	38.75057	3	24S	4E	169	106 multiple sections	7,700	4.5	1	7,532
302	OWP-M63	Spieker-USGS-Bull819pl30	-111.42637	38.75031	2	24S	4E	132	106 multiple sections	7,840	5.1	2	7,709
303	JNP-C125	USGS OFR-78-363 Blanch	-111.48512	38.74311	8	24S	4E	730	204 w/e log	7,935	0.0	0	7,225
304	JNP-C127	USGS OFR-78-363 Blanch	-111.43943	38.73244	11	24S	4E	515	204 drillers log	8,190	6.5	2	7,760
305	JP17	Davis&Doelling,1977	-111.45158	38.72628	15	24S	4E	221	216 coal test	7,965	10.3	3	7,746
306	JNP-C126	USGS OFR-78-363 Blanch	-111.46548	38.71729	16	24S	4E	520	204 drillers log	8,200	4.0	1	7,749
307	JP19	Davis&Doelling,1977	-111.46224	38.70493	21	24S	4E	487	216 coal test	8,571	4.1	2	
308	JNP-C124	USGS OFR-78-363 Blanch	-111.47388	38.69513	28	24S	4E	735	204 drillers log	8,886	11.0	2	8,265
309	JNP-M11	Spieker-USGS-Bull819pl30	-111.47347	38.66924	4	25S	4E	35	106 multiple sections	9,000	7.8	1	8,966

Geophysical logs were not available for all of the known subsurface data points; where possible, coal thicknesses for these points were verified or corrected against data in other publications that had drawn their data from the original geophysical logs. Data exists in the NCRDS data set that is proprietary in nature; that is, the State of Utah and the Utah Geological Survey has access to drill holes and logs that are owned by companies. Some of these proprietary data have been entered into NCRDS and were available for examination in the southern Wasatch Plateau database. These proprietary data points and their stratigraphic information were used for coal-bed correlations; however, none of these proprietary data points is shown on the location maps, and none of the stratigraphic data or coal thicknesses are presented in the data tables or in Appendix 1. Additional company coal drill holes exist west of Ferron Canyon in the northern part of the southern Wasatch Plateau in T. 19 S., R. 5 E., but these drill holes and geophysical logs were not available for inclusion in this study.

It was beyond the scope of this investigation to reexamine in the field every measured stratigraphic section in the database. Wherever possible, the stratigraphic data from measured sections were checked against the original source or verified against other reports that subsequently published the sections to evaluate that the data were entered correctly into the NCRDS database (e.g., Doelling, 1972a; Hayes and Sanchez, 1979; Sanchez and others, 1983a, 1983b; Brown and others, 1987; and numerous other reports that are more completely discussed in the Previous Geologic Studies section). We deleted from the database any measured section that recorded simply a thickness of coal and that did not also record the stratigraphic interval in which it occurred or for which no section of underlying or overlying rocks was measured. Without the stratigraphic interval recorded, or without the adjacent rock record to ensure correct stratigraphic placement under present understanding of coal-bed correlations, we could not endorse or corroborate the coal correlation and thus did not include that data point in the coal-assessment database for resource analysis.

For this study in the southern Wasatch Plateau, six stratigraphic sections of the coal-bearing section of the Blackhawk Formation and the underlying Star Point Sandstone were measured to elucidate the subsurface correlations of marine shoreface sandstones to coal beds and to aid in the correlation of the geophysical well logs and construction of the subsurface cross sections.

Geophysical logs obtained for this study were reproduced at a scale of 50 ft = 1 inch for visual correlation. They were digitized in Digi-Rule (Digi-Rule, Inc., 1995) and imported into the StratiFact database to aid in coal identification and correlation within the database. The Digi-Rule files were subsequently converted to log-ASCII format and imported to a drafting program for presentation on the cross sections included in this report. Lithologic interpretations of coal and other strata on the geophysical logs were made from a combination of natural-gamma (gamma ray), density, resistivity, and neutron logs (e.g., Kowalski and Holter, 1975; Seimers, 1978; Reeves, 1981; Wood and others, 1983), depending on the logs available for each hole. On the geophysical logs, coal displays a low natural gamma and density response and a high resistivity and neutron response. Sandstone displays a moderate natural gamma and resistivity response. Mudstone displays a high natural gamma and a low resistivity response. Caliper logs, which measure variations in the diameter of the drill hole, were used in conjunction with density logs to verify that low-density log deflections were due to coal rather than to drill-hole washouts. Coal-bed thicknesses had previously been entered into the NCRDS database in feet and inches, and when imported into the StratiFact program they were converted to feet and tenths of a foot, and in some cases into hundredths of a foot because of the conversion of inches to decimal values. Values for coal-bed thickness recorded as part of this study were measured and recorded to tenths of a foot due to the scale of some of the available logs. The values output from StratiFact were rounded and recorded to an accuracy of a tenth of a foot. The StratiFact output was programmed to generate a file that did not report any isolated coal bed that was less than 1.2 ft thick. In addition, thicknesses of more than one coal bed were combined on output into a single coal bed if an intervening parting was thinner than either the overlying or the underlying coal bed. The thickness of the parting was not included in the reported thickness of the coal, according to the methods and definitions in Wood and others (1938, p. 31, 36).

Geologic Maps and Data

ARC/INFO coverages of geologic features include the location of stratigraphic boundaries and geologic units of the coal-bearing formations and underlying and overlying rock units, along with minor faults and folds within the study area and major fault systems that bound the study area on the east and west (fig. 4; also see Appendix 1). Several minor fold axes occur along canyons on the east side of the Wasatch Plateau (fig. 6), but they are not a part of the digital geologic coverage because they represent only minor disruption to the strata. The geologic coverage of the southern Wasatch Plateau (fig. 4) was digitized from the geologic map of Spieker (1931), one of the earliest comprehensive evaluations of the Wasatch Plateau coal field in central Utah. Spieker's (1931) map was originally surveyed in the field for both geology and topography, and it was produced at a scale of 1:62,500. Other newer geologic maps available for possible geologic coverages for this report were at scales of 1:250,000 (Williams and Hackman, 1971; Witkind, 1995), or the State map of Utah (Hintze, 1980) at a scale of 1:500,000. After projecting each of these different digital geologic map coverages to the same map projections in ARC/INFO, at scales of 1:62,500 and 1:100,000, the location of data points from the NCRDS data set for measured stratigraphic sections along outcrops most accurately plotted to match the outcrop pattern of Spieker's (1931) original geologic map and not the newer 1:62,500 and 1:100,000 maps. Thus, Spieker's (1931) geologic coverage was used in maps, coverages, and figures for this report. In a small area between Quitchipah Canyon and Muddy Creek, the digitized coverage for the outcrop of the Star Point Sandstone did not accurately match the typical cliff-forming topography of the Star Point when superimposed on the digital elevation models (DEM's) obtained for the study area. The outcrop of the Star Point on the geologic coverage was adjusted slightly to match the topography as depicted on the DEM. Everywhere else, Spieker's (1931) geology accurately reflected the expected DEM topographic expression of slopes and cliffs formed by the different geologic units.

Cartographic Data and Geographic Boundaries

ARC/INFO coverages for geographic boundaries were imported from existing public-domain databases. Township boundaries were obtained from a 1:24,000-scale Public Land Survey System (PLSS) coverage produced by the Automated Geographic Reference Center (AGRC) in Salt Lake City, Utah. Towns and roads were obtained from 1:100,000-scale digital line graphs created by the U.S. Geological Survey EROS Data Center in Sioux Falls, S. Dak. Areas of surface land ownership were digitized from 1:100,000-scale U.S. Bureau of Land Management (BLM) maps by the National Biological Survey, Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, Utah, for the National Geographic Approach to Planning for Biological Diversity (GAP) Program in 1993. Areas of coal ownership were obtained from digital compilations by the former U.S. Bureau of Mines for their inventory of federally owned minerals for exploration and development program in Utah and from a 1:24,000-scale PLSS coverage from the Utah School and Institutional Trust Lands Administration. Later, land and mineral exchanges took place in Utah after the Grand Staircase–Escalante National Monument was created by Presidential Proclamation. In 1999, the Utah School and Institutional Trust Lands Administration (SITLA) provided updated data on those exchanges, and the USGS incorporated those land and mineral ownership changes into the data set for this report. County and State lines were obtained from 1:100,000-scale Topographically Integrated Geographic Encoding and Referencing (TIGER) files produced by the U.S. Bureau of Census in 1990. Surface topography for the study area was obtained from 1:24,000-scale U.S. Geological Survey DEM's of the 7.5-minute quadrangles.

Geologic Setting

Structure of the Southern Wasatch Plateau Study Area

The Wasatch Plateau lies on the western margin of the Colorado Plateau between the northeast-trending, doubly plunging anticline of the San Rafael Swell on the east and the highly faulted, structurally complex physiography of the Great Basin on the west. In the eastern part of the southern Wasatch Plateau, the beds dip gently westward along the gently dipping west flank of the San Rafael Swell. The western part of the Wasatch Plateau forms a monoclinal fold along the eastern boundary of the Great Basin (Spieker, 1931, 1946). The western boundary of the study area was chosen at a series of north-south-trending normal faults termed the Musinia fault zone (fig. 6) and closely matches the western edge of the Wasatch coal field as originally defined (Spieker, 1927, 1931; Doelling, 1972a). The Musinia fault zone is succeeded to the west by the Water Hollow fault zone and the Sevier-Sanpete Valley fault zone, both of which are eastward extensions of basin-and-range-style faulting. These fault zones produced major displacements of the Star Point Sandstone and coal-bearing Blackhawk Formation in the area west of the present study area. The fractured nature of the area between those faults and the great depth to coals due to vertical fault displacement would be a significant impediment to coal extraction there. Thus, this highly faulted area, including the Salina Canyon district, was not included in the present study area of the southern Wasatch Plateau.

Faults

In the eastern part of the Wasatch Plateau, three graben systems form the eastward extension of the basin-and-range faulting: the Joes Valley fault zone, the Pleasant Valley fault zone, and the North Gordon fault zone (Spieker, 1931, fig. 4, p.78). The Pleasant Valley and North Gordon fault zones are in the northern part of the Wasatch Plateau. The Joes Valley fault zone (fig. 6) (see also Spieker, 1931) is a 75-mile-long system of normal faults (fig. 6) with vertical downward displacement in a central graben of between 1,500 and 2,500 ft (Spieker, 1931, p. 57). It trends northeast adjacent to the eastern flank of the Southern Wasatch Plateau study area. It turns north between the towns of Emery and Ferron and runs north through the Wasatch Plateau, where it is at or near the western boundary of the Northern Wasatch Plateau study area of Tabet and others (1999). The graben structure is several miles wide and contains numerous minor faults parallel to the major faults, along with innumerable subsidiary fractures. South of the town of Emery,

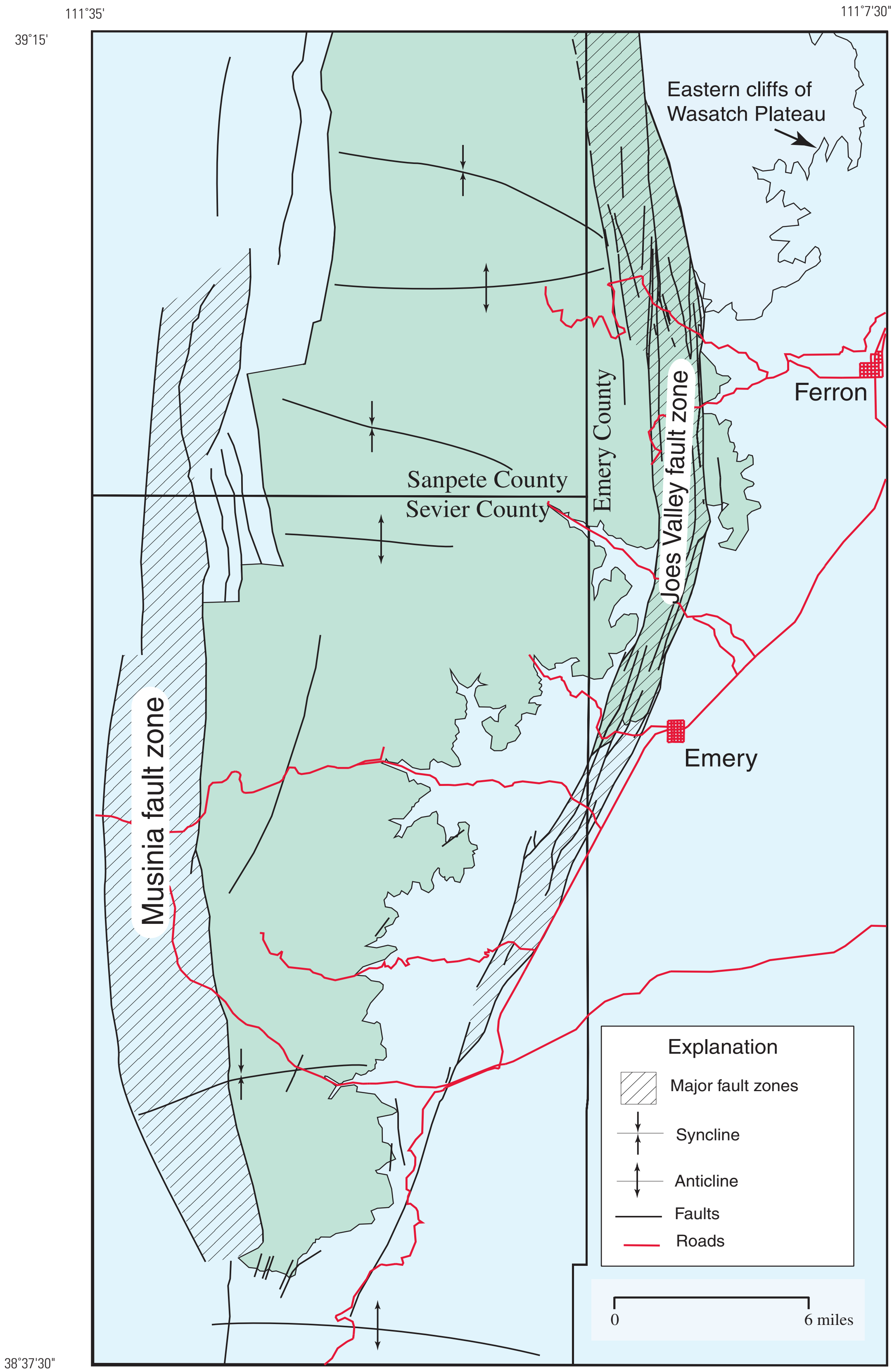


Figure 6. Map showing principal structural features in the Wasatch Plateau (modified from Davis and Doelling, 1977).

the faults of the Joes Valley graben become less numerous (fig. 6), and near the southern terminus of the study area they turn south toward Paradise Valley (Spieker, 1931, p. 57–58).

Between the Joes Valley fault zone and the western boundary of the study area, the strata are relatively unbroken, except for a single normal fault about 3 mi west of Convulsion Canyon and several minor faults near the southern margin of the study area (fig. 6).

Part of the Joes Valley graben is included in the Southern Wasatch Plateau study area, and the region between major faults of the graben system has been mapped and described by several studies as being a zone of intensely shattered and broken rock (Spieker, 1931; Sanchez and Brown , 1983; Sanchez and Brown, 1987; Doelling, 1972a). Because of the highly broken nature of the rocks in this area, the shattered zone is denoted on the maps for the coal assessment as a separate GIS polygon area, and the calculations for coal resources treat this area as separate from the rest of the study area. Coal resources for the shattered area are reported in a separate table. The westernmost fault of the Joes Valley fault zone was not mapped by Spieker (1931) all the way to the northern boundary of the study area, and subsequent mapping (Witkind, 1995) was complied from Spieker's (1931) map. It shows part of that fault to the north being covered by Quaternary landslide and alluvial-fan deposits. It is likely that the fault extends to the northern boundary of the study area, and the shattered zone of the Joes Valley fault zone is drawn to the northern study-area boundary (fig. 6). However, because there are no data or mapping available to demonstrate this conclusively, subsequent figures for coal resources delineate the shattered zone only where available geologic mapping specifically shows the faults to exist.

Folds

Strata in the southern Wasatch Plateau generally dip to the west at attitudes less than about 5°, except locally near faults where they may dip as much as 20° (Doelling, 1972a, p. 75). In several places in the study area, strata have been gently warped into broad anticlines and synclines that trend generally east-west, perpendicular to the major north-trending fault systems (fig. 6) (see also Davis and Doelling, 1977, fig. 8, p. 8). In places, the synclines roughly parallel the east-trending erosional canyons of Ferron Creek, Muddy Creek, and Ivie Creek. The dips of beds on the limbs of these minor folds are usually less than 10° and generally average only 3° or 4° (Davis and Doelling, 1977).

