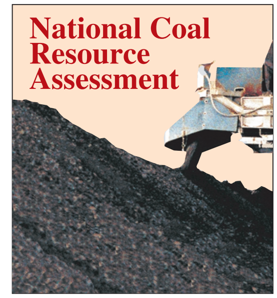
Executive Summary—Geologic Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah



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By Mark A. Kirschbaum[1]

Executive Summary *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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Executive Summary—Geologic Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah

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Introduction

In the Southwestern United States, significant deposits of Cretaceous coal are concentrated in a coherent physiographic and geologic province known as the Colorado Plateau, located within a 165,000-mi^2 area of the States of Arizona, Colorado, New Mexico, and Utah (figs. 1 and 2). The Colorado Plateau is one of five coal-producing areas that are being studied as part of the National Coal Resource Assessment Project (fig. 1). Presented here is a geologic assessment of coal deposits of the Colorado Plateau region and new resource estimates for selected assessment units within the Colorado Plateau. Detailed cross sections and maps of coal distribution, structure, and overburden were produced for each assessment unit from digital stratigraphic and geographic databases newly created during this study. The geology was interpreted by individuals with long-term experience in coal geology and in the geographic areas chosen for assessment. Original resource estimates (in-place resources before production) for the 12 priority assessment units of the Colorado Plateau exceed one half trillion short tons of coal in beds greater than 1 ft thick and under less than 6,000 ft of overburden. The original resource number provides a means of comparing one assessment unit to another and is useful for estimating the potential volumes of gas in the coal. The large total resource number in the Colorado Plateau is only a starting point for understanding how much coal is actually minable because of the many geologic, geochemical, economic, and technical restrictions that are limiting factors to the ultimate recovery of coal from the ground.

As of 1995, there were 10 major surface and 21 major underground mines on the plateau that produced more than 85 million cumulative short tons of coal (Resource Data International, 1998). About 85 percent of the coal mined in the Colorado Plateau is used for the generation of electric power. Coal from this region was sold to electric generating power plants in 20 States in the United States (as of 1995), but the main consumers were the States of Arizona, New Mexico, Utah, Colorado, and Nevada. Between 1990 and 1997, Colorado Plateau coal was also shipped to Colombia, Chile, Hong Kong, Japan, Philippines, South Korea, and Taiwan; in 1995 about 2.5 million short tons were exported (Resource Data International, 1998). The plateau is not only an important coal-mining region, but also has large natural gas resources that are derived in part from the coal. The Colorado Plateau is estimated to contain as much as 173 trillion cubic feet of in-place coal-bed-gas resources within three producing areas: the Piceance Basin in Colorado, the San Juan Basin in Colorado and New Mexico, and the Uinta Basin (Wasatch Plateau) in Utah (ICF, 1989; Rice, 1996).

Previous USGS Assessments

The U.S. Geological Survey (USGS) has explored for coal and provided estimates of the coal resources within the Colorado Plateau region since the beginning of the 20th century (fig. 3). The first comprehensive studies of the original coal resources of the continental United States were compiled by Campbell and Parker (1909) and by Campbell (1917) as a result of the 1906 withdrawal from public acquisition of about 66 million acres of coal lands by President Theodore Roosevelt following the misuse of the Homestead Act in acquiring federally administered lands for mining purposes. Detailed studies of all the major coal fields in the United States continued into the 1930's, and the USGS and State geological surveys subsequently summarized the results for each State in the 1950's through the early 1970's (e.g., Landis, 1959). These State reports were compiled and updated by Averitt (1975). Abundant data collected and analyzed during the last 30 years following the energy crisis of the early 1970's supplements older data to provide the most up-to-date assessment of 12 areas within the Colorado Plateau.

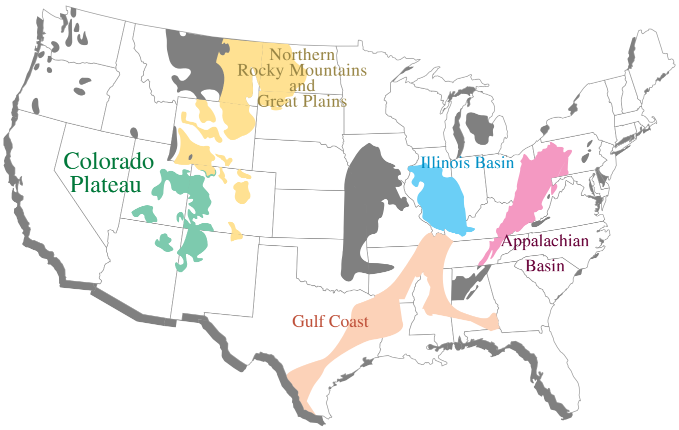


Figure 1. Map showing location of Colorado Plateau study area (green) in the United States in relation to other coal assessment areas (other colors) of the National Coal Resource Assessment Project. Gray areas represent coal regions not studied in detail during this National Assessment.

