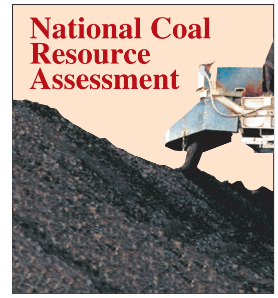
Chapter A

Introduction: Geologic Assessment of Coal in the Colorado Plateau

By Mark A. Kirschbaum[1]



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Chapter A *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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* This report, although in the USGS Professional Paper series, is available only on CD-ROM and is not available separately

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Introduction: Geologic Assessment of Coal in the Colorado Plateau

Figure 1. View of western part of Colorado Plateau in central Utah. Shale slopes in the distance are capped by the Star Point Sandstone and coal-bearing Blackhawk Formation.

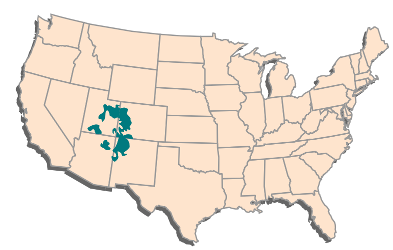


Figure 2. Map of conterminous United States showing location of Colorado Plateau study area (in green).

Introduction

Coal mining and gas production from coal deposits are important contributors to the generation of electric power in the United States. In 1992, for example, on average, about 69 percent of the total electricity generated within the States of Arizona, Colorado, New Mexico, and Utah was derived from coal (Energy Information Administration, 1995, p. 84).

In the Western United States, large deposits of coal are concentrated in a coherent physiographic and geologic province known as the Colorado Plateau, located within the States of Arizona, Colorado, New Mexico, and Utah. The coal deposits are concentrated in sedimentary basins isolated during the Late Cretaceous Laramide orogeny. The Plateau is not only an important coal-mining region but also contains large natural gas resources that have been derived in part from the coal deposits.

Figure 3. Electric transmission lines running westward from a coal-fired power plant.

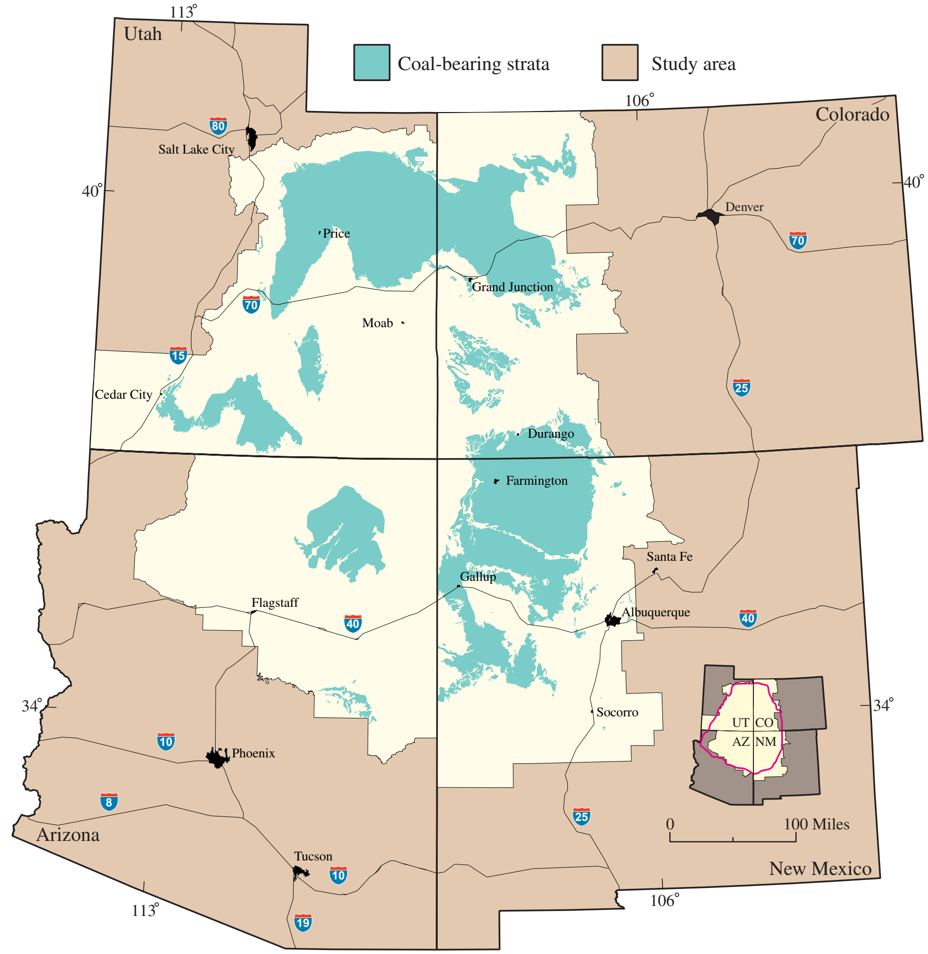


Figure 4. Location map of the Colorado Plateau study area. The outline of the study area is defined by county lines. The study area is within the States of Arizona, Colorado, New Mexico, and Utah. Areas of coal-bearing strata, shown in green, are generalized from various sources. Such strata consist of formations containing coal that crop out at the surface and formations containing coal in the subsurface beneath younger rock units. The inset shows the difference between the Colorado Plateau study area (defined by counties) and the combined physiographic and geologic province boundary of the Colorado Plateau (red line) as defined by Fenneman (1930) and Kelley (1955).

Purpose

The purpose of this study is to provide a geologic assessment of coal deposits of the Colorado Plateau region. This CD-ROM set provides information on the geologic framework of the coal-bearing strata, on the quality and distribution of the coal, on coal resources, and on the infrastructure related to production of the coal. The CD-ROM set also contains geologic and geographic databases stored in a digital format.

This introductory chapter provides an overview of the material presented in this CD-ROM, summarizes our work on the Colorado Plateau Assessment, and provides nontechnical background information on coal from resources to utilization within the plateau.

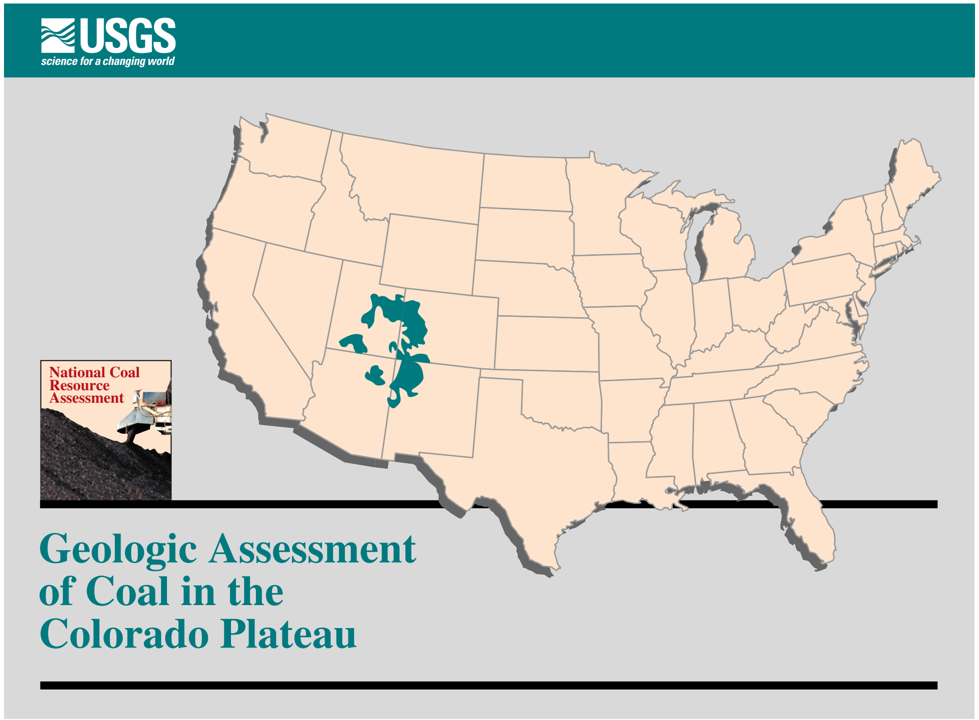


Figure 5.

CD-ROM Content

The CD-ROM contains information on 47 coal fields within the Colorado Plateau and includes three types of reports as well as databases containing supporting information.

The coal-field summary report provides information for 47 coal fields of the Colorado Plateau. Each summary includes basic information on the field's location, stratigraphy, coal zones, coal quality, resources, production history, and references. Each summary is essentially an annotated bibliography (see Kirschbaum and Biewick, chap. B, this CD-ROM).

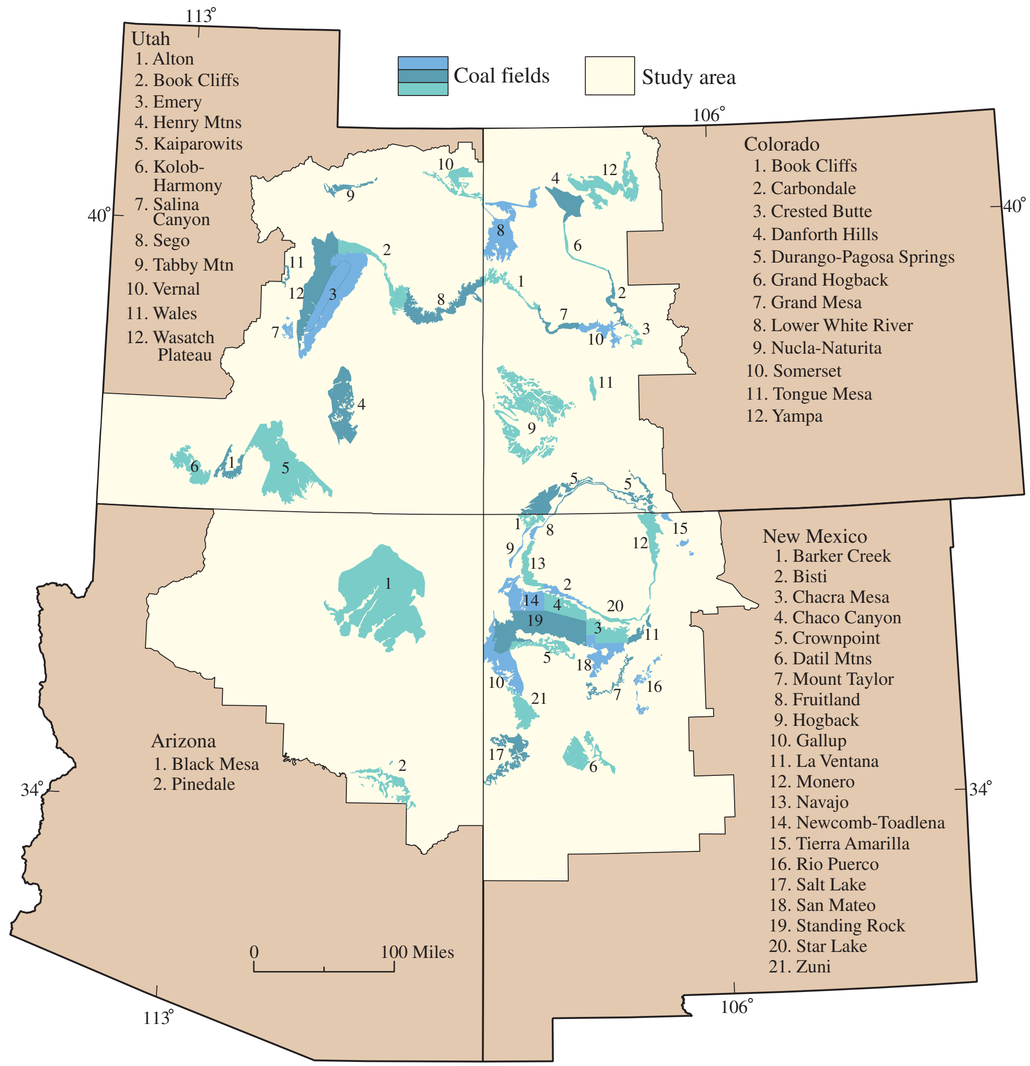


Figure 6. Coal fields in the Colorado Plateau that have summary reports (see Kirschbaum and Biewick, chap. B, this CD-ROM). The different colors are used to help distinguish separate fields. For areas assessed in detail during this study, see figure 14.

Regional Papers

These reports contain subject matter that applies to the entire Colorado Plateau and include an executive summary; an introduction; two methods papers, one on acquisition of geographic information and one on the methodology of the integration of geologic and geographic coverages; a paper on coal geochemistry; coal-field summaries; and a summary paper on coal availability/recoverability.

Overview Presentations

These five reports provide information on the coal geology of selected areas of the Colorado Plateau. The reports are presented in a "slide-show" format that allows the user to gain an overview of the area in about 15–20 minutes of viewing. In addition to four presentations on selected coal-assessment study areas, this section includes a report on a new method for estimating in-place coal-bed methane resources.

Technical Reports

This section contains detailed technical reports of eight assessment areas of the Colorado Plateau. The papers contain detailed geologic-based coal resource assessments, and all the reports, except the one on the Henry Mountains coal field, include the stratigraphic and geographic data sets that were used to create the assessments.

Databases

The CD-ROM contains three types of databases: a coal geochemistry database, stratigraphic databases of the detailed assessment units, and a geographic information system (GIS) that includes geologic and geographic data for all other reports.