Cretaceous Paleogeography of the Southern Wasatch Plateau

During the Late Cretaceous (approximately 98 to 65 million years ago (Ma)), the region now forming the southern Wasatch Plateau was located about 45°N. paleolatitude within the Cretaceous Rocky Mountain foreland basin (fig. 7). Clastic sediment sourced from the west in the Sevier highlands (Young, 1955; Armstrong, 1968; Fouch and others, 1983; Peterson and Smith, 1986) was deposited in coastal-plain settings and along shorelines on the western margin of the Cretaceous Western Interior Seaway (Weimer, 1986; Roberts and Kirschbaum, 1995, fig. 19, p. 39). The following paragraph summarizing the paleogeography and tectonic setting of the Cretaceous Western Interior is taken essentially verbatim from Roberts and Kirschbaum's (1995, p. 1–3) introduction to paleogeography, coal distribution, and sediment accumulation of the Western Interior. (Several figure citations and references from the original text have been omitted for brevity; the complete text can be found in the original publication.)

> A vast seaway occupied the Western Interior of North America during the Late Cretaceous, connecting the Circum-Boreal sea with the proto-Gulf of Mexico. This seaway formed during a time of maximum eustatic sea level for the Phanerozoic (Vail and others, 1977; Haq and others, 1987), when water levels flooded the stable cratonic areas of the world. At its maximum extent, the seaway extended for 3,000 mi from the North Slope of Alaska to northern Mexico and was approximately 1,000 mi wide from central Utah to Minnesota. The seaway existed within an asymmetric foreland basin bordered on the west by the Columbian-Sevier orogen and flanking foredeep and on the east by the stable cratonic platform. The structural basin originated as the result of pre-Cretaceous tectonic processes. The thrusting and resulting crustal loading are related to the subduction of the Farallon plate (Keith, 1978) and the accretion of numerous terranes to the North American craton (Coney, 1981). At various times during the Late Cretaceous, these plate tectonic movements resulted in magmatic activity in western Canada, Idaho and Montana, Arizona and New Mexico, and the Sierra Nevadas of California. A transition from Sevier-style deformation (thin-skinned thrusting with associated uplifts and intermontane basins) took place in the Late Cretaceous as a result of a shallowing of the angle of the subducting slab and compressional stresses in the lithosphere (Keith, 1978). During phases of uplift in the Columbian-Sevier orogen, great volumes of coarse-grained terrigenous sediments were deposited as clastic wedges in the western side of the basin. Lithofacies grade, west to east, from coarse-grained (conglomerate) and sandstone facies, through interbedded sandstone and shale, to shale, chalk, and ultimately, limestone. These generalized facies patterns were interrupted by effects on sedimentation caused by major movements along the thrust belt, growth of arches, increase in subsidence rate, periodic subaerial exposure and erosion, and shoreline migration. Major unconformities separate clastic rocks into sequences that can be documented over wide areas and may be linked to eustatic lowstands as identified in the Exxon global cycle chart (Haq and others, 1987; Van Wagoner and others, 1990). North America occupied middle to high paleolatitudes, from 30°N. to 85°N., in the Late Cretaceous, and the vegetation ranged from tropical in Mexico and the southeastern United States to temperate in northern Canada and Alaska. Based on analyses of physiognomy of leaf assemblages, most Late Cretaceous plants evolved in a climate characterized by the absence of freezing temperatures and low to moderate amounts of precipitation. Evidence of polar glaciation is lacking.
>
> —Roberts and Kirschbaum (1995, p. 1–3).

The sediments that were deposited in this Cretaceous coastal setting included a variety of continental, coastal-plain, marginal-marine, and marine facies. The rocks that derived from those sediments in the southern Wasatch Plateau, as elsewhere in the Cretaceous, form a complexly interfingered package. The nomenclature that evolved to describe them is a mix from historical studies prior to current understanding of sedimentology and sequence stratigraphy and from subsequent attempts to rectify previous confusion and to apply the modern concepts that were valid at the time. The following discussion attempts to place the stratigraphic nomenclature in its historical perspective, to address issues of nomenclature confusion, and to describe the depositional setting and present sequence stratigraphic understanding of the package of coal-bearing rocks in a modern sedimentologic framework that bears on defining units, describing coal zones, and calculating resources for the coal assessment.

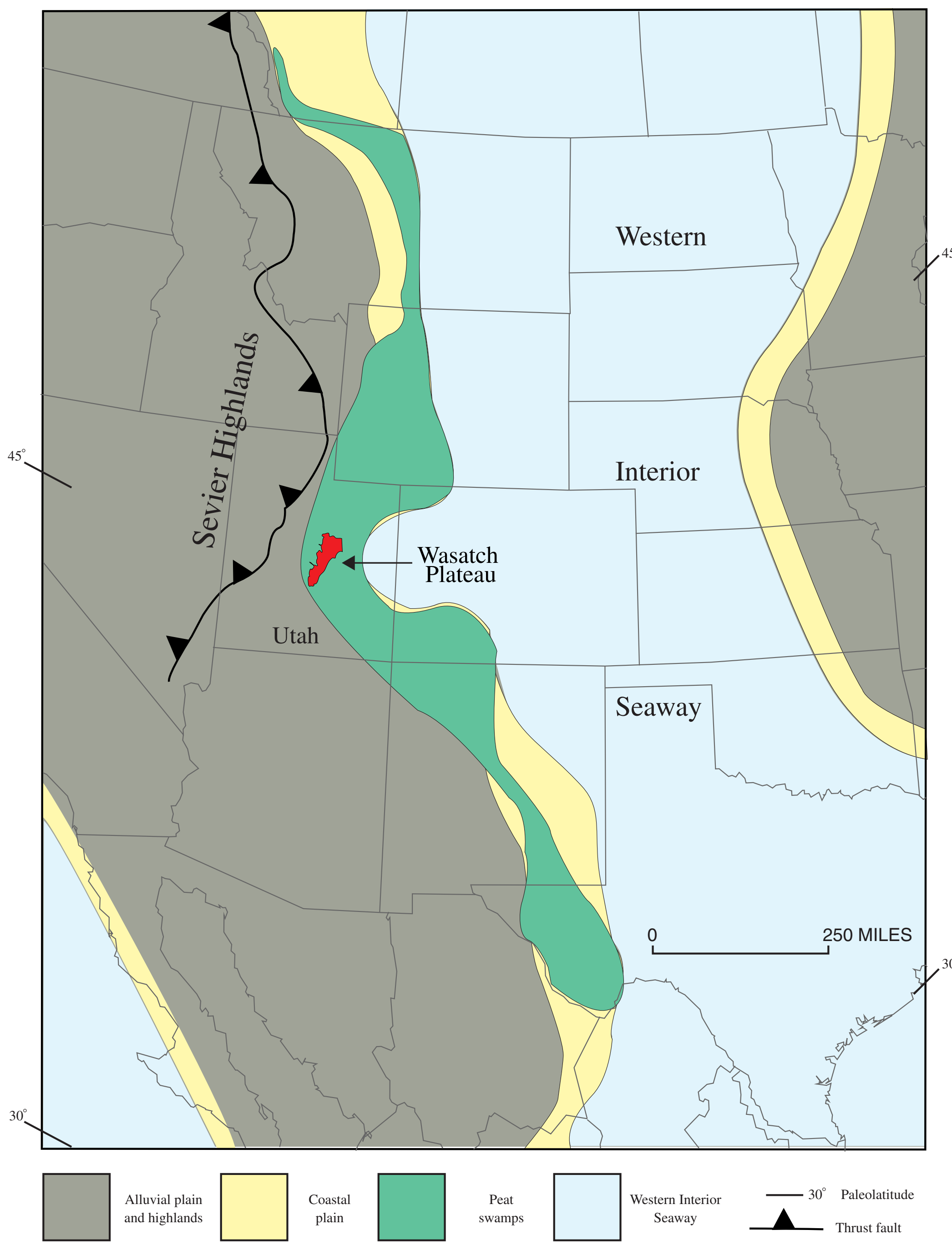


Figure 7. Late Cretaceous (early Campanian) paleogeography plotted on paleolatitude, showing location of the Wasatch Plateau in central Utah (modified from Roberts and Kirschbaum, 1995)

General Stratigraphy of Cretaceous Rocks

Rocks in the vicinity of the Wasatch Plateau range in age from Late Cretaceous to early Eocene (Hintze, 1980) (fig. 8*A*). The column of rocks exposed, starting at Castle Valley—east of the study area near the towns of Emery, Ferron, and Castle Dale, Utah—and extending to the tops of the highest points in the southern Wasatch Plateau, exceeds 10,000 ft in thickness. The strata consist of a variety of conglomerate, sandstone, shale, mudstone, coal, and limestone. In the central part of the San Rafael Swell, east of the study area, the Lower Permian White Rim Sandstone and Kaibab Limestone are the oldest rocks exposed (Hintze, 1980, 1988). Units exposed on the gently dipping western flank of the San Rafael Swell extend from these Lower Permian strata, through the Triassic, Jurassic, and Cretaceous section to lower Eocene rocks, which are located west of the study area (e.g., see Hintze, 1988, for discussion of the geologic history and diagrammatic sections of the rocks).

In the Wasatch Plateau coal field, the Upper Cretaceous section consists of, in ascending order, the Dakota Sandstone; Mancos Shale with its Tununk, Ferron Sandstone, Blue Gate Shale, Emery Sandstone, Masuk Shale Members; and Mesaverde Group (fig. 8*A*). The Upper Cretaceous Mesaverde Group consists of upper Campanian strata (Hintze, 1988; Roberts and Kirschbaum, 1995) assigned to the Star Point Sandstone, Blackhawk Formation, Castlegate Sandstone Member of the Price River Formation, and the main body of the Price River Formation. These rocks in turn are overlain by the Cretaceous and Tertiary North Horn Formation (Maastrichtian to Eocene), and by the Tertiary Flagstaff Limestone (Paleocene and Eocene), Colton Formation (Eocene), and Green River Formation (Eocene) (e.g., Hintze, 1975; Fouch and others, 1982, 1983; Hintze, 1988; Franczyk and Pitman, 1991).

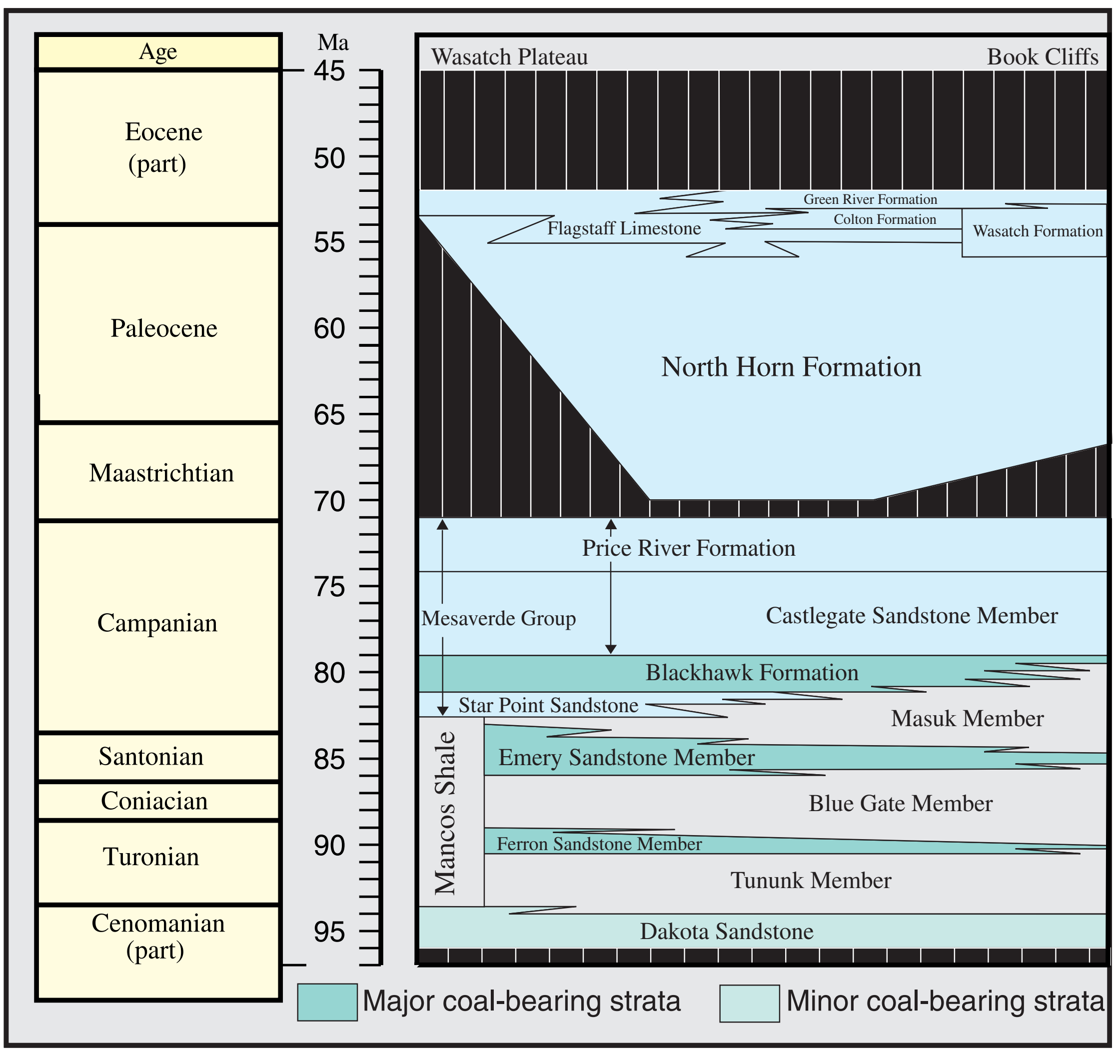


Figure 8*A*. Time-stratigraphic chart showing nomenclature, facies relations, and coal- and non-coal-bearing strata in the Wasatch Plateau and Book Cliffs (stratigraphic and age relations from Fouch and others, 1983; Eaton and others, 1990; Obradovich, 1993; Elder and Kirkland, 1994; Krystinick and DeJarnett, 1995; and Kirschbaum, 1995).

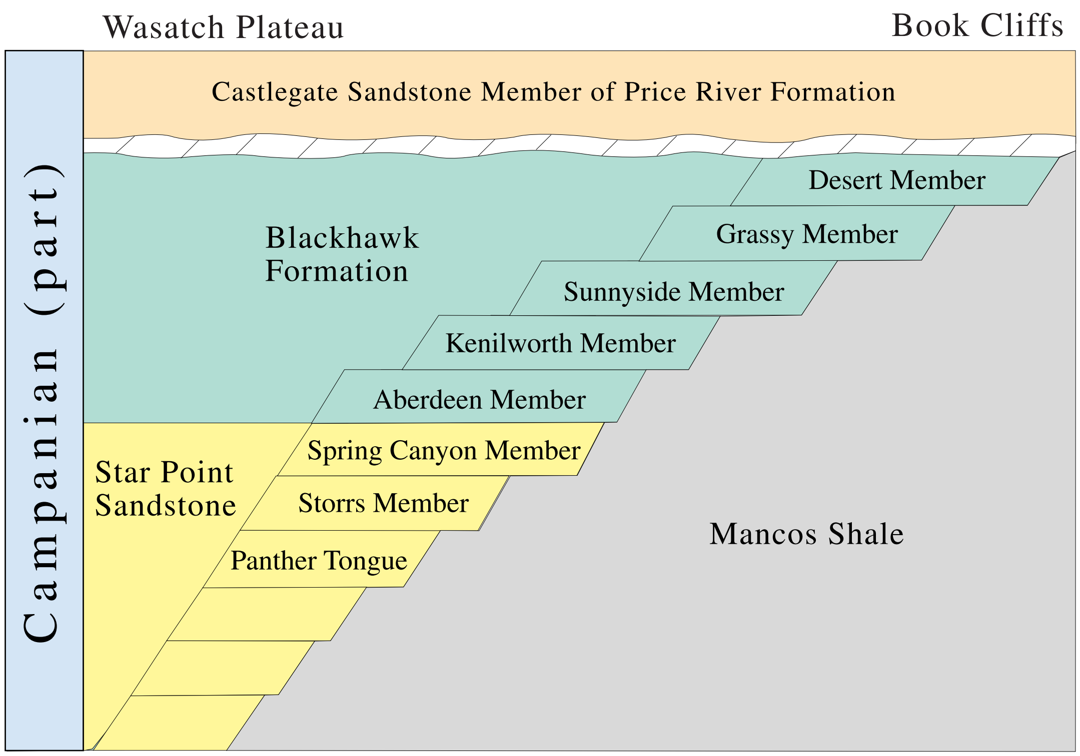
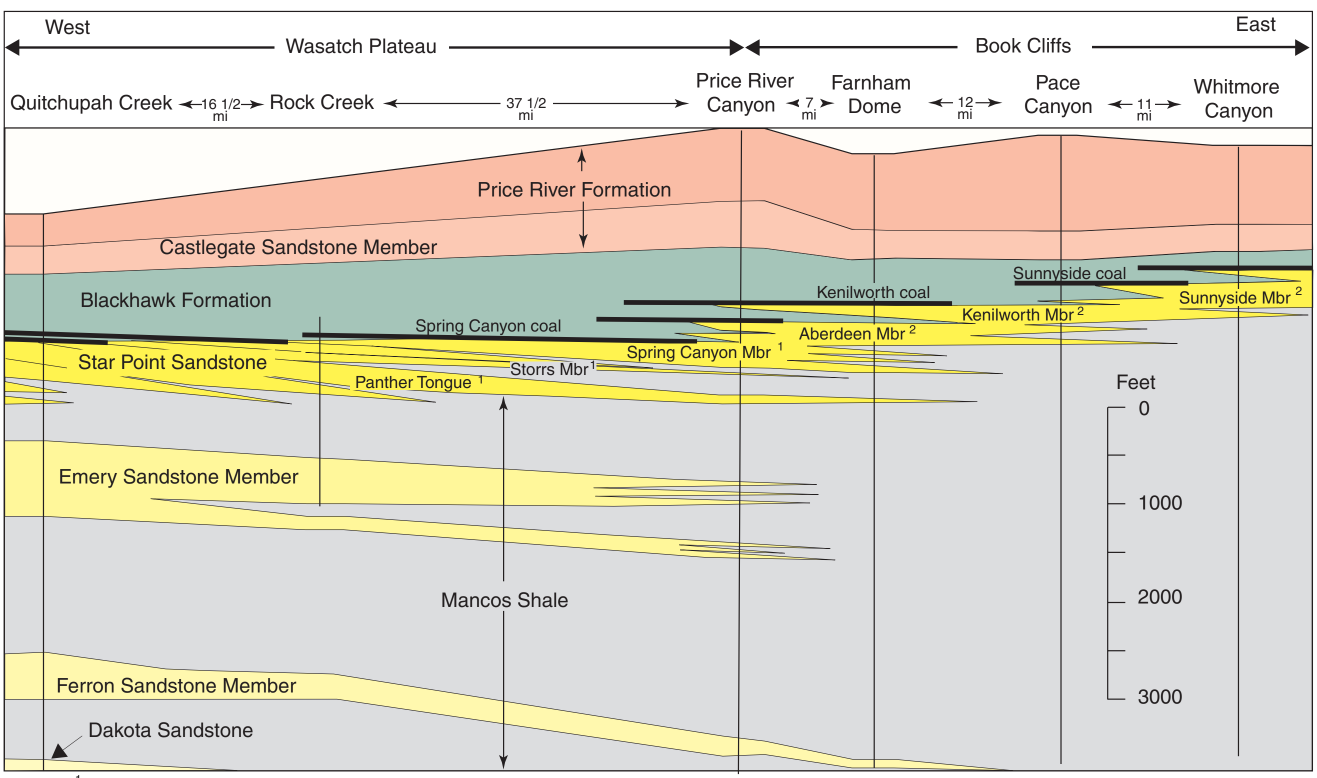