Assessment Methodology

Four main criteria were used to determine coal assessment units within the Colorado Plateau region: (1) areas with significant amounts of federally owned coal, (2) areas with active coal mining, (3) areas where coal-bed methane is currently being produced, and (4) areas with a high coal resource or development potential.

Twelve areas ranging from 22 mi^2 to 6,218 mi^2 were assessed using different levels of detail (fig. 2). In most of the assessment areas, digital databases were not available for analysis. Raw data was collected from outcrop measurements and interpreted from geophysical logs. Analysis was limited in some areas because data were sparse. In other areas, information was selected from large amounts of raw data—for example, in the Kaiparowits Plateau. The variability and availability of the data determined the scale and detail of the studies. Some areas were analyzed at a basin or coal-field scale, in which case correlations were restricted to distinguishing coal zones, whereas, in other cases, for instance the Northern Wasatch Plateau assessment unit, it was possible to analyze individual coal beds.

Methods for gathering data and computing the volumes of coal were adapted from Wood and others (1983) (see Roberts and others, chap. C, this CD-ROM). Due to the digital nature of the data and the many data formats and sources, new methods were established to manipulate and manage the data. Ultimately, all data were managed and stored using a geographic information system (GIS) (see Biewick and Mercier, chap. D, this CD-ROM). An automated process was developed to extract data from the stratigraphic databases in order to generate structure, coal isopach, and overburden maps and to calculate coal resources. A new method for estimating uncertainty in calculating resource estimates was developed during the course of the National Coal Resource Assessment Project that places 90 percent confidence limits on the volumes of coal calculated (see Schuenemeyer and Power, in press).

Assessment Results

Geology

Economically produced coals of the Colorado Plateau are entirely Cretaceous in age. The coal originally accumulated in coastal-plain wetlands located adjacent to ancient shorelines of a seaway that covered middle North America for much of the Cretaceous Period. A record of these paleoshorelines is preserved today as continuous sandstone deposits. An understanding of the sandstones is critical to correlating the associated coal deposits because the sandstones are more visible on outcrop, have a more consistent geophysical log signature, and can be used to predict the limits of thick coal deposits.

Therefore, a stratigraphic framework was developed from outcrop and drill-hole data for each of the assessment units,

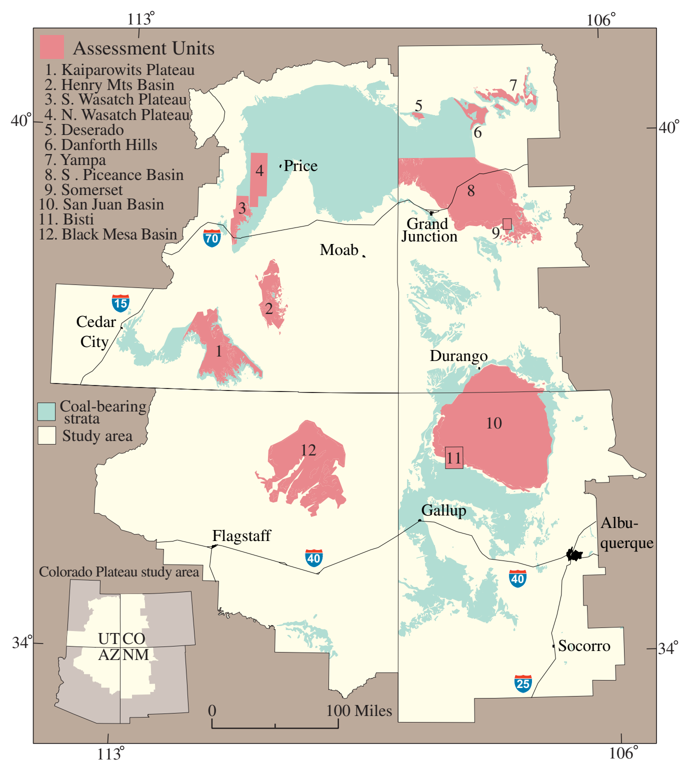


Figure 2. Map showing assessment units of the Colorado Plateau Project. Twelve areas were studied in various levels of detail, and the results of these studies are presented within this CD-ROM. The Northern Wasatch Plateau (4) (Tabet and others, 1999), the Somerset (9) (Eakins and others, 1998), and the Bisti area (11) (Hoffman and Jones, 1998) are summarized in Rohrbacher and others (chap. F, this CD-ROM).