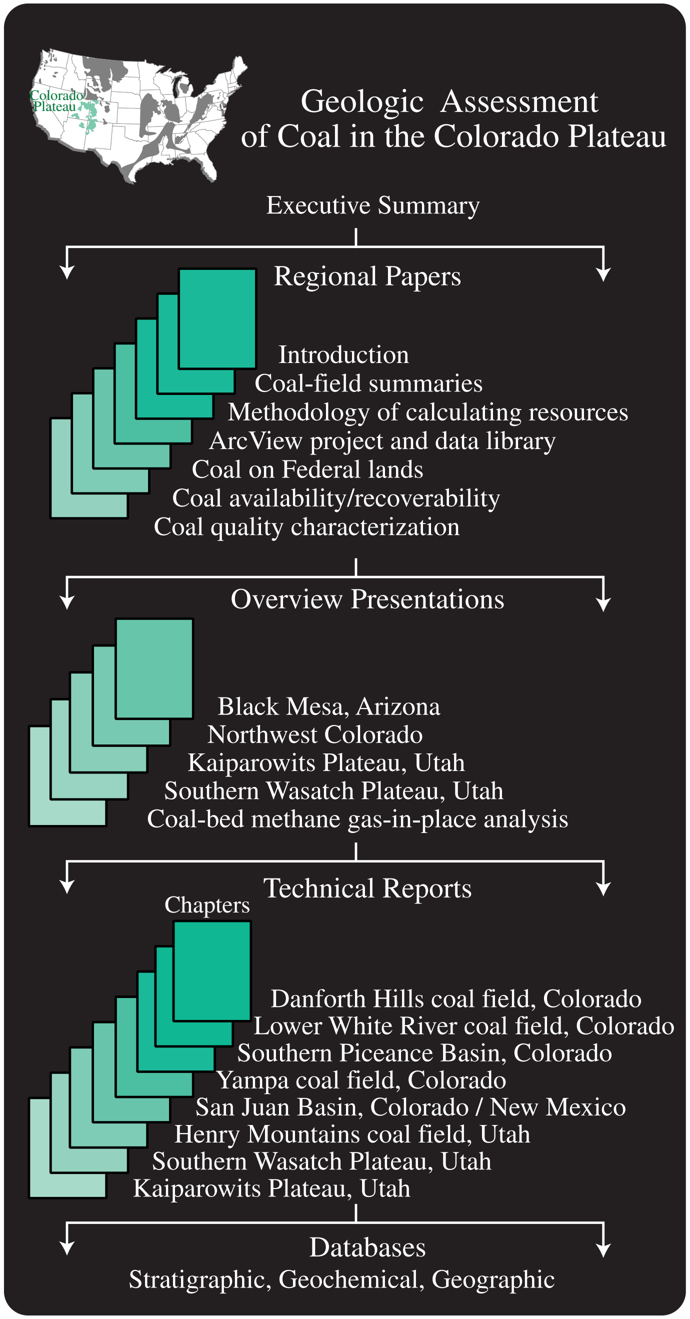


Figure 7. Titles of reports on CD-ROM. Individual reports are accessed through the Volume Table of Contents for each disc. Databases in DBF, Excel, and ASCII formats are on disc 2 of this 2-CD-ROM set. Some appendixes to reports are presented as views in the Colorado Plateau ArcView project, which is present on both disc 1 and disc 2—disc 1 contains the ArcView project that is accessed through the ArcView Data Publisher (ESRI, 1999), and disc 2 contains the ArcView project that is fully accessible to those with ArcView 3.1 (ESRI, 1998).

Origin and Controls on Coal Deposition

The major coal deposits in the Colorado Plateau are Cretaceous in age. The coals are generally older in the western areas and younger in the eastern areas across the plateau.

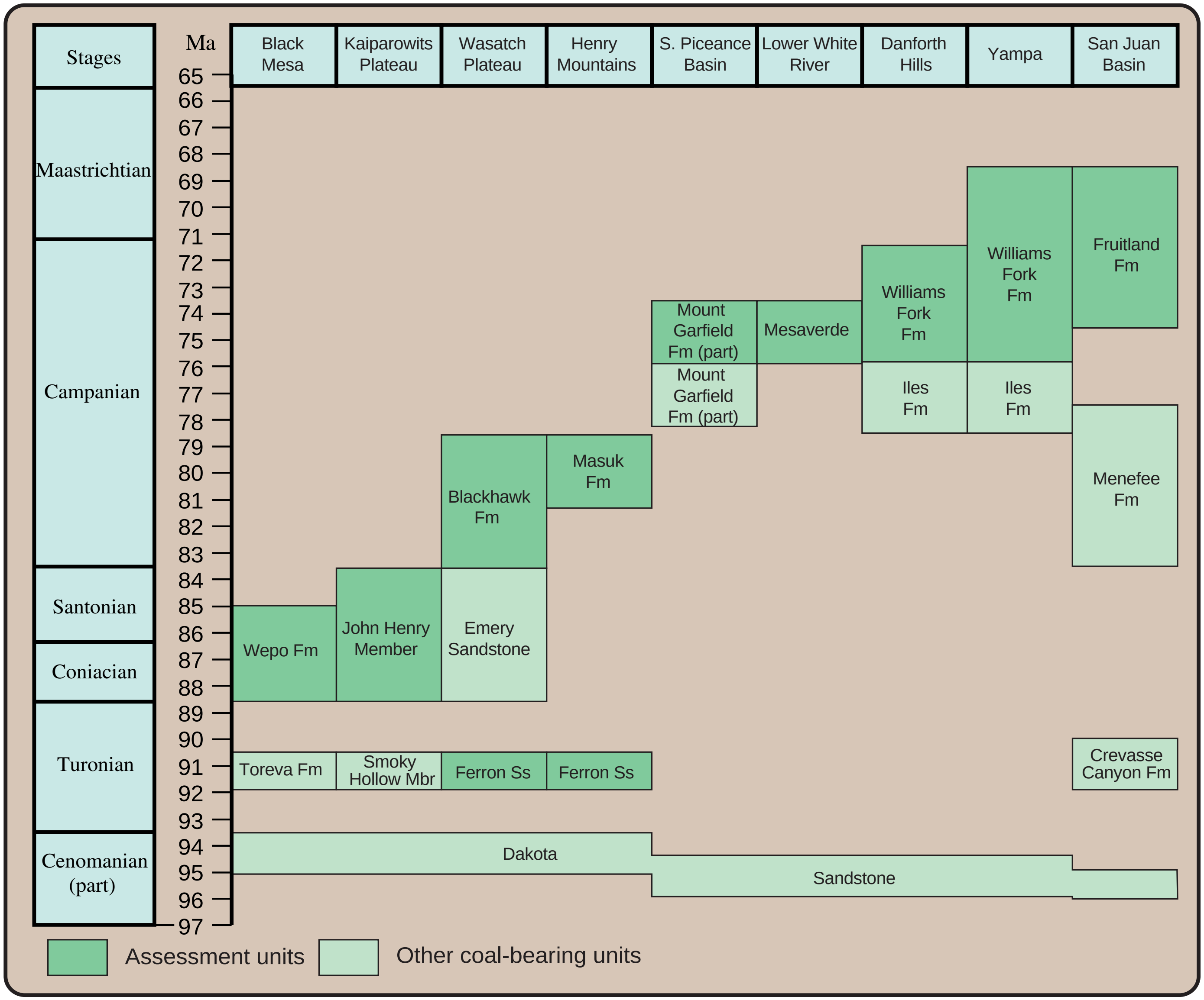


Figure 8. Correlation diagram showing the relative age of Cretaceous coal deposits in selected areas of the Colorado Plateau. The data for the diagram is derived from Roberts and Kirschbaum (1995).

Origin and Controls on Coal Deposition—*Continued*

Initially, vegetation grew and was deposited in freshwater wetlands (mires) located landward of shorelines. Over time, vegetation continued to accumulate and was transformed to peat, a precursor to coal.

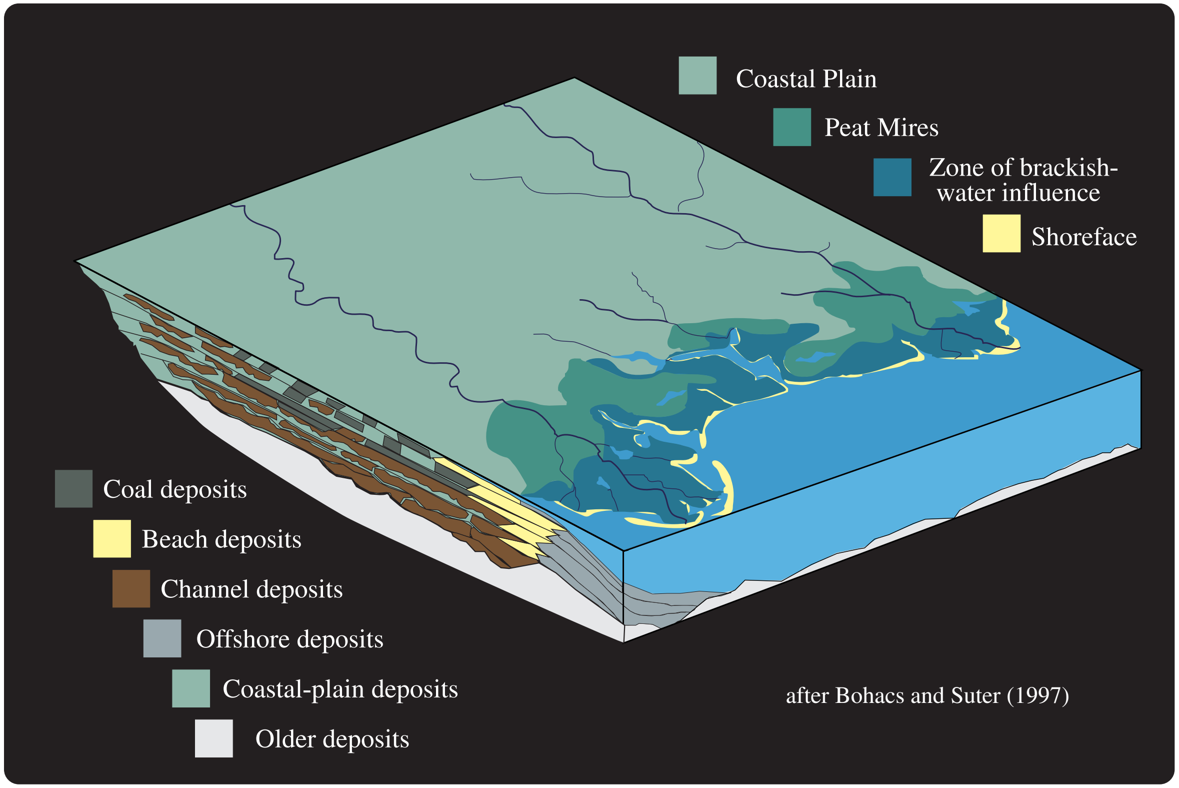


Figure 9*A*. Block diagram showing the generalized coastal environments that were present in the Cretaceous and the location of wetlands in which peat accumulated (modified from Bohacs and Suter, 1997).

Figure 9*B*. Photograph of a cypress swamp in North Carolina, a modern equivalent to the type of environment in which peat accumulated during the Cretaceous.

Origin and Controls on Coal Deposition—*Continued*

The shorelines and adjoining peat mires existed on the edge of a large inland sea, the Cretaceous Western Interior Seaway, that occupied parts of the present-day Colorado Plateau from about 98 to 65 million years ago.

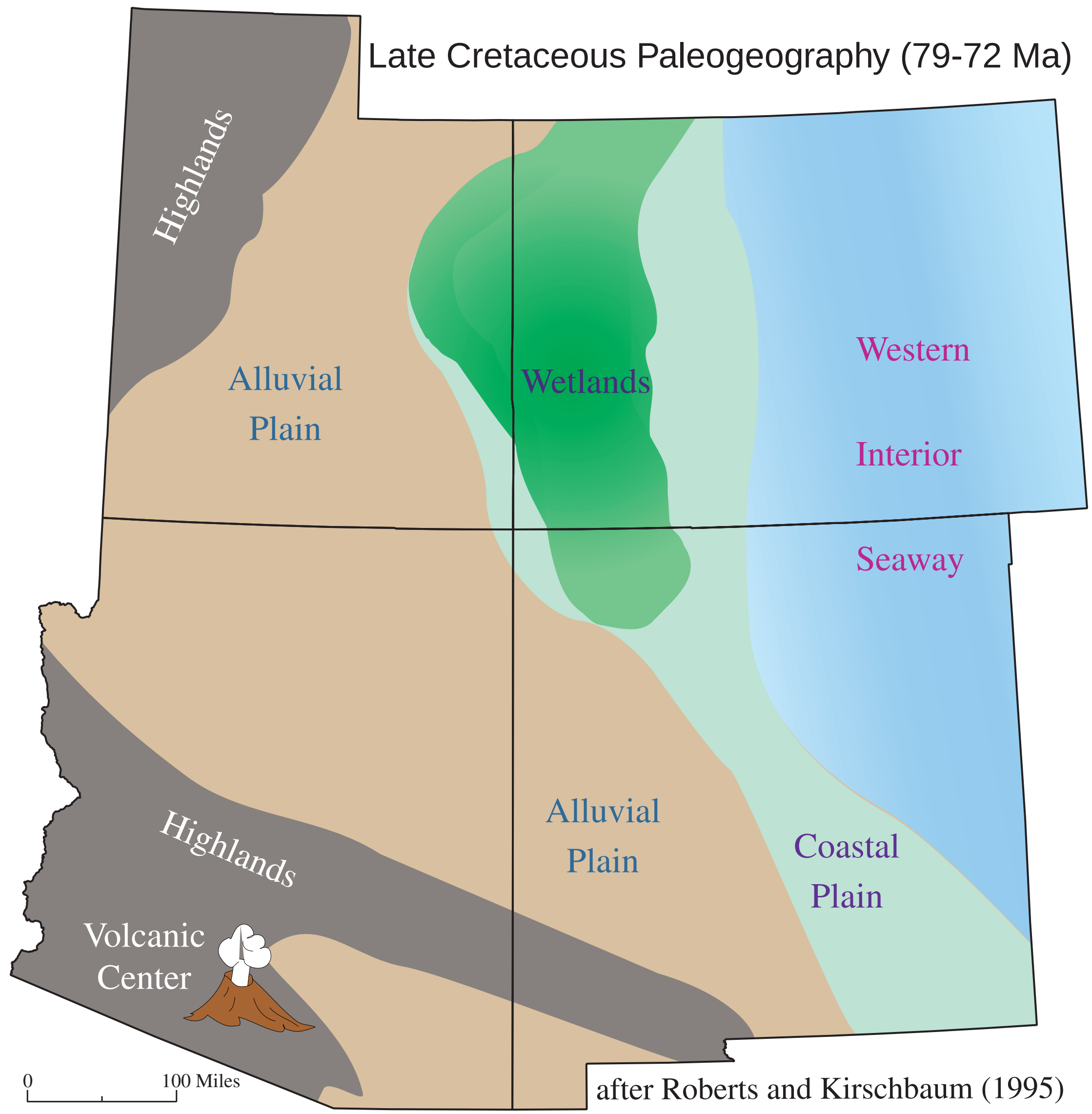


Figure 10. Composite paleogeographic map of the Late Cretaceous during a period of about 7 million years, from approximately 79 to 72 Ma., showing the location of extensive peat-accumulating wetlands (modified from Roberts and Kirschbaum, 1995). Older Cretaceous peat, deposited before 72 Ma in central Utah and northern Arizona, was overlain by alluvial deposits during this time.

