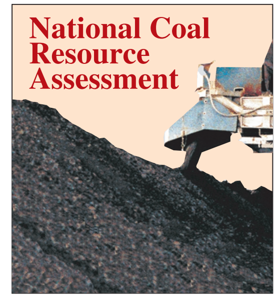
Chapter G

Quality Characterization of Cretaceous Coal from the Colorado Plateau Coal Assessment Area



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By Ronald H. Affolter[1]

Chapter G *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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Introduction

The goal of the Colorado Plateau coal assessment is to provide an overview of the geologic setting, distribution, resources, and quality of Cretaceous coal in the Colorado Plateau. This assessment is part of the U.S. Geological Survey's National Coal Resource Assessment Program (NCRA), which includes, along with the Colorado Plateau, the Northern Rocky Mountains and Northern Great Plains, Illinois Basin, Appalachian Basin, and Gulf Coast Region of the United States (fig. 1). This assessment is different from previous coal assessments in that the major emphasis is placed on coals that are most likely to provide energy over the next few decades (Gluskoter and others, 1996). Data is also being collected and stored in digital format that can be updated as new information becomes available. Environmental factors may eventually control how coal will be mined and determine to what extent preventative measures will be implemented in order to reduce sulfur and trace-element emissions from coal-burning power plants. In the future, increased emphasis will be placed on coal combustion products and the challenges of disposal and use of these products. Therefore, coal quality includes not only ash, sulfur, and calorific content, but also the major, minor and trace-element content of the coal mined. Coal quality characterization is an important aspect of the assessment program in that it provides a synthesis and analysis of important data that will influence future utilization of this valuable resource.

The Colorado Plateau study was completed in cooperation with the U.S. Bureau of Land Management, U.S. Forest Service, Arizona Geological Survey, Colorado Geological Survey, New Mexico Bureau of Mines and Mineral Resources, and the Utah Geological Survey. Restrictions on coal thickness and overburden were applied to the resource estimations, and the resources were categorized by land ownership. In some areas these studies also delineate areas where coal mining may be restricted because of land-use, industrial, social, or environmental factors. Emphasis is placed on areas where the coal is controlled by the Federal Government.

Colorado Plateau

The Colorado Plateau coal assessment area includes portions of Colorado, Utah, New Mexico, and Arizona and has been an important coal mining area since the early 1870's. Historically, the U.S. Geological Survey (USGS) has explored for coal in and provided resource estimates for the Colorado Plateau area since the early 1900's (Campbell, 1917). The last major coal assessment by the U.S. Geological Survey was done in 1974 (Averitt, 1975). Currently there are more than 30 active mines within the Colorado Plateau that produce a total of more than 90 million short tons of coal each year (Resource Data International, Inc., 1998). The coal produced supplies fuel for many of the region's electrical power plants. Some of the coals within this assessment region contain significant methane resources (Gautier and others, 1996).

Priority Assessment Areas

There are more than 40 coal fields within the Colorado Plateau coal assessment area, and the U.S. Geological Survey has coal quality data from 31 of these fields. Nineteen fields have been designated as high-priority assessment areas based on coal that will be mined within the next few decades, and 13 fields have been designated as low-priority areas. For the current study, the high-priority areas in the Colorado Plateau were selected based on (1) current production, (2) significant Federal coal ownership, and (3) high coal resource potential. The high-priority areas are the (1) Black Mesa coal field, (2) northern Piceance Basin (which includes the Lower White River, Danforth Hills, and Yampa coal fields), (3) southern Piceance Basin (which includes the Book Cliffs, Grand Mesa, Somerset, Crested Butte, Carbondale, and Grand Hogback coal fields), (4) San Juan Basin coal region (which includes the Durango, Fruitland, Navajo, Monero, Bisti, and Star Lake coal fields), (5) Henry Mountains coal field, (6) Kaiparowits

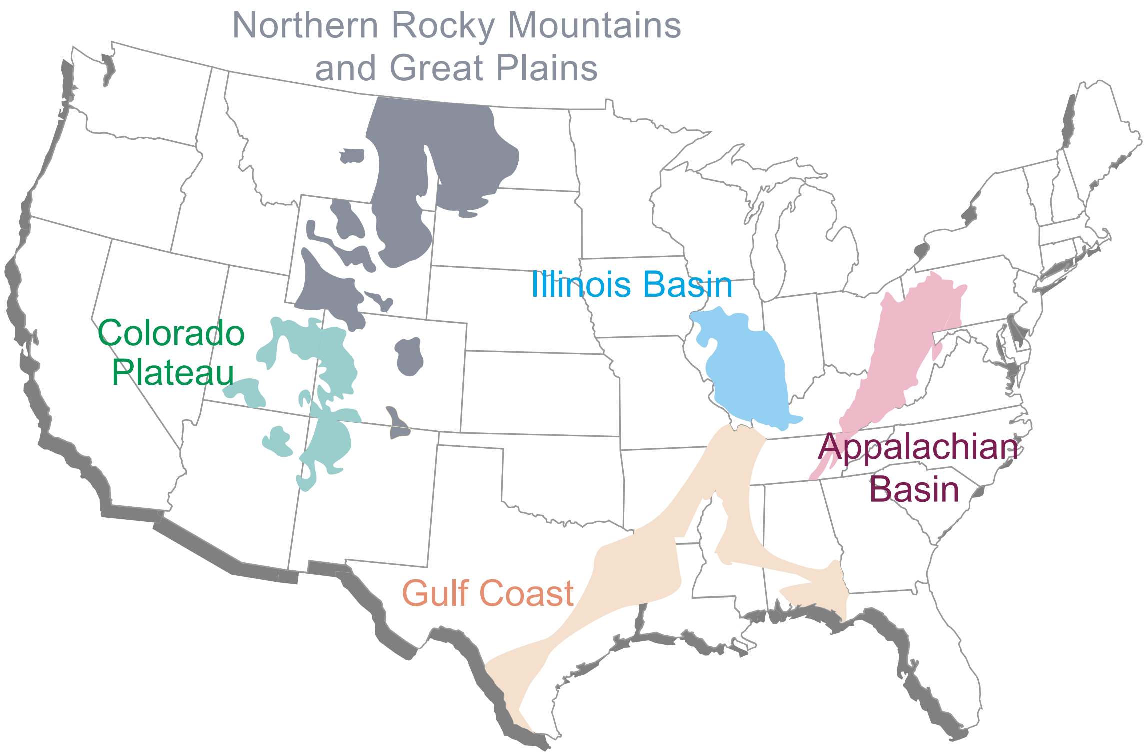

Figure 1. Location of the major coal assessment areas for the U.S. Geological Survey National Coal Resource Assessment Program (NCRA).

Plateau, and (7) Wasatch Plateau. The low-priority areas include the Alton, Book Cliffs (Utah), Datil Mountains, Emery, Gallup, Kolob, Nucla-Naturita, Salt Lake, San Juan (Deep Basin), San Mateo, Sego, Tabby Mountain, and Zuni coal fields. Figure 2 shows the location of both high-priority and low-priority coal fields for the Colorado Plateau coal assessment area. Table 1 lists the high-priority coal fields, stratigraphic units, and their associated coal beds. This paper mainly discusses the chemical composition of coal from the high-priority coal fields. The low-priority coal fields are included only in summary charts or graduated symbol maps in order to provide a better regional view of the overall quality and characterization of coal from this assessment area.

Geology

The Colorado Plateau is not one single plateau, but rather a province of diverse features that geologically comprise a large area of relative structural stability that has been uplifted by various tectonic processes (Kelley, 1955). The coals of economic value in the Colorado Plateau are of Cretaceous age. The Cretaceous accounts for more total, in-place coal than any other geologic Period in North America (Wood and Bour, 1988). Most of the coals in this study formed from peat that accumulated in wetlands located landward of the shoreline of a large seaway that occupied the Western Interior of North America during the Cretaceous (Kauffman, 1980; Roberts and Kirschbaum, 1995). Most Cretaceous peat in North America accumulated in coastal-plain settings, and the resulting coals are typically associated with nearshore marine sandstones. These coals formed at paleolatitudes between 35 and 50 degrees and in temperate to subtropical climates (Roberts and Kirschbaum, 1995). Regional subsidence buried and preserved the peat deposits. Near the end of the Cretaceous, the seaway withdrew, and uplifts associated with the Laramide orogeny divided the area into a number of structural basins. Continued uplift during the Tertiary, and subsequent dissection by streams, has exposed the coals at the surface (Kirschbaum and others, 1996). Volcanic activity occurred during the accumulation of most of Cretaceous peat, which is evident by many volcanic ash partings that are found in the coal (Brownfield and Johnson, 1986; Affolter and Brownfield, 1987; Brownfield and Affolter, 1988). The coal fields in the Colorado Plateau display a diversity in chemical composition that can be affected by several factors, such as differences in depositional history and changes in rank, age, and the various amounts and types of partings found within the coal.

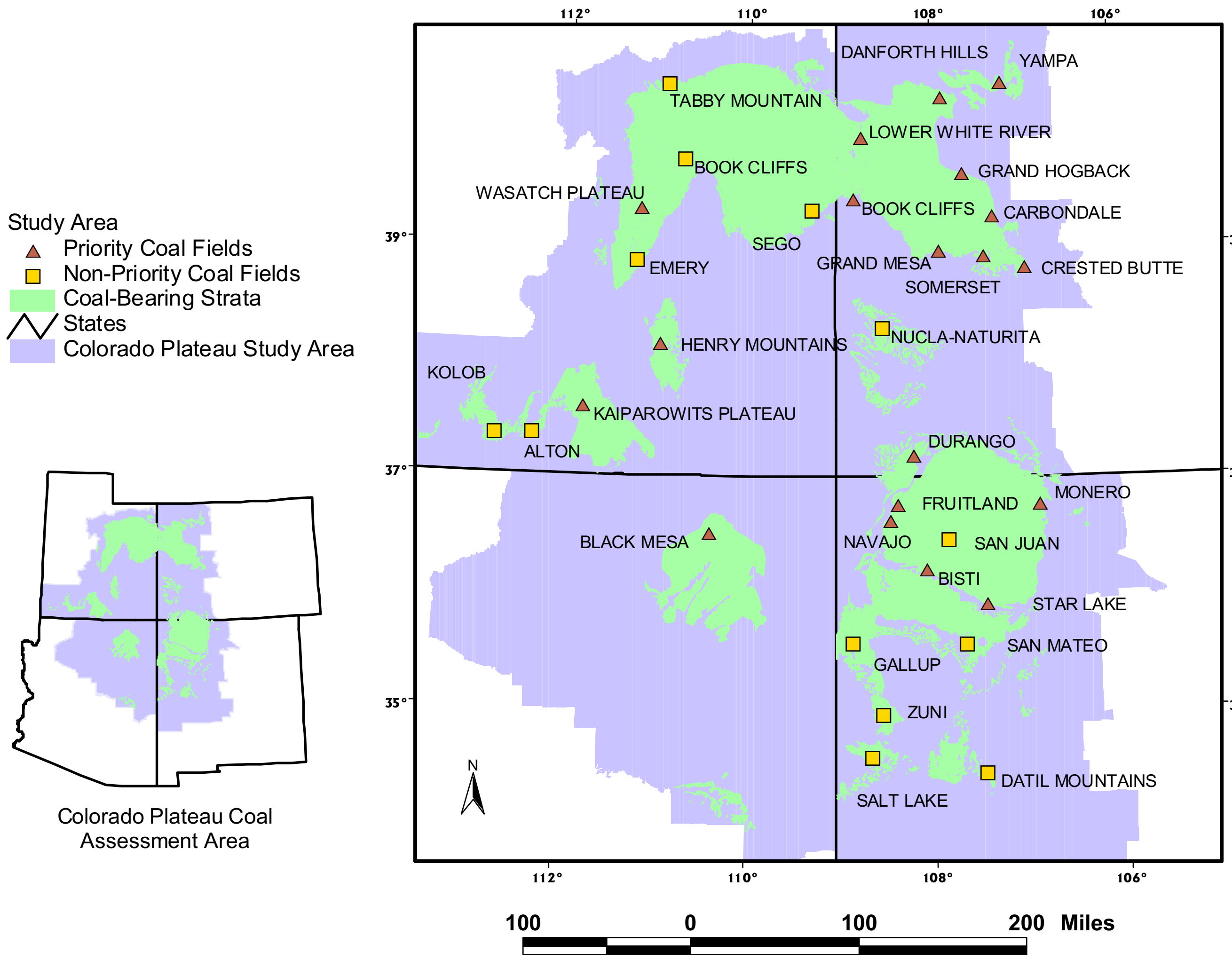

Figure 2. Map showing the high-priority and low-priority coal fields in the Colorado Plateau coal assessment area.