Figure 8*B*. Diagrammatic time-stratigraphic chart showing nomenclature of the Star Point Sandstone and the Blackhawk Formation in the Wasatch Plateau and the Book Cliffs (modified from Kamola and Van Wagoner, 1995).



[1] Members of Star Point Sandstone

[2] Members of Blackhawk Formation

Figure 8*C*. Generalized stratigraphic sections of Star Point Sandstone and Blackhawk Formation showing facies relations, nomenclature, and intertonguing of strata from the southern Wasatch Plateau to the western Book Cliffs (modified from Clark, 1928, plate 15, p. 114–115).

Detailed Stratigraphy of Upper Cretaceous Rocks

The eastern boundary of the Southern Wasatch Plateau study area was chosen at the outcrop contact between the Star Point Sandstone and the underlying Mancos Shale. This contact was picked because the Blackhawk Formation is the major coal-bearing unit in the Wasatch Plateau and because the stacking patterns of the marine-shoreface sandstones of the Star Point influenced the distribution of the coals in the Blackhawk. Four geologic units are designated on the geologic map for the study area (fig. 4; plate 1), in ascending order: (1) the Upper Cretaceous Mancos Shale (the map area includes minor outcrops of older rocks), (2) the Upper Cretaceous Star Point Sandstone, (3) the Upper Cretaceous Blackhawk Formation, and (4) undifferentiated Cretaceous and Tertiary strata, which include the Castlegate Sandstone Member of the Price River Formation and the main body of the Price River Formation, North Horn Formation, Flagstaff Limestone, and Colton Formation. The undifferentiated Cretaceous and Tertiary strata are grouped into a single stratigraphic unit on maps for this report because they overlie the primary coal-bearing Blackhawk and they contain little, if any, significant coal resources. The location and thickness of the undifferentiated strata do bear on the discussions and calculations of overburden related to coals in the Blackhawk.

Coal beds examined as part of this resource assessment occur in the lower 150 ft of the Blackhawk Formation (fig. 8*B*), and their distribution is related to intertonguing relations with the underlying Star Point Sandstone (figs. 8*C*, 9; plate 1). Spieker and Reeside (1925) named the Star Point Sandstone after a prominent headland of the Wasatch Plateau in Carbon County, Utah, and the Blackhawk Formation for exposures near the Blackhawk mine (renamed the King No. 1 mine) near the town of Hiawatha. Clark (1928) included the Star Point as the base of the Mesaverde Group in the Book Cliffs; however, the term Mesaverde is no longer used in the Book Cliffs. Clark's (1928) Star Point Sandstone comprised, in ascending order, the Panther, Storrs, and Spring Canyon Tongues. Clark (1928) also named the Aberdeen Sandstone Member of the Blackhawk Formation, which overlies the Spring Canyon (fig. 8*B*). Fisher (1936) divided the Blackhawk in the Book Cliffs coal field into lower, middle, and upper sandstone members and included tongues of the Mancos Shale in the Blackhawk, but few if any workers used this terminology in later papers.

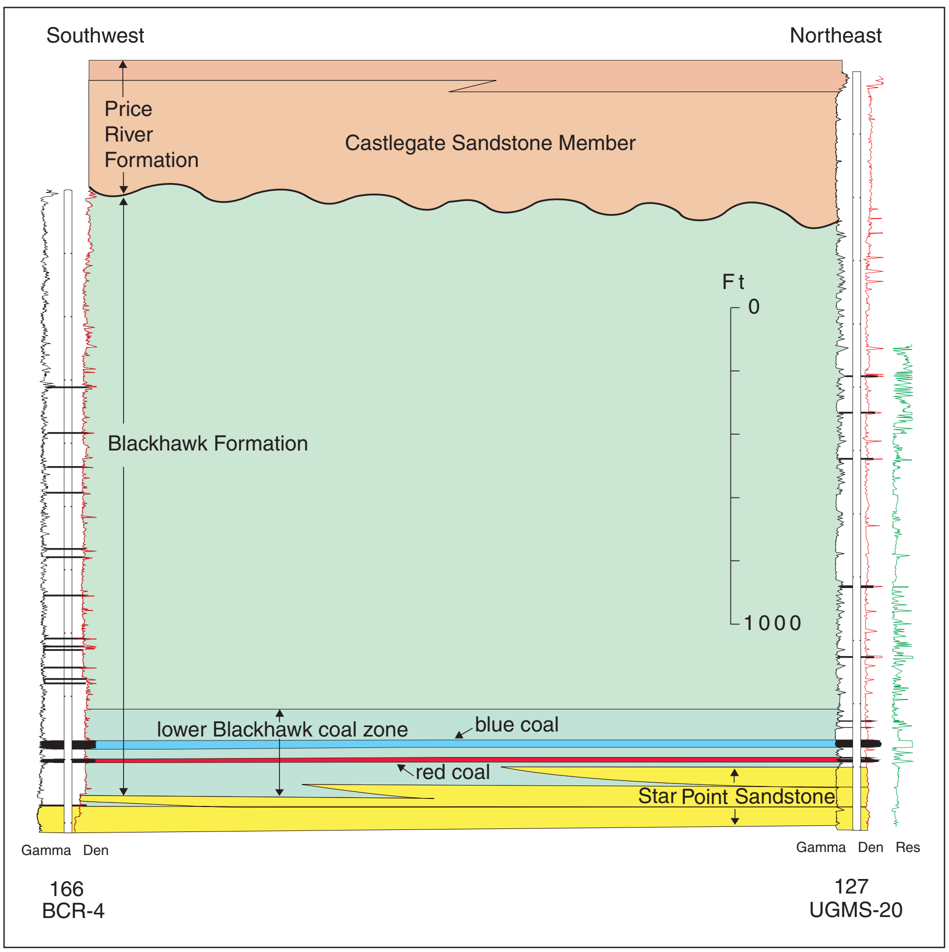


Figure 9. Stratigraphic correlations, sedimentary facies relations, and generalized coal-bed occurrences and correlations in the Mesaverde Group in the southern Wasatch Plateau, with typical geophysical well-log traces.

Young (1955) described the intertonguing of the shoreface sandstone members of the Blackhawk with the marine shale of the Mancos to the east, an idea that both Clark (1928) and Spieker (1931) referred to in their reports as intertonguing of the Star Point of the Wasatch Plateau with the marine Mancos of the Book Cliffs to the east. Young (1955) reassigned the Spring Canyon Tongue of the Book Cliffs area from the Star Point Sandstone below to the Blackhawk Formation above to "...conform to the writer's scheme of classification," but he did not address the issue of the Spring Canyon in the Wasatch Plateau to the south, and there it remained assigned to the Star Point. Despite Young's (1955) claims that change of the upper boundary of the Star Point was impractical to the west and south in the Wasatch Plateau because the Panther, Storrs, and Spring Canyon sandstones unite to form a single massive littoral marine tongue, Spieker (1931) had noted and described that those separate units were recognizable as far south in the Wasatch Plateau as Rock Canyon, which is adjacent to the extreme northern part of the Southern Wasatch Plateau study area. This relation is discussed further in a following section of this report on Sequence Stratigraphy and Coal-Bed Correlations.

Young (1955) redefined the Star Point Sandstone to contain only the Panther and Storrs, and he combined the Spring Canyon Tongue with Clark's (1928) Spring Canyon coal group into the Spring Canyon Member and placed it in the overlying Blackhawk Formation beneath the Aberdeen Member to conform with his classification scheme in the Book Cliffs. One might describe Young's (1955) classification scheme as somewhat arbitrary considering today's sedimentologic understanding of shoreface sandstone stacking in the Star Point (Dubiel and Kirschbaum, 1997, 1998) and the fact that the original works by Spieker (1931) and Clark (1928) had placed each of the marine sandstones in the Star Point and each of the coal-bearing and overlying parts of the section into the Blackhawk. In keeping with the original established stratigraphic nomenclature of placing the marine sandstones as members or tongues of the Star Point (Clark, 1928; Spieker, 1931), one might argue that shoreface sandstone members fit more logically as units of the Star Point Sandstone as it was originally defined by Spieker (1931) rather than with the marginal-marine and coastal-plain rocks and coals of the Blackhawk Formation as is done in the Book Cliffs. Most subsequent reports that deal with geology, and especially sequence stratigraphy, of the Cretaceous units in the Book Cliffs (e.g., Balsley, 1982; Van Wagoner 1995; Kamola and Van Wagoner, 1995; and many other references) have continued to follow Young's (1955) scheme of nomenclature specifically developed for the Book Cliffs, in which the Blackhawk Formation contains, in ascending order, marine sandstone units that were previously named by others the Spring Canyon and Aberdeen and those that he named the Kenilworth, Sunnyside, Grassy, and Desert Members (fig. 8*B*).

However, south of the Book Cliffs in both the Northern and Southern Wasatch Plateau study areas, Young's (1955) stratigraphic nomenclature cannot be as readily applied. Young (1955) recognized this and quoted Spieker (1931, p. 24) that the Book Cliffs stratigraphy was "...impractical to the west and south in the Wasatch Plateau where the Spring Canyon, Storrs, and Panther sandstones unite to form a single massive littoral marine tongue..." In the northern Wasatch Plateau, south from Gentile Wash and Spring Canyon near the town of Helper to Straight Canyon west of Castle Dale and Orangeville, the Star Point Sandstone is recognized to contain the Panther, Storrs, and Spring Canyon as they were originally defined, and the overlying coastal-plain, coal, and marginal-marine rocks are referred to the Blackhawk Formation (Spieker, 1931; Flores and others 1982; Mercier and others, 1982; Flores and others, 1984). Mercier and others (1982) pointed out that subsurface drilling for coal on the Wasatch Plateau demonstrated that each of the named marine sandstones within the Star Point is traceable west and landward into lower coastal-plain deposits of the Blackhawk. They considered each sandstone to be a seaward equivalent facies of the Blackhawk Formation, similar to the definition established by Young (1955). Nevertheless, the Star Point Sandstone in the Wasatch Plateau remains today as it was originally defined by Spieker (1931), comprising the Panther, Storrs, and Spring Canyon (fig. 8*B*).

Both Spieker (1931) and Mercier and others (1982) described the Panther, Storrs, and Spring Canyon as recognizable units as far south as Straight Canyon near Orangeville and Castle Dale, Utah. Farther south past Straight Canyon, in the area of the Southern Wasatch Plateau study area and south to its southern terminus near highway I-70 and Ivie Creek, researchers generally have not distinguished or recognized the individual Panther, Storrs, and Spring Canyon sand bodies. They simply refer the cliff-forming marine sand bodies to the Star Point Sandstone and the overlying slope and ledge-forming coal, coastal-plain, and marginal-marine rocks to the Blackhawk with no subsidiary member designations in either unit (e.g., Flores and others, 1980, 1982, 1984). During the present assessment study, the Panther, Storrs, and Spring Canyon were traced south from their well-known localities near Helper, Utah, to the northern study area boundary near Huntington Canyon and as far south as Muddy Canyon in about the middle of the study area. Additional fieldwork is needed to decipher the sequence stratigraphy and the stacking pattern of the marine shoreface sandstones and to trace these units and correlate them within the Star Point Sandstone farther south from Muddy Canyon to the southern boundary of the study area. One observation demonstrated by photomosaics and measured stratigraphic sections for the present study is that additional marine shoreface units are present below what has traditionally been called the Panther Tongue in a stacking pattern similar to that described for the other marine sandstones recognized in the Blackhawk and Star Point (Dubiel and Kirschbaum, 1987, 1998). These concepts are discussed and developed further in following sections of this report on Sedimentology and Depositional Environments and on Coal Distribution. In this report, the names Star Point Sandstone and Blackhawk Formation are used without member designations for both geologic mapping and for units on the stratigraphic cross sections (fig. 4; plate 1).

Although designation of members within the Star Point Sandstone may not be essential to general correlations, it would be helpful for understanding detailed stratigraphy and sedimentology of the shoreface sandstone units. In addition, recognition of the sandstone stacking patterns and intertonguing of the shoreface parasequences, both with the marine shale to the east and with the coastal-plain rocks to the west, is crucial to correlation of individual coal beds (Flores and others, 1979). A more in-depth discussion of these relations follows in the sections of this report on Sequence Stratigraphy and Coal-Bed Correlations and on Coal Distribution.

Sedimentology and Depositional Environments

The Star Point Sandstone and the Blackhawk Formation contain a variety of marine, marginal-marine, lagoonal, and continental rocks. Depositional environments of these rocks have been interpreted by many studies, ranging from the first insightful work in the Wasatch Plateau by Spieker (1931) to recent studies of sequence stratigraphy in the Book Cliffs (Kamola and Howard, 1985; Kamola, 1987; Van Wagoner and others, 1990, 1991; Kamola and Van Wagoner, 1995). Although these latter studies all focused on the Blackhawk Formation in the Book Cliffs, the characteristics of the Star Point Sandstone and the Blackhawk Formation in the Wasatch Plateau, and in the southern Wasatch Plateau in particular, are similar in many respects, and they were deposited in similar depositional environments.

The Star Point Sandstone is composed of massive cliff-forming sandstones that are fine to medium grained and that generally coarsen upward. Tongues of the Star Point interfinger eastward into the Mancos Shale. The Blackhawk Formation contains a variety of lithologies, including coal, siltstone, shale, and coarse- to medium- and fine-grained sandstone. The following is a brief discussion of the depositional environments and salient references to the historical evolution of understanding and interpreting the Star Point and Blackhawk depositional systems related to the coal assessment.

Spieker (1931, p. 26) recognized the Star Point Sandstone as a beach and near-shore deposit that interfingered eastward with marine shales of the Mancos Shale. He also described the Blackhawk as continental rocks but focused primarily on its coal deposits. Spieker (1931, p. 37) described a low-lying coastal plain with rivers, swamps, and lagoons in which the Blackhawk was deposited, using sedimentary features and fossil evidence to support his distinctions between marine and freshwater environments. He summarized the depositional environments as: (1) inland flood-plain, channel, and lake sandstones and shales; (2) lagoonal, estuarine, flood-plain and swamp sandstones, shales, and coals; (3) littoral marine sandstones; and (4) offshore marine shales and siltstones.