Origin and Controls on Coal Deposition—*Continued*

Regional subsidence resulted in the burial and preservation of the peat deposits. In the later stages of the Cretaceous, the seaway withdrew, and uplift caused by the Laramide orogeny divided the area into a number of intermontane basins. Burial of the peat within the intermontane basins was accompanied by heat and pressure that were responsible for the transformation of the peat to coal. In later Tertiary time, uplift of the Colorado Plateau and its subsequent dissection by rivers and streams has brought the coal close to the surface, allowing commercial exploitation of the coal resources.

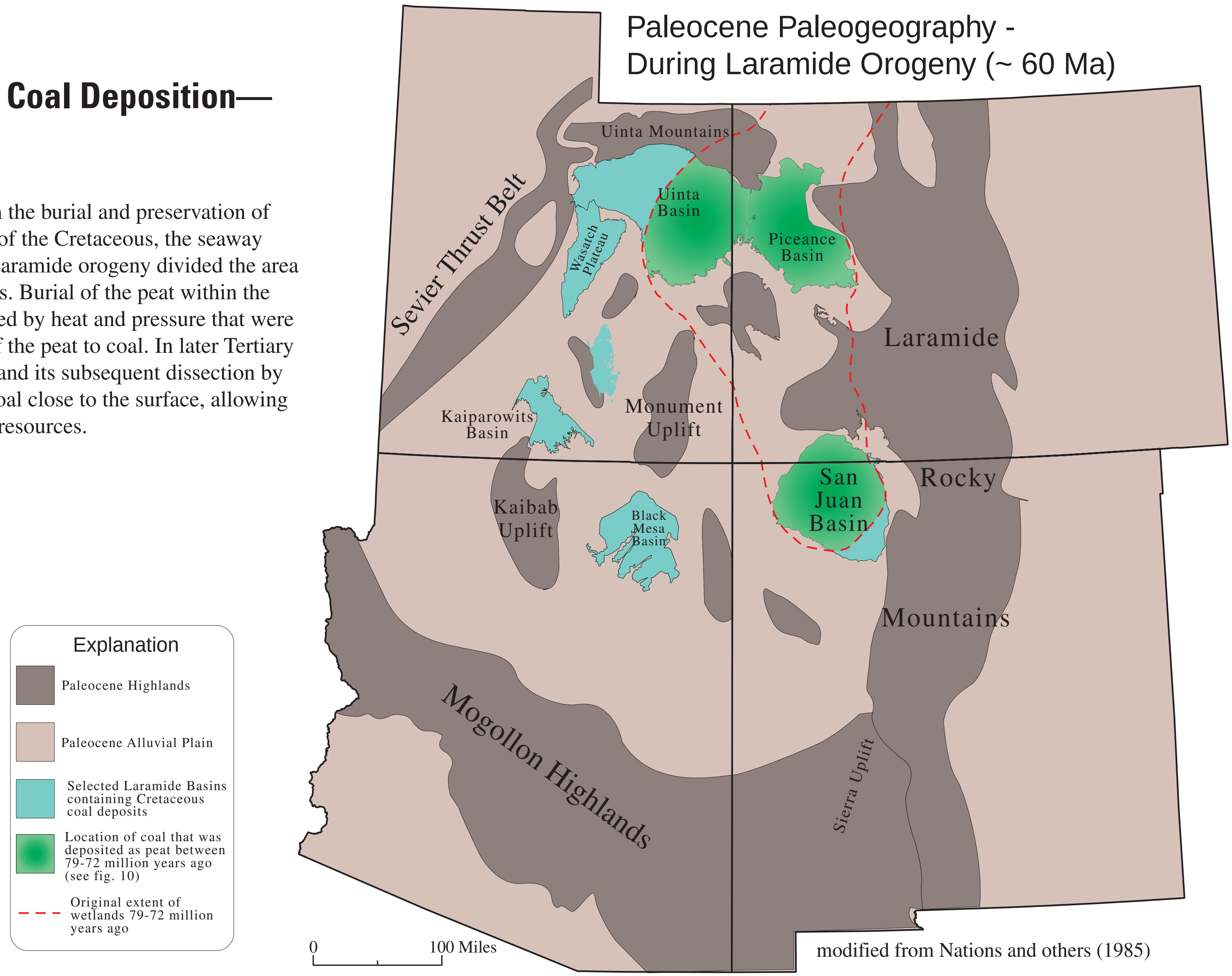


Figure 11. Composite paleogeographic map of the Paleocene at about 60 million years before the present showing uplifts and basins that restricted the location of coal deposits with respect to their original distribution as wetlands (modified from Nations and others, 1985). The peat that was deposited between about 79 to 72 million years ago is shown in darker green outlined by the red dashed line. Note how much of the original hypothesized wetland (fig. 10) was eroded during uplift.

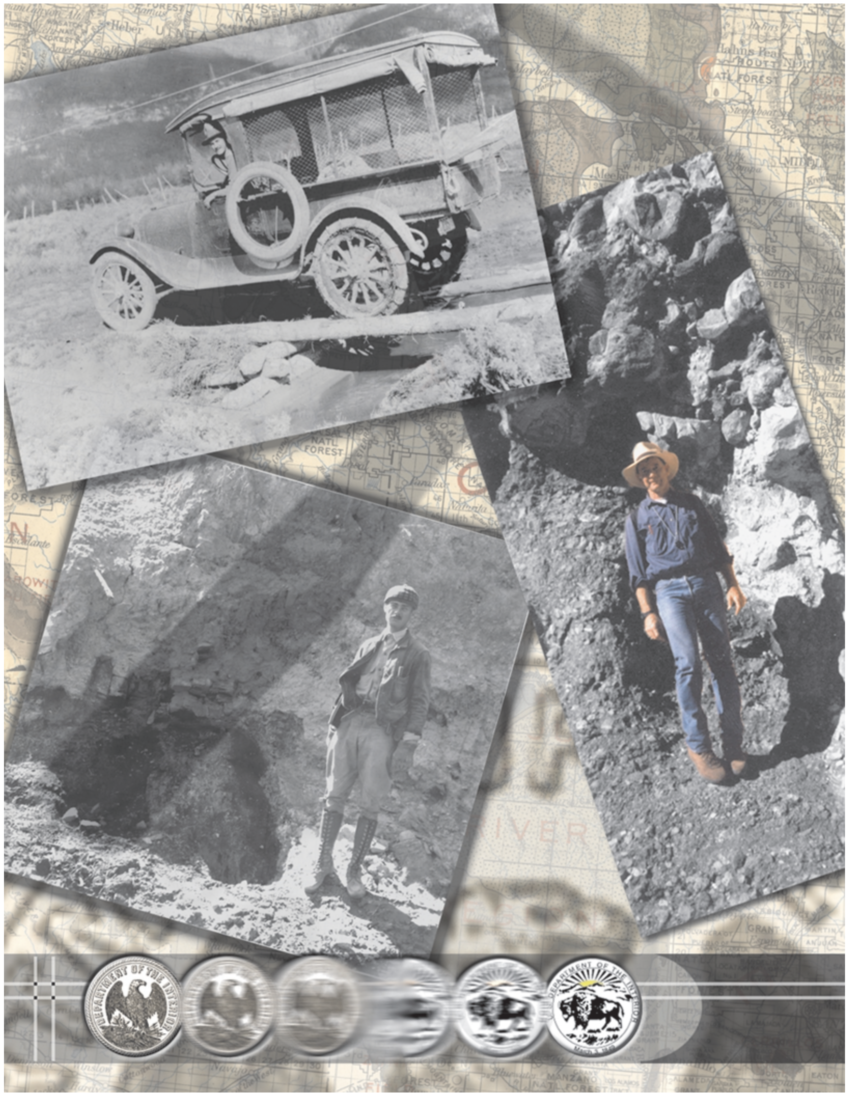


Figure 12. Montage of geologists who worked for or worked in cooperation with the USGS in the Colorado Plateau. Left, Edmund Spieker in the Wasatch Plateau coal field; right, Timothy F. Lawton, New Mexico State University; top, early field vehicle of the Wasatch Plateau field party. Black and white photos are from Field Records Archives of the USGS Library in Denver, Colo. The logo of the Department of Interior, shown at the bottom of the montage, changed from an eagle in its early history to a buffalo at present.

History of USGS Coal Exploration and Resource Estimates

Since the beginning of the 20th century, the U.S. Geological Survey has explored for coal and provided estimates of coal resources for areas within the Colorado Plateau area.

The first comprehensive studies of the original resources of the continental United States were compiled by Campbell and Parker (1909) and by Campbell (1917, reprinted 1922 and 1929). In these studies, they estimated the total original resource for the conterminous United States to be about 3–3.5 trillion short tons of coal. Original resources are the amount of coal in the ground before mining (Wood and others, 1983).

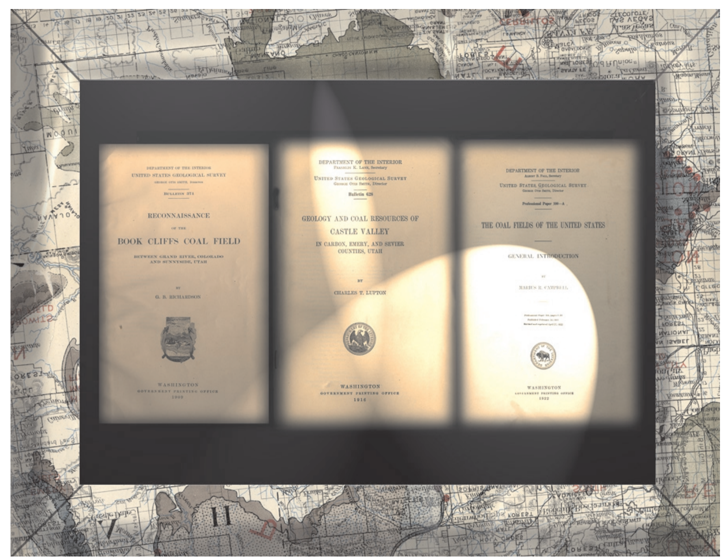


Figure 13*A*. Montage of title pages from some early USGS coal studies.

History of USGS Coal Exploration and Resource Estimates—*Continued*

The basis for Campbell's analysis (1917) was a series of classic studies of individual coal fields across the United States in which he and his colleagues mapped the geology and, in many cases, developed the stratigraphic frameworks that, with modifications, are still in use today (see Kirschbaum and Biewick, chap. B, this CD-ROM; Richardson, 1909; Gale, 1910; Campbell, 1912; Lupton, 1916).

The motivation for these studies was the 1906 withdrawal of some 66 million acres of coal lands by President Theodore Roosevelt following the misuse of the Homestead Act for acquiring federally administrated lands for mining purposes (see Campbell, 1917; Rabbitt, 1986, p. 45). The USGS was asked to classify these lands and determine their worth as soon as possible so that the coal might be sold at a fair market value (Campbell, 1917).

These early geologic studies and more detailed studies from the 1930's through 1970's (e.g., Spieker, 1931; Fassett and Hinds, 1971) provided data on most of the coal fields present in the United States. These detailed geologic investigations were subsequently summarized for each State by the USGS and State geological surveys in the 1950's through the early 1970's (e.g., Landis, 1959). The State reports were then compiled and updated by Averitt (1975, his table 2), who, like Campbell in earlier studies, also compiled estimates of resources totaling about 3.5 trillion short tons of coal for the continental United States (in beds beneath less than 3,000 ft of overburden).

The profusion of reports in the late 1970's, 1980's, and early 1990's resulted from an increased interest in coal following the energy crisis of the early 1970's; these reports are summarized in the current assessment. Clearly, the total amount of original coal resources in the United States is fairly well constrained. In this assessment, resources are reported from various historical sources along with new resource estimates for selected assessment units within the Colorado Plateau. An important addition in this assessment are the detailed geologic, geographic, and stratigraphic databases that are made available.