Methods

Since 1971, the USGS has maintained a program to evaluate the chemical composition of coal in the United States. This has been accomplished through a cooperative effort in the collection of coal samples by many different workers from State and Federal agencies, the coal mining industry, and various colleges and universities. Many samples were collected through the Energy Mineral Rehabilitation Inventory and Analysis (EMRIA) program in cooperation with the U.S. Bureau of Land Management, U.S. Bureau of Reclamation, and USGS. (For more information see Affolter and Hatch, 1995.) The EMRIA program was designed to provide baseline chemical and geologic data through the evaluation of site-specific proposed surface mining and future reclamation areas.

Determination of ash yields, and analysis of major-, minor-, and trace-element contents were conducted by the USGS (Denver, Colo., and Reston, Va., laboratories). For detailed descriptions of analytical methods used, see Swanson and Huffman (1976), Baedecker (1987), and Golightly and Simon (1989). Figure 3 is a flow diagram of procedures for the analysis of coal samples collected by the USGS (modified from Finkelman and others, 1994). Proximate and ultimate analyses, calorific value, and forms of sulfur were determined by commercial and Government laboratories according to ASTM standards (American Society for Testing and Materials, 1999). The raw analytical data are stored digitally in the USGS USCHEM coal quality database. The chemical information presented in this report was modified to include only samples from the Colorado Plateau coal assessment area and should be considered a subset of the USGS USCHEM coal quality database.

Data for the Colorado Plateau coal assessment consists of geologic, stratigraphic, and chemical information collected between 1974 and 1990. Samples for the coal quality study

Table 1. List of selected coal fields, location by State, major coal beds, coal-bearing stratigraphic units, and number of coal samples chemically analyzed for the Colorado Plateau coal assessment area.

Coal field	State	Coal beds	Stratigraphic unit	No. of samples
Black Mesa	Arizona	Blue, Green, Red	Wepo	31
Book Cliffs	Colorado	Cameo B	Mount Garfield	22
Carbondale	Colorado	A, B, Coal Basin B, Dutch Creek, Upper Sunshine	Williams Fork, Mesaverde, Iles	10
Crested Butte	Colorado	C, Cheyenne	Mesaverde	3
Danforth Hills	Colorado	B, E, Rienau, X	Williams Fork	50
Durango	Colorado	A, B, C, Lower A-1, Pueblo, Upper A-1	Fruitland, Menefee, Dakota	31
Grand Hogback	Colorado	E, Sunnyridge	Williams Fork	6
Grand Mesa	Colorado	D, Unnamed	Mesaverde	51
Lower White River	Colorado	B, F, Unnamed	Mesaverde	17
Somerset	Colorado	A, B, C, D, E, F, Lower B, Upper B, Wild	Mesaverde	58
Yampa	Colorado	A, B, C-D, E, Ellgen, F, Fish Creek, H, I-K, J, K, L, Lennox, M, Q, R, S, Wadge, Wolf Creek	Williams Fork, Lance	349
Bisti	New Mexico	Unnamed	Fruitland	68
Fruitland	New Mexico	Main, San Juan, Unnamed	Fruitland	32
Monero	New Mexico	Unnamed	Menefee	8
Navajo	New Mexico	No. 6, No. 7, No. 8,	Fruitland	9
Star Lake	New Mexico	Unnamed	Fruitland	46
Henry Mountains	Utah	Dugout Creek, Factory Butte, Unnamed	Mancos, Masuk (Muley Canyon)	18
Kaiparowits Plateau	Utah	Alvey, Bald Knoll, Christiansen, Rees	Straight Cliffs, Dakota	10
Wasatch Plateau	Utah	Acord Lakes, Axel Anderson, Bear Canyon, Blind Canyon, Castlegate A, Castlegate B, Hiawatha, Ivie, Knight, Lower Wattis, Upper Hiawatha, Upper O'Conner, Upper Wattis, Wattis	Blackhawk	86

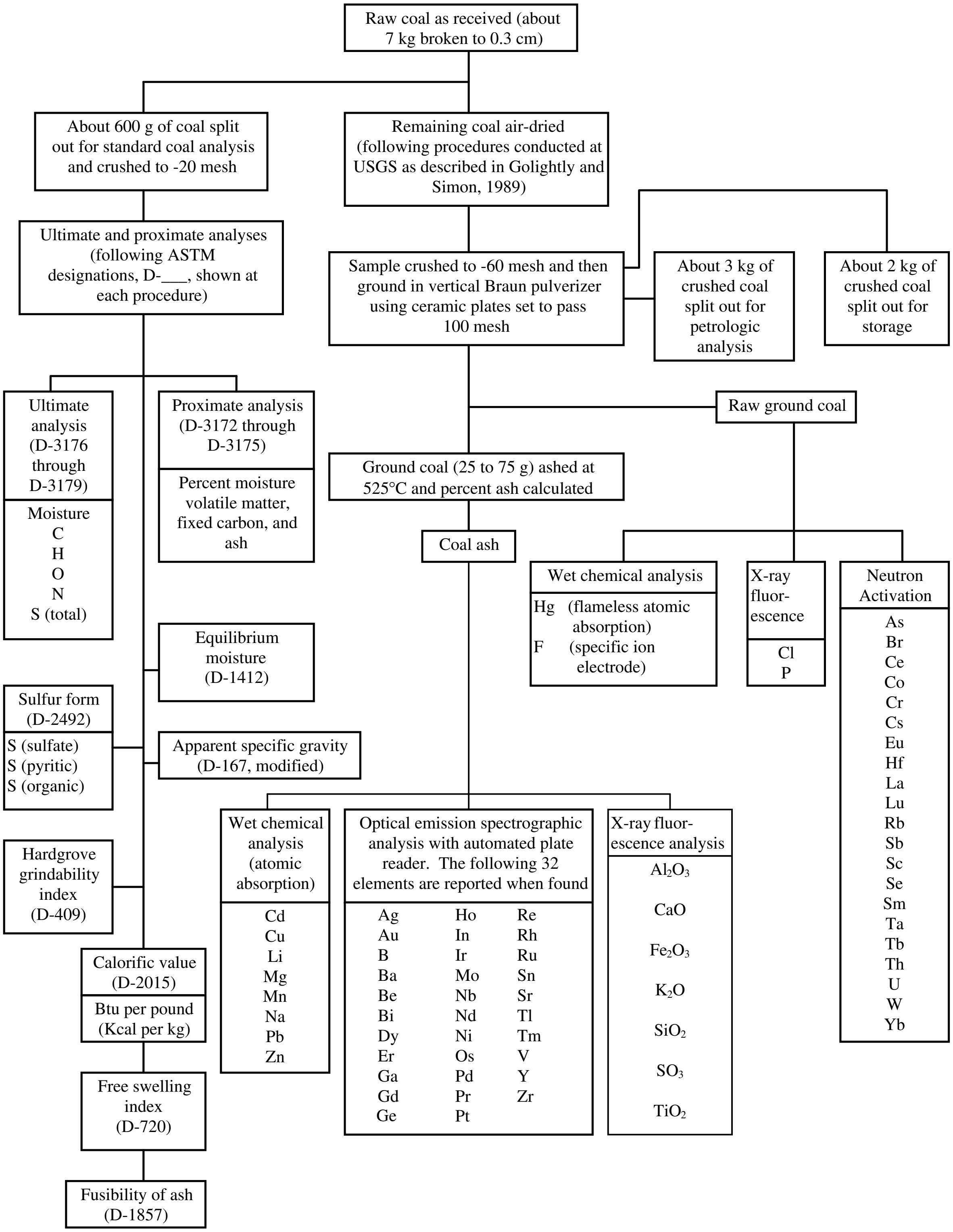

Figure 3. Flow diagram of analytical procedures used through September 1990 for the analysis of coal samples. Modified from Finkelman and others, 1994. (ASTM, American Society for Testing and Materials, 1999; USGS, U.S. Geological Survey.)