Young (1955) did not add significantly to Spieker's (1931) interpretations of marine shales; littoral marine sandstones; and the lagoons, estuaries, flood plains, swamps, and lowlands of the coal-bearing facies, but he added an interpretation of off-shore bars. These ideas were substantiated and slightly modified in the early 1970's in numerous coal-related studies that advocated a deltaic and barrier-island setting for the littoral sandstones and associated coal deposits (e.g., Blanchard and others, 1977; Marley and Flores, 1977; Marley, 1978; Flores and others, 1980; Hayes and Sanchez, 1979; Sanchez and Hayes, 1979; Ellis, 1980; Marley and others, 1979; Muldoon, 1980; Blanchard, 1981; Ellis, 1981a, 1981b; Flores and others, 1982; Sanchez and Brown, 1983; Sanchez and others, 1983a, 1983b; Flores and others, 1984; Sanchez and Brown, 1986, 1987; Brown and others, 1987; Sanchez, 1990; Sanchez and Ellis, 1990). Some of those studies focused on rocks in the study area of this report.

A major contribution emerged from geologic mapping (Hayes and Sanchez, 1977; Sanchez and Hayes, 1977) and measured stratigraphic sections (Marley and Flores, 1977) that described a zone of intertonguing near Muddy Creek between the upper part of the Star Point Sandstone and the lower part of the Blackhawk Formation, which is in the present Southern Wasatch Plateau study area. Subsequent work (Flores and others, 1980, 1984) interpreted several of these intertonguings in an area from Ivie Creek on the south to Ferron Canyon on the north as the landward pinch-outs of sandstone tongues within the Star Point. Not only do the sandstones of the Star Point interfinger with the marine shales of the Mancos to the east as recognized by earlier researchers, but apparently they also interfinger with the continental rocks of the Blackhawk to the west. This recognition led to reinterpretations (Flores and others, 1980, 1984) of depositional environments and coal correlations within this area on the Wasatch Plateau. These studies were proponents of a depositional model in which the marine sandstones were formed by wave-reworking of fluvially dominated deltas and in which marginal-marine and coastal-plain rocks hosted the coals, ideas similar to those advocated by Balsley and Horne (1980). However, the former studies did not address the controls on the stacking pattern of the shoreface sandstones or of the coals.

Balsley and Horne (1980) were also proponents of interpretations of fluvial, coastal-plain, deltaic, inter-deltaic, and barrier-island environments, and they emphasized the nuances between river-dominated and wave-dominated deltaic systems to account for the facies variations seen in the Blackhawk Formation of the Book Cliffs. They also advocated an interpretation in which deltaic sedimentation and lobe-switching explained the cyclic stacking of sandstones rather than invoking periodic pulses of basinal subsidence, cyclic sea-level changes, or cyclic sediment supply espoused by some contemporary and many subsequent proponents of sequence stratigraphy. Balsley and Horne's (1980) observations and interpretations are contrasted by several recent studies (e.g., Van Wagoner and others, 1988, 1990) that advocate relative sea-level changes to account for sandstone stacking patterns and depositional environments in the Blackhawk of the Book Cliffs.

In an early paper that employed data from trace fossils and sedimentary structures, Howard (1966a) interpreted the Panther Tongue of the Star Point Sandstone depositional environments as deltaic rather than shoreface. His study was part of a larger body of work that began to accumulate on clastic shorelines and depositional processes (e.g., Howard; 1966b; Reineck and Singh, 1975, p. 311–346; Reading, 1978, p. 143–177). These texts and others describe the sedimentary structures and facies associated with clastic shoreline depositional systems, and the reader is referred to them for specific details. Many of these papers laid the groundwork for subsequent development and application of sequence stratigraphy to shoreline sandstones, and the Blackhawk Formation of the Book Cliffs was one of the primary study areas and proving grounds of many new ideas and concepts for interpreting shoreface and related depositional systems. The reader is referred to the seminal works on shoreface sequence stratigraphy for background in parasequence definitions and stacking patterns, depositional environments, and facies relations (Van Wagoner and others, 1990; Van Wagoner and others 1991).

Swift and others (1987) provided an early application of concepts of depositional sequences to the Kenilworth Member of the Blackhawk Formation in the Book Cliffs, including a detailed sedimentologic analysis of shelf construction and depositional processes in a foreland basin.

Kamola and others (1985), Kamola and Howard (1985), Kamola (1987), Kamola and Huntoon (1995), and Kamola and Van Wagoner (1995) each applied recently developed concepts in sequence stratigraphy and clastic shoreline sedimentology to analysis of the Blackhawk shoreface sandstones in the Book Cliffs. In addition to the interpretation of shoreface depositional environments, Kamola and Huntoon (1995) and Kamola and Van Wagoner (1995) investigated two repetitive shoreface-sandstone stacking patterns in the Blackhawk of the Book Cliffs by comparing the progradational distances of individual parasequences and the position of the updip termination of marine facies for each parasequence. They also noted and described the updip or landward pinch-outs of shoreface parasequences into marginal-marine or nonmarine deposits where tidal-inlet facies cut out the shoreface sandstones. Despite the recognition of coal beds and their relation to marine or marginal-marine facies, these and other sequence stratigraphic studies of the Blackhawk in the Book Cliffs did not extend sequence stratigraphic concepts to an analysis of the continental coal-bearing part of the section. Along with the earlier cited works by Flores and coworkers, they do provide the basis for recognizing the relation of marine or marginal-marine environments to the adjacent coastal-plain settings where peat swamps were deposited. They also provide the sedimentologic and sequence stratigraphic basis for understanding the relation of original peat deposition to shoreface sandstone deposition and the subsequent distribution of coal beds—on outcrop and in the subsurface—that is related to parasequence stacking.

Sequence Stratigraphy and Coal-Bed Correlations

In the present coal assessment study of the Star Point Sandstone and Blackhawk Formation, analysis of measured stratigraphic sections, photomosaic panels of outcrops along canyon walls oriented perpendicular to depositional dip of the shoreface parasequences, and subsurface well logs all led to recognition of depositional facies and a shoreface sandstone stacking pattern cyclicity similar to that described for the Blackhawk shoreface-sandstone members in the Book Cliffs (Kamola and others, 1985; Kamola and Howard, 1985; Kamola, 1987; Kamola and Huntoon, 1995; Kamola and Van Wagoner, 1995). The following discussion is by no means a complete analysis of the sequence stratigraphy of the Blackhawk and Star Point in the study area akin to the detailed sequence stratigraphic studies of comparable rocks in the Book Cliffs. More detailed sedimentologic fieldwork is necessary to document and distinguish parasequence and parasequence set stacking patterns, facies distribution within the parasequences, and recognition of internal sequence boundaries. Nevertheless, the current study recognizes several broad relations that elucidate the coal-bed occurrence, geometry, correlation, and distribution in the subsurface, all of which improve the assessment of coal resources in the study area. Coal beds generally occur landward of the updip pinch-outs of marine shoreface sandstones, as noted by the mapping and sequence stratigraphic studies referenced in the previous section of this report. Understanding both the stacking pattern and correlation of shoreface sandstone parasequences on the outcrop and the parasequence sets in which they are grouped aids in understanding the distribution and correlation of individual coal beds in the subsurface and in the analysis of coal resources in the study area.

Shoreface Sandstone Parasequences

For the present study, stratigraphic sections were measured near photomosaic panels of outcrops to (1) decipher sedimentary structures and sedimentary facies, (2) apply an interpretation of parasequences and sequence stratigraphy, and (3) investigate the relation of coal-bed occurrence to shoreface sandstone stacking patterns on outcrop that could then be applied to the subsurface well-log cross sections, coal-bed correlations, and coal assessment (Dubiel and Kirschbaum, 1997, 1998).

Depositional environments were interpreted from sedimentary structures, trace fossils, and facies associations. Cliff-forming sandstones in the Star Point are primarily upward-coarsening successions of marine, lower-shoreface, upper-shoreface, and backshore deposits similar to parasequences described for the marine sandstone members in the Blackhawk of the Book Cliffs (Kamola, 1985; Kamola and Van Wagoner, 1995). Marine parts of individual parasequences display features that indicate shallowing- and coarsening-upward successions from offshore through shoreface to foreshore facies. In contrast, the nonmarine parts of the parasequences that are assigned to the Blackhawk Formation consist of estuarine and lagoonal to continental deposits, including fluvial channels and thin to thick coals. Shoreface parasequences amalgamate as generally forward-stepping parasequence sets, and coals associated with shoreface sandstone parasequence pinch-outs extend in a landward direction over lagoonal deposits and older shoreface parasequences. The upper part of the Blackhawk is exclusively continental in origin, composed of primarily fluvial sandstones and overbank mudstones with minor coal beds.

Spieker (1931) noted that the Star Point Sandstone thickens to the west along the canyons eroded in the eastern escarpment of the Wasatch Plateau. Spieker (1931, p. 24) discusses the fact that the Star Point, including the interval from the base of the Panther to the top of the Spring Canyon, increases in thickness from about 350 ft on the eastern flank of the plateau near Ferron Canyon, to about 600 ft in the central part of Huntington Canyon, to as much as 1,000 ft on the western side of the Wasatch Plateau near Pleasant Valley and Scofield, Utah. Spieker (1931) interpreted this to mean that the western shoreline of the Cretaceous Seaway at the time was not far west of the present Wasatch Plateau, an interpretation supported by more recent tectonic and sedimentologic analyses (Fouch and others, 1983; Roberts and Kirschbaum, 1995; Schwans, 1995). Photomosaics of outcrops in canyon walls and stratigraphic sections measured for this study (Dubiel and Kirschbaum, 1997, 1998) corroborate Spieker's (1931) observation of the Star Point thickening to the west. This relation can also be observed in well logs in the subsurface (plate 1). Our interpretation is that successive shoreface parasequences are generally progradationally stacked in the Star Point. In a landward direction where they are superposed—there has been minor truncation of underlying sand bodies, so that one shoreface parasequence directly overlies the next older shoreface sandstone, thus forming the single Star Point Sandstone cliff recognized by Spieker (1931) and Clark (1928). Spieker (1931) and Clark (1928) perhaps also did not recognize the parasequences below the Panther that were observed in the present study and the fact that those shoreface sandstones thicken to the west and are overlain by the Star Point, thus contributing to the apparently thickened Star Point section to the west and the south.

The Star Point Sandstone in the Wasatch Plateau and in the Southern Wasatch Plateau study area comprises at least three parasequence sets of shoreface and deltaic sandstones; they are the original three tongues of marine sandstones described and named by Clark (1928) and Spieker (1931) as the Panther, Storrs, and Spring Canyon. In addition, several as yet unnamed parasequence sets of stacked shoreface sandstones are present in the Star Point below the Panther (Dubiel and Kirschbaum, 1998) and above the thick westward-thinning tongue of Mancos Shale that lies above the Emery Sandstone Member in the southern part of the study area (figs. 8*B*, 8*C*). These unnamed parasequences and parasequence sets extend to the southern boundary of the study area, farther south than the Panther's southern limit (as recognized in the literature) in the vicinity of Muddy Creek, and they extend to the west into the subsurface of the study area (plate 1).

Spieker (1931, p. 23) refers to the character of the Panther Tongue of the Star Point and how it changes character, becomes less prominent, and then grades upward into the main body of the Star Point to the south between Rock Canyon and Ferron Canyon, within the northern boundary of the Southern Wasatch Plateau study area. This relation is confirmed in the present study from measured stratigraphic sections and on subsurface well-log cross sections (fig. 8*C*; plate 1). The deltaic nature of the Panther Tongue is expressed as imbricate, seaward-dipping foreset beds overlain and cut into by distributary channels (Howard, 1966a; Balsley and Horne, 1980). Farther south than Ferron Creek, the Panther contains sedimentary facies and bedding interpreted here as indicative of shoreface deposition. The Panther is overlain by the Storrs Member (or Tongue), and south of Ferron Canyon the shoreface parasequences of the Panther merge upward and are overlain by the lowermost parasequences of the Storrs.

Spieker (1931) and Young (1955) apparently did not recognize that, farther south than Muddy Canyon where the Panther Tongue merges with the Storrs and Spring Canyon Members (or Tongues) to form one massive Star Point cliff, several additional shoreface parasequences that interfinger with the Mancos Shale are present below the main body of the Star Point. These each thicken to the west and south in the study area and merge upward toward the southwest with the Star Point Sandstone. The overlying sandstone parasequences of the Spring Canyon, Storrs, and Panther successively pinch out into or interfinger with nonmarine strata of the Blackhawk to the southwest, or they are cut out, similar to the relations described for the shoreface sandstones of the Blackhawk in the Book Cliffs (Kamola and Huntoon, 1995; Kamola and Van Wagoner, 1995).

These interfingerings were mapped by Flores and others (1980, 1982, 1984), and they appeared in more detail on their contemporary maps of coal resources (Sanchez and others, 1983a, 1983b; Sanchez and Brown, 1983a; Sanchez and Brown, 1986, 1987; Brown and others, 1987; Sanchez and Ellis, 1990; Sanchez, 1990). These interfingerings were interpreted in those studies to represent the shoreline deposited by repeated transgressions and regressions in a micro-tidal, fluvially dominated delta system.

Our current interpretation is that the interfingering relations represent the successive landward pinch-outs of shoreface parasequences that were deposited by marine flooding and subsequent basinward migration of the shoreline, similar to interpretations expressed by Kamola and Huntoon (1995) and Kamola and Van Wagoner (1995). Marine flooding surfaces that indicate an abrupt increase in water depth separate individual parasequences within the parasequence sets. The increase in water depth on flooding also served to elevate water tables in the nonmarine and continental settings, thereby providing the accommodation space for plant growth, peat development, and coal preservation. Wave-dominated shoreface features characterize most of the easily recognizable sandstone parasequences. Fluvial-dominated deltaic sandstones predominate in the Panther Tongue north of the study area and near its typical exposures at Panther Canyon near Helper, Utah, with a gradational change to wave-dominated shoreface deposits to the south near Muddy Canyon in the central part of the study area.

Each of these landward pinch-outs of shoreface sandstone parasequences has associated with it coal that extends from on top of the shoreface sandstone into the nonmarine strata in a landward direction. In a seaward direction, the coals commonly thin and pinch out below the next stratigraphically higher shoreface sandstone. In places, the coals are absent, but their former presence is indicated by a bleached zone in the top of the underlying shoreface sandstone, commonly referred to as a white cap (e.g., Spieker, 1931; Balsley and Horne, 1980). Spieker (1931) attributed the white color to leaching of iron-bearing minerals by acidic waters derived from the overlying peat swamps. Balsley and Horne (1980, p. 71–75) discounted this theory as being only part of the answer: They attributed the leaching instead to sediment bypass of labile iron-bearing minerals in the original depositional setting, admitting that some of the white cap may be due to influence from the peat swamp. Observations from the present study that support a former peat-swamp presence include root trace fossils extending downward from coal beds into the white cap and isolated pods of coal at the top of the white cap that are cut out below overlying shoreface sandstones, indicating a previously more extensive coal bed. These observations suggest that the formation of the white caps is related to leaching of iron-bearing minerals by solutions expelled from overlying peat swamps. The peat swamps originally developed in continental settings that either prograded over the shoreface deposits or that developed on top of the shoreface sediments as sea level began to turn around and transgress the shoreface environment. This scenario would raise water tables in the freshwater continental depositional system, providing the accommodation space to grow and preserve thick peat deposits that could subsequently form coal.

The coals that extend landward from the upper surfaces of the shoreface sandstones can be correlated in the subsurface based on stratigraphic position above the Star Point Sandstone and based on similarity of geophysical log response. A crucial step in correlating individual coal beds is to recognize the geographical location and stratigraphic position of the sandstone parasequence pinch-outs in the well-log cross section (fig. 10). These pinch-out locations were based on both previous studies (Flores and others, 1980, 1982, 1984; Sanchez and others, 1983a, 1983b; Sanchez and Brown, 1983a; Sanchez and Brown, 1986, 1987; Brown and others, 1987; Sanchez and Ellis, 1990; Sanchez, 1990), and from observations and photomosaics of outcrops along canyon walls, from stratigraphic sections measured for this study, and from the subsurface well-log cross sections.

Coal Distribution, Quality, and Resources of the Blackhawk Formation in the Southern Wasatch Plateau

Coal Distribution

Cretaceous rocks along the eastern escarpment of the Wasatch Plateau and in the Book Cliffs to the north contain coal-bearing sections within several rock units. The section of Cretaceous strata on the western flank of the San Rafael Swell dips to the west so that potentially coal bearing sections in each of the Dakota Sandstone, Ferron Sandstone and Emery Sandstone Members of the Mancos Shale—and in the Blackhawk Formation—may underlie the Southern Wasatch Plateau study area.

Coal may be present in the Dakota Sandstone in the subsurface of the study area, but field investigations east of the Wasatch Plateau identified only thin, discontinuous coal beds in the Dakota (M.A. Kirschbaum, unpub. measured sections). Coal also may be present in the Ferron and Emery Sandstone Members, which lie in the subsurface and stratigraphically lower in the section than the Blackhawk—these units are known to contain coal in Castle Valley, east of the study area (e.g., Ryer, 1981, 1984; Methany and Picard, 1985; Bunnell and Hollberg, 1991). However, because the beds dip west into the subsurface on the west flank of the San Rafael Swell, the Ferron and Emery coals would be present in the study area at depths greater than 5,000 ft or more for the Ferron (Bunnell and Hollberg, 1991; oil and gas drill hole Porcupine Ridge Unit # 1, T. 22 S., R. 3 E., sec. 30, Pan American Petroleum Corporation) and 3,000 ft or more for the Emery (e.g., Ryer, 1992; Roberts and Kirschbaum, 1995; oil and gas drill hole Porcupine Ridge Unit # 1, T. 22 S., R. 3 E., sec. 30, Pan American Petroleum Corporation). Because of the great depth to these coal-bearing units, the coal resources of the Ferron and Emery were not assessed as part of this study. It should be noted that the Ferron and Emery coals, along with the more deeply buried coals of the Blackhawk Formation west of the Southern Wasatch Plateau study area boundary, all may have potential for containing coal-bed methane resources throughout the Wasatch Plateau. The Ferron currently produces methane from a coal-bearing interval just east of the Wasatch Plateau near Price, Utah (see Doelling and others, 1979; Smith, 1981c; Gloyn and Sommer, 1993; Dallegge and Barker, chap. L, this CD-ROM, and references therein for a discussion on coal-bed methane resources).