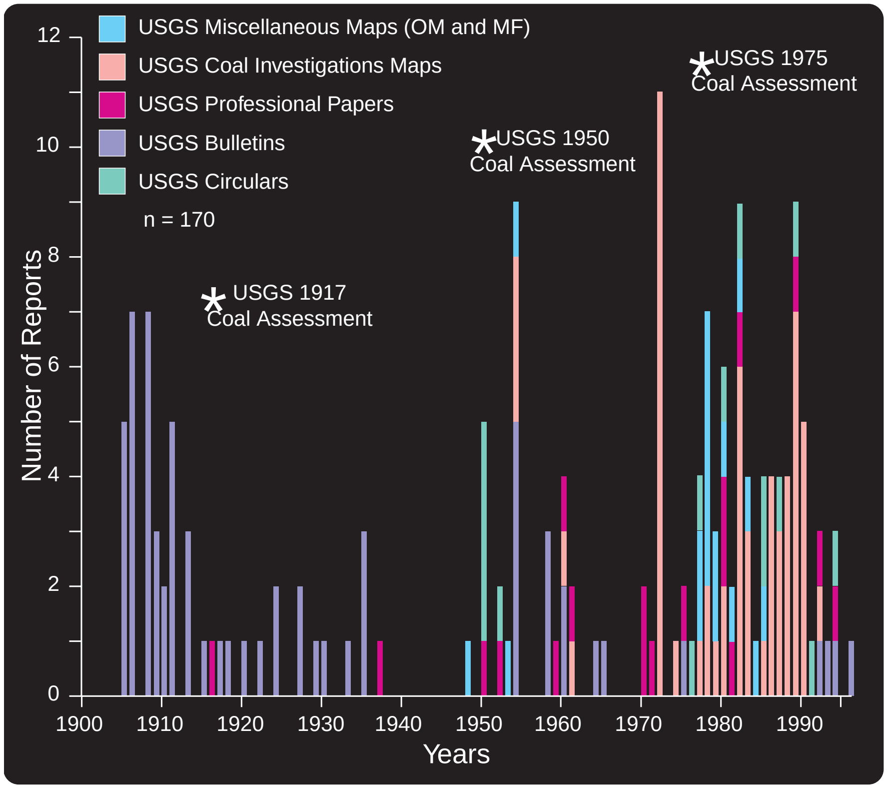


Figure 13*B*. Chart of USGS publications on coal in the Colorado Plateau. The histograms were constructed based on data from the American Geological Institute's 1998 database of USGS publications. The database was queried for each formal USGS series from 1900 to 1997. The basic query for each series was (coal or fuel) + (Arizona, Colorado, New Mexico, or Utah), and then these lists were printed and publications outside of the Colorado Plateau assessment study area were eliminated. Compilation of abstracts or short papers on coal were only counted as one data source.

Assessment Units in the Colorado Plateau

The current coal assessment of the Colorado Plateau used four main criteria for prioritizing assessment units within the region: (1) areas containing significant mineral ownership that is administered by the Federal Government, (2) areas that have active coal mining, (3) areas where coal-bed methane is currently being produced or coal is the source rock for gas production, and (4) areas that have a high resource or development potential. In two cases, coal fields and areas between known coal fields were combined to form a single assessment unit: (a) the Southern Piceance Basin assessment unit (fig. 14, no. 8), includes part or all of the Book Cliffs, Grand Mesa, Somerset, Crested Butte, Carbondale, and Grand Hogback coal fields (see fig. 7 for coal fields); and (b) the San Juan Basin assessment unit (fig. 14, no. 10), encompasses the Durango, Fruitland, Hogback, Bisti, Star Lake, and Monero coal fields (see fig. 7).

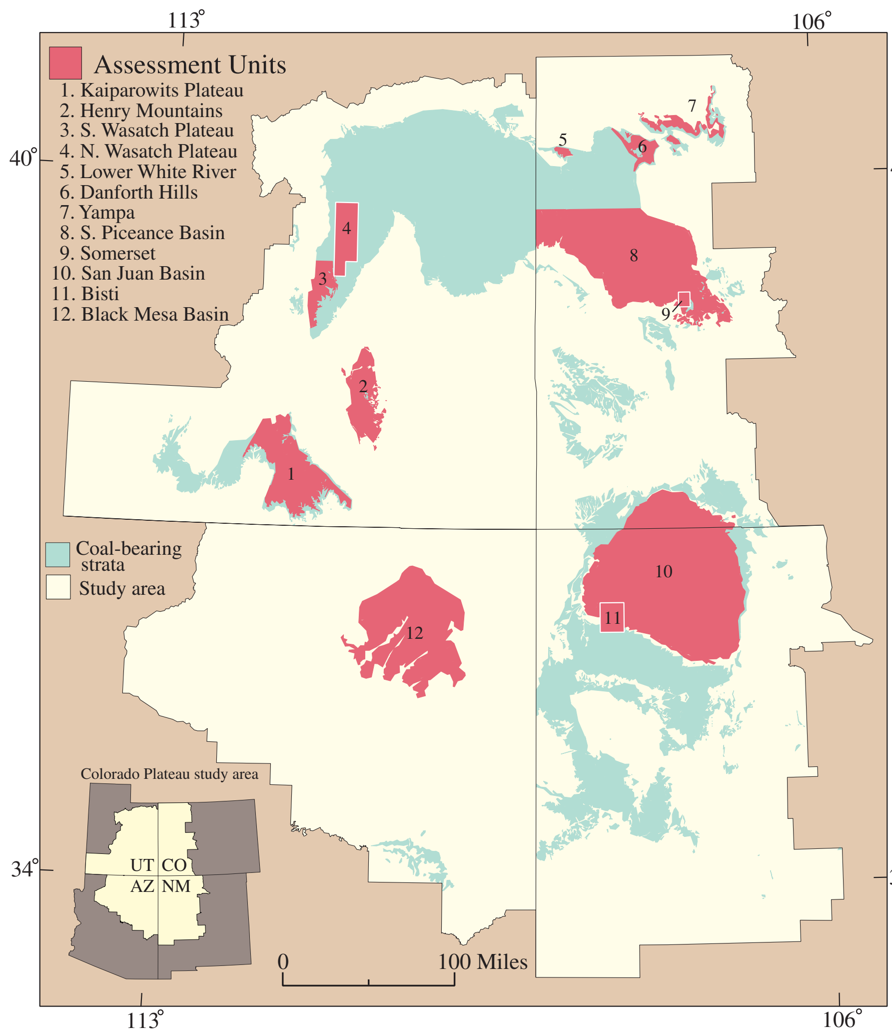


Figure 14. Map showing assessment units of the Colorado Plateau project. Twelve areas were studied in various levels of detail, and the results of these studies are presented within the CD-ROM. The Northern Wasatch Plateau (4), the Somerset (9), and the Bisti (11) areas are summarized together in Rohrbacher and others (chap. F, this CD-ROM).

Counties of the Colorado Plateau

Coal is present in 41 of the 43 counties in the study area (fig. 15). More than 20 coal zones were assessed during this study in parts of 20 counties within the four-State region of Arizona, Colorado, New Mexico, and Utah.

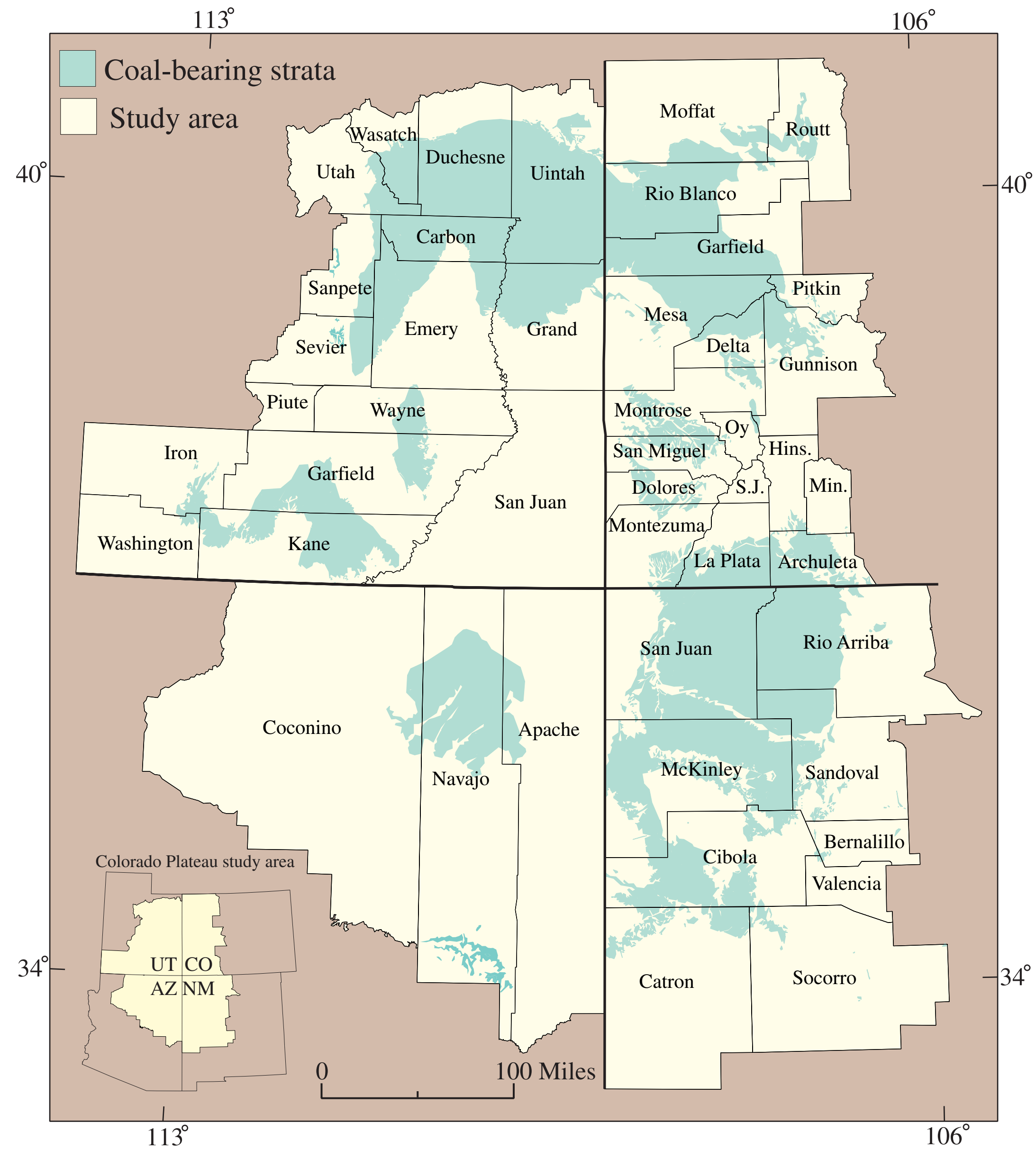


Figure 15. Map showing geographic distribution of coal-bearing strata in the study area and counties where coal is present. Oy, Ouray; S.J., San Juan; Hins., Hinsdale; Min., Mineral.

Original Resources in the Assessment Units

Original resource numbers (the amount of coal in place before mining) are useful when comparing coal fields within a region or from region to region. The original resource is also useful in understanding the in-place volumes of gas that may be extractable from a coal deposit (see Dallegge and Barker, chap. L, this CD-ROM). Once original resources have been documented, coal-bed frameworks have been established, and databases have been created and quality-controlled, it is possible to appraise how much coal can be extracted from an area.

A rough method of estimating how much coal can still be extracted from a mature mining area is to subtract mine production data from the original resource estimate. The Wasatch Plateau is such a mature area. Tabet and others (1999) estimated about 9.2 billion short tons of coal in the Northern Wasatch Plateau assessment unit, and Dubiel and others (chap. S, this CD-ROM) estimated about 6.8 billion short tons of coal for the Southern Wasatch Plateau assessment unit, for a total of about 16.2 billion short tons (beds greater than 1 ft thick). These estimates of original resources are close to Spieker's estimates. Spieker (1931) estimated 13 billion short tons of coal for the Wasatch Plateau in beds greater than 14 inches thick and 7.8 billion short tons in beds greater than 30 inches thick.

Cumulative production in the Wasatch Plateau between 1870 and 1996 was about 386 million short tons (Jahanbani, 1996) or about 5 percent of beds greater than 30 inches thick in Spieker's estimate or about 2.5 percent of our most recent estimate of beds greater than 1 ft thick. This kind of estimation is instructive because it shows that large original resource numbers can be deceiving when trying to estimate how much coal can be taken out of an area. A methodology has been developed to better determine how much of the resource is available or is suitable for mining (see next page and also Carter and others, 1998; Rohrbacher and others, chap. F, this CD-ROM).

Assessment Area	Resources
Bisti	1,600
Black Mesa	*
Danforth Hills	21,000
Henry Mountains	1,700
Kaiparowits Plateau	61,000
Lower White River	370
S. Wasatch Plateau	6,800
San Juan Basin	230,000
S. Piceance Basin	120,000
N. Wasatch Plateau	9,200
Somerset	3,100
Yampa	76,000
Grand Total	**530,000**

* not calculated

Figure 16*A*. Original resource figures (in millions of short tons) for the assessment areas of the Colorado Plateau. Resource estimates are rounded to two significant figures. Locations of assessment areas are shown on fig. 14.

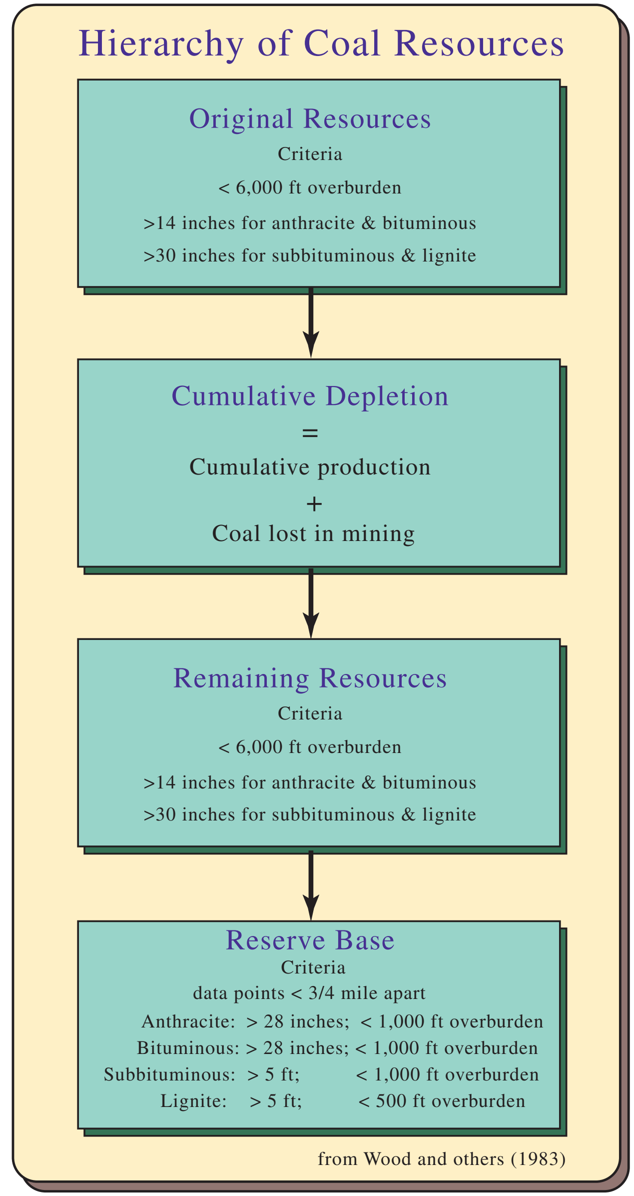


Figure 16*B*. Figure showing key resource categories. Original resources are present before mining; remaining resources are original resources minus cumulative depletion (cumulative depletion = cumulative production + coal lost in mining); and reserve base is the amount of resource that meets specified minimum physical and chemical criteria related to current mining practice (Wood and others, 1983). The measurements in inches and feet refer to the minimum thickness of coal and the maximum thickness of overburden for each category.