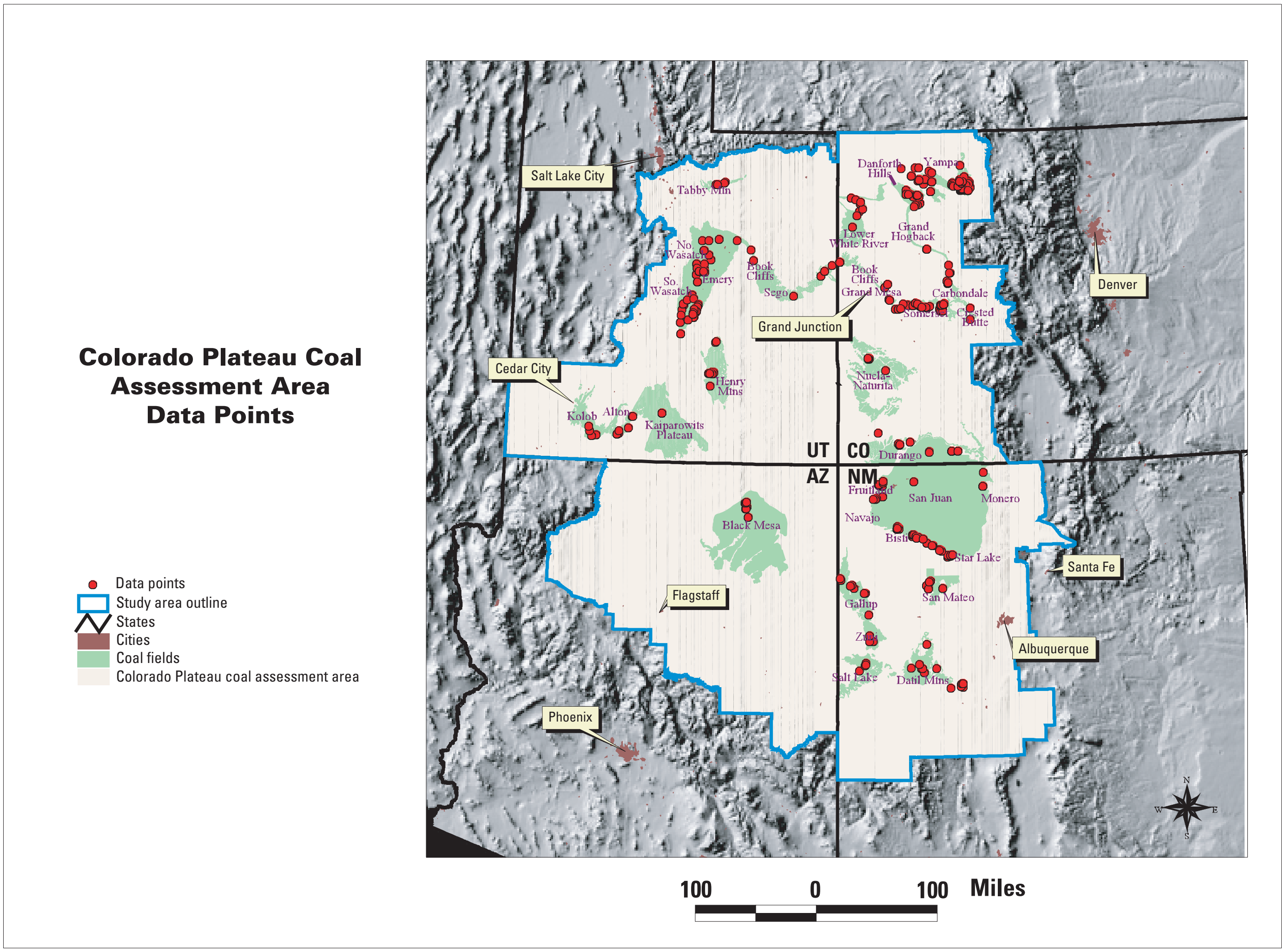

Figure 4. Locations of Cretaceous samples for which there is chemical data.

were primarily from drill core or mine samples. However, in some cases samples from drill cuttings and outcrops were included when insufficient drill core or mine samples were available to adequately evaluate an individual coal field, or when more data was necessary to provide a regional view of the quality of the coal field. The samples had to be representative of the coal bed sampled, which restricted samples to those containing less than 50 percent ash (Wood and others, 1983). Samples were carefully selected to provide a regional view of the overall coal quality. Figure 4 shows the location of samples from both the high-priority and low-priority areas of the Colorado Plateau coal assessment area that have been chemically analyzed.

Explanation of Data Selected for the Colorado Plateau Area

The chemical information presented in this report is a compilation of data that was collected over a 15-year time period. These samples were collected from various mines and drill cores through the various Government and State drilling programs in the late 1970's and early 1980's. The limitations of the data and their distribution preclude a thorough analysis of all coal beds from the assessment area. Because of this, a regional approach was used to describe the composition of coal from Colorado Plateau coal fields. In order to adequately characterize coal from the Colorado Plateau, some chemical comparisons are made between the Colorado Plateau coal and other major U.S. coals of Tertiary, Cretaceous, and Pennsylvanian age, which make up the majority of marketable coal in the United States. Comparison with these other coals allows us to evaluate the quality of Colorado Plateau coal relative to other U.S mined coal.

The USCHEM database is a geologic database in that it represents the quality of the coal as it is found in the ground and only represents single coal beds. Information on coal mine products or washed coals that are directly utilized by utilities was not available at this time. A complete description of the USCHEM database along with a discussion of its weaknesses and strengths can be found in Finkelman and others, 1994 (their table 7). Despite its limitations, the USCHEM database is one of the few comprehensive and publicly available sources of proximate and ultimate analyses; forms of sulfur; calorific values; and major-, minor-, and trace-element content of U.S. coals.

Most of the Cretaceous coal chemical data collected by the USGS is from seven States (fig. 5). Four of these States—Colorado, Utah, New Mexico, and Arizona—provide the bulk of the data, are within the Colorado Plateau coal assessment area, and will be discussed in this report. Idaho has very few samples, but Wyoming and Alaska have a significant number. The Wyoming coal samples are from the Rock Springs, Little Snake River, Kemmerer, and Jackson Hole fields; the Alaska coal data is from the Northern Alaskan coal field. These two States contain significant coal but will not be discussed in this coal assessment report.

Documentation and chemical analyses for more than 2,000 Cretaceous coal samples processed during the USGS' collection program are available to the public in more than 40 reports (Finkelman and others, 1991). These reports range from large data summaries (Swanson and others, 1976), to regional comparisons (Affolter and Hatch, 1995) to Coal Resource Occurrence and Coal Development Potential maps (CROCDP). These reports list location, depth, thickness, and the basic geology of the sampled beds, and summarize proximate and ultimate analyses, and major-, minor- and trace-element composition of the coal samples. When available, coal mineralogy data are included. Some of this data is also available digitally on the USGS COALQUAL database (Bragg and others, 1998) and the national PLUTO geochemical database (Baedecker and others,1998).

Analytical procedures have changed through time and detection limits have been lowered as new and improved analytical methods were used. Because of these changes in ana-

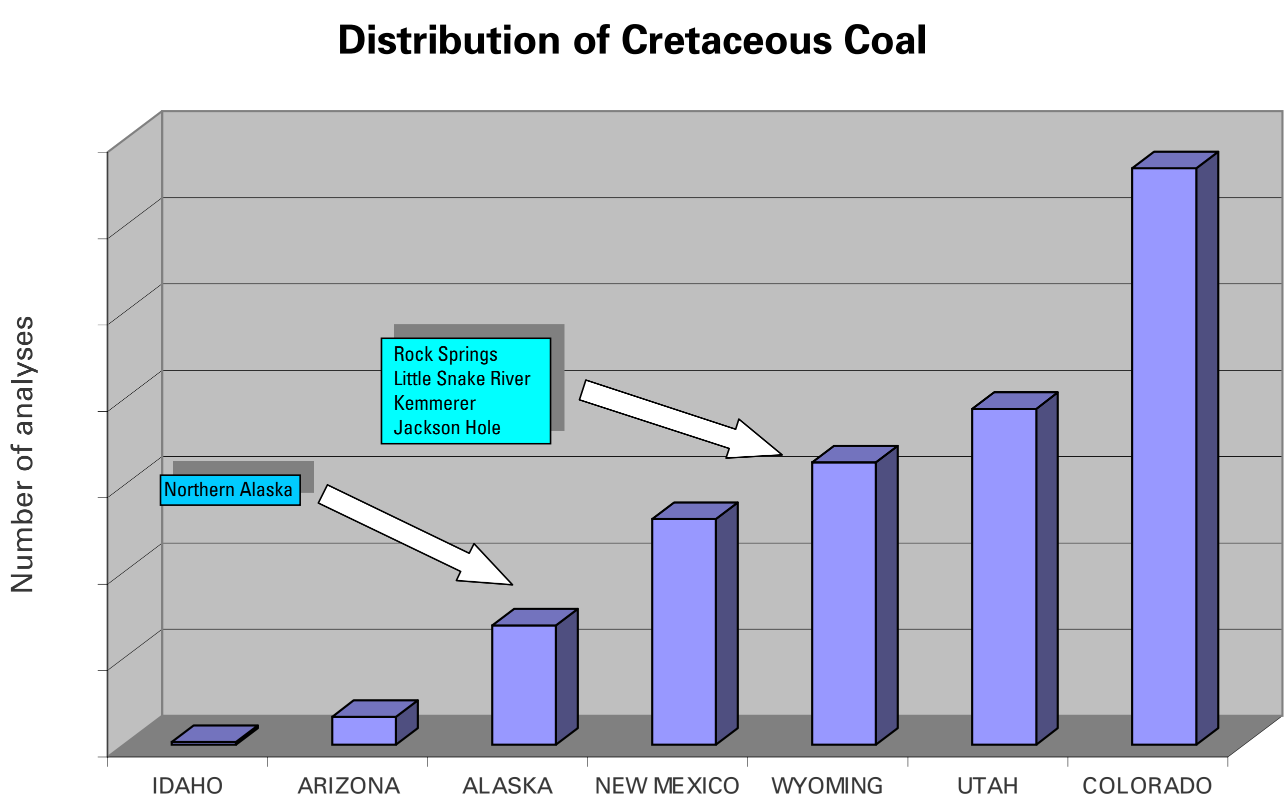

Figure 5. Geographic distribution of analyses of Cretaceous coal samples in the USGS USCHEM database.

lytical techniques and in order to be consistent, analytical values in our trace-element summary tables are only reported to two significant figures for most elements. Mercury and cadmium are reported to no more than two decimal places and antimony and selenium to only one decimal place. Proximate and ultimate analyses and total sulfur are reported to one decimal place. Calorific values are reported to the nearest 10, ash-fusion temperatures to the nearest 5, and forms of sulfur to 2 decimal places. To make all of our comparisons consistent and reflect the true nature of the chemical composition of these coals, all elements are calculated to a whole-coal basis and are presented in percent or as parts per million (ppm). Because some of these coal fields show a wide range in values, the mean is not always a good estimate of the average value. Therefore we have also included the median, which is a better measure of the central tendency when values have large ranges.

A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of censored data for the summary statistics (tables in Appendixes 1 and 2) in this report, we adopted the protocol of reducing all “less than” values by 50 percent before summary statistics were generated.

Appendix 1 includes 19 tables that contain summary statistics of the number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion temperatures for the 19 high-priority coal fields. Appendix 2 contains 19 tables that contain summary statistics of the number of samples, mean, median, range, and standard deviation of ash and the contents of 38 elements for the 19 high-priority coal fields. Coplateau.txt is an ASCII text database file listing all coal samples used in this study and there compositional values (in correct significant figures). In ArcView, this text file was added as a table; the table was added as an event theme; and then the theme was converted into a shapefile. Qualified data contained in coplateau.txt are indicated by L (less than), B (not determined), N (not detected), G (greater than). A data dictionary explaining all the fields within coplateau.txt can be found in Appendix 3 and as chemterm.pdf in the ArcView project. This data dictionary is also linked to the ArcView geochemical shapefiles. Selected references on the geology and chemistry from the Colorado Plateau coal assessment area and surrounding coal field areas were compiled by the author and are included in Appendix 4.

Coal Quality

Hatch and Swanson (1977) suggested four general reasons why coal quality data are necessary for the proper assessment and utilization of coal:

1. The evaluation of environmental impacts of mining of coal;
2. The evaluation of the best and most effective technological use of coal (combustion, liquefaction, gasification, etc.);
3. Determination of the economic aspects of extracting elements such as Ge, Se, U, V, and Zn from the coal;
4. Development of geologic and geochemical models to help interpret and predict coal quality and relate these factors to the stratigraphic and sedimentological framework.

Health issues related to the toxic or carcinogenic effects of increased utilization of coal, either as a result of mining or combustion, are also important factors. Current coal quality issues related to coal combustion are now focusing on the release of particulate matter, sulfur, and trace elements as well as acid rain and greenhouse effects. The quality of the coal mined and burned impacts air and water quality and affects disposal of the solid waste (fly ash and bottom ash), recovery of economic coal combustion product (CCP’s), and power plant efficiency.