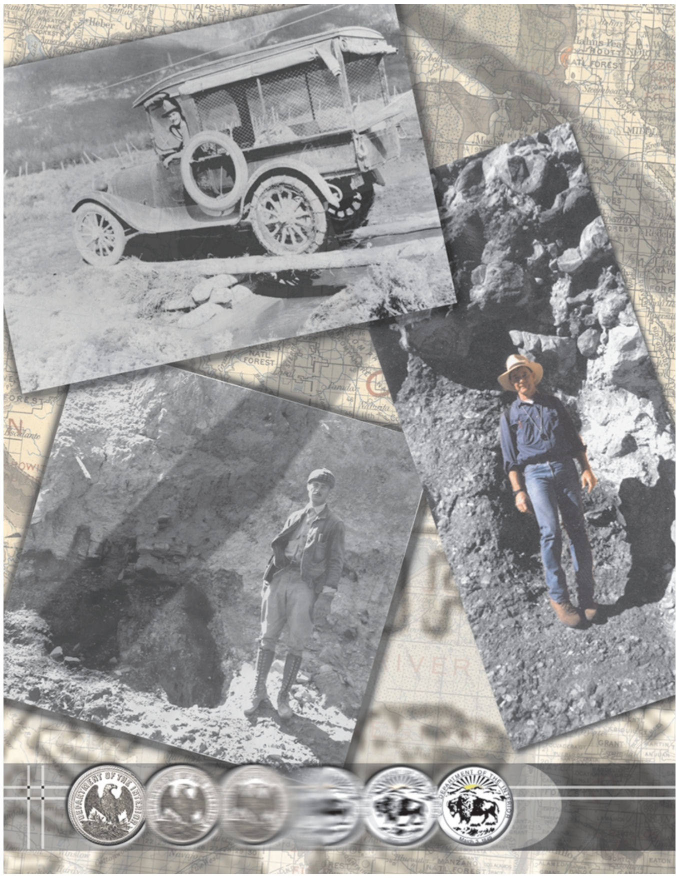


Figure 3. Montage of geologists who worked for or in cooperation with the USGS on coal in the Colorado Plateau.

and cross sections were generated. The cross sections show correlations of the sandstone units as well as the coals to illustrate the importance of the relationship of the shoreline deposits to the coal deposits (fig. 4). Stratigraphic databases were assembled along with framework studies. The framework studies and accompanying databases were used to construct isopach maps that show the areal distribution of the coal (fig. 5) and overburden maps that show the depth of burial of the main coal deposits.

Databases

Stratigraphic databases are provided here for seven areas and contain public, but not proprietary, information on point location (latitude and longitude), key formation tops, and coal thickness. The databases include 226 locations for the Kaiparowits Plateau, 308 locations for the Southern Wasatch Plateau unit, 10 locations from the Lower White River (Deserado) coal field (about 200 additional proprietary logs were used in this study), 108 locations from the Danforth Hills coal field (another 432 are proprietary), 175 locations from the Yampa coal field, 627 data points from the Southern Piceance Basin unit, and about 800 data points from the San Juan Basin. Although proprietary data was used in some of these projects, none of that proprietary data is included in the databases. The database files are stored on disc 2 of this CD-ROM in DBF, ASCII, and Excel formats. Databases are not provided for the Henry Mountains, Black Mesa, Bisti, Somerset, or Northern Wasatch Plateau assessment units.