Coal Availability/Recoverability in the Colorado Plateau

After the coal deposits are delineated and the in-place tons are estimated, economic geologists and engineers estimate how much of the resource is restricted from mining using legal, regulatory, social, environmental, and technical considerations. That information is then used to determine how much of the resource may be mined at a profit in today's market. The data can also be used to determine what the social implications of mining are or, in the case of a developed mining district, what the loss of mining means to the local and regional population (Carter and others, 1998; Rohrbacher and others, chap. F, this CD-ROM).

Definitions of resource terms used in figure 17:

Original Resource: The amount of coal in place before mining.

Mined out: This refers to coal that has been produced historically and coal that was lost in mining during production (such as coal left behind for roof support).

Remaining Resources: Those resources in the ground after mining. Includes coal that will be lost in mining.

Restricted Resources: Those parts of the resource that are restricted by law or regulation and social, environmental, or general technical concerns such as coal underlying alluvial valley floors, National Parks, or environmentally protected areas.

Available Resource: The remaining resource minus restricted resources.

Recoverable Resource: That part of the resource that can potentially be mined after taking into account the amount of coal that may be lost due to technical mining restrictions, or due to recovery losses and washing losses.

Mining Economics: Mining costs can be applied to predict if a certain coal can be produced at a profit in the present day economy.

Compliance: This term refers to coal that meets a prescribed quality as required by the Clean Air Act.

Reserves: Economically recoverable resource.

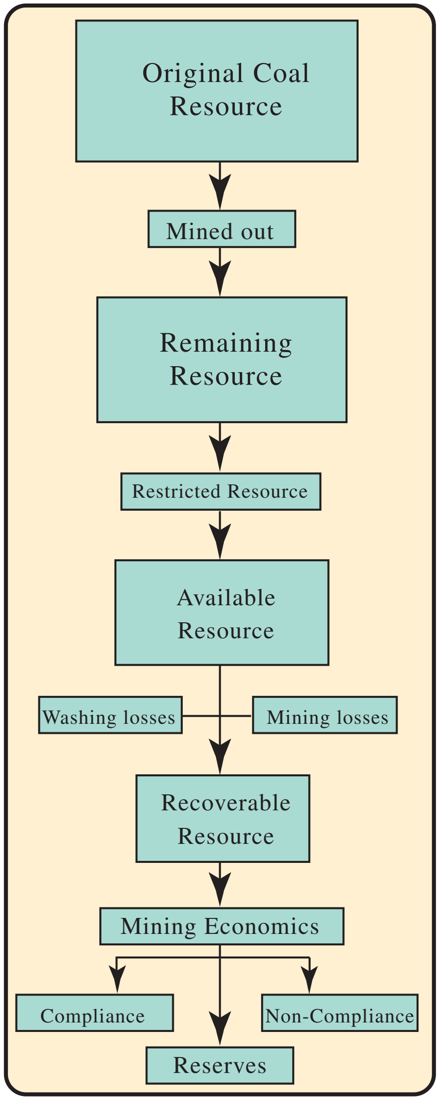


Figure 17. Chart showing the categories of resources and the order in which they must be determined and subtracted from "original coal resource" to arrive at "available," "recoverable," and "economic" resource volumes. Definitions are from Wood and others (1983) and Rohrbacher and others (1993).

Coal Availability/Recoverability—*Continued*

Numerous studies conducted in areas outside of the Colorado Plateau (e.g., the Appalachian Basin, and the Illinois Basin) have shown that the average amount of coal recoverable from a coal field may be as little as 24 percent or as much as 82 percent of the original resource when social, economic, environmental, technical, legal, and regulatory restrictions are applied to the resource (Carter and others, 1998).

Coal availability studies conducted in the Colorado Plateau are limited but show a range of 40 percent to 68 percent for the availability of coal that can be mined (Eakins and others, 1998 (68 percent); Hoffman and Jones, 1998 (60 percent); Tabet and others, 1999 (40 percent)).

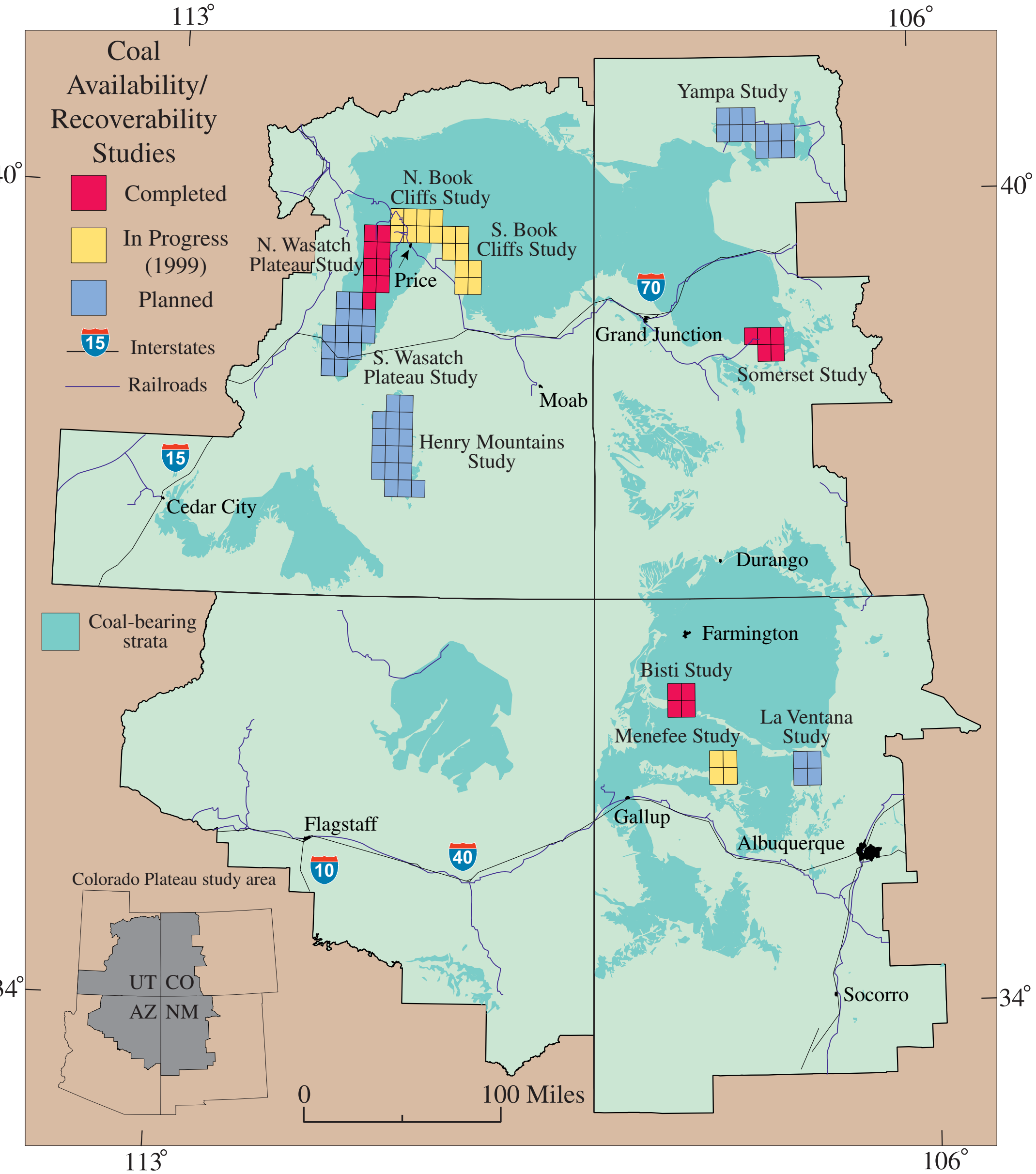


Figure 18. Index map of coal availability/coal recoverability studies in the Colorado Plateau study area. The Somerset study in Colorado was completed in cooperation with the Colorado Geological Survey; the Bisti study in New Mexico in cooperation with the New Mexico Bureau of Mines and Economic Geology; and the Northern Wasatch Plateau study in cooperation with the Utah Geological Survey (see Rohrbacher and others, chap. F, this CD-ROM).

Coal Geochemistry

Proximate/ultimate and trace-element geochemistry data is presented in this CD-ROM for 30 coal fields in the plateau (Affolter, chap. G, this CD-ROM).

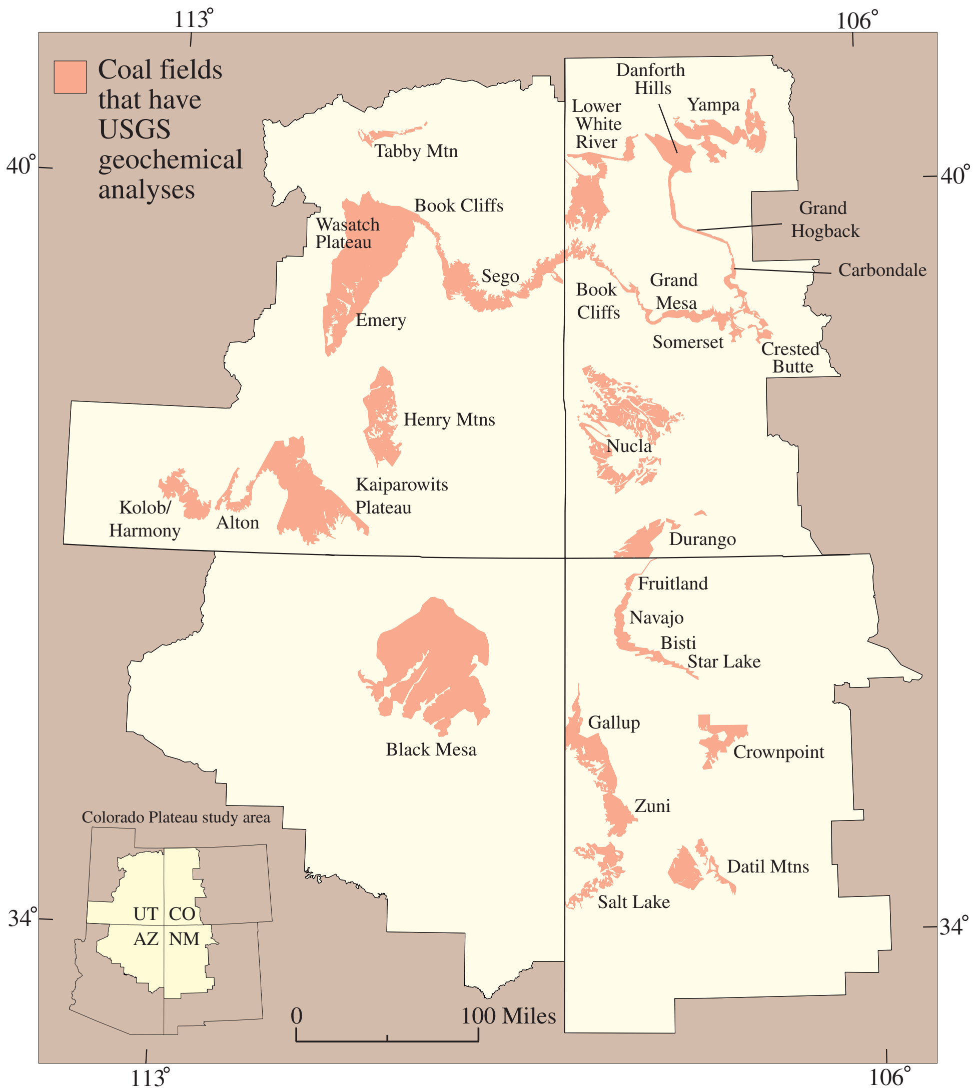


Figure 19. Distribution of coal fields of the Colorado Plateau that have USGS coal geochemistry data.

Coal Geochemistry—*Continued*

Mean average values, on an as-received basis, for ash yield, calorific value, and sulfur content are shown here (figs. 20*A*–20*C*) for the assessment units of the Colorado Plateau. Coals of the Colorado Plateau are generally subbituminous to bituminous in rank with mean calorific values as much as 14,000 Btu/lb; low in sulfur, mean values below 1 percent, (although some areas within the Plateau exceed 1 percent—see Affolter, chap. G, this CD-ROM); and generally low in ash yield, although the range is from about 5 percent to almost 25 percent.

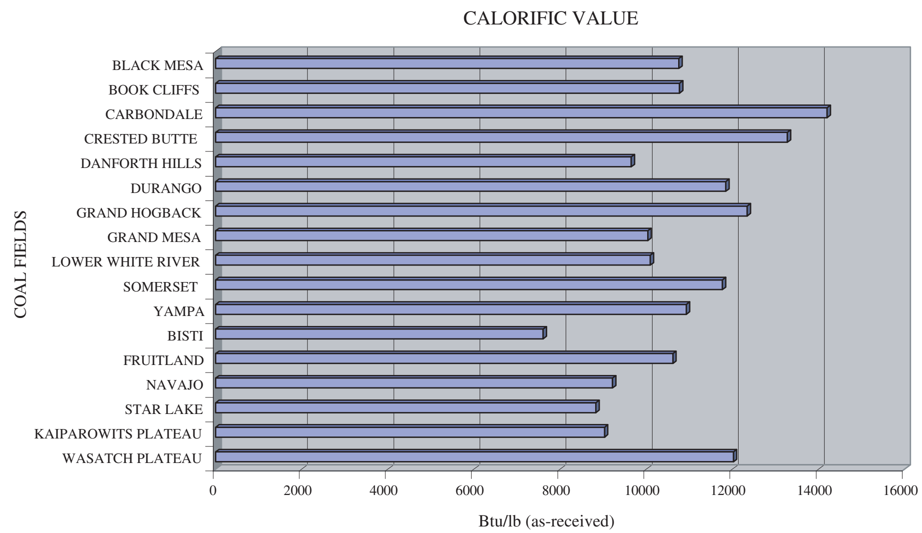


Figure 20*B*.