With emphasis on elements of environmental concern as indicated in the 1990 Clean Air Act Amendment (U.S. Statutes at Large, 1990, Public Law 101-549), there has been concern about the effects of increased coal utilization. This Clean Air Act Amendment has identified several potentially hazardous air pollutants, which include antimony, arsenic, beryllium, cadmium, cobalt, lead, manganese, mercury, nickel, selenium, and uranium. Because coal quality data are an essential component of the USGS’ resource classification system (Wood and others, 1983), and because utilization of coal may be regulated by its effect on the environment, any evaluation of future coal resource potential must and should consider quality as well as quantity.

Coal Quality Characterization

High-priority coal fields of the Colorado Plateau can be characterized by mean ash yield (fig. 6) ranging from 5.1 percent in the Crested Butte coal field to 24 percent in the Bisti coal field, and low-priority coal fields can be characterized by mean ash yield (fig. 7) ranging from 7.8 percent in the Book Cliffs coal field to 22 percent in the Zuni coal field. Mean sulfur content in high-priority coal fields (fig. 8) ranges from 0.45 percent in the Black Mesa coal field to 1.1 percent in the Henry Mountains coal field, and in low-priority coal fields (fig. 9) it ranges from 0.3 percent in the Tabby Mountain coal field to 1.6 percent in the Emery coal field. Mean calorific value of high-priority coal fields (fig. 10) ranges from 7,600 Btu/lb in the Bisti coal field to 14,200 Btu/lb in the Carbondale coal field, and in low-priority coal fields (fig. 11) it ranges from 5,450 Btu/lb in the Tabby Mountain coal field to 12,880 Btu/lb in the Book Cliffs coal field. Graduated symbol maps show the location of the coal fields studied and the mean values for ash (fig. 12), sulfur (fig. 13), and Btu/lb (fig. 14). Appendix 5 includes the minimum, maximum, and mean values for ash

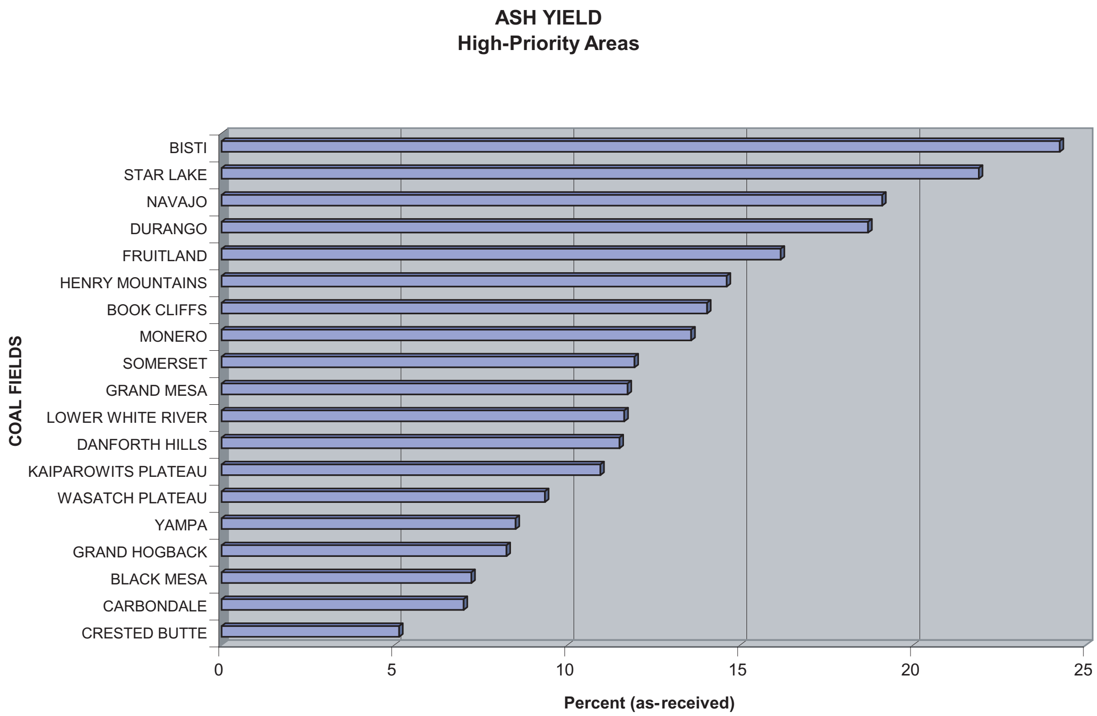

Figure 6. Distribution of the mean ash yield for high-priority coal fields in the Colorado Plateau coal assessment area.

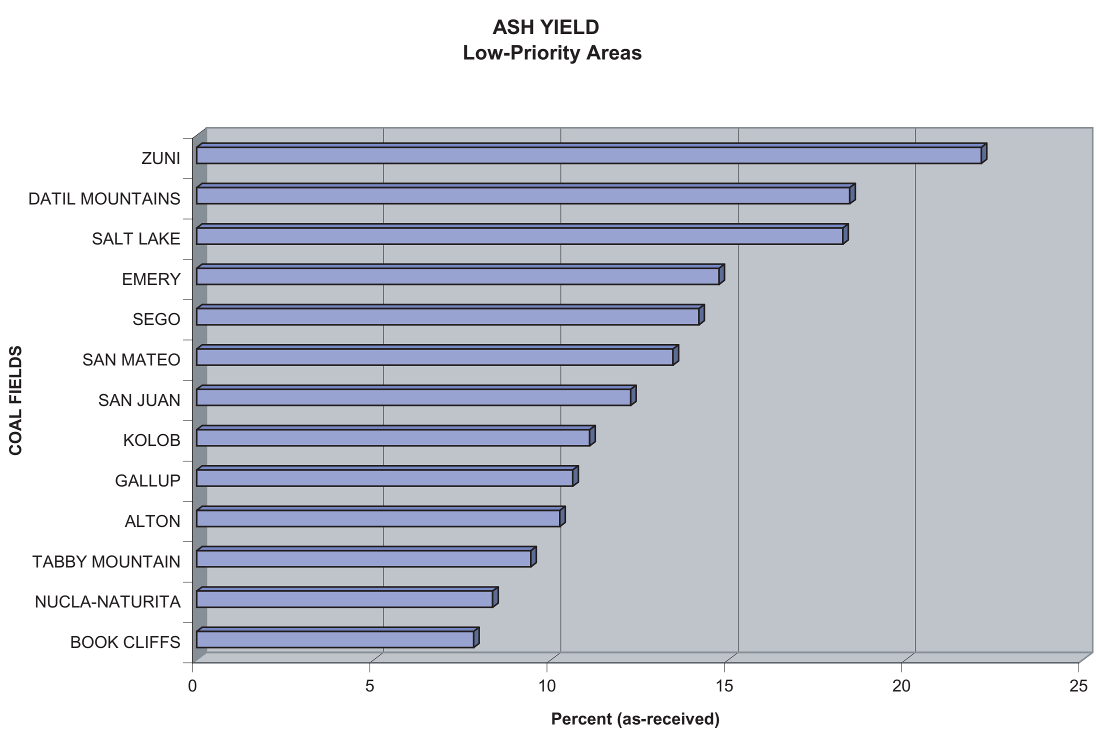

Figure 7. Distribution of the mean ash yield for low-priority coal fields in the Colorado Plateau coal assessment area.

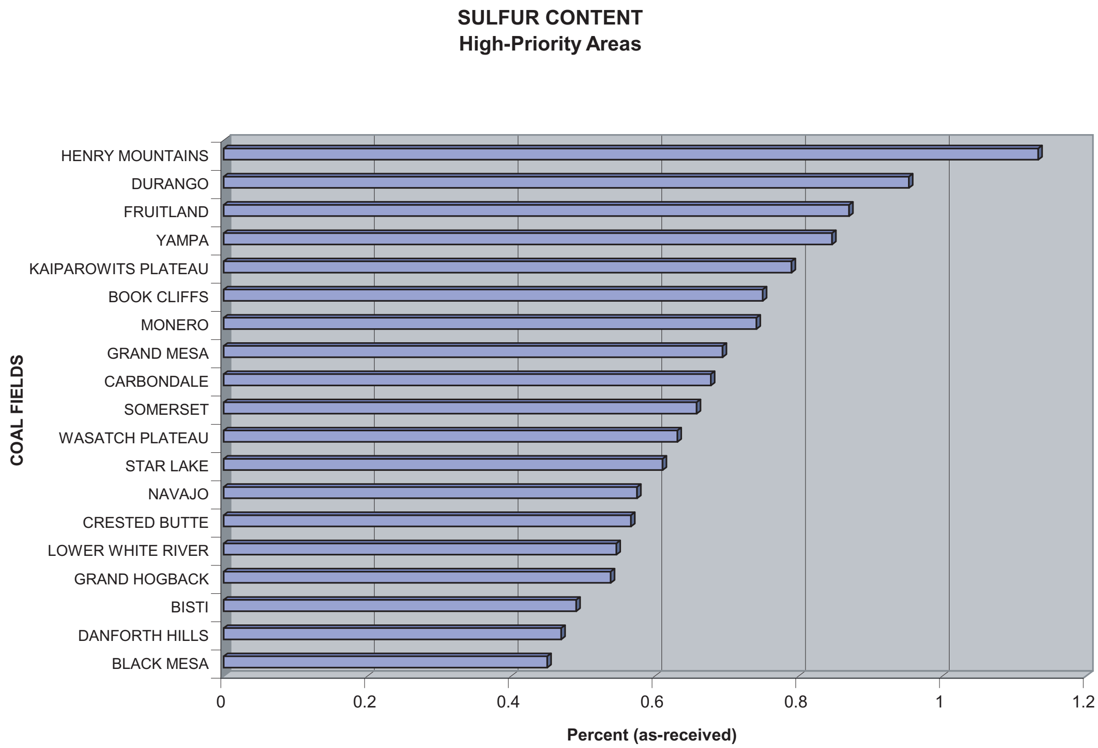

Figure 8. Distribution of the mean sulfur content for high-priority coal fields in the Colorado Plateau coal assessment area.