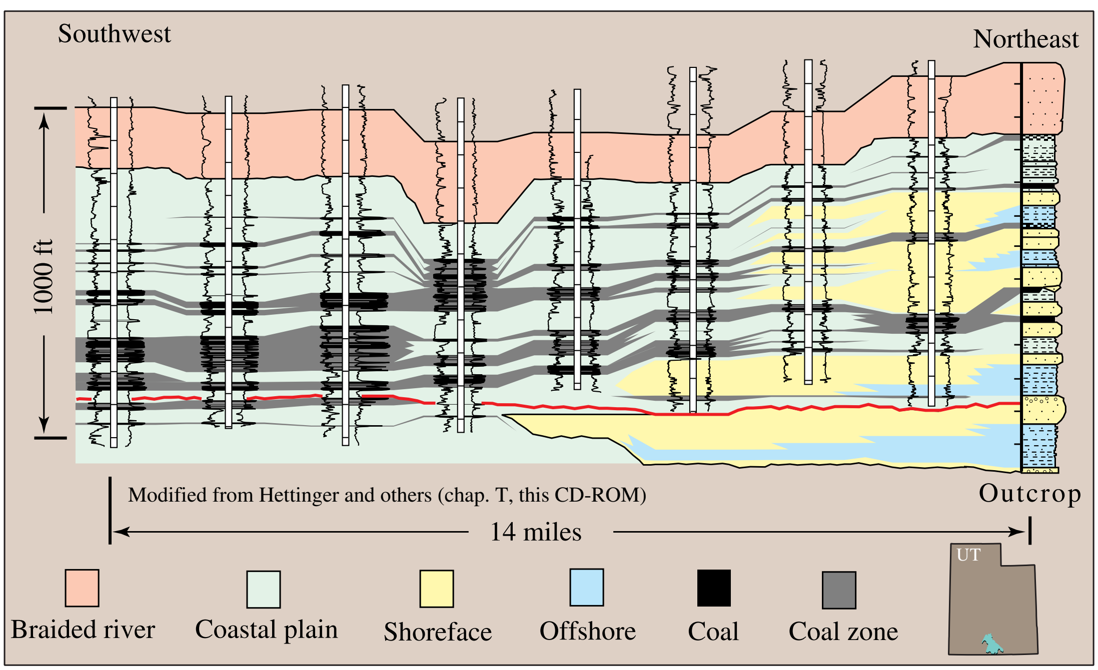


Figure 4. Diagrammatic cross section showing coal and sandstone correlations, and depositional environments from subsurface information interpreted from geophysical logs and outcrop measurements (after Hettinger and others, chap. T, this CD-ROM). Cross section is located southwest to northeast across the Kaiparowits Plateau; see inset of State of Utah for location of Kaiparowits Plateau.