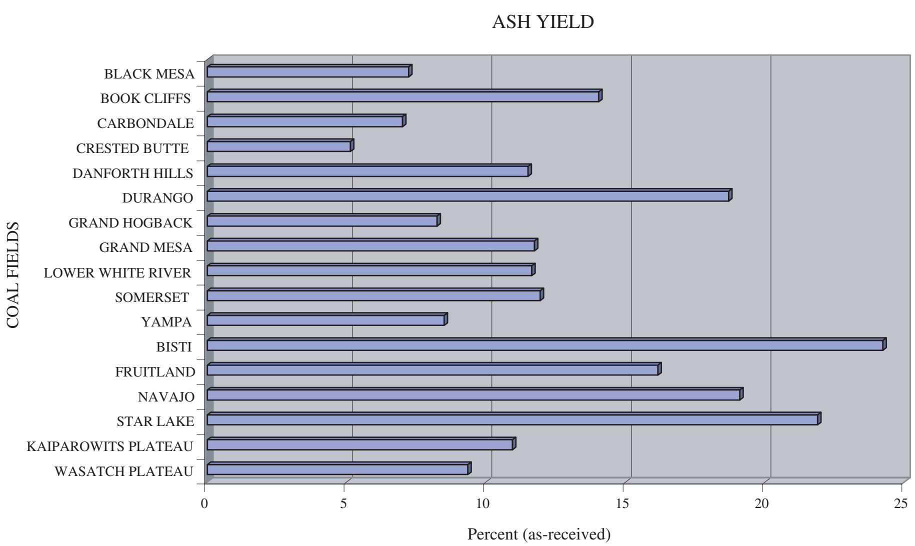


Figure 20*A*.

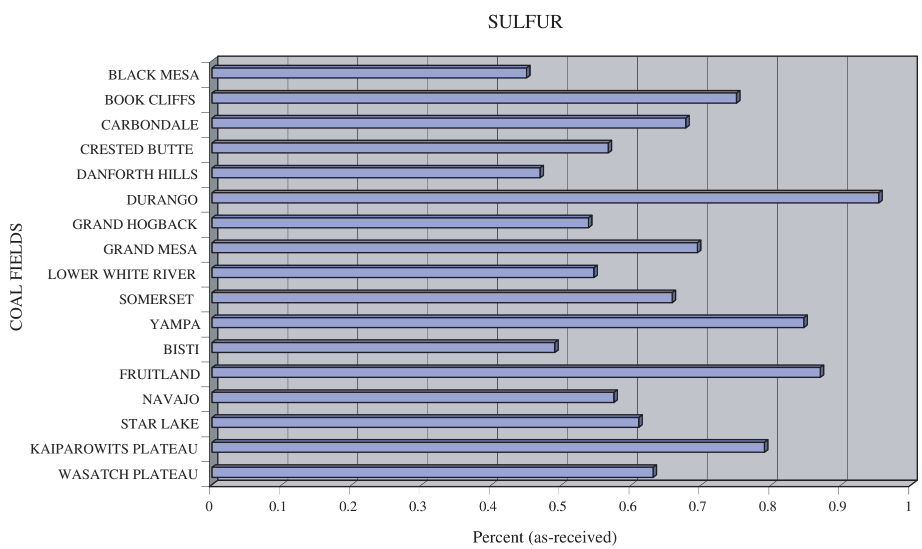
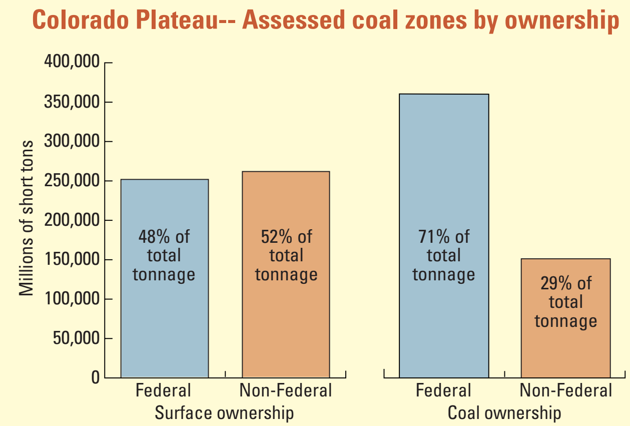


Figure 20*C*.

Coal on Federal Lands

The U.S. Government owns the rights to large resources of coal in the Colorado Plateau region. However, these resources do not necessarily lie under surface land that is administered by the Federal Government. For example, of the 510 billion short tons of coal resources calculated for 20 assessed coal zones in the Colorado Plateau, 48 percent of the coal underlies federally administered lands, but 71 percent of the total coal is owned by the public and is administered by the Bureau of Land Management (see Molnia and others, chap. E, this CD-ROM). The leasing of coal by the Bureau of Land Management has generated more than 200 million dollars of royalties per year to the Federal Government during the first half of the 1990's (Energy Information Administration, 1995).



Surface	Total*	Percent of total tonnage
Federal	250,000	48
Non-Federal	260,000	52
Grand Total	510,000	
Coal	**Total***	**Percent of total tonnage**
Federal	360,000	71
Non-Federal	150,000	29
Grand Total	510,000	

*in millions of short tons

Figure 21. Coal resource estimates for 20 assessed coal zones in the Colorado Plateau shown by percentage of Federal versus non-Federal ownership and differentiated by surface and mineral (coal) ownership (Molina and others, chap. E, this CD-ROM). The 20 assessed coal zones include two in the Lower White River coal field, seven in the Danforth Hills coal field, four in the Yampa coal field, one in the Southern Wasatch Plateau coal field, one in the San Juan Basin, four in the Southern Piceance Basin assessment unit, and one in the Kaiparowits Plateau coal field.

Coal on Federal Lands—*Continued*

Large coal holdings are present beneath lands administered by the U.S. Forest Service and Bureau of Land Management. Additionally, coal is present on many Indian Reservations in the Colorado Plateau. Although the reservations are not Federal lands, the USGS has historically assessed the coal resources of many of the reservations in cooperation with the Tribes and the Bureau of Indian Affairs.

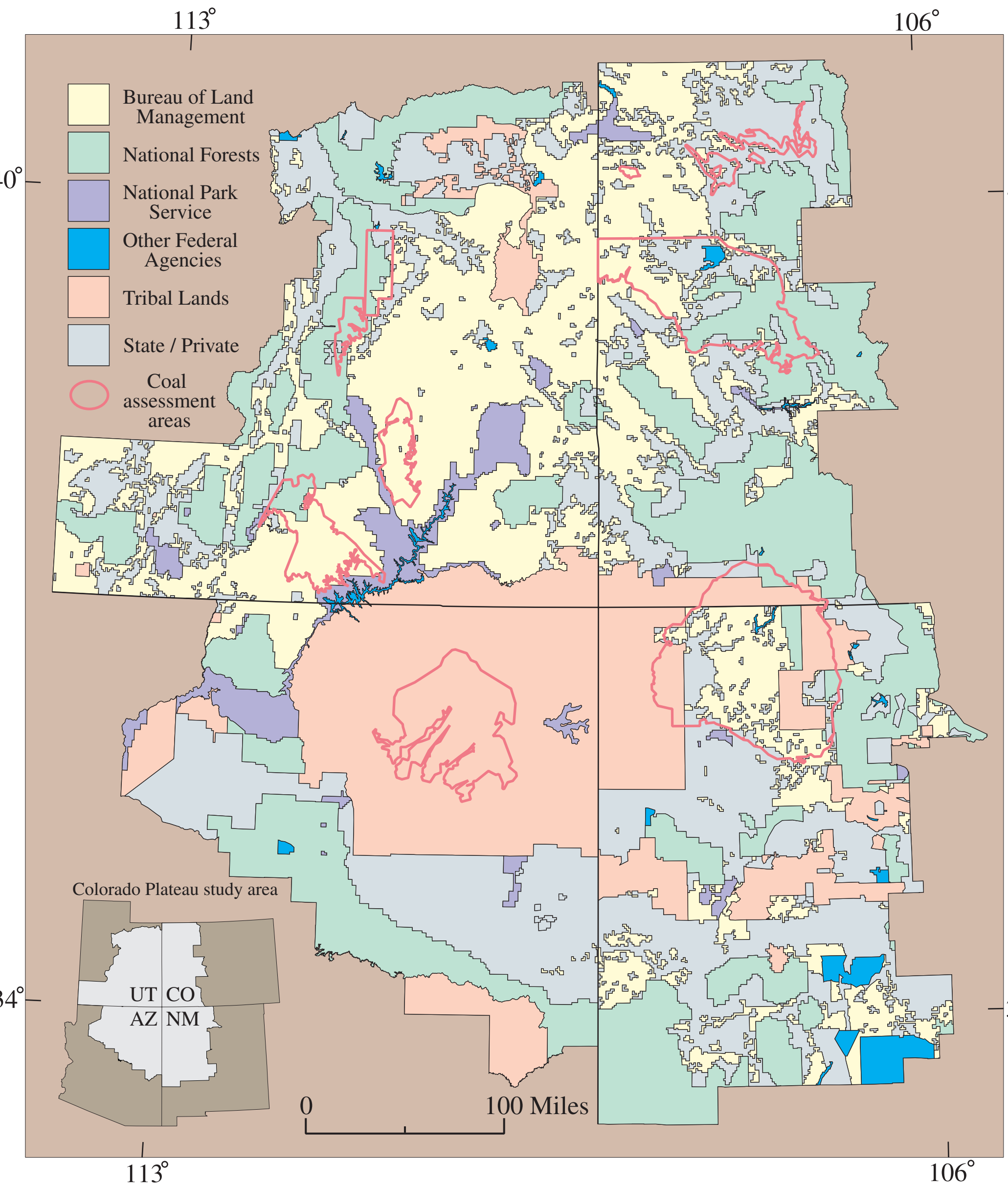


Figure 22. Generalized surface ownership of lands in the study area within Arizona, Colorado, New Mexico, and Utah. The outlines of the assessment units are shown in red, and the names of the areas are shown on fig. 14.

Coal on Federal Lands—*Continued*

Some coal in the plateau is not currently available for leasing. For example, at this time, coal located beneath National Parks is not available for exploitation, and the resources there are classified as restricted. Large deposits are present beneath Bryce Canyon National Park and beneath the Escalante–Grand Staircase National Monument, which is administered by the Bureau of Land Management (see Hettinger and others, chap. T, this CD-ROM). Some resources are present within Mesaverde National Park and Chaco Culture National Historic Park and adjacent to Zion National Park, Capitol Reef National Park, Glen Canyon National Recreation area, El Malpais National Monument, and Dinosaur National Monument. Two National Monuments, Black Canyon of the Gunnison and Colorado are shown adjacent to coal-bearing rocks, but here the coal is thin and probably not a resource (fig. 23). For a more complete analysis of coal on Federal lands within the Colorado Plateau see Molnia and others (chap. E, this CD-ROM).

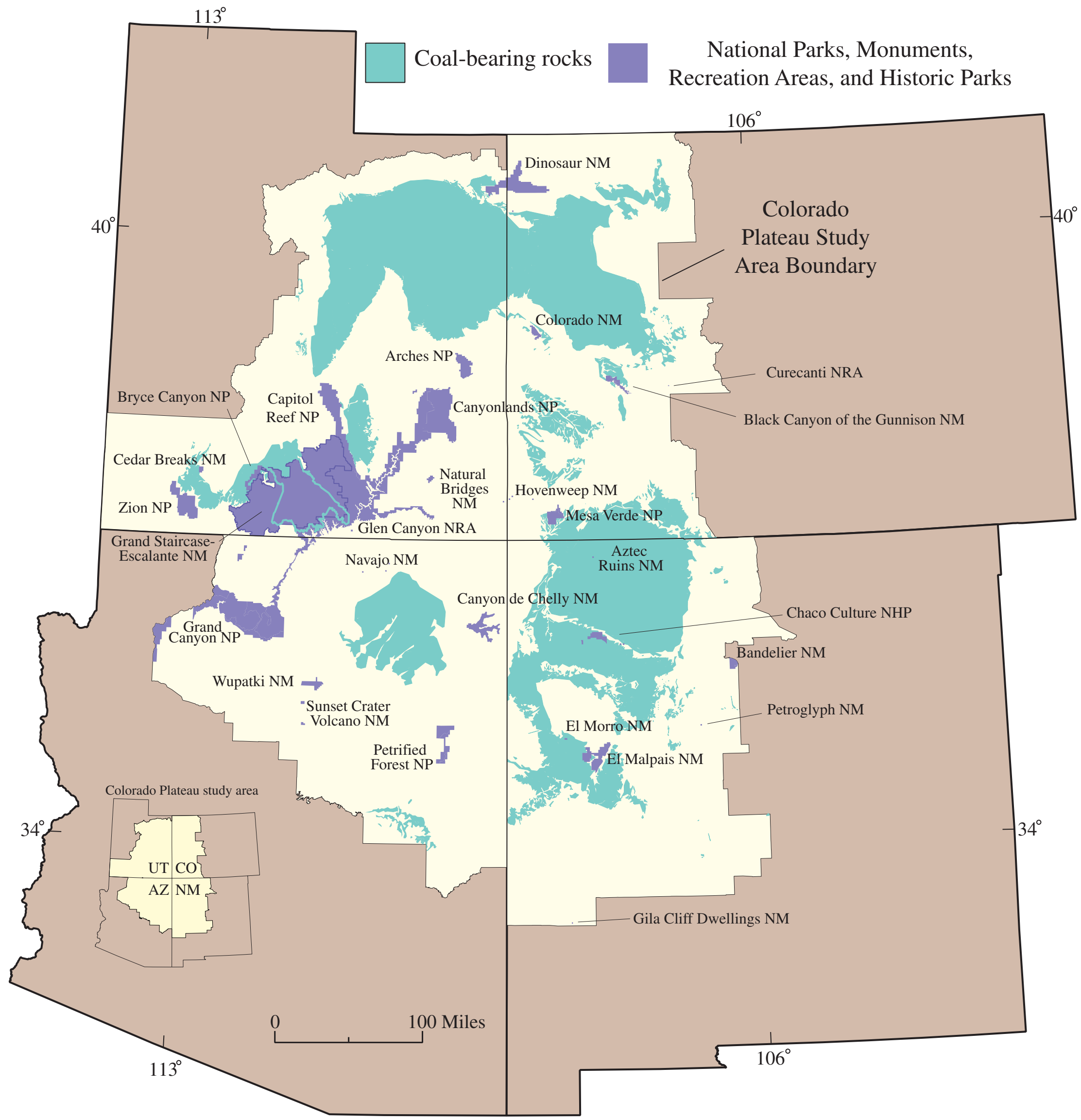


Figure 23. Relationship of coal-bearing strata to National Parks (NP), Monuments (NM), Recreation Areas (NRA) and Historic Parks (NHP). All of the areas (purple shading) are administered by the National Park Service, except the Grand Staircase–Escalante National Monument (GSENM) in southern Utah, which is administered by the Bureau of Land Management. Within the GSENM, the outline of the Kaiparowits Plateau coal field is shown in green to delineate the extent of coal within the Monument.