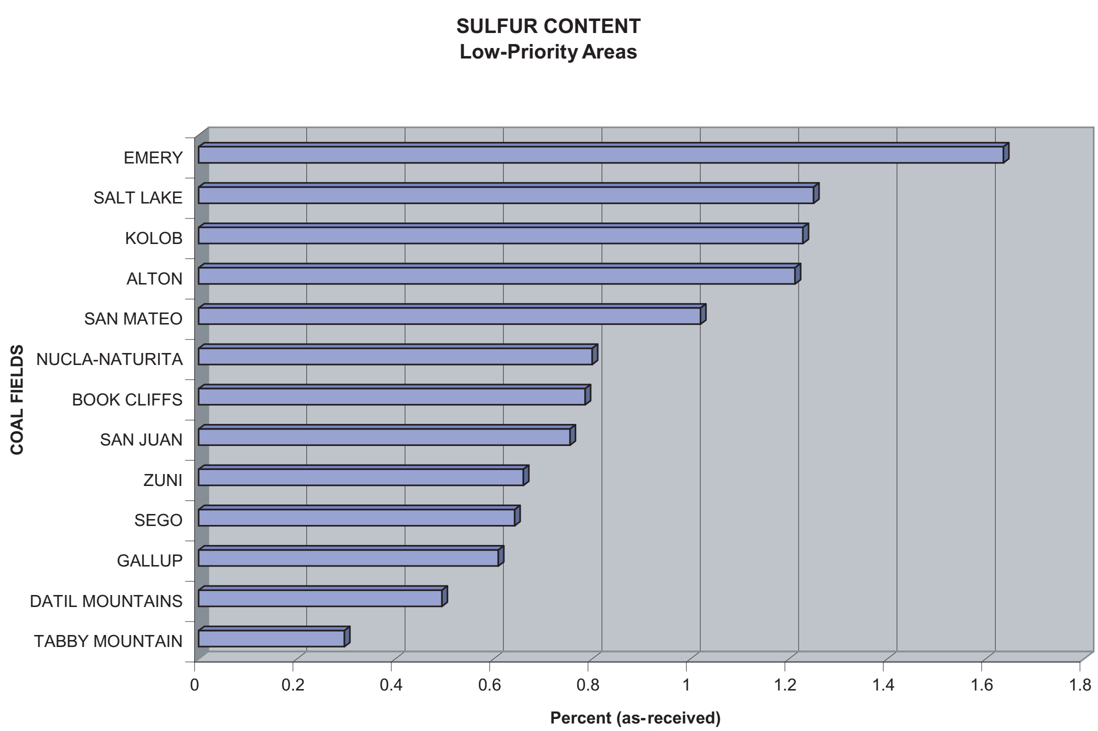

Figure 9. Distribution of the mean sulfur content for low-priority coal fields in the Colorado Plateau coal assessment area.

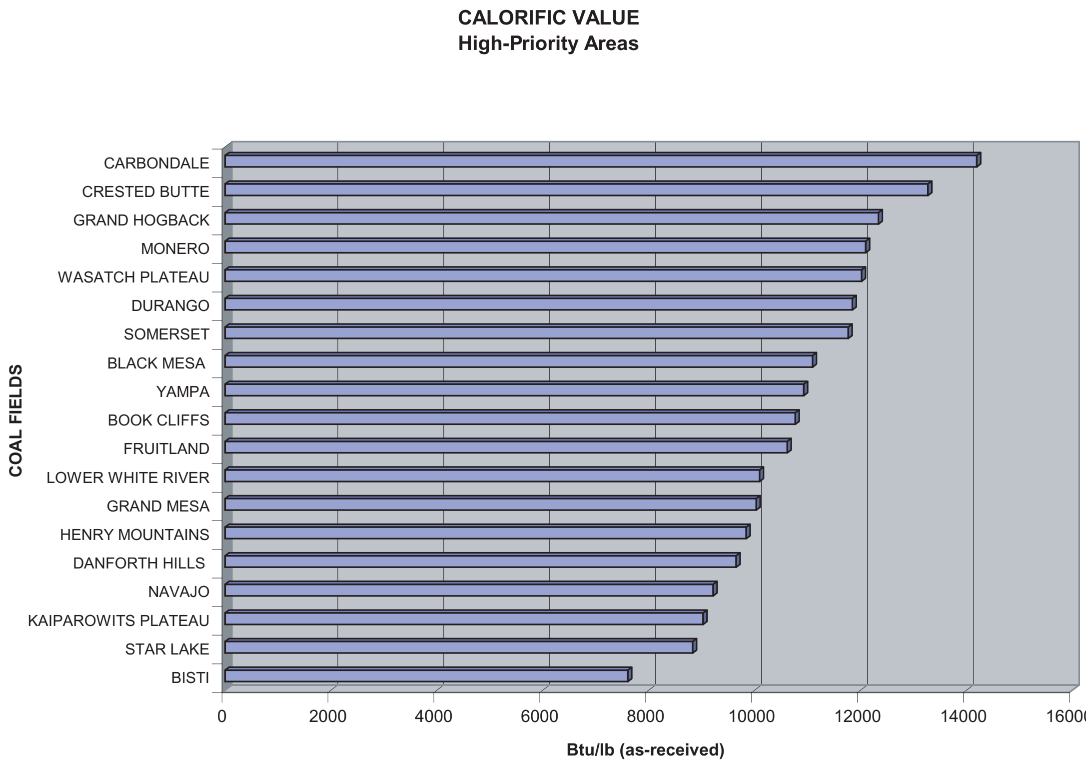

Figure 10. Distribution of the mean calorific values for high-priority coal fields in the Colorado Plateau coal assessment area.

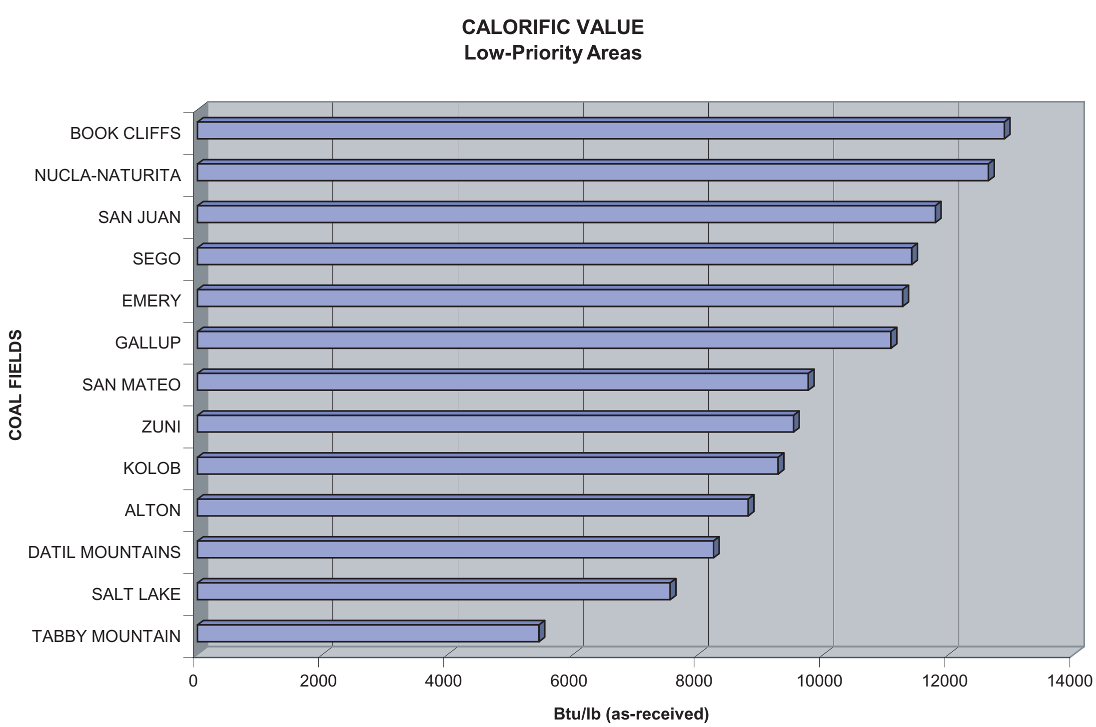

Figure 11. Distribution of the mean calorific values for low-priority coal fields in the Colorado Plateau coal assessment area.

yield, sulfur, calorific value, and moist, mineral-matter-free Btu grouped by high-priority coal fields and stratigraphic unit. The mean apparent rank for coal in the Colorado Plateau coal assessment area ranges from subbituminous B coal in the San Juan Basin coal region, to high-volatile A bituminous coal in the southern Piceance Basin (which includes the Book Cliffs, Grand Mesa, Somerset, Crested Butte, Carbondale, and Grand Hogback coal fields). The higher ranks in these coal fields are probably the result of regional metamorphism and intrusion of igneous bodies following coalification.

When compared to United States Tertiary coals, Colorado Plateau Cretaceous coals show a high clastic influence with a higher mean content of ash, silica, aluminum, potassium, titanium, and lithium. The contents of silicon and aluminum correlate well with ash contents (fig. 15, correlation coefficients > 0.8) as do those of potassium and titanium (fig. 16). Also, the contents of copper, gallium, lead, scandium, thorium, uranium, vanadium, yttrium, ytterbium, and zirconium show strong correlations with ash, silicon, and aluminum. Many of these coals within the Colorado Plateau assessment area are laterally discontinuous and are interspersed and interbedded with siltstone, sandstone, and carbonaceous shale. The abundance of clastic constituents is evidenced by the slightly higher ash content and predominant mineral assemblages of quartz and kaolinite (Affolter and Hatch, 1993).

The contents of calcium, magnesium, and sodium are generally lower in Cretaceous Colorado Plateau coals and Tertiary coals than other U.S. coals, which is probably the result of the loss of functional groups that can act as cation exchange sites on organic matter during coalification (Affolter and Hatch, 1993). Evidence of this can be seen when magnesium is plotted versus rank for the Colorado Plateau coals (fig. 17). Similar trends are observable but not as strong for barium, calcium, and sodium. Total sulfur, organic sulfur, pyritic sulfur, and iron content are similar to Tertiary coals.

The sulfur content of Colorado Plateau coals is relatively low when compared to other U.S. coals. In the Colorado Plateau, most of the sulfur is in the form of organic sulfur with small amounts of pyritic sulfur, and little sulfate sulfur (fig. 18 and Appendix 1). The sulfur content in most U.S. coals is mainly dependent on pH-controlled levels of bacterial activity in the ancestral peat swamps (Cecil and others, 1982). This bacterial activity, along with the general absence of marine carbonates such as limestone and dolomite and the rare occurrences of extensive overlying marine shales, probably accounts for the low sulfur content in many of the Colorado Plateau Cretaceous coals. Sulfur content might also be controlled by the location of the peat swamp. Affolter and Stricker (1989) suggested that the activity of sulfate-reducing bacteria in peat, along with the paleolatitude of the peat swamp, could affect

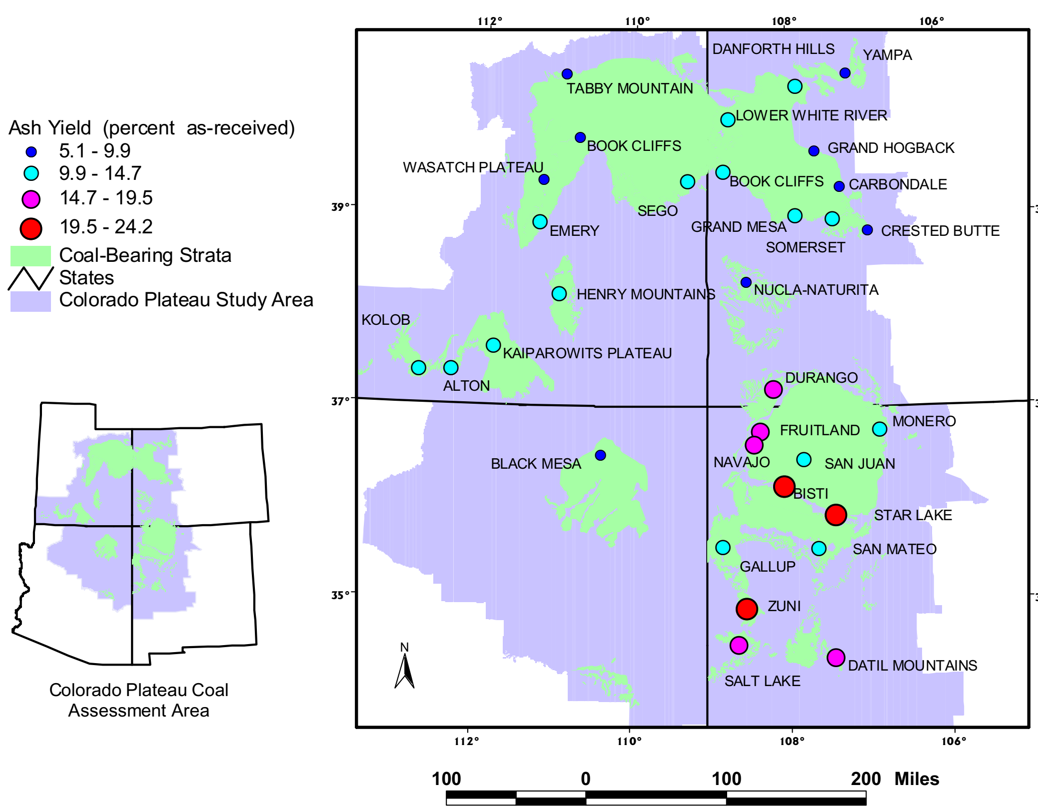

Figure 12. Graduated symbol map of the mean values of ash yield for all coal fields studied (including high- and low-priority coal fields) in the Colorado Plateau coal assessment area.