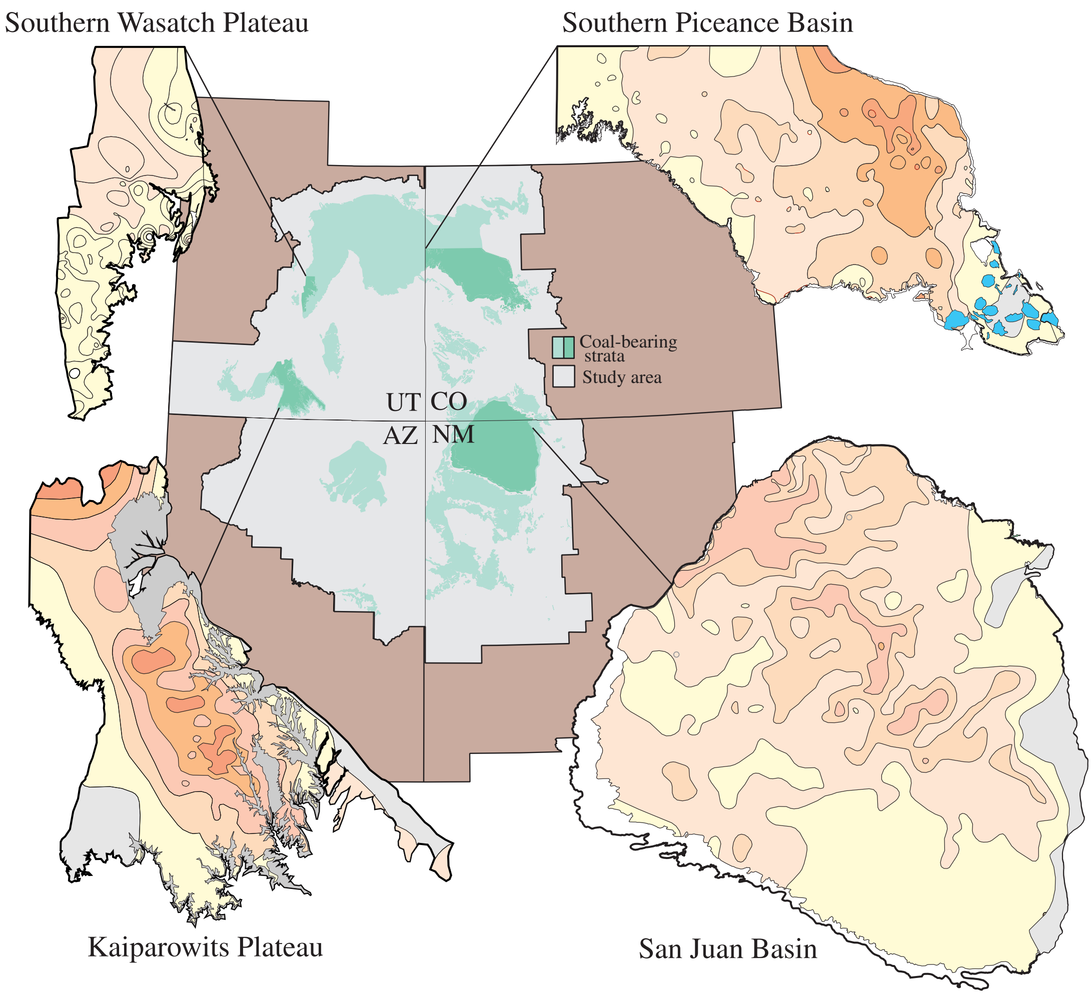


Figure 5. Diagrammatic maps showing total-coal thickness of selected assessment units with respect to their locations within the Colorado Plateau and the four-State region of Arizona, Colorado, New Mexico, and Utah. For details of maps see technical reports. On maps of the assessment units, yellow represents areas of thinner total coal (approximately 0–40 ft thick) and dark orange represents areas where total coal is greater than 100 ft thick. Areas of gray show where there is no coal or indicate the outcrop of the assessment unit; blue indicates igneous intrusions (Southern Piceance Basin assessment unit only).

Resources

Original resource estimates for the 12 priority assessment units of the Colorado Plateau exceed one-half trillion short tons of coal (fig. 6) in beds greater than 1 ft thick and under less than 6,000 ft of overburden. Resources do not include mined-out coal, and in most cases do not include areas currently under lease by mining companies. Twenty coal zones are compared to estimate the relative concentrations of coal in seven assessment units of the Colorado Plateau (fig. 7). The Yampa A zone has the highest concentration of coal—68 million short tons per square mile (mst/mi^2)—and the Deserado D zone of the Lower White River coal field has the lowest concentration—7 mst/mi^2. Presenting the data in this way allows comparison between areas and may suggest areas of high potential for mining or gas exploration.

Once stratigraphic frameworks and databases have been created and original resources have been calculated, we can estimate how much of the resource is restricted from mining because of legal, regulatory, social, environmental, and technical considerations (see Rohrbacher and others, chap. F, this CD-ROM). Coal availability studies conducted in the Somerset, Bisti, and Northern Wasatch Plateau assessment units (Eakins and others, 1998; Schultz and others, 1999; Hoffman and Jones, 1998; and Tabet and others, 1999) show that a range of 40 to 86 percent of the original coal resource is available for mining. Recoverability studies have been completed on 14 7.5′ quadrangles, including one in Somerset, four in Bisti, and nine in the Northern Wasatch Plateau assessment unit.

Uncertainty estimates are provided for 10 coal zones from five of the assessment units (fig. 8). The estimated error for identified resources (that is, coal resources within 3 miles of

Assessment area	Resources	Ash yield* (percent)	Sulfur* (percent)	Calorific value* (Btu/lb)
Bisti	1,600	22.9	0.5	8,130
Black Mesa	***	7.7	0.5	11,050
Danforth Hills	21,000	6.5	0.4	10,010
Henry Mountains	1,700	13.7	0.7	10,050
Kaiparowits Plateau	61,000	9.2	0.7	9,360
Lower White River	370	10.0	0.5	10,830
S. Wasatch Plateau	6,800	8.1	0.6	12,480
San Juan Basin	230,000	20.1	0.6	8,940
S. Piceance Basin	120,000	10.1	0.6	11,090
N. Wasatch Plateau	9,200	**	**	**
Somerset	3,100	10.6	0.6	11,730
Yampa	76,000	7.3	0.5	11,190
Grand total	**530,000**	**10.2**	**0.6**	**10,790**

* Median values on as-received basis ** N. Wasatch is combined with S. Wasatch *** not calculated

Figure 6. Chart of combined original identified and hypothetical resources and median values of ash, sulfur, and heating values for priority assessment units of the Colorado Plateau. Coals assessed are in beds greater than 1 ft thick and under less than 6,000 ft of overburden. Resources are in millions of short tons and are rounded to two significant figures; total will not sum due to independent rounding. Geochemistry is reported using data analyzed from USGS database.

a coal measurement) ranges from 3 to 39 percent for the 10 sampled areas. This error appears to be largely a function of the data density and the uniformity of data distribution.