The continental, coastal-plain, and marginal-marine Blackhawk Formation is the primary coal-bearing unit in the Southern Wasatch Plateau study area, and it is the major focus of the present assessment of coal resources in that area. Marine-shoreface sandstones of the Star Point Sandstone are intimately associated with coal beds of the Blackhawk because

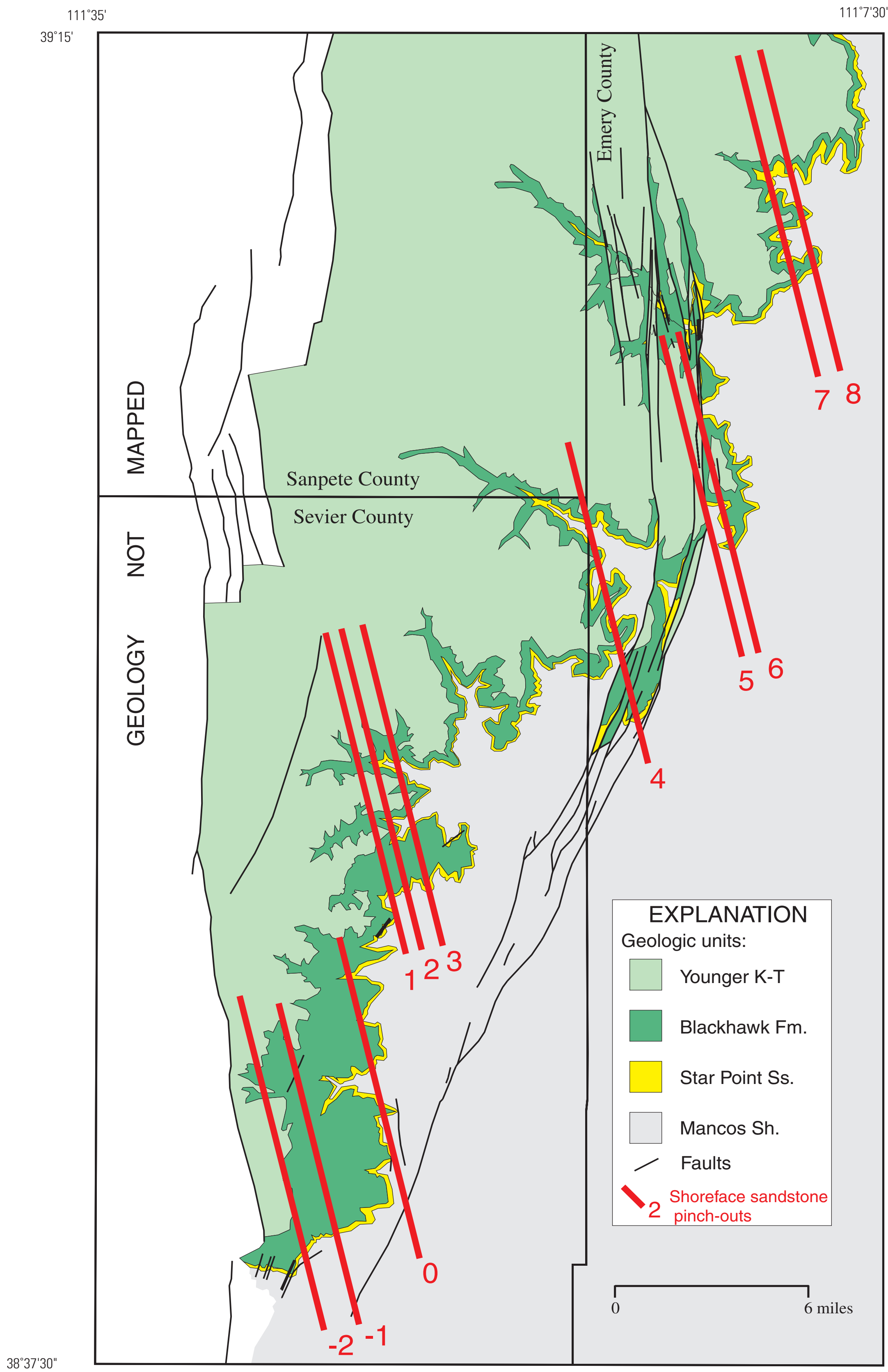


Figure 10. Map showing location of sandstone pinch-outs in the Star Point Sandstone in the Southern Wasatch Plateau study area (modified from Flores and others, 1982; Flores and others, 1984; Dubiel and Kirschbaum, 1997, 1998). Numbers correspond to labeled sandstone pinch-outs correlated on plate 1.

the shoreface parasequence stacking patterns and related flooding surfaces in part dictate the location and distribution of those coals. Fluctuations in sea-level, sediment supply, and (or) tectonic subsidence produced an interfingered repetitive pattern of stacked shoreface sandstones and peat swamp deposits that dictated the present distribution of coal in the outcrop and the subsurface.

Earlier Nomenclature and Correlation of Coal Beds

At the time of Spieker's (1931, p. 62) initial study of coal resources in the Wasatch Plateau, none of the coal beds were recognized by generally accepted names, and only the Castlegate "A" bed was determined to be continuous with a named bed in another area, having been correlated to exposures in the Book Cliffs coal field at Castlegate, Utah. Spieker (1931, p. 62) acknowledged the difficulty in correlating beds of coal along outcrops, especially in areas where rocks were not continually exposed, and he did not have the benefit of the extensive suite of drill holes or geophysical well logs that exist today. Based on what appeared to be consistent coal-bed occurrences at regular, recognizable distances above the Star Point Sandstone in certain canyons, Spieker (1931) named the Hiawatha, Upper Hiawatha, Muddy No. 1, Muddy No. 2, Ivie, Upper Ivie, Saleratus, Blind Canyon, Bear Canyon, Wattis, Bob Wright, U.P., Haley, and Gordon coal beds and several other minor coal beds. He named the Hiawatha bed after exposures at the town of Hiawatha for a thick continuous coal bed that he believed was typically at or near the base of the Blackhawk and on top of the Star Point Sandstone over much of the Wasatch Plateau. Many of these coal-bed names have persisted to this day (e.g., Doelling and Smith, 1982, fig. 11, p. 13; Hayes and Sanchez, 1979; Sanchez and Hayes, 1979, and other maps in this series), although the present correlations may not be the same as those reported by Spieker (1931; see also, discussion in Flores and others, 1980).

At the time of Doelling's (1972a) comprehensive compilation, there were 22 named coal beds that were more than 4 ft thick in the Wasatch Plateau, and he retained most of the coal-bed names as Spieker (1931) had defined them. Significant reinterpretations of these original coal-bed correlations were made (Flores and others, 1980) based on landward pinch-outs recognized within the Star Point Sandstone (Hayes and Sanchez, 1979; Marley and Flores, 1977; Sanchez and Hayes, 1979). These reinterpretations demonstrated that the Hiawatha bed of Spieker (1931) and Doelling (1972a) was not continuous throughout the Wasatch Plateau and that many of Spieker's (1931) correlations of coal beds were thought to be in error based on the reinterpreted stratigraphy. As a specific example, in the area of Muddy Canyon in the central part of the Southern Wasatch Plateau study area, the Hiawatha coal bed northeast of Muddy Canyon was shown to correlate with the Muddy No. 2 coal bed southwest of Muddy Canyon, which was stratigraphically higher than the Hiawatha coal bed as recognized in that area (Flores and others, 1979).

Based on these interpretations of sandstone interfingerings within the Star Point, a series of maps and charts depicted measured sections and drill holes and proposed new names and correlations for coal beds in the Wasatch Plateau (Sanchez and others, 1983a, 1983b; Sanchez and Brown, 1983; Sanchez and Brown, 1986; Brown and others, 1987; Sanchez and Brown, 1987; Sanchez and Ellis, 1990; Sanchez, 1990). Previously recognized coal beds were identified by zone names in these reports because of discontinuities (pinch-outs) and bifurcations in the coal beds (Sanchez and others, 1983a). These reports named the Last Chance, Upper Last Chance, Knight, Acord Lakes, Axel Anderson, and Blind Canyon coal zones for the area covered in this report on the Southern Wasatch Plateau study area. Several additional coal-zone names were proposed for the area in the Northern Wasatch Plateau study area (see Tabet and others, 1999).

In the present study of the southern Wasatch Plateau, several discrepancies were noted between coal correlations of these older reports and the correlations developed as a result of fieldwork and stratigraphic cross sections of well logs constructed for the present report. Therefore, the coal-zone names and coal-bed names from those previous papers were not used in the present report. Reinterpretations of coal-bed correlations for the present study have important implications for exploration, for current mining plans and production, and for the assessment of coal resources because they revise not only the terminology applied to certain coal beds but also the way in which specific coal beds are precisely correlated in the subsurface of the southern Wasatch Plateau.

Lower Blackhawk (LBH) Coal Zone

For the present study of the southern Wasatch Plateau, measurement of stratigraphic sections in the field, construction of well-log cross sections, and application of sequence stratigraphy to shoreface sandstone parasequences and coal stacking patterns indicated correlations for some coal beds that were different than those previously published in the literature. For these reasons, the following approach was used to identify a single coal zone in the Blackhawk Formation and to correlate individual coal beds within that coal zone.

In the southern Wasatch Plateau, coal occurs primarily in and is produced exclusively from the Blackhawk Formation. Spieker (1931, p. 61) noted that all of the principal coal beds occur in the lower 250 to 350 ft of the Blackhawk Formation. Doelling (1972a) stated that all of the minable coal occurs in the lower third of the Blackhawk Formation. Sanchez and others (1983a) stated that the thickest and most persistent coals in their study area were within 180 ft of the base of the Blackhawk Formation. Sanchez and Hayes (1979) reported that the thickest and most persistent coal beds in the Flagstaff Peak quadrangle were within 83 ft of the base of the Blackhawk. These studies and their observations of coal occurrences in the Blackhawk suggest that there is some precedence for defining a coal zone in the lower part of the Blackhawk Formation.

The upper part of the Blackhawk contains only thin, discontinuous coal beds, based on previous published accounts (e.g., Spieker, 1931; Doelling, 1972a) and on observations and analyses of outcrop measured sections, geophysical well logs, and cross sections constructed for this study (fig. 9; plate 1). The stratigraphic cross sections substantiate the fact that the thickest and most laterally extensive coal beds in the Southern Wasatch Plateau study area are confined to the lower part of the Blackhawk Formation. For the purposes of this study, the lower Blackhawk (LBH) coal zone was defined as the lower part of the Blackhawk Formation that contains significant, thick, and laterally extensive coal beds that could be traced and correlated in well logs and on the outcrop. In general, the lower Blackhawk coal zone in the southern Wasatch Plateau contains from one to five, laterally extensive, thick coal beds in a stratigraphic interval that extends about 150 ft above the Star Point Sandstone (fig. 9). Stratigraphically higher in the Blackhawk section, coal beds are present, but they are thinner and more discontinuous. Typically, the discontinuous coal beds cannot be traced for any significant distance in the subsurface between available well logs. Commonly they are present in only one well log and are not traceable to the next adjacent well log. Within the LBH coal zone, individual coal beds can be correlated and traced throughout the study area both on the outcrop and in subsurface cross sections of well logs, based on similarity in geophysical log traces and the sequence stratigraphic concepts and parasequence stacking patterns described earlier in this report. Locally in the LBH coal zone, a coal bed may be absent in one well log due to channeling by a fluvial sandstone or to depositional thinning of the coal, but commonly it is present again in adjacent well logs in the cross section (fig. 9; plate 1).

Coal-Bed Correlations in the Southern Wasatch Plateau Study Area

Landward interfingerings of shoreface sandstones of the Star Point Sandstone with nonmarine rocks of the Blackhawk Formation that were previously mapped by Flores and others (1979) are reinterpreted here (fig. 10) to represent the landward updip extent of marine shoreface parasequences both in the Panther, Storrs, and Spring Canyon Members (or Tongues) of the Star Point and in the several unnamed parasequences below the Panther Tongue. Our reinterpretation recognizes that several of the interfingerings are true interfingering of beds, in that the shoreface sandstone parasequences actually are interbedded with nonmarine strata of the Blackhawk; however, several other of the relations described by Flores and others (1979) as interfingerings actually represent erosional truncations of the shoreface parasequences by barrier-inlet sand bodies, spits, or flood-tidal deltas (e.g., Reinson, 1992) similar to those described for the Blackhawk in the Book Cliffs (see Kamola and Huntoon, 1995; Kamola and Van Wagoner, 1995). We refer to these relations here collectively as parasequence pinch-outs regardless of whether they were formed by depositional interfingering or by erosional truncation.

Although these relations may not all be interfingerings as originally described, the locations mapped by Flores and others (1979) are accurate in that they show the general location of the updip extent of the parasequences. Flores and others (1979, 1982) mapped three pinch-outs in Convulsion Canyon, which we observed, although one is present at a slightly different locality than they indicated. We noted similar multiple shoreface parasequence pinch-outs in other areas, some of which were not noted by the previous studies. Along I-70 and Ivie Creek, there are three shoreface parasequence pinch-outs. In Muddy Canyon there is one pinch-out. In Ferron Canyon there are two pinch-outs, and in Rock Canyon there are two pinch-outs. There may be additional parasequence pinch-outs, as yet unrecognized, due to the limited fieldwork performed to address this issue in the study area.

Recognizing the updip extent of the shoreface parasequence pinch-outs is important because coal beds that extend landward from them either directly overlie the shoreface sandstones or they overlie lagoonal rocks that are about 10 ft thick on top of the shoreface sandstones. To the northeast in the study area, stratigraphically higher shoreface sandstones successively pinch out to the southwest into nonmarine rocks of the Blackhawk, as they do in the Book Cliffs (Young, 1955; Balsley and Horne, 1980; Kamola and Van Wagoner, 1995). Thus, both the shoreface parasequences and their associated coals appear to “step up” in the stratigraphic section (fig. 9; plate 1). Each coal in the LBH of the study area, when correlated and traced to the northeast, can be demonstrated to overlie a shoreface sandstone parasequence. Coal-bed correlations on the cross sections (plate 1; fig. 9) were made using colored patterns, such as red, blue, green, and gray. The coal beds are simply referred to in this discussion by the color with which they are correlated on the figures and plate, for example, as the red coal or the blue coal.

In the southernmost part of the study area from Ivie Creek north to Convulsion Canyon, three thin and discontinuous coals and two extensive and thick coals are present and recognizable on the subsurface cross section (plate 1). The purple coal is the lowermost of the thin coals, and it lies directly on or just above the Star Point shoreface sandstone in this southernmost part of the study area. The green coal and the orange coal are the next two thin coals, and they lie about 30 ft and 50 ft, respectively, above the purple coal. The two coals that are more continuous and thicker lie stratigraphically higher in the section. Of these two thicker coals, the red coal lies about 25 ft above the orange coal in the section, and the blue coal lies another 20 to 50 ft above the red coal in the section. The red coal can be traced to the north and east where, in the vicinity of Convulsion Canyon, it lies directly on the top of a shoreface parasequence sandstone of the Star Point. Overlying the red coal is the blue coal, which can be traced throughout the study area. To the northeast of Muddy Canyon, it also lies directly on the next, stratigraphically higher, shoreface parasequence sandstone of the Star Point.

The red coal on top of one of the sandstone parasequences extends from south of Convulsion Canyon northward to Muddy Canyon, where it thins and terminates beneath the next overlying sandstone parasequence up-dip pinch-out observed in Muddy Canyon. The blue coal also extends from south of Convulsion Canyon north to Muddy Canyon, and it lies on top of the next higher parasequence pinch-out of the Star Point. The model developed for this study (fig. 9), in which coals occur on top of sandstone parasequences, would suggest that the blue coal extends farther to the northeast in the subsurface, even though well logs from northeast of Muddy Canyon were not publicly available during this study to demonstrate this extension. Measured stratigraphic sections (Spieker, 1931; Sanchez and Brown, 1983) on outcrops to the northeast of Muddy Canyon do show an extension of the blue coal to the northeast of Muddy Creek.

A stratigraphic section measured for this study in Convulsion Canyon indicates that the bed currently being mined at the SUFCO mine in the subsurface north of Convulsion Canyon is the blue coal. In the SUFCO mine, the red coal and the blue coal are referred to as the Hiawatha and Upper Hiawatha, respectively (Chris Kravitz, SUFCO mine geologist, oral commun., 1998), following the original terminology of Spieker (1931).