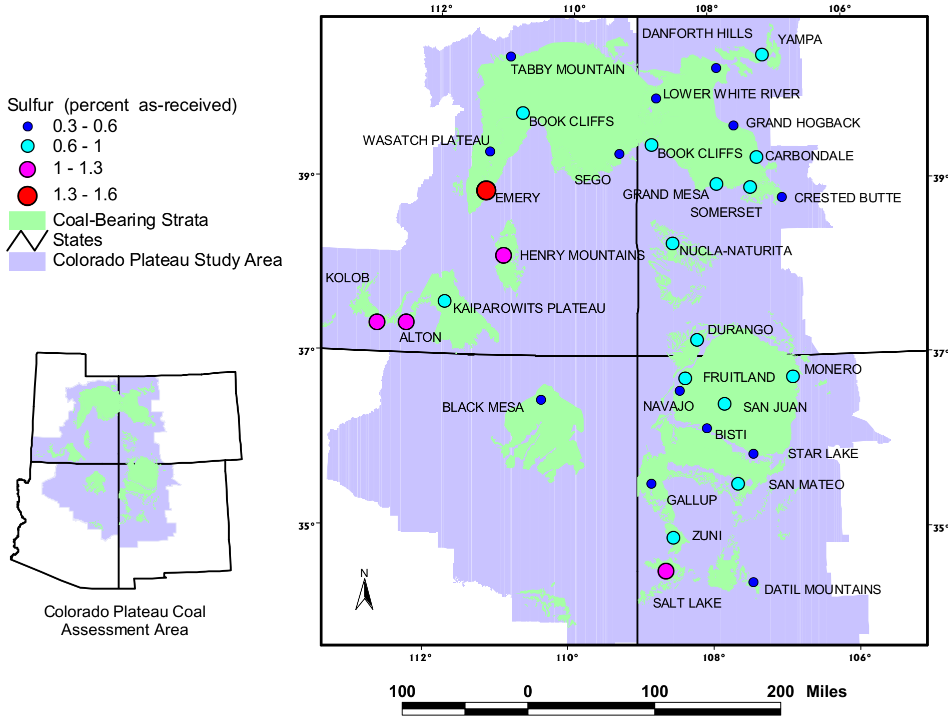

Figure 13. Graduated symbol map of the mean values of sulfur content for all coal fields studied (including high- and low-priority coal fields) in the Colorado Plateau coal assessment area.

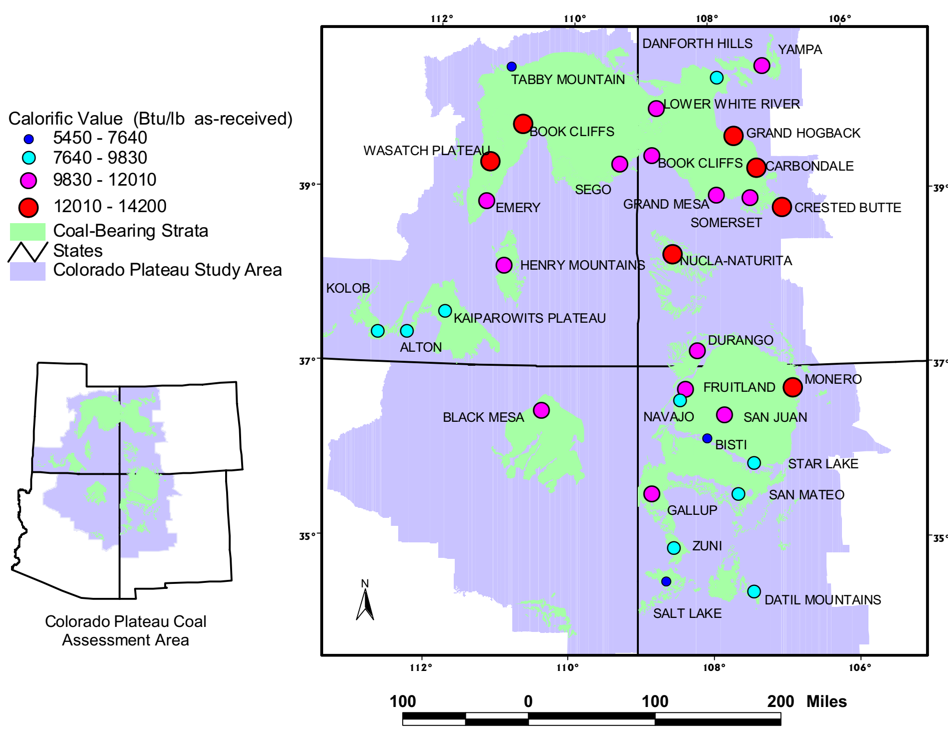

Figure 14. Graduated symbol map of the mean values of calorific value for all coal fields studied (including high- and low-priority coal fields) in the Colorado Plateau coal assessment area.

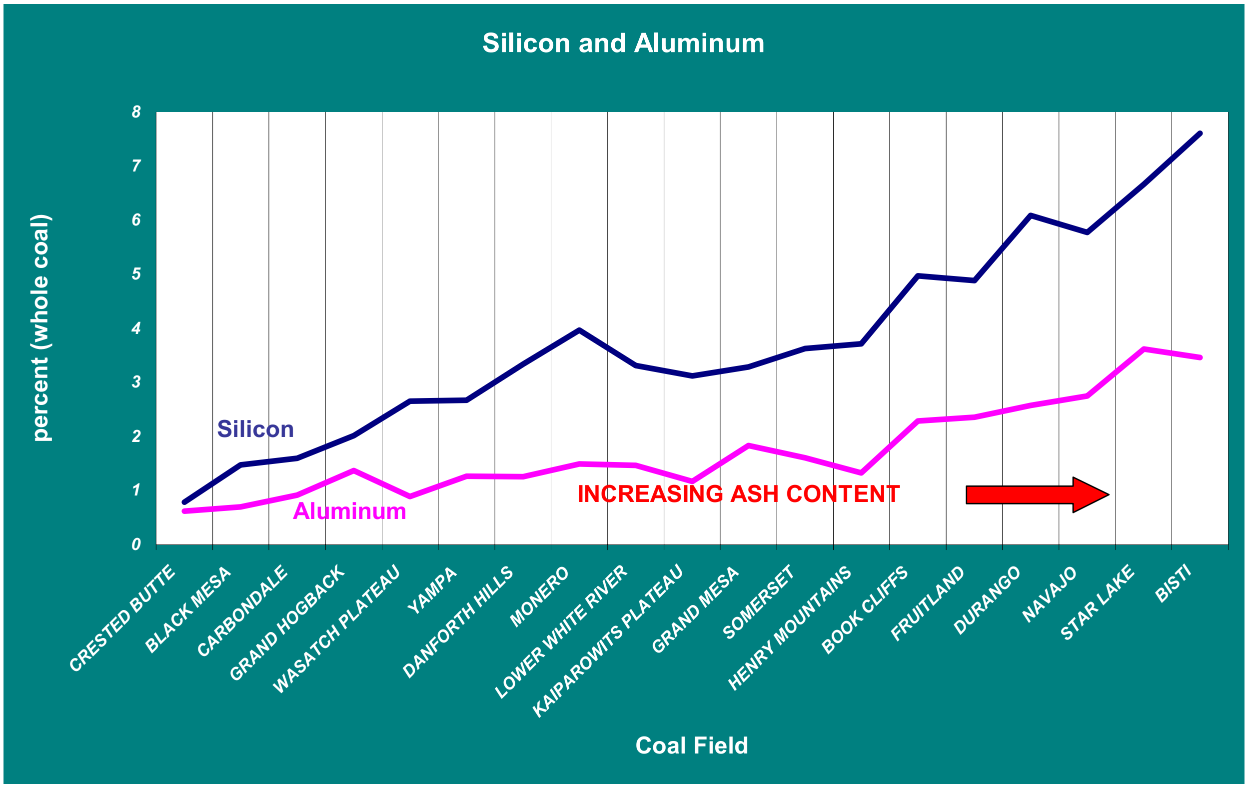

Figure 15. Plot of silicon and aluminum for Colorado Plateau coal fields arranged in order of increasing ash yield.

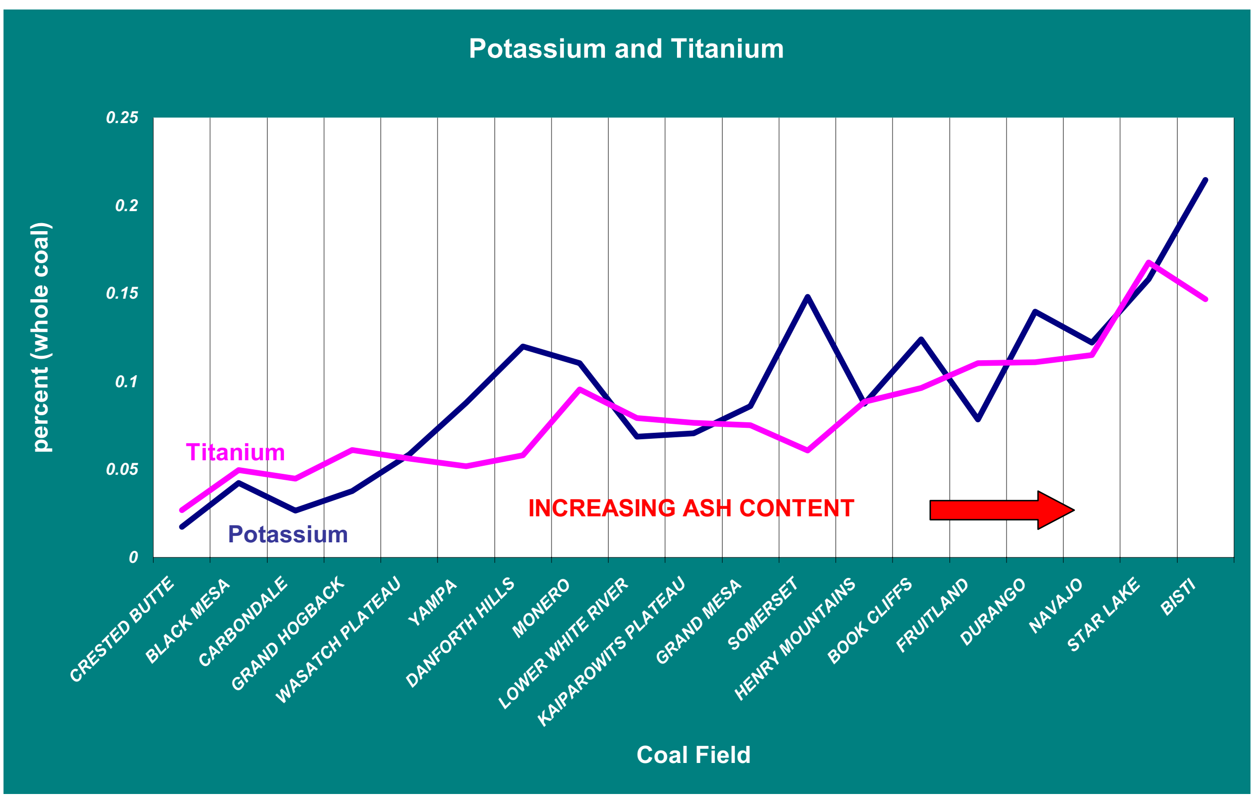

Figure 16. Plot of potassium and titanium for Colorado Plateau coal fields arranged in order of increasing ash yield.