Coal Quality

Coals of the Colorado Plateau are generally subbituminous to bituminous in rank, with mean calorific values as low as 8,130 Btu/lb in the Bisti coal field to as high as 14,000 Btu/lb in the Carbondale coal field. The sulfur content is relatively low when compared to other U.S. coal, and the mean range of sulfur is between 0.3 and 1.6 percent throughout the Colorado Plateau. Within the assessment units, mean values are less than 1 percent sulfur. Ash yields are also generally low, although the range is from about 5 percent to almost 25 percent. Mean values for the assessment units based on USGS data (see Affolter, chap. G, this CD-ROM) are provided in figure 6.

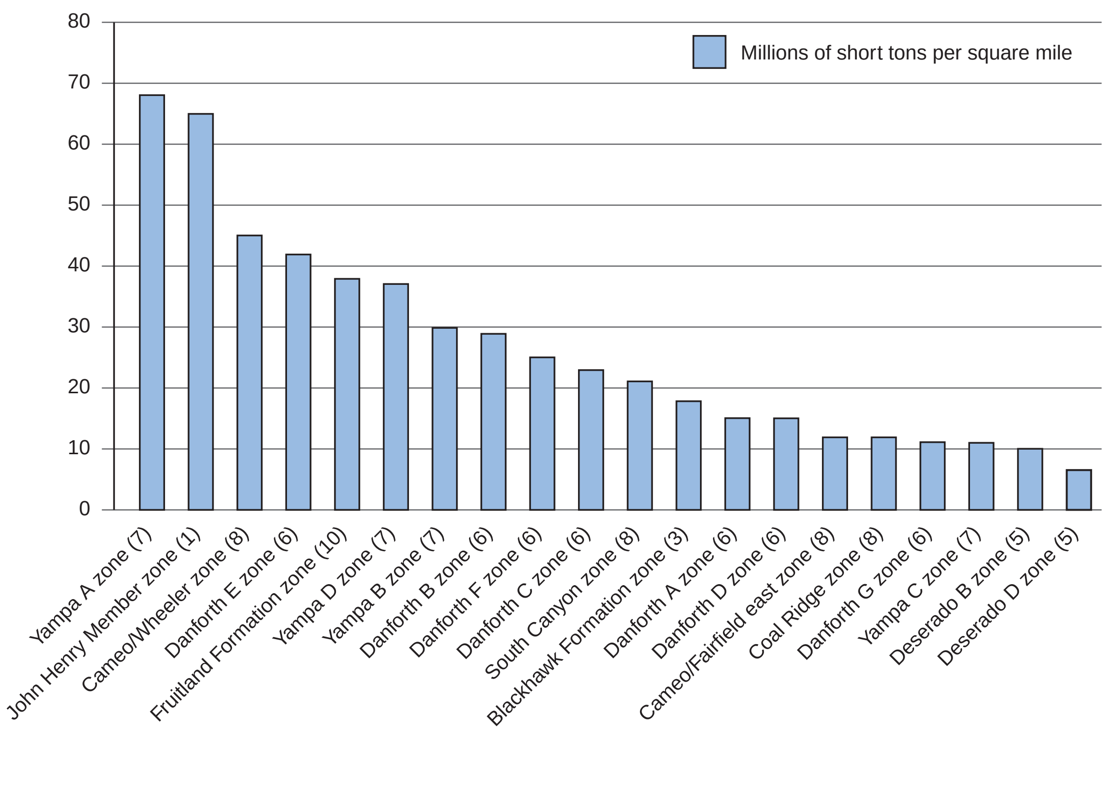


Figure 7. Chart of resource estimates for 20 selected coal zones of the Colorado Plateau in millions of short tons per mi^2. Number in parentheses indicates assessment unit in fig. 2. The John Henry Member, Blackhawk Formation, and the Fruitland Formation contain more than one coal zone, but these zones were not assessed individually. The total volume of coal was divided by the area of the assessment unit to give an average concentration of coal in millions of short tons per mi^2.