Figure 24*A*. Sunnyside, Utah, coke ovens, which first operated in 1902 (Clark, 1928). The coke was used in the production of steel.

Figure 24*B*. Present-day view of Sunnyside coke ovens.

Coal Production in the Colorado Plateau

The Colorado Plateau has been an important coal mining area since the 1870's (Doelling and Smith, 1982). Earliest usage for the coal was for home heating and as fuel for steam engines owned by the railroads. Coal production boomed during World War I, dropped off during the depression of the 1930's, and then rebounded during World War II and into the 1950's. Production in Utah alone reached about 6 million short tons a year in the 1950's (Doelling and Smith, 1982). Production dropped to a lower plateau, just above 4 million short tons a year in the 1960's as diesel fuel replaced coal for the railroads, as the steel industry of Utah declined, and as oil and gas competed for energy consumption. The Arab oil embargo of 1973 and the increased reliance on western, low-sulfur coals following the Clean Air Act of 1970 helped spur growth in Utah to its current levels (fig. 25).

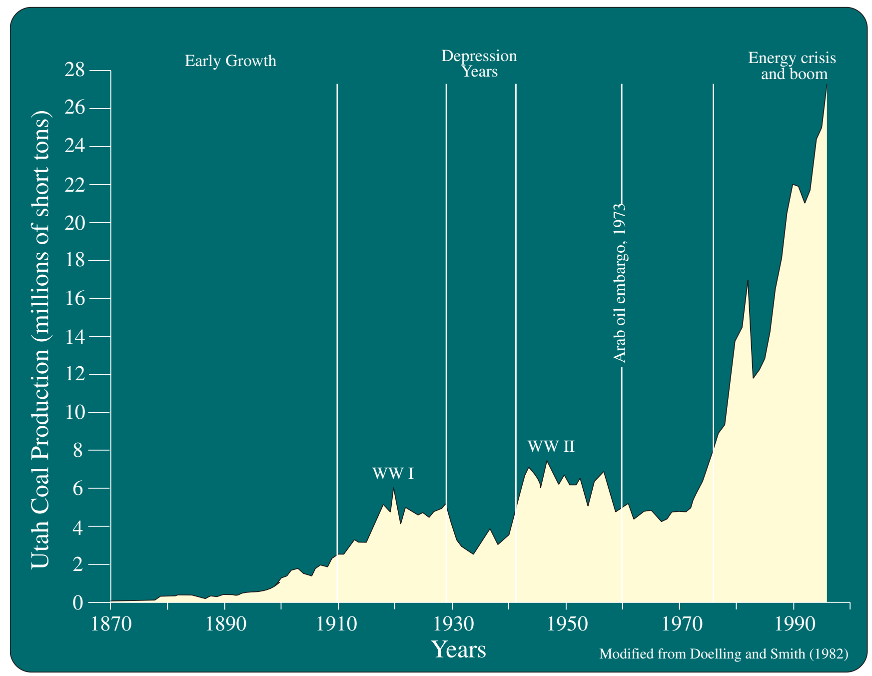


Figure 25. Graph showing coal production in Utah between 1870 and 1995. The graph is modified from Doelling and Smith (1982) with updated production from Jananbani (1996).

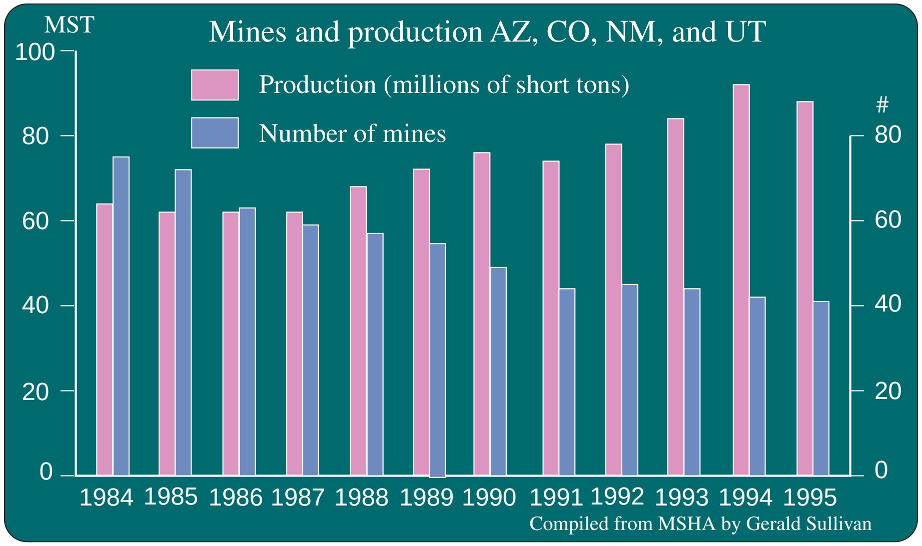


Figure 26. Coal production and the number of coal mines in the States of Arizona, Colorado, New Mexico, and Utah between 1984 and 1995 (Gerald Sullivan, written commun., 1997, compiled from Mine Safety and Health Administration database).

Coal Production in the Colorado Plateau—*Continued*

Production of coal from mines in the States of Arizona, Colorado, New Mexico, and Utah has been rising from just more than 60 million short tons in 1984 to about 89 million short tons in 1995. During the last 10 years, production has climbed while the total number of mines has declined. This is largely due to the increased efficiency of longwall mining practices and the opening of large surface mines versus conventional room-and pillar-mining using continuous mining equipment. The number of active mines has remained relatively constant at about 40 within the four-State region, while, in the Colorado Plateau itself, the number has stabilized to about 30 mines in the 1990's.

Figure 27*A*. Modern strip mine: Dragline in pit at Peabody-Western's Black Mesa mine located in the Navajo-Hopi joint-use area in Arizona.

Coal Production in the Colorado Plateau—*Continued*

Within the Colorado Plateau in 1995, there were 10 major surface and 21 major underground mines (Gerald Sullivan, written commun., 1997, compiled from Mine Safety and Health Administration database) with a total production of more than 85 million short tons during 1995 (Resource Data International, 1998). Of the underground mines, 11 were longwall operations (Fiscor, 1998): four in Colorado (Deserado, Empire, Twentymile, and West Elk); and seven in Utah (Aberdeen, Crandal Canyon, Deer Creek, SUFCO, Skyline 1 and 3, Trail Mountain). A new longwall is being opened in Utah (Willow Creek).

Figure 27*B*. Photo of the tipple and company town at the Utah Fuel Company near the Sunnyside mine. Photograph probably taken prior to 1914 (Clark, 1928, plate 12B).

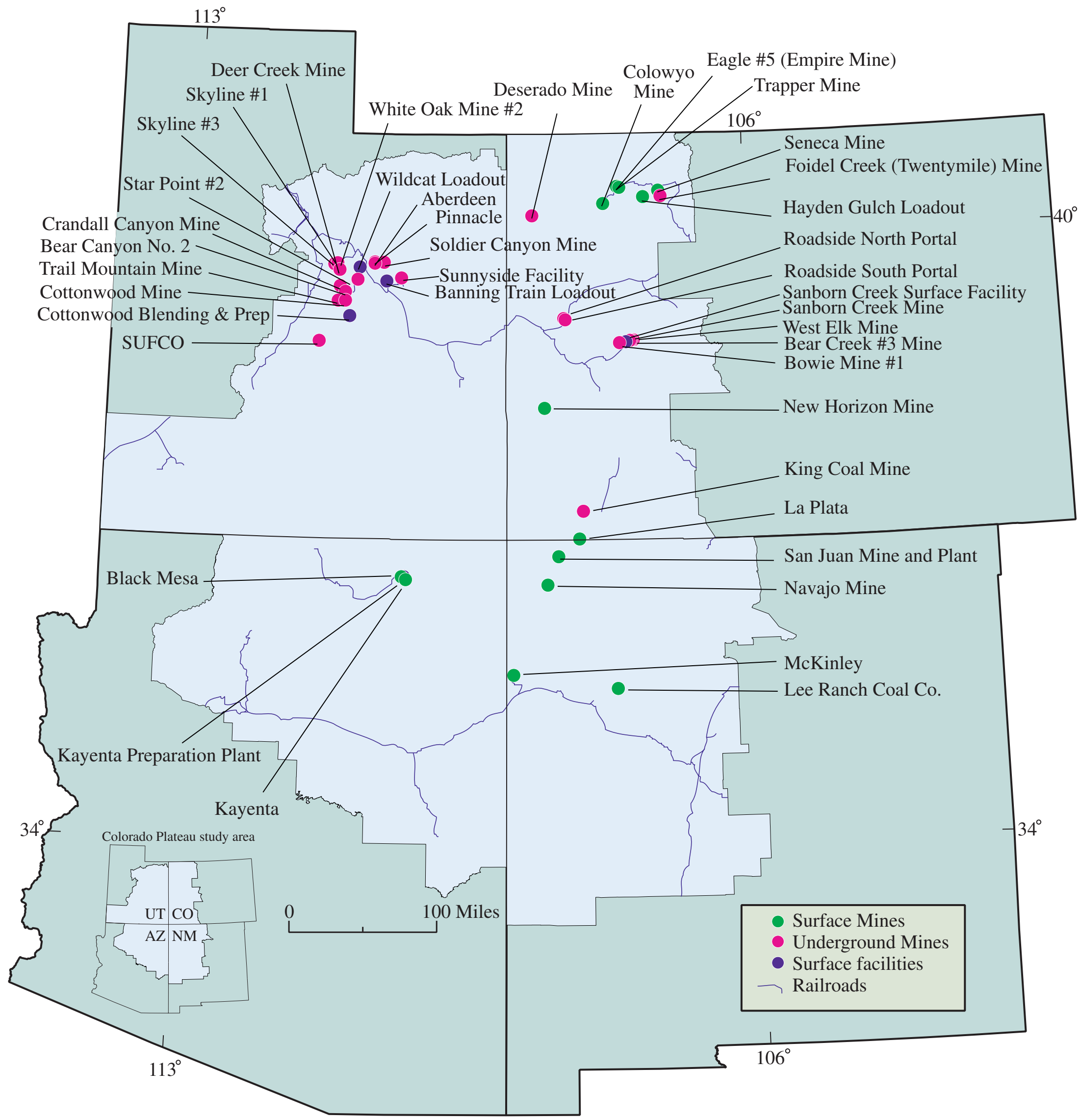


Figure 28. Map of active mines, preparation plants, and train loadout facilities in the study area. The individual mines that are shown produced at least 100,000 short tons of coal during 1995. Major rail lines are also shown.

Figure 29*A*. Tramway system at the Wattis mine in the Wasatch Plateau, Utah (first published by Spieker, 1931, plate 1B). The tramway is 1.25 mi long, had a maximum grade of 36 percent, and could move 10 cars at a time to a tipple that had a capacity of handling 1,500 short tons a day (Spieker, 1931, p. 115). Note the cable running up the length of track that allowed the hoist to pull the cars up the incline.

Figure 29*B*. Part of the 17-mi-long conveyor system from the Kayenta mine to the Black Mesa and Lake Powell Railroad. The belt can transport as much as 1,800 short tons per hour.

Transportation

Large, light-alloy trucks that can haul as much as 45 short tons per unit have changed the way coal is hauled. The SUFCO mine in the Wasatch Plateau, Utah, transports about 3–4 million short tons a year by truck about 120 mi to a railhead in central Utah. However, at most mines the coal is still transported mainly by railroad. Two mines transport their coal to power plants via electric trains. The most unique method of transport in the Plateau is by slurry pipeline from the Black Mesa mine in Arizona to the Mohave generating station in Nevada. The 273-mi pipeline is operated by the Black Mesa Pipeline, Inc.

Figure 30. Loadout facility of the Soldier Canyon mine in the Book Cliffs of Utah showing the loading of specialized trucks for transporting coal. Photograph by Russell Dubiel, U.S. Geological Survey.

Coal Sales

About 85 percent of the coal mined in the Colorado Plateau region is used directly for the generation of electric power. Sales of coal from this region go to electric generating power plants in 20 States in the United States (as of 1995), but the main consumers are five States: Arizona, New Mexico, Utah, Colorado, and Nevada. About 85.9 million short tons of coal was produced in 1995, but only about 74.4 million short tons were sold to domestic power plants (Resource Data International, 199). Several million short tons were sold to industrial power plants, for example, those in the steel industry.

In addition to the coal sold domestically, between 1990 and 1997, Colorado Plateau coal was shipped to Colombia, Chile, Hong Kong, Japan, Philippines, South Korea, and Taiwan (Resource Data International, 1998). In 1995 only about 2.5 million short tons were exported (Resource Data International, 1998).