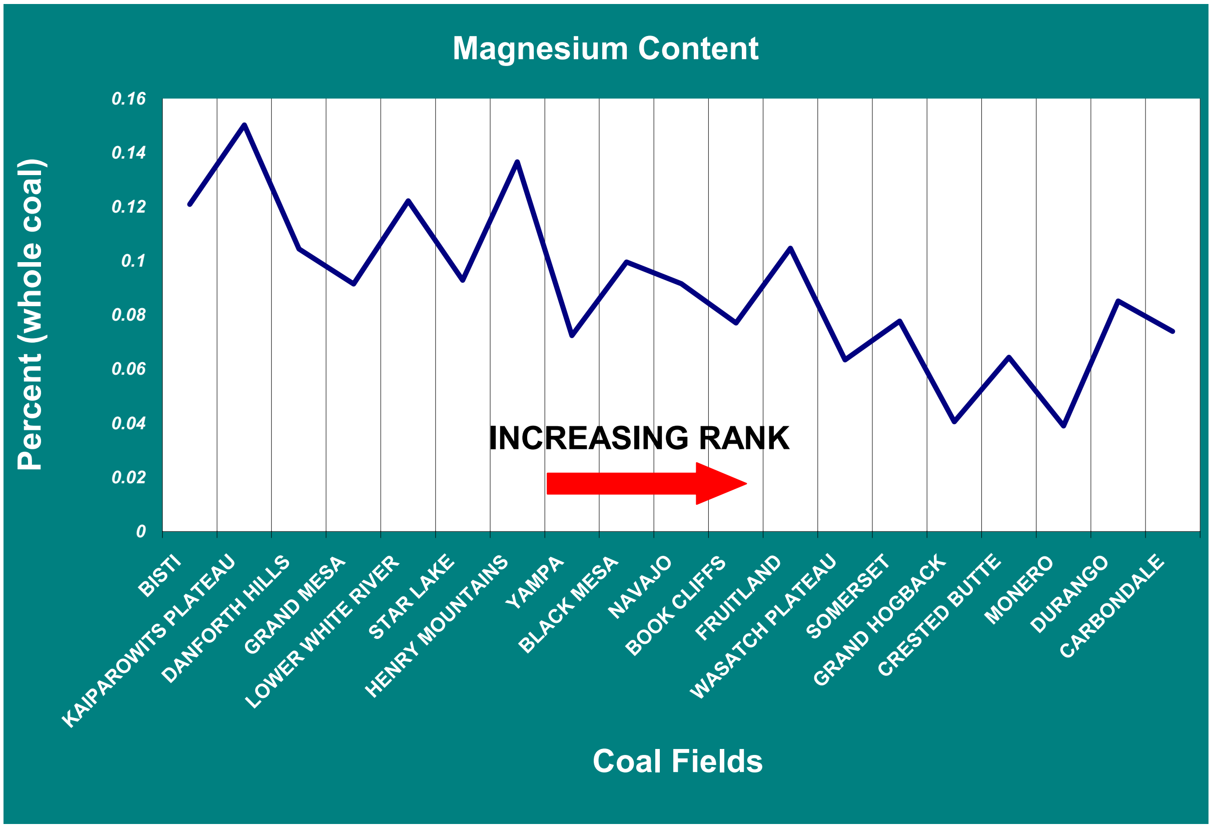

Figure 17. Plot of magnesium for Colorado Plateau coal fields arranged in order of increasing rank.

the sulfur content. A comparison of paleolatitudes that were calculated from paleomagnetic poles and sulfur contents of U.S. coals indicates that the higher the latitude in which a peat swamp developed, the lower the mean sulfur content of the subsequent coal. Low-sulfur coals such as the Cretaceous Colorado Plateau coals formed at higher paleolatitudes (>35 degrees), and high-sulfur coals (Pennsylvanian coals) formed at low paleolatitudes (0–15 degrees). The low sulfur content in most western Cretaceous coal is probably a result of several depositional as well as environmental factors.

Elements of environmental concern as determined by the 1990 Clean Air Act Amendment (antimony, arsenic, beryllium, cadmium, cobalt, lead, manganese, mercury, nickel, selenium, and uranium) are generally lower in content for Colorado Plateau assessment area coals when compared to other coal regions within the United States. Table 2 shows the mean content of elements of environmental concern for the Colorado Plateau assessment area. Table 3 compares the mean content of elements of environmental concern between the Colorado Plateau and the Appalachian Basin, Interior Province, Gulf Coast, and Western U.S. Tertiary coals. Appendix 6 contains graduated symbol maps for each element of environmental concern within the Colorado Plateau coal assessment area for all coal fields studied (including high- and low-priority coal fields). Appendix 7 contains minimum, maximum, and mean contents for elements of environmental concern shown by high-priority coal field and stratigraphic unit.

Unusually high contents of phosphorous (30 times greater than the average Cretaceous values), strontium (5 to 10 times higher), and barium (6 times higher) have been reported in the Wadge and Wolf Creek coal beds from the Yampa coal field. These high values probably resulted from the alteration of apatite-bearing air-fall tuffs that were deposited into the reducing environment of the peat swamps (Brownfield and others, 1987). X-ray diffraction, scanning electron microscope (SEM), and chemical analysis have indicated the presence of hydrated aluminum-phosphate minerals of the crandallite group (Affolter and Brownfield, 1987; Brownfield and Affolter, 1988). These minerals probably formed during early diagenesis in the peat swamps and are localized in and near kaolinitic, altered, volcanic-ash partings. High contents of strontium, barium, and phosphorous have also been found in coal from the Danforth Hills, Bisti, Durango, and Grand Mesa coal fields and in coal from the Iles Formation. However no crandallite group minerals have been identified in these units. These high values of phosphorus are characteristic of Colorado

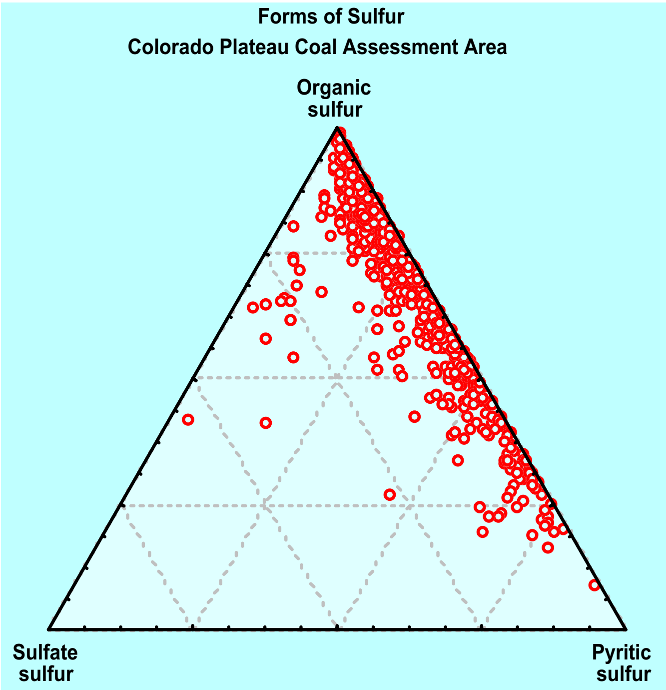

Figure 18. Distribution of sulfate, and organic and pyritic sulfur for Colorado Plateau coals.

Plateau coals as a result of the abundance of volcanic ash partings found in these coals. They are also useful in the correlation of coal beds within the various basins (Brownfield and Johnson, 1986). Figure 19 shows the graduated symbol map for phosphorus values in the Colorado Plateau coal assessment area.

Conclusion

Differences in the quality of coal result from variations in the total and relative amounts of inorganic minerals, the elemental composition of these minerals, and the total and relative amounts of any organically bound elements. The chemical form and distribution of a given element are dependent on the geological history of the coal bed. A partial listing of the factors that might influence element distributions would include chemical composition of original plants making up the peat swamp; amounts and compositions of the various detrital, diagenetic, and epigenetic minerals; chemical characteristics of the ground waters that come in contact with the coal bed; temperature and pressures during burial; and extent of chemi-

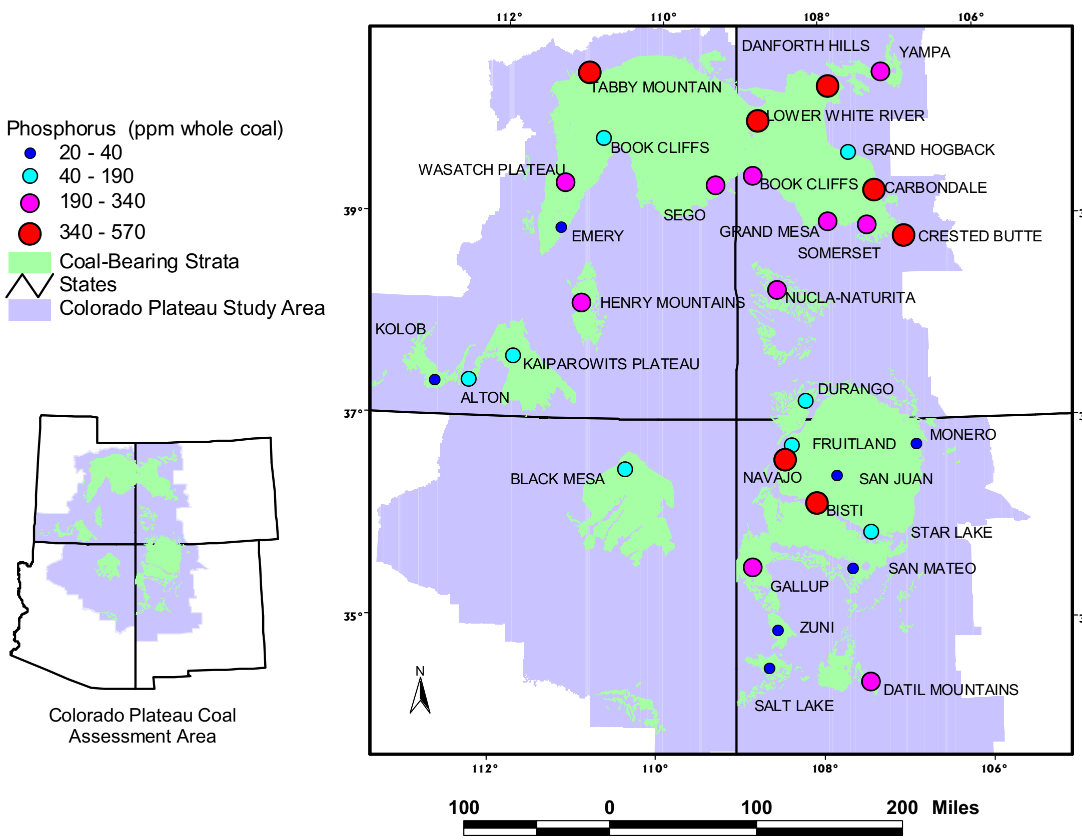

Figure 19. Graduated symbol map of the mean values of phosphorus for all coal fields studied (including high- and low-priority coal fields) in the Colorado Plateau coal assessment area.