Coal zone	Lower	Mean	Upper	n*	% error
Cameo/Wheeler (8)	136,200	141,000	145,800	111	3
Coal Ridge (8)	11,290	14,100	16,900	42	20
Fruitland (10)	204,600	214,600	224,500	200	5
John Henry (1)	41,830	47,150	52,460	26	11
Blackhawk (3)	3,449	4,231	5,013	8	18
South Canyon (8)	22,090	24,750	27,400	42	11
Yampa A (7)	19,28	21,480	23,690	11	10
Yampa B (7)	3,940	5,066	6,192	6	22
Yampa C (7)	1,164	1,893	2,622	6	39
Yampa D (7)	4,836	6,851	8,866	7	29

Figure 8. Uncertainty estimates for the identified category of coal resources of selected coal zones. Resources are reported in millions of short tons with four significant figures to show details of statistical analysis. The n* is called the "pseudo n" by Schuenemeyer and Power (in press) and represents a calculated sample size that compensates for differences in data-point densities across an assessment area. Number in parentheses indicates study area shown in fig. 2.

Summary of Assessment Units

Kaiparowits Plateau Assessment Unit

The Kaiparowits Plateau (fig. 2) was initially assessed because the area contained the largest undeveloped coal resource in Utah and few comprehensive coal-resource studies were available. Our investigation was in progress when most of the plateau was included in the Grand Staircase–Escalante National Monument in 1996. A preliminary version of the assessment by Hettinger and others (1996) was released to the general public and land-use planners, and the final version of the assessment is released here by Hettinger and others, (chap. T, this CD-ROM). Our study concentrated on the overall coal distribution in the John Henry Member of the Straight Cliffs Formation. Subsurface data collected during the investigation represent about 15 percent of the coal exploration holes drilled in the area by private companies, and, with their permission, these data are made available to the public.

Henry Mountain Basin Assessment Unit

The Henry Mountains Basin (fig. 2) became important for coal resources following the inclusion of the Kaiparowits area in a National Monument. The Henry Mountains Basin contains significant deposits of Federal coal. The assessment unit contains three main coal deposits, of which the coal in the Masuk Formation is the most important for possible mining (Tabet, chap. R, this CD-ROM). Limitations to future mining may be the lack of an infrastructure to transport the coal or energy out of the basin and its proximity to Capitol Reef and Canyonlands National Parks and Glen Canyon National Recreation Area.

Southern Wasatch Plateau Assessment Unit

The Southern Wasatch Plateau (fig. 2) has high-quality coal and a very high potential for mining. About 4 million acres of land is unexplored for coal and likely contains large resources. One longwall mine (SUFCO) produces coal and trucks the coal to rail lines and power plants. In the assessment unit, the Federal Government owns 96 percent of the coal (6.5 billion short tons), and manages 94 percent of the land surface, most of which is administered by the Manti–LaSal National Forest. Four main coal beds are present in one thick zone in the Blackhawk Formation (Dubiel and others, chap. S, this CD-ROM). The main limitation for future mining is lack of direct access to rail transport.

Northern Wasatch Plateau Assessment Unit

The Northern Wasatch Plateau unit has been mined since the late 1800's and has large deposits of coal underlying the Manti–LaSal National Forest (fig. 2). Several high-production longwall mines operate in the area. The main purpose of this study was to determine the availability and recoverability of coal following such intense mining (Rohrbacher and others, chap. F, this CD-ROM). Of the original resource, 8 percent of the total has been mined or is lost to mining, and 7 percent of the total is presently economic and compliant to the Clean Air Act. The area still has high mining potential—about 1.1 billion short tons of coal might ultimately be produced, but the best coals may be depleted by 2040.

Deserado Assessment Unit of the Lower White River Coal Field

A 22-mi^2 area was assessed outside of the present longwall mining operation at the Deserado mine (fig. 2). The coal is concentrated in two zones of the Mesaverde Group and has good development potential (Brownfield and others, chap. N, this CD-ROM). Ninety-nine percent of the coal is federally owned.

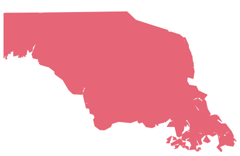
Danforth Hills Assessment Unit

The Danforth Hills (fig. 2) has a high concentration of coal resources in its 162-mi^2 area. The Colowyo surface mine produces coal from the area, and there is high potential for further development. The Federal Government owns 89 percent of the coal, yet manages only 25 percent of the surface land. There are seven assessed coal zones within the Fairfield coal group of the Williams Fork Formation (Brownfield and others chap. M, this CD-ROM).

Yampa Assessment Unit

This is the most important coal-producing area in Colorado (fig. 2) with several large surface operations including the Seneca, Trapper, and Foidel Creek mines. Future expansion is expected to be underground using longwall technology. The Federal Government owns 69 percent of the coal but manages only 7 percent of the surface. The area has coal-bed methane potential. Four coal zones were correlated and assessed in the Williams Fork Formation (Johnson and others, chap. P, this CD-ROM).