Above the blue coal, two additional coals, the brown coal and the gray coal, are present in the area west of Muddy Creek, and they undoubtedly extend farther in the subsurface to the northeast. They do not extend farther south than Muddy Canyon into the area west of Link Canyon, Quitchipah Canyon, or Convulsion Canyon. The brown coal is about 30 ft above the blue coal, and the gray coal is another 40 ft above the brown coal. These coals thin and become discontinuous to the west and south in the study area, in a direction that is landward from their presumed sandstone parasequences, which lie to the northeast in the subsurface. The coals also thicken to the northeast, presumably where they extend to a position overlying their respective sandstone parasequence pinch-outs, although that relation cannot be seen directly due to the lack of publicly available well logs in the study area northeast of Muddy Creek.

Coal Quality

The coal in the Blackhawk Formation of the Southern Wasatch Plateau study area has an apparent rank of high-volatile B and C bituminous and is noncoking (Doelling, 1972a, p. 126; Hucka and others, 1997). The Blackhawk coals are generally low in sulfur, low in ash, and generally contain a high percentage of resin (Spieker, 1931; Doelling, 1972a). Proximate analysis data for the southern Wasatch Plateau from Doelling (1972a) are summarized in table 2*A* and indicate (on an as-received basis) an average ash content of about 7 percent (20 samples), an average sulfur content of about 0.5 percent (20 samples), and an average caloric value of 12,260 Btu/lb (19 samples). Analyses from sites from north to south across the area, for the Ricci mine (closed), the Link Canyon mine (closed), the SUFCO mine (presently operating), and the Clear Creek mine (closed) are summarized from Doelling (1972) on table 2*B*. These analyses indicate that the rank of the coal decreases toward the southern end of the Wasatch Plateau. More recent compilations of chemical analyses for the southern Wasatch Plateau (SUFCO mine) are reported by Keith (1989) and Sommer and others (1991) and show similar values and ranges to the earlier analyses reported by Doelling (1972a). A summary of the U.S. Geological Survey USCHEM database can be found in Affolter (chap. G, this CD-ROM). Other physical and petrographic data is presented in Hucka (1991) and Hucka and others (1997), including maceral composition, coal hardness and rank of coal at the SUFCO mine, and data on correlation of the chemical structure of the coals in the Wasatch Plateau with methane formation and retention.

Coal Resources

GIS (Geographic Information Systems) Methods and Calculations

To assess the coal resources of the southern Wasatch Plateau, digital files were created for various geologic, geographic, physiographic, and cultural features. These spatial data are stored, analyzed, and manipulated in a geographic information system (GIS) using ARC/INFO and ARC/VIEW software developed by the ESRI (Environmental Systems Research Institute, Inc.). The GIS coverages and ArcView Projects for the southern Wasatch Plateau are in Appendix 2 (see Biewick and Mercier, chap. D, this CD-ROM, for explanation on accessing these coverages). Spatial data that required gridding for the generation of contour and isopach maps were processed using EarthVision (EV; Dynamic Graphics, Inc.). Contour lines generated in EV were converted into ARC/INFO coverages using a program called ISMARC, which the USGS received from the Illinois Geological Survey. Various geographical, cultural, and physiographic features within the southern Wasatch Plateau were compiled and manipulated as coverages in ARC/INFO. Integrating these coverages with the geologic information in the spatial database allowed calculations of the coal resources and characterization of the coal distribution within a variety of geologic and geographic parameters. The following paragraphs describe the GIS methods and the procedures that were used to produce the various ARC/INFO polygon coverages utilized to make calculations for the assessment of the coal resources of the southern Wasatch Plateau.

In the Rocky Mountains and Colorado Plateau region of the United States, more than 20 coal zones in five different formations are being assessed for the National Coal Resource Assessment. Certain steps in the process of calculating coal resource estimates and of producing the numerous accompanying maps for each assessment unit were automated and

Table 2*A*. Table showing the average and range of values for proximate chemical analyses of Blackhawk Formation coals from the southern Wasatch Plateau.

[Number of analyses shown in parentheses. Values reported on an as-received basis; modified from Doelling, 1972a]

	Moisture (22)	Volatile matter (19)	Fixed carbon (19)	Ash (22)	Sulfur (22)	Btu/lb (19)
Average	9	38.1	46.1	7	0.5	11,626
Maximum	13.9	40.6	50.4	10	0.6	12,260
Minimum	5.6	35.2	43.3	5.4	0.3	10,540

Table 2*B*. Table showing average as-received chemical analyses of coal from mines in the southern Wasatch Plateau.

[Modified from Doelling, 1972a]

Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu/lb	Mine
8.4	39.1	45.2	7.3	0.5	11,922	Ricci
8.3	38.1	46	8	0.4	11,674	Link Canyon
8.7	38.3	46.6	6.5	0.5	11,770	SUFCO
13.4	36.2	43.8	6.7	0.6	10,570	Clear Creek

standardized for the project. Roberts and others (1998) established an accurate, reliable, and time-efficient method of combining an ASCII file containing location data (*x*, *y* coordinates) and coal-thickness data with multiple layers of digital spatial data pertaining to coal distribution and coal resource-reporting parameters to ultimately arrive at coal tonnage estimates. As many as six commercially available software packages were used in conjunction with three custom programs to process digital data. These programs range from simple conversion programs to highly sophisticated geographic information systems (GIS), two-dimensional modeling programs, graphics packages, and spread-sheet software. The following discussion (adapted from Roberts and others, 1998; see also Roberts, chap. C, this CD-ROM) summarizes the GIS methodology used to calculate coal resources in the southern Wasatch Plateau from the digital StratiFact (GRG Corp., 1996) spatial database.

First, a bounding polygon (usually a rectangle) is defined that encompasses the area confining all the geologically referenced data points and polygon coverages. Polygon coverages were created and stored in ESRI (Environmental Systems Research Institute, Inc.) ARC/INFO software. Individual polygon coverages contain geologic, geographic, and cultural elements such as States, counties, townships, sections, 7.5′ quadrangles, coal and surface ownership (procedures used to produce the individual GIS coverages were described in the earlier section of this report on Methods Employed in the Assessment), and they are all clipped to internally fit within the original bounding polygon. The *x*, *y*-coordinate maximum and minimum values of the polygon are specified when gridding coal and overburden thickness.

For each outcrop and subsurface data point within the StratiFact database, files were generated that contain the elevation of a datum used to calculate a “ structure contour” map of a horizon on which to calculate the overburden thickness at each point (fig. 11). In the southern Wasatch Plateau, the top of the Star Point Sandstone (equivalent to the base of the coal-bearing Blackhawk Formation) was used because it is an easily identifiable stratigraphic unit recognized in virtually all of the data points in the database. The generated file also contains data on the coal thickness and the overburden thickness (thickness from the coal to the surface of the ground) at each data point, which are then introduced into Dynamic Graphics, Inc., Earth Vision (EV) program. The data are gridded using the *x*, *y*-coordinate extent of the bounding polygon. One map is produced that displays isopach lines of total (net) coal thickness at each data point (fig. 12). U.S. Geological Survey digital elevation models (DEM’s) of the 7.5′ quadrangles in the study area were used to subtract the elevation of the Star Point Sandstone from the ground-surface elevation at each data point, producing a map of the overburden thickness (fig. 13) overlying the coal at each data point. Once satisfied with the coal and overburden isopach lines from the gridding process, the lines and files were saved in an ASCII format as a “contour output file," which is one of the EarthVision plotting options. The program ISMARC was then used to convert the contour output file from EarthVision to a file that is in "arc-generate" format. The output file from ISMARC was then processed in ARC/INFO using an Arc Macro Language (AML) program (convert-ism.aml), also received from the Illinois Geological Survey, that converts it into an ARC/INFO polygon coverage. Each polygon created using this AML was attributed with a value for thickness, which is the mean thickness of the value for the contour lines that define each polygon. The ISMARC and "convert-ism.aml" programs expedite conversion of the EarthVision contour lines from overburden or coal-isopach calculations into ARC/INFO coverages. The resultant coverages can then be displayed and checked for errors using ArcView (ESRI). Because the contours were transformed into ARC/INFO coverages (both polygons and lines), the coverages could then be converted to shapefiles and imported into graphic software, such as Adobe Illustrator, through a commercially available plug-in: MAPublisher (Avenza Software Marketing, Inc.). MAPublisher allows lines to be labeled and polygons filled with colors or patterns based on the attributes of the original ARC/INFO coverage.

Calculating coal resource tonnages for the assessment area was straightforward using EarthVision. First, a polygon coverage was created that is the union of all the polygons for which tonnages would be reported (i.e., county, quadrangle, township, surface ownership, coal mineral ownership, reliability, overburden, coal-thickness categories, etc.). This polygon coverage next was imported into EarthVision as a single polygon file. Although several attributes were associated with the individual polygons making up the unioned polygon, only one attribute label is allowed when importing the unioned polygon. The "coverage-id" attribute was chosen to label the individual polygon within the unioned polygon because it represents a unique identifier for each polygon.

Short tons of coal were calculated using the volumetrics utility within EarthVision. The two-dimensional grid of coal thickness supplied the thickness values used to calculate the coal tonnage within each polygon. Running the volumetrics routine produced an ASCII-formatted file (volumetrics report) that lists by polygon-id (same as coverage-id) a value for area and short tons for each polygon within the polygon file. A program written at the USGS called "evrpt" converts this volumetrics report to a tab-delimited ASCII-formatted file. The "evrpt" program strips the header information from the volumetrics report and calculates the average coal thickness for each polygon that EarthVision used to calculate the short-ton value. The resultant output file from the "evrpt" program was then imported into ArcView as a table.

In ArcView, the table was joined to the attribute table of the ARC/INFO unioned polygon coverage using the "polygon-id" (EarthVision) and "coverage-id" (ARC/INFO). The result of joining the two tables was a new table with a record that contains a short-ton value for every polygon in the unioned polygon. The joined table was next exported from ArcView as a delimited ASCII file or a ".dbf" file and read directly into a spreadsheet program such as Microsoft Excel. Once in Excel, the "Pivot Table" utility was used to create tables that reported resource estimates using several categories in the spreadsheet.

Coal Resources in the Southern Wasatch Plateau

Coal resources in the Southern Wasatch Plateau study area were calculated using the methodology of Wood and others (1982, 1983). The overall methodology was discussed in the Methods Employed in the Assessment section of this report; specific salient details are referred to in the following discussion. Coal resources reported here represent all beds of coal within the lower Blackhawk (LBH) coal zone of this report that are greater than 1.2 ft thick and under less than about 5,500 ft of overburden. Coal that is deeper than 6,000 ft is not considered to be a resource according to Wood and others (1983), and, within the Southern Wasatch Plateau study area, Blackhawk coal beds do not occur at depths greater than about 5,500 ft. Coal resources were determined by multiplying the volume of coal by the average density of coal (Wood and others, 1983, table 2, p. 22). The volume of coal was the product of the net coal thickness and the areal distribution shown on the net coal isopach map (fig. 12). The density of coal used in resource calculations in the southern Wasatch Plateau is 1,800 short tons per acre-foot for bituminous coal (Wood and others, 1983, table 2, p. 22). Note that coal resources reported in the tables were rounded to two significant figures after all calculations were completed, including the addition of some categories to give subtotals and totals. Thus, some categories in the resource tables may appear to not equal the sum of their components because of the independent rounding.

Coal resources are reported by coal overburden categories. Overburden categories represent a maximum overburden because the overburden thickness was calculated from the Earth's surface to the top of the Start Point Sandstone (which is equivalent to the base of the lower Blackhawk coal zone). The top of the Star Point Sandstone was used because: (1) this horizon is easily identified in both measured sections and geophysical logs, and (2) it is a relatively uniformly dipping surface (except for the small area of parasequence pinch-outs) upon which to make the "structure" contour map. Overburden thickness (fig. 13) was calculated by gridding the elevation data for the top of the Star Point Sandstone in both measured sections and in drill holes, and then subtracting that grid from the surface elevation grid imported from 1:24,000 digital elevation models for each of the 7.5′ quadrangles in the study area. Maximum overburden lines are shown on resultant maps at intervals of 500, 1,000, 2,000, and 3,000 ft (fig. 13). Coal resources are reported in overburden categories for intervals of 0–500 ft, 500–1,000 ft, 1,000–2,000 ft, 2,000–3,000 ft, and greater than 3,000 ft by integrating the overburden and net-coal isopach map.

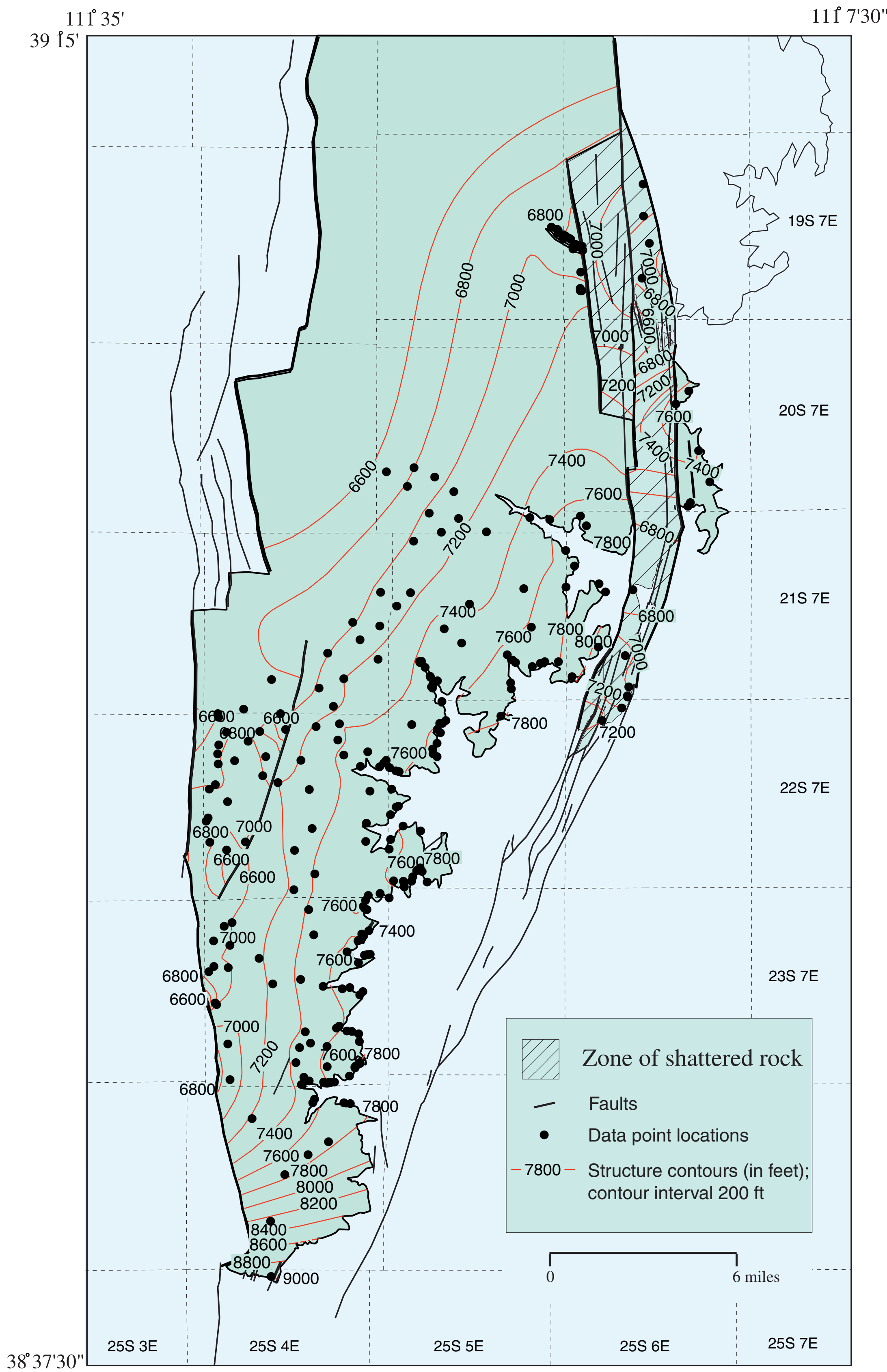


Figure 11. Map showing elevation contours on the top of the Star Point Sandstone in the Southern Wasatch Plateau study area (referred to in the text as a structure contour map) and the location of the zone of shattered rock. Map shows only faults that bound the western margin of the study area and faults that bound the shattered zone.