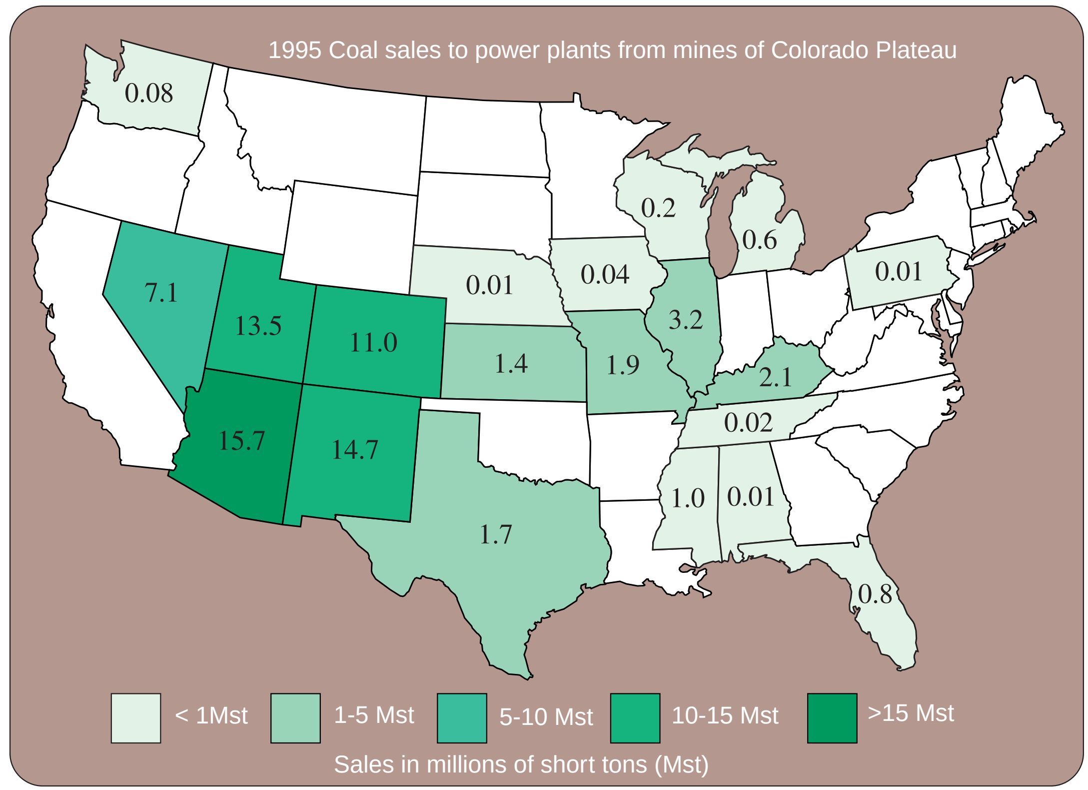


Figure 31. Total sales of coal, by State, to power plants across the conterminous United States supplied by mines of the Colorado Plateau, 1995 (data queried from Resource Data International, 1998).

Figure 32*A*. The Hayden power plant located in northwestern Colorado in the Yampa coal field. Photo by Edward A. Johnson, U.S. Geological Survey.

Figure 32*B*. Cooling towers generating steam during winter at the Hayden power plant. Photo by Edward A. Johnson, U.S. Geological Survey.

Reclamation

Coal mines are required by the Surface Mining Control and Reclamation Act of 1977 and the Abandoned Mine Reclamation Act of 1990 to reclaim lands disturbed by mining and to prevent disturbances following underground mining (e.g., subsidence problems) (Energy Information Administration, 1995). During strip mining, care is taken to prevent erosion, protect wildlife, and prevent ground-water contamination. Following strip mining, the disturbed lands are recontoured to approximate the original topography, covered with topsoil that was previously stockpiled, and reseeded. For more information and photographs of reclaimed land see Narton and others (1983), Ferris and others (1996), or the Office of Surface Mining Web site at <http://osm.osmre.gov/> .

Figure 33. Edna mine in the Yampa coal field of Colorado being reclaimed during 1995.

Figure 34. Reclaimed lands in an area previously part of the Trapper mine in the Yampa coal field with the Craig power plant in the background. Photo courtesy of Chuck Meyers, Office of Surface Mining.

Coal-Bed Methane

The Colorado Plateau is estimated to contain as much as 173 trillion cubic feet of in-place coal-bed-gas resource within three sedimentary basins: the Piceance Basin in Colorado, the San Juan Basin in Colorado and New Mexico, and the Unita Basin in Utah (ICF Resources, Inc., 1989). In the Colorado Plateau, coal-bed methane is currently being produced from the San Juan Basin (plays 2250, 2252, and 2253—Rice, 1996), the Wasatch Plateau (plays 2052 and 2050—Rice 1996), and the Piceance Basin (plays 2053, 2054, and 2056—Rice, 1996). The Colorado Plateau also contains a number of hypothetical coal-bed methane plays defined by Rice (1996): play 2055, Piceance Basin–Grand Hogback; play 2057, Piceance Basin–Igneous Intrusion; and play 2051, Uinta Basin–Sego.

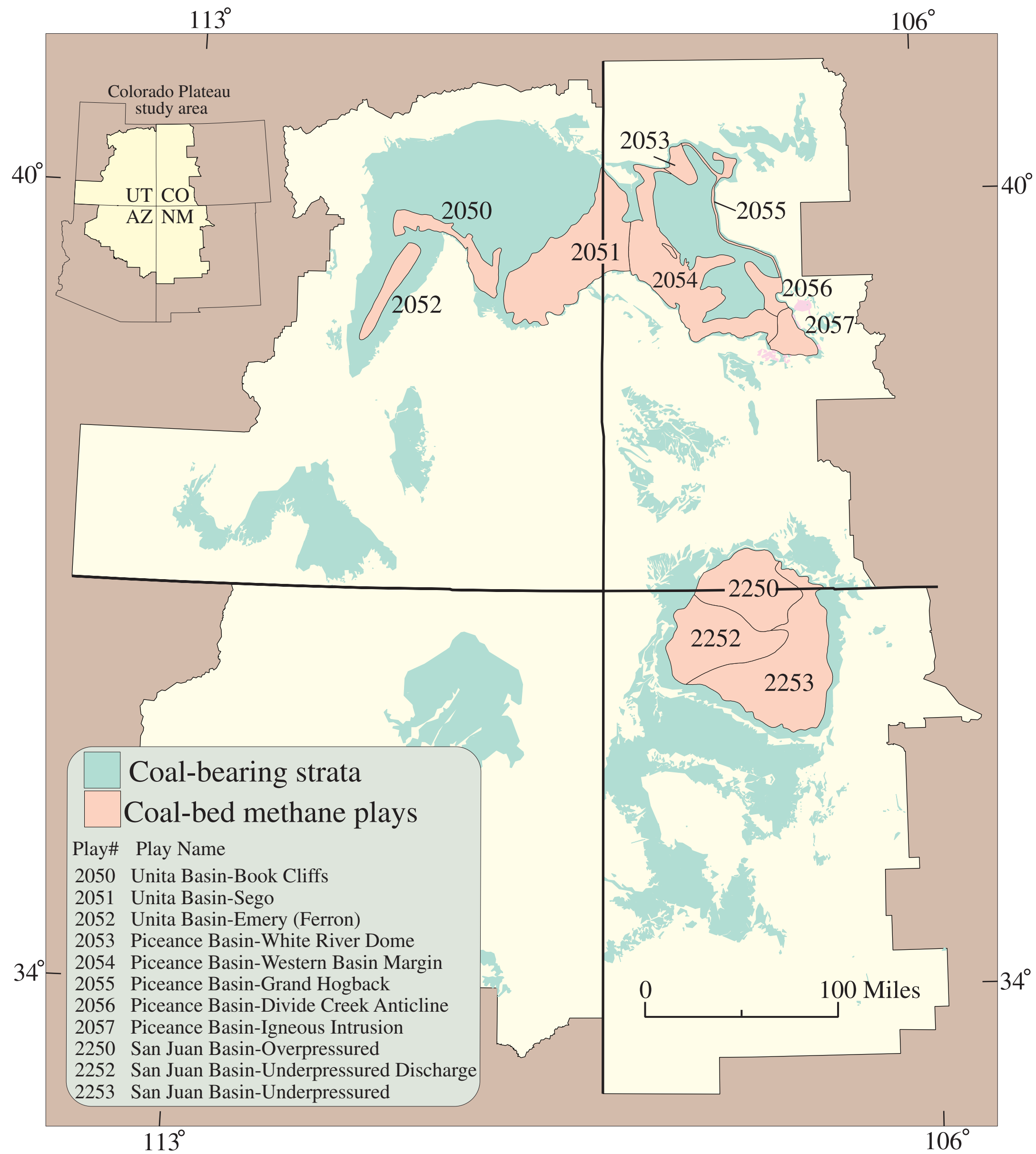


Figure 35. Map showing coal-bed methane plays as defined from the 1995 USGS Oil and Gas Assessment (Gautier and others, 1996; Rice, 1996).

Coal-Bed Methane—*Continued*

The most productive area for coal-bed gas in the Colorado Plateau is in the San Juan Basin, producing 447 billion cubic feet of gas in 1992 and with more than 780 wells completed in Fruitland Formation coal beds (Kaiser and Ayers, 1994). The area has been the subject of numerous articles in the last decade (e.g., Fassett, 1988; Ayers and Kaiser, 1994). Coal-bed gas was first produced from the Piceance Basin in 1978 (Johnson and others, 1996). The White River dome contains the best production in the Piceance Basin as of 1996 (Johnson and others, 1996). In the Wasatch Plateau, exploration has been very active in the Drunkards Wash field (Unita Basin—Emery play, 2052) since 1990 (Gloyn and Sommer, 1993). Resource data collected during this coal assessment can contribute to estimates of in-place gas resources. A comparison of three different methods of obtaining in-place estimates is provided in this CD-ROM (Dallegge and Barker, chap. L, this CD-ROM).

Figure 36. Photo showing a geologist measuring a gas seep from an area of the San Juan Basin. Photo by Edward A. Johnson, U.S. Geological Survey.

Databases

Three types of databases are provided on this CD-ROM (disc 2): geochemistry data, stratigraphic data, and Geographic Information System (GIS) data.

Tables of geochemical data are included in the report by Affolter (chap. G, this CD-ROM), and a geochemical database is included in the ArcView projects on discs 1 and 2. The database is unique in that all samples were collected and analyzed in accordance with American Society for Testing and Materials standards and therefore can be used as a baseline to compare coal fields within the United States.

Stratigraphic databases are provided for seven areas and contain information on point location (latitude and longitude), key formation tops, and coal-thickness values. The databases include 226 locations for the Kaiparowits Plateau, 309 locations for the southern Wasatch Plateau; 10 locations from the Lower White River coal field (about 200 logs from this field are proprietary); 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 assessment 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 stratigraphic or other databases. Databases are not provided for the Henry Mountains, Black Mesa, Bisti, Somerset, or Northern Wasatch Plateau assessment units. The files are stored on the CD-ROM in DBF, ASCII, and Excel formats.

The GIS databases contain all the geographic and geologic data sets for this assessment in ArcView shapefiles, Arc/Info coverages, and Arc/Info EXPORT files. These data can be accessed using the ArcView Data Publisher project found on disc 1 of the CD-ROM or by accessing the complete data set on disc 2 by means of ArcView 3.1 (ArcView 3.1 must be owned by the reader in order to access the ArcView project on disc 2). Each view within the ArcView project is an appendix to one of the reports on disc 1 of the CD-ROM.

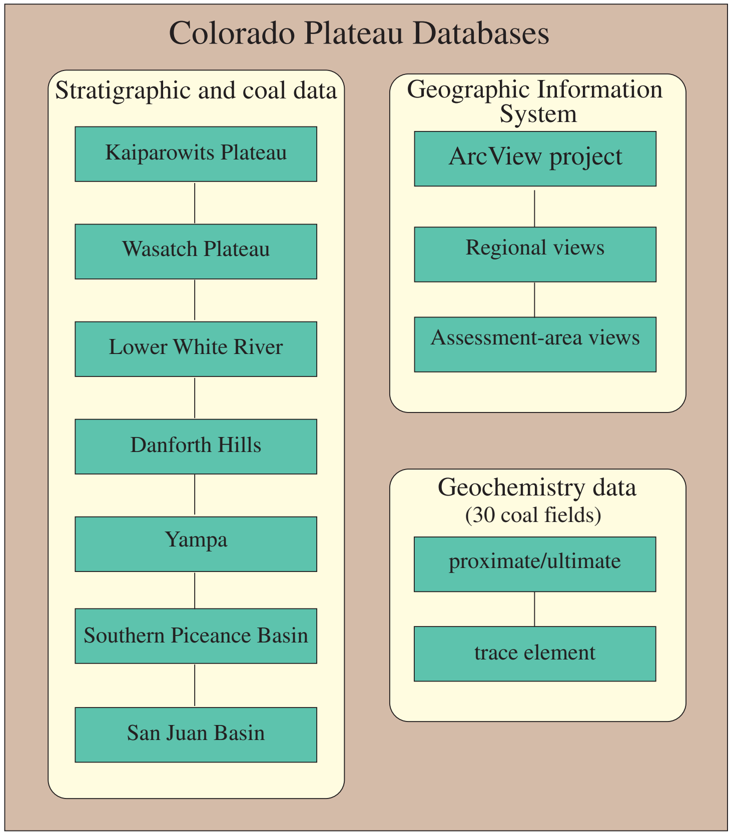


Figure 37. Diagram of stratigraphic, geographic, and geochemical databases and ArcView projects.

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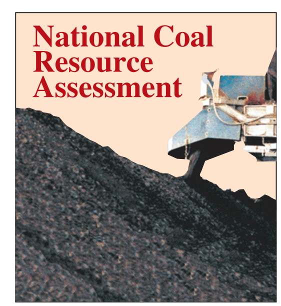

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