Southern Piceance Assessment Unit



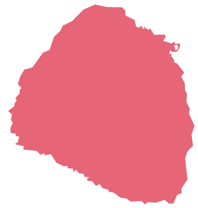
The southern part of the Piceance Basin (fig. 2) has a coal resource of about 120 billion short tons within the Mesaverde, Mount Garfield, and Williams Fork Formations; however, only about 34 billion short tons are in beds of minable thickness (greater than 3 ft) and depth (less than 3,000 ft). The coal is mined from several large underground mines along the basin's southern boundary, and gas is also produced from coal in the basin's interior. The Federal Government owns about 74 percent of the coal and manages 64 percent of the surface land; much of the resource underlies the Grand Mesa and Gunnison National Forests. The distribution and resources of coal are assessed by Hettinger and others (chap. O, this CD-ROM).

Somerset Assessment Unit

This area has several large underground mines and a moderately high percentage (64 percent) of federally administered lands (fig. 2). Within a one-quadrangle map area, the available coal resources may be as much as 75 percent of the remaining coal (Rohrbacher and others, chap. F, this CD-ROM). Potential problems are posed by the steep topography and associated landslide areas, by igneous intrusions (in adjacent areas), and by restriction of rail service to one line in the narrow valley of the North Fork of the Gunnison River.

San Juan Basin Assessment Unit

The Fruitland Formation contains 230 billion short tons of bituminous coal in the San Juan Basin, 160 billion short tons of which are federally owned. Most of these resources



are less than 4,000 ft deep. Of this total, about six billion short tons are at strippable depths of less than 200 ft. Through 1998, three large strip mines had produced more than 350 million short tons of coal, most of which went to feed two mine-mouth power plants in the northwest part of the basin in New Mexico. These three mines produced more than 15 million short tons of coal in 1998. The discovery of commercial coal-bed methane in Fruitland coals in the 1970's spurred rapid development of this resource, and Fruitland coal beds today produce about one trillion cubic feet of gas annually, making the San Juan Basin the world's largest coal-bed-methane-producing basin. Fruitland coals contain in excess of 50 trillion cubic feet of gas in place. The Fruitland coal data presented in this assessment will provide valuable insights for understanding coal-bed methane generation and reservoir characteristics that will enhance coal-bed methane exploration elsewhere (Fassett, chap. Q, this CD-ROM).

Bisti Assessment Unit

The coal seams in the Bisti area (fig. 2) have good continuity and, in the San Juan Basin, are the closest undeveloped resource to a major highway and a population center (Farmington, N. Mex.). The area is about 50 mi from existing power plants, but there is currently no rail infrastructure to transport the coal to them efficiently. Trucking the coal would be relatively expensive. Of the original resources in the area, 1 percent has been mined out, 68 percent is available, and 47 percent is recoverable (Rohrbacher and others, chap. F, this CD-ROM). Presently, none of this coal is considered economic or is compliant with the Clean Air Act.

Black Mesa Basin Assessment Unit

Coal of the Wepo Formation is produced from the Kayenta and Black Mesa surface mines, and the area has future development potential (Nations and others, chap. H, this CD-ROM). We provide a geologic assessment of the area (fig. 2), but no new resource figures. The assessment unit is completely within the Hopi and Navajo Reservations.

Conclusions

The Colorado Plateau region contains a substantial quantity of high-quality, low-sulfur coal resources. A portion of these resources will provide future energy production for the

United States in the 21st century. Coal that will be mined throughout the next 20 to 25 years is essentially known, most of it occurring within active mines or in adjacent leased areas. The geologic interpretations and digital data presented in this report provide industry geologists, land-use planners, Congress, and the public with comprehensive information on the location, distribution, and quality of these resources. The study also identifies coal deposits that have future coal and coal-bed-gas development potential. This knowledge and data will be crucial if unforeseen energy events, market trends, or environmental concerns require the transfer of emphasis from one coal region to another. This is especially relevant to federally owned coals, as seen recently in the case of the Kaiparowits Plateau and related land and resource trades. The digital data and interpretations presented in this study can be updated as new data become available to provide geologically based assessments within the region and can be used as a base of comparison to other important coal-producing regions of the Nation.

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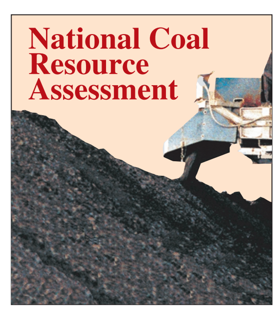

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