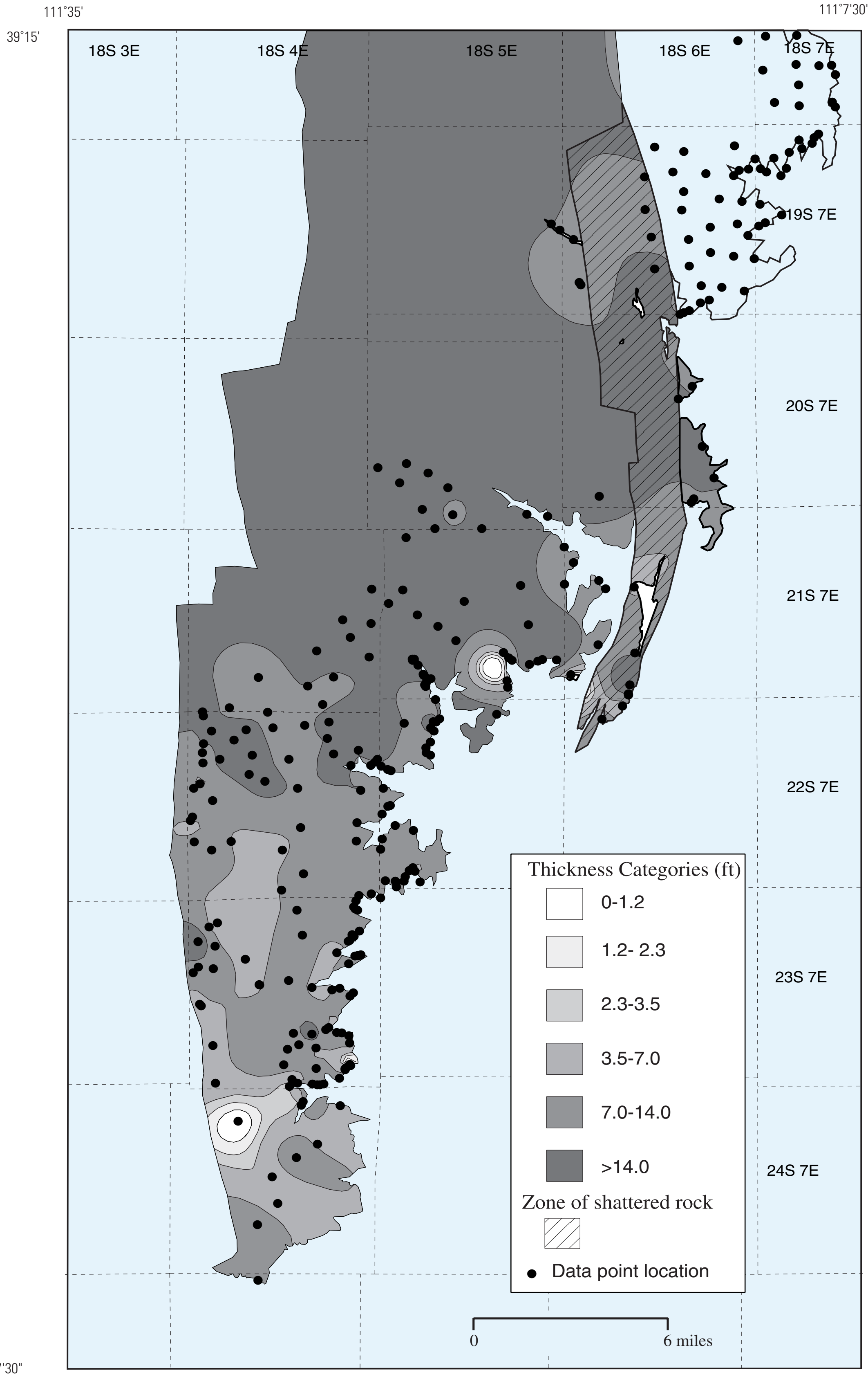


Figure 12. Map showing data point locations, isopachs of net coal, and net-coal thickness categories (thickness categories according to Wood and others, 1983) in the lower Blackhawk coal zone in the Southern Wasatch Plateau study area. Note that isopachs show net coal and not individual bed thickness.

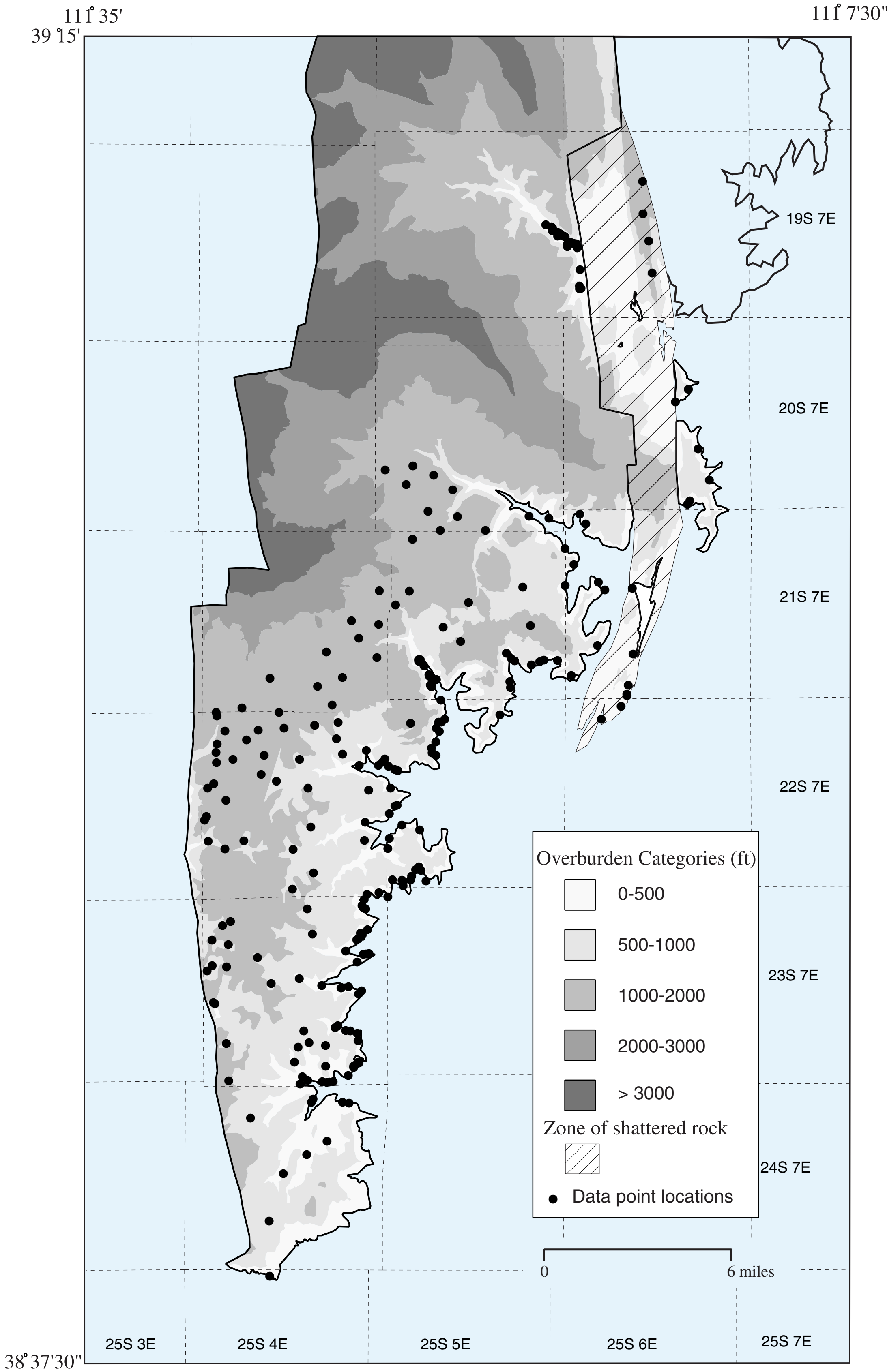


Figure 13. Map showing data point locations, overburden thickness, and thickness categories above the base of the Blackhawk Formation in the southern Wasatch Plateau.

Reliability categories (fig. 14) are based on the distance that the coal occurs from each data point for coal thickness measurement. Identified resources are located within a 3-mi radius of a data point, and hypothetical resources are located beyond a 3-mi radius from a data point (Wood and others, 1983). The majority of the area of the southern Wasatch Plateau is considered to contain identified resources. In the northwestern part of the study area, where there is both a lack of data from measured sections due to no outcrops and a lack of drill-hole data, there are primarily hypothetical resources. The area just west of the zone of shattered rocks that lies in the northeastern part of the study area contains little subsurface data, but the resources calculated there are considered to be in the identified category because the data that was used from measured stratigraphic sections and from drill holes east of the zone of shattered rock were within a 3-mi radius, even though they are located in the Northern Wasatch Plateau study area around North Horn Mountain (see Tabet and others, 1999).

Although confidence levels have not been established for these categories of identified and hypothetical resources, hypothetical resources are defined to reside more than 3 mi from a data point (Wood and others, 1983), and thus they are considered to be less accurate.

Coal Resources in the Lower Blackhawk Coal Zone

Coal resources reported in this study are for total in-place original resources of coal in the lower Blackhawk coal zone in the southern Wasatch Plateau, and they do not indicate the amount of coal that can be economically mined from the southern Wasatch Plateau. All coal resources in this report are reported as short tons. The coal resources reported here also do not account for coal already produced from active and (or) inactive mines within the study area. The amount of coal produced by mining in the southern Wasatch Plateau from 1870 through 1997 can be derived by subtracting the production for the Salina Canyon coal field from the Sevier County total production (Doelling, 1972a; Jahanbani, 1996). This calculation gives a total amount of 63 million short tons of coal mined in the study area. During the period from 1990 to 1997, when only the SUFCO mine was producing, 28.7 million short tons of coal were produced from the Sevier County portion of the southern Wasatch Plateau. (Comments on the technical availability and production of the coal resources in the Southern Wasatch Plateau study area and comparison of availability and production of the coal resources of the Northern Wasatch Plateau study area are at the end of the following discussion on the overburden and net thickness categories of coal resources.) Note that the numbers reported in the resource tables and discussed in this report are rounded to two significant figures, according to the methodology of Wood and others (1983) and to match the inherent precision in some of the units used in the coal assessment calculations. All calculations of resources were carried out to the precision of the original data, and all numerical calculations such as summing categories in the tables carried the original precision of the data. Finally, all values were rounded to report the categories in the tables. Thus, due to this independent rounding as a final step, some categories may appear to not sum correctly in the tables.

Coal resources of the lower Blackhawk coal zone are cross-tabulated for five net-coal thickness categories, two reliability categories, five overburden categories, and two county categories for the Southern Wasatch Plateau study area (table 3); resources are reported separately for the zone of shattered rock (table 4) within the Joes Valley fault zone that lies near the northeast margin of the study area. The coal resource data are also summarized by surface ownership (table 5), by coal ownership (table 6), by township (table 7), and by 7.5′ quadrangle (table 8).

According to a recent census on longwall coal mining in the United States (Fiscor, 1998, p. 26), current longwall mining at the SUFCO mine, the only active operation in the Southern Wasatch Plateau study area, is in the Upper Hiawatha bed (the blue coal of the lower Blackhawk coal zone of this report). The SUFCO mine has a reported seam height of 14.2 ft (170 in), the cutting height of the longwall mining operation is 12.5 ft (150 in), and the overburden is 1,000 ft (Fiscor, 1998, p. 26). Comparing these current mining parameters to the coal resources reported in table 3, the following observations and coal resource figures can be summarized for net-coal thickness categories and overburden categories in ranges similar to those being currently mined in the Southern Wasatch Plateau study area. Note that the maps and tables in this report refer to the net-coal thickness for the aggregate of all beds greater than or equal to 1.2 ft in the lower Blackhawk coal zone and not to individual coal beds. However, the stratigraphic cross sections (plate 1) demonstrate that individual coal beds of similar minable thickness, such as the red coal and the blue coal, are prevalent in the study area. The area that these beds individually cover may not be as large as the overall area encompassed by the greater-than-7-ft thickness categories on the isopach map of total net coal (fig. 12).

For the overburden category of 500 to 1,000 ft and for the net-coal thickness category of 7.0 to 14.0 ft, there are 35 million short tons of identified coal resources in Emery County (with 5.3 million short tons of hypothetical coal resources), 2.5 million short tons of identified coal resources in Sanpete County (with no hypothetical coal resources), and 370 million short tons of identified coal resources in Sevier County (with no hypothetical coal resources). For this overburden category of 500 to 1,000 ft and for the net-coal thickness category of 7.0 to 14.0 ft, there is a total of 420 million short tons of coal resources in the Southern Wasatch Plateau study area. In the same overburden category of 500 to 1,000 ft but for the net-coal thickness category of greater than 14.0 ft, there are 71 million short tons of identified coal resources in Emery County (with 5.7 million short tons of hypothetical coal resources), 87 million short tons of identified coal resources in Sanpete County (with 4.8 million short tons of hypothetical coal resources), and 290 million short tons of identified coal resources in Sevier County (with no hypothetical coal

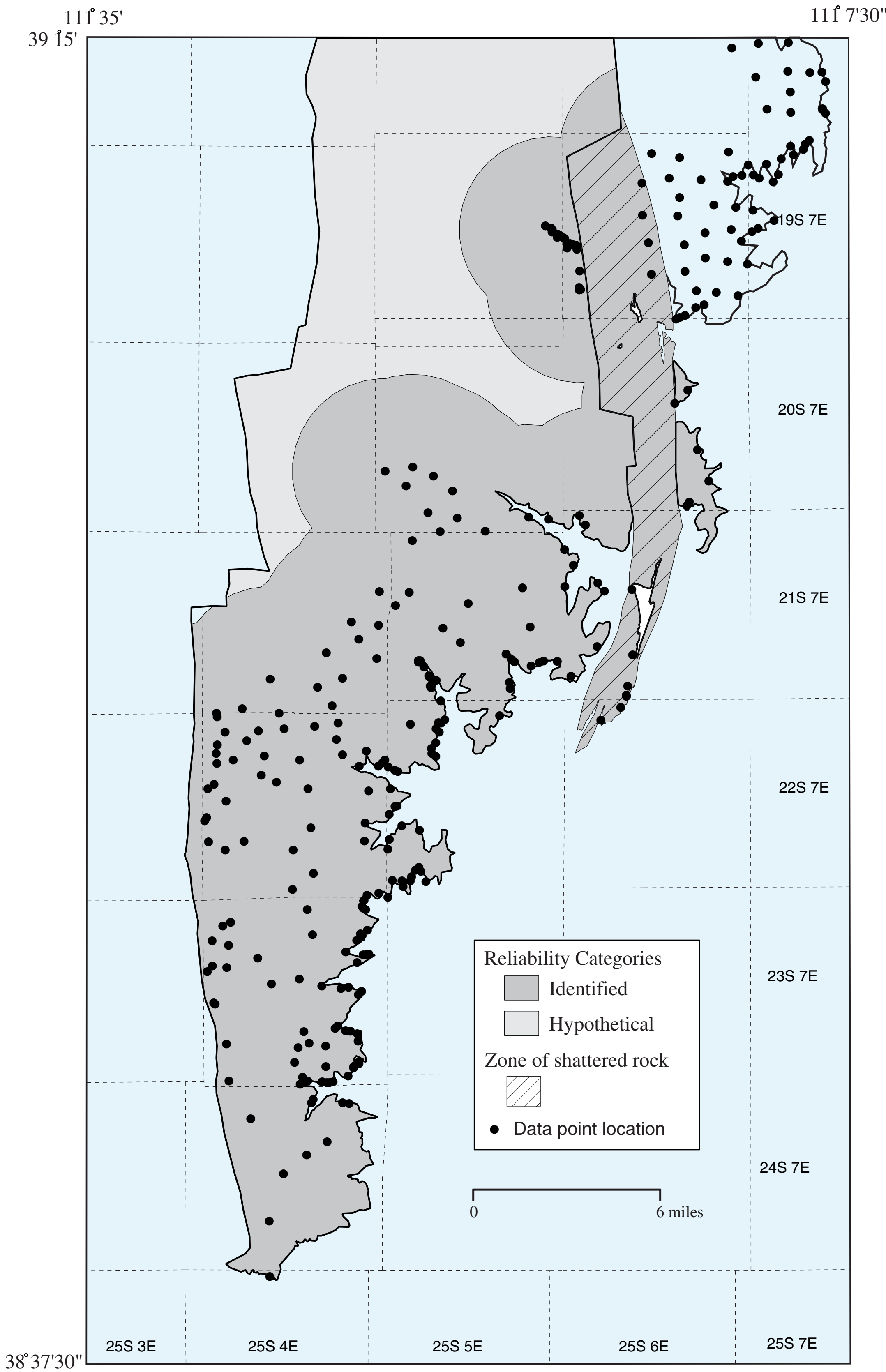


Figure 14. Map showing data point locations and coal reliability categories in the southern Wasatch Plateau.

Table 3. Table showing estimated coal resources in beds 1.2 ft thick or greater in several overburden categories in the lower Blackhawk (LBH) coal zone in the southern Wasatch Plateau.

[Resources shown in millions of short tons. Does not include coal within the zone of shattered rock. Values rounded to two significant figures. Totals may not add due to independent rounding. Includes both identified and hypothetical resources, by county]

County	Reliability	0-500 ft overburden Net-coal thickness					0-500 total	500-1,000 ft overburden Net-coal thickness					500-1,000 total
		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0	
Emery	Identified	0.04	0.10	0.78	45	28	73	0	0	0.29	35	71	110
	Hypothetical	0	0	0	0	0	0	0	0	0	5.3	5.7	11
Emery total		0.04	0.10	0.78	45	28	73	0	0	0.29	40	76	120
Sanpete	Identified	0	0	0	1.4	25	26	0	0	0	2.5	87	90
	Hypothetical	0	0	0	0	0	0	0	0	0	0	4.8	4.8
Sanpete total		0	0	0	1.4	25	26	0	0	0	2.5	92	94
Sevier	Identified	0.39	2.1	43	120	84	240	1.6	4.4	59	370	290	730
	Hypothetical	0	0	0	0	0	0	0	0	0	0	0	0
Sevier total		0.39	2.1	43	120	84	240	1.6	4.4	59	370	290	730
Grand total		0.43	2.2	44	160	140	340	1.6	4.4	60	420	460	940

County	Reliability	1,000-2,000 ft overburden Net-coal thickness					1,000-2,000 total	2,000-3,000 ft overburden Net-coal thickness		2,000-3,000 total	>3,000 ft overburden Net-coal thickness	>3,000 total	Grand total
		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0		7.0-14.0	>14.0		>14.0		
Emery	Identified	0	0	0	11	220	230	0	43	43	0	0	450
	Hypothetical	0	0	0	0.54	46	47	0	5.8	5.8	0	0	63
Emery total		0	0	0	11	270	280	0	49	49	0	0	520
Sanpete	Identified	0	0	0	26	750	770	0	430	430	9.7	9.7	1,300
	Hypothetical	0	0	0	0	240	240	0	1,100	1,100	1,100	1,100	2,400
Sanpete total		0	0	0	26	990	1,000	0	1,509	1,509	1,100	1,100	3,700
Sevier	Identified	1.2	2.1	61	280	810	1100	1.43	260	260	63	63	2,400
	Hypothetical	0	0	0	0	2.8	2.8	0	27	27	72	72	100
Sevier total		1.2	2.1	61	280	810	1,200	1.43	290	290	140	140	2,500
Grand total		1.2	2.1	61	310	2,100	2,400	1.43	1,800	1,800	1,200	1,200	6,800

Table 4. Table showing estimated coal resources in beds 1.2 ft thick or greater in the lower Blackhawk (LBH) coal zone within the zone of shattered rock in the Southern Wasatch Plateau study area.

[Resources shown in millions of short tons. Values rounded to two significant figures. Totals may not add due to independent rounding. All resources in the shattered zone are in the identified reliability category and are in Emery County, Utah]

0-500 ft overburden Net-coal thickness					0-500 total	500-1,000 ft overburden Net-coal thickness			500-1000 total	1,000-2,000 ft overburden Net-coal thickness		1,000-2,000 total	Grand total
1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0		3.5-7.0	7.0-14.0	>14.0		7.0-14.0	>14.0		
0.07	0.31	9.9	120	150	280	2.2	48	100	150	36	79	110	540

resources). For the overburden category of 500 to 1,000 ft and for this net-coal thickness category of greater than 14.0 ft, there is a total of 460 million short tons of coal resources in the Southern Wasatch Plateau study area.

For the next overburden category, similar to that presently being mined in the study area, of 1,000 to 2,000 ft and for the net-coal thickness category of 7.0 to 14.0 ft, there are 11 million short tons of identified coal resources in Emery County (with 0.54 million short tons of hypothetical coal resources), 26 million short tons of identified coal resources in Sanpete County (with no hypothetical coal resources), and 280 million short tons of identified coal resources in Sevier County (with no hypothetical coal resources). In the overburden category of 1,000 to 2,000 ft and for the net-coal thickness category of 7.0 to 14.0 ft, there is a total of 310 million short tons of coal resources in the Southern Wasatch Plateau study area. For the same overburden category of 1,000 to 2,000 ft and for the net-coal thickness category of greater than 14.0 ft, there are 220 million short tons of identified coal resources in Emery County (with 46 million short tons of hypothetical coal resources), 750 million short tons of identified coal resources in Sanpete County (with 240 million short tons of hypothetical coal resources), and 810 million short tons of identified coal resources in Sevier County (with 2.8 million short tons of hypothetical coal resources). In the overburden category of 1,000 to 2,000 ft and for the net-coal thickness category of greater than 14.0 ft, there is a total of 2,100 million short tons of coal resources in the Southern Wasatch Plateau study area.

For the next overburden category, similar to that presently mined in the study area, of 2,000 to 3,000 ft and for the net-coal thickness category of 7.0 to 14.0 ft, only Sevier County has identified resources, with a total of 1.43 million short tons. In the same overburden category of 2,000 to 3,000 ft but for the net-coal thickness category of greater than 14.0 ft, there are 43 million short tons of identified coal resources in Emery County (with 5.8 million short tons of hypothetical coal resources), 430 million short tons of identified coal resources in Sanpete County (with 1,100 million short tons of hypothetical coal resources), and 260 million short tons of identified coal resources in Sevier County (with 27 million sort tons of hypothetical coal resources). For the overburden category of 2,000 to 3,000 ft and for the net-coal thickness category of greater than 14.0 ft, there is a total of 1,800 million short tons of coal resources in the Southern Wasatch Plateau study area.

There are also resources in the overburden category of 0 to 500 ft, although this overburden thickness is slightly less than that for the current mining location. For the overburden category of 0 to 500 ft and for the net-coal thickness category of 7.0 to 14.0 ft, there are 45 million short tons of identified coal resources in Emery County (with no hypothetical coal resources), 1.4 million short tons of identified coal resources in Sanpete County (with no hypothetical coal resources), and 120 million short tons of identified coal resources in Sevier County (with no hypothetical coal resources). In the overburden category of 0 to 500 ft and for the net-coal thickness category of 7.0 to 14.0 ft, there is a total of 160 million short tons

Table 5. Table showing estimated coal resources by surface ownership in beds 1.2 ft thick or greater in the lower Blackhawk (LBH) coal zone in the Southern Wasatch Plateau study area.

[Resources shown in millions of short tons. Non-Federal surface includes both State and private land. Values rounded to two significant figures. Totals may not add due to independent rounding. Surface ownership accurate as of September 1998; see figure 5 and text for explanation]

Surface owner	Overburden (ft) 0-500	500-1,000	1000-2,000	2,000-3,000	>3,000	Grand Total
Federal	320	870	2,300	1,800	1,200	6,500
Non-Federal	26	75	190	1.7	0	290
Grand total	340	940	2,400	1,800	1,200	6,800

Table 6. Table showing estimated coal resources by coal ownership in beds 1.2 ft thick or greater in the lower Blackhawk (LBH) coal zone in the Southern Wasatch Plateau study area.

[Resources shown in millions of short tons. Non-Federal surface includes both State and private land. Values rounded to two significant figures. Totals may not add due to independent rounding. Coal ownership accurate as of September 1998; see figure 5 and text for explanation]

Coal ownership	Overburden (ft)					Grand Total
	0-500	500-1,000	1000-2,000	2,000-3,000	>3,000	
Federal	320	890	2,300	1,800	1,200	6,500
Non-Federal	21	54	170	1.5	0	250
Grand total	340	940	2,400	1,800	1,200	6,800

Table 7. Table showing estimated coal resources by township in beds 1.2 ft thick or greater in the lower Blackhawk (LBH) coal zone in the southern Wasatch Plateau.

[Resources shown in millions of short tons. Values rounded to two significant figures. Totals may not add due to independent rounding]

Township	Overdurden (ft)					Grand Total
	0-500	500-1,000	1000-2,000	2,000-3,000	>3,000	
18S 4E	0	0	0	56	170	230
18S 5E	0	0	36	250	160	450
18S 6E	0	22	68	3.3	0	94
19.5S 5E	0	0	21	55	78	150
19S 4E	0	0	0	160	250	400
19S 5E	14	55	410	290	110	870
19S 6E	10	12	20	0.6	0	43
20S 4E	0	0	52	400	300	760
20S 5E	32	57	580	390	26	1,100
20S 6E	32	46	190	45	0	310
21S 3E	0	0	20	1.6	0	22
21S 4E	0	5.4	380	190	110	690
21S 5E	43	200	330	1.5	0	570
21S 6E	31	36	3.4	0	0	71
22S 3E	2.9	13	12	0	0	28
22S 4E	33	210	220	0	0	460
22S 5E	46	49	24	0	0	120
23S 3E	0	5.6	1.1	0	0	6.7
23S 4E	39	170	68	0	0	270
23S 5E	0.74	0	0	0	0	0.74
24S 4E	59	72	8.1	0	0	140
25S 4E	1.7	0	0	0	0	1.7
Grand Total	340	940	2,400	1,800	1,200	6,800

Table 8. Table showing estimated coal resources by 7.5′ quadrangle in beds 1.2 ft thick or greater in the lower Blackhawk (LBH) coal zone in the Southern Wasatch Plateau study area.

[Resources shown in millions of short tons. Values rounded to two significant figures. Totals may not add due to independent rounding]

7.5′ quadrangle	Overburden (ft)					Grand Total
	0-500	500-1,000	1000-2,000	2,000-3,000	>3,000	
Acord Lakes	45	210	570	130	39	990
Emery West	64	140	140	0	0	350
Ferron	34	28	0	0	0	61
Ferron Canyon	22	86	420	310	70	900
Ferron Reservoir	0	0	100	430	470	1,000
Flagstaff Peak	55	140	590	370	76	1,200
Heliotrope Mountain	0	4.20	390	600	550	1,500
Hilgard Mountain	0	0.03	0.29	0	0	0.32
Johns Peak	56	68	6.3	0	0	130
Old Woman Plateau	63	220	81	0	0	360
Walker Flat	2.9	1.7	0	0	0	4.60
Water Hollow Ridge	1.3	9.6	110	11	0	130
Yogo Creek	2.00	32	37	0	0	71
Grand Total	340	940	2,400	1,800	1,200	6,800

of coal resources in the Southern Wasatch Plateau study area. For the same overburden category of 0 to 500 ft and for the net-coal thickness category of greater than 14.0 ft, there are 28 million short tons of identified coal resources in Emery County (with no hypothetical coal resources), 25 million short tons of identified coal resources in Sanpete County (with no hypothetical coal resources), and 84 million short tons of identified coal resources in Sevier County (with no hypothetical coal resources). In the overburden category of 0 to 500 ft and for the net-coal thickness category of greater than 14.0 ft, there is a total of 140 million short tons of coal resources in the Southern Wasatch Plateau study area.

Finally, there are resources in the overburden category of greater than 3,000 ft. For the overburden category of greater than 3,000 ft there are only resources in the category of net-coal thickness of greater than 14.0 ft. There are no identified or hypothetical resources in Emery County, 9.7 million short tons of identified coal resources in Sanpete County (with 1,100 million short tons of hypothetical coal resources), and 63 million short tons of identified coal resources in Sevier County (with 72 million short tons of hypothetical coal resources). In the overburden category of greater than 3,000 ft and for the net-coal thickness category of greater than 14.0 ft, there is a total of 1,200 million short tons of coal resources in the Southern Wasatch Plateau study area. All of the overburden categories and all of the net-coal thickness categories for each of the three counties results in a total of identified and hypothetical coal resources in the Southern Wasatch Plateau study area of 6,800 million, or 6.8 billion, short tons of coal.

For a perspective on the portion of this 6.8 billion short tons of coal resources that might potentially be mined, one can make a comparison to the northern Wasatch Plateau, which has similar stratigraphy, coal occurrences, and mining practices (for discussion, see Tabet and others, 1999). For the northern Wasatch Plateau, Tabet and others (1999) report original in-place coal resources of 9.4 billion short tons, of which they state that 57 percent were originally potentially minable. From what is potentially minable, they estimate that 30 percent can actually be economically produced; thus, only about 17 percent of the original in-place resource is estimated to be recoverable. For comparison, studies of coal resources in the Eastern United States have determined that less than 10 percent of the original coal resource reported in the ground, in the areas studied, could actually be mined economically at today's prices (Rohrbacher and others, 1994).

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Appendix 1—Location, Lithologic, and Stratigraphic Data for Coal Assessment of the Southern Wasatch Plateau

Appendix 1 contains location, lithologic, and stratigraphic data used in the coal assessment of the Southern Wasatch Plateau study area. The data are available in ASCII format, .dbf, and Excel spreadsheet files on disc 2 of this CD-ROM.

Appendix 2—ArcView project for the Coal Assessment of the Southern Wasatch Plateau, Utah

The digital files used for the coal resource assessment of the southern Wasatch Plateau are presented as views in the ArcView project.

The ArcView project and the digital files are stored on both discs of this CD-ROM set—Appendix 2 of chapter S resides on both discs. Persons who do not have ArcView 3.1 may query the data by means of the ArcView Data Publisher on disc 1. Persons who do have ArcView 3.1 may utilize the full functionality of the software by accessing the data that reside on disc 2. An explanation of the ArcView project and data library—and how to get started using the software—is given by Biewick and Mercier (chap. D, this CD-ROM). Metadata for all digital files are also accessible through the ArcView project.

Click on image below to bring up high-resolution image of plate 1.

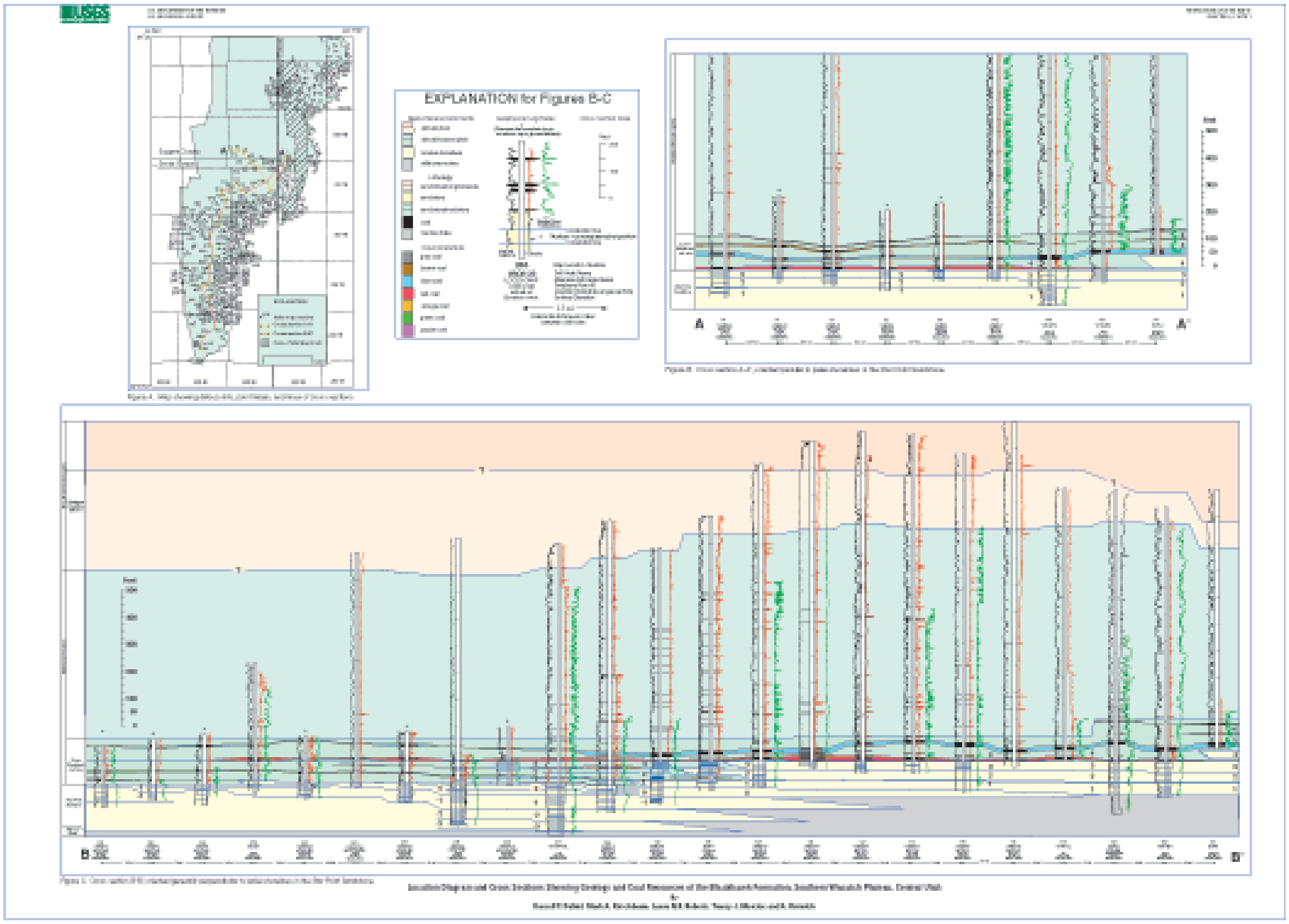
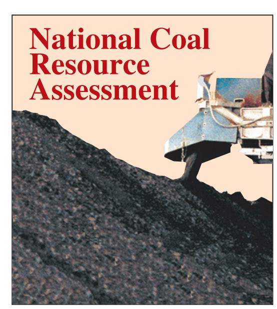


Plate 1. Location diagram and cross section showing geology and coal resources of the Blackhawk Formation, southern Wasatch Plateau, central Utah.



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