Table 2. List of the mean content of elements of environmental concern (1990 Clean Air Act Amendment) for the high-priority coal fields in the Colorado Plateau coal assessment area.

[All elements are in parts per million (ppm) on a whole-coal basis. Element contents are reported to two significant figures for most elements. However, mercury and cadmium are reported to two decimal places and antimony and selenium are reported to one decimal place. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to an insufficient number of analyses above the lower detection limit]

Coal field	Element analyzed												
	As	Be	Cd	Co	Cr	Hg	Mn	Ni	Pb	Sb	Se	Th	U
Black Mesa	1.3	0.76	---	1.0	4.0	0.04	9.6	2.3	2.6	0.3	1.4	---	0.74
Book Cliffs	1.5	2.9	0.13	2.1	10	0.07	5.6	6.7	9.6	1.7	1.5	4.6	2.5
Carbondale	1.0	0.39	0.06	1.0	1.9	0.07	12	1.9	2.8	0.2	1.0	2.0	0.6
Crested Butte	0.39	0.33	0.07	1.3	2.1	0.06	31	2.8	---	---	0.9	1.5	1.1
Danforth Hills	1.5	1.2	0.08	2.3	7.5	0.05	21	7.0	4.8	0.8	0.7	2.4	1.4
Durango	4.8	1.2	0.15	2.5	4.4	0.08	15	4.9	6.6	0.7	1.7	3.8	2.0
Grand Hogback	1.3	0.56	---	1.5	2.4	0.04	32	2.1	5.5	0.3	1.2	2.5	1.0
Grand Mesa	1.3	0.71	0.09	1.5	3.5	0.05	34	2.8	7.5	0.5	1.1	3.1	1.4
Lower White River	0.47	0.66	---	1.6	7.5	0.04	40	4.2	7.5	0.3	1.1	3.3	1.6
Somerset	2.2	1.3	0.07	1.6	5.5	0.07	15	3.6	5.3	0.7	1.0	4.0	1.5
Yampa	1.8	1.2	0.06	1.3	4.3	0.06	23	3.8	5.2	0.3	1.0	2.6	1.0
Bisti	2.7	4.0	0.15	3.2	8.5	0.08	89	4.9	13	1.3	1.8	8.2	3.3
Fruitland	4.6	0.97	0.14	1.5	3.7	0.13	45	2.6	130	0.4	2.0	7.0	2.8
Monero	3.0	5.8	0.09	7.6	12	0.19	11	14	4.6	2.7	2.3	4.5	2.1
Navajo	4.3	1.4	---	1.6	4.7	0.08	33	4.2	11	0.6	1.6	8.1	2.4
Star Lake	2.2	2.5	0.13	2.8	6.4	0.07	57	5.6	13	1.3	2.3	7.4	3.7
Henry Mountains	1.6	1.2	0.09	1.8	9.8	0.09	25	3.6	5.5	0.6	1.6	3.7	2.8
Kaiparowits Plateau	4.2	0.85	---	1.3	9.4	0.06	30	4.1	5.6	0.4	1.5	2.1	1.3
Wasatch Plateau	0.91	1.2	0.07	1.4	9.0	0.05	7.8	4.6	10	0.3	1.5	1.8	1.0

Table 3. Comparison of the mean content of elements of environmental concern (1990 Clean Air Act Amendment) for the Colorado Plateau coal assessment area with coal from the Appalachian Basin, Interior Province, Gulf Coast, and Western U.S. Tertiary coal.

[All elements are in parts per million (ppm) on a whole-coal basis]

Element	Colorado Plateau coal assessment area Cretaceous Mean[1] (n=1265)	Appalachian Basin Pennsylvanian Mean[2] (n=4700)	Interior Province Pennsylvanian Mean[2] (n=800)	Gulf Coast Tertiary Mean[2] (n=200)	Western U.S. Tertiary Mean[3] (n=520)
Antimony	0.5	1.4	1.5	1.0	0.6
Arsenic	1.6	35	20	10	7.4
Beryllium	1.2	2.5	2.4	2.4	1.1
Cadmium	0.1	0.1	4.2	0.55	0.1
Chromium	4.5	17	19	24	10
Cobalt	1.5	7.2	10	7.2	3.5
Lead	6.5	8.4	40	21	4.2
Manganese	22	29	78	150	60
Mercury	0.06	0.21	0.15	0.22	0.12
Nickel	3.7	17	27	13	4.6
Selenium	1.2	3.5	3.2	5.7	0.7
Uranium	1.3	1.7	3.1	23	1.7

[1] This report.
[2] Finkelman and others (1994).
[3] Summarized from Affolter and Hatch (1993).

cal weathering. Many of these factors have not been evaluated in detail for many of the Colorado Plateau assessment coal fields.

In order to better predict future environmental impacts on the utilization of coal, we need to identify the modes of occurrence of the various elements within the coal beds and coal mine products. This will involve collecting additional samples and obtaining mineralogical data through low-temperature ashing, X-ray diffraction, and scanning electron microscopy techniques. The Colorado Plateau assessment chemical database is not complete, and additional samples will be required to adequately characterize all the major producing coal beds in detail. Currently the database represents only a regional view of the quality based on a limited amount of samples, which is only a first step in evaluating their potential.

More than 88 percent of the United States yearly production of coal is consumed in the production of electricity by utilities (Energy Information Administration, 1997). Environmental concern over the composition of stack emissions and coal combustion byproducts has become a major concern because of the increased combustion of coal. Since the rate of coal utilization has been steadily increasing, specific concern about the chemical composition of coal and its byproducts has become a growing concern mainly because of the 1990 Clean Air Act Amendment.
The future of coal utilization depends on a careful evaluation of the coal quality, mining costs, beneficiation costs, transportation, coal combustion byproducts, and waste disposal. With increasing emphasis on environmental concerns, information on the quality of coal (which includes ash yield, sulfur content, calorific value, major-, minor-, and trace-element content) has become almost as important as information on the quantity of the resource. Because Colorado Plateau assessment coals are low in sulfur, high in calorific value, and low in many of the elements of environmental concern, these coals should play a major role in supplying future United States energy needs.

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Appendix 1—Number of Samples, Mean, Median, Range, and Standard Deviation of Proximate and Ultimate Analyses, Calorific Value, Forms of Sulfur, and Ash-Fusion Temperatures for High-Priority Coal Fields in the Colorado Plateau Coal Assessment Area

Table A1-1. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Black Mesa coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F)]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	30	10.4	10.7	8.6	12.1	1.1
Volatile matter	30	38.8	38.9	34.3	41.2	2.1
Fixed carbon	30	43.7	43.7	41.4	45.7	1.1
Ash	30	7.2	7.7	2.7	11.1	2.2
Hydrogen	30	5.7	5.7	5.4	5.9	0.2
Carbon	30	63.5	63.2	59.2	67.2	2.1
Nitrogen	30	1.1	1.1	0.9	1.2	0.1
Oxygen	30	22.1	22.3	20.7	23.7	0.8
Sulfur	30	0.5	0.5	0.3	0.7	0.1
Calorific value						
Btu/lb	30	11,100	11,050	10,360	11,800	380
Forms of sulfur						
Sulfate	17	0.02	0.02	0.01	0.03	0.01
Pyritic	30	0.04	0.04	0.01	0.08	0.02
Organic	30	0.40	0.38	0.28	0.63	0.08
Ash-fusion temperatures (˚F)						
Initial deformation	28	2,185	2,155	2,120	2,290	57
Softening temperature	28	2,250	2,200	2,160	2,400	90
Fluid temperature	28	2,315	2,305	2,190	2,480	115

Table A1-2. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Book Cliffs coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F). G, greater than value shown]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	19	9.3	9.5	5.1	11.4	1.7
Volatile matter	19	32.0	32.1	22.8	37.7	3.4
Fixed carbon	19	44.7	45.4	31.5	48.5	3.9
Ash	19	14.0	12.1	4.8	36.6	7.1
Hydrogen	19	5.3	5.4	4.3	5.8	0.4
Carbon	20	59.4	60.9	36.4	67.6	7.9
Nitrogen	19	1.6	1.6	1.2	1.9	0.2
Oxygen	19	17.8	18.2	13.9	20.5	1.8
Sulfur	20	0.8	0.7	0.5	1.5	0.3
Calorific value						
Btu/lb	19	10,770	10,830	7,350	12,040	1,050
Forms of sulfur						
Sulfate	18	0.01	0.01	0.01	0.06	0.01
Pyritic	19	0.10	0.04	0.02	0.57	0.16
Organic	19	0.61	0.61	0.50	0.76	0.06
Ash-fusion temperatures (˚F)						
Initial deformation	19	2,750	2,800	2,460	2,800G	111
Softening temperature	19	2,770	2,800	2,560	2,800G	78
Fluid temperature	19	2,785	2,800	2,665	2,800G	38

Table A1-3. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Carbondale coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F)]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	9	1.4	1.0	0.8	4.0	1.0
Volatile matter	9	27.9	27.3	21.8	39.3	5.5
Fixed carbon	9	63.7	65.4	50.7	69.6	6.5
Ash	9	7.0	6.5	3.9	11.3	2.1
Hydrogen	9	5.2	5.3	4.8	5.8	0.3
Carbon	9	80.0	81.7	70.4	85.7	4.6
Nitrogen	9	1.9	1.9	1.7	2.1	0.1
Oxygen	9	5.2	3.8	2.6	14.8	3.7
Sulfur	9	0.7	0.5	0.3	1.5	0.4
Calorific value						
Btu/lb	9	14,200	14,490	12,610	15,090	750
Forms of sulfur						
Sulfate	9	0.03	0.01	0.01	0.1	0.04
Pyritic	9	0.19	0.03	0.01	0.78	0.29
Organic	9	0.46	0.48	0.28	0.66	0.12
Ash-fusion temperatures (˚F)						
Initial deformation	9	2,235	2,250	2,030	2,410	115
Softening temperature	9	2,305	2,300	2,080	2,500	131
Fluid temperature	9	2,455	2,450	2,360	2,610	79

Table A1-4. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Crested Butte coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F)]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	3	5.0	1.4	1.4	12.3	6.3
Volatile matter	3	18.0	10.3	8.1	35.7	15.3
Fixed carbon	3	71.8	82.9	46.4	86.1	22.1
Ash	3	5.1	5.4	4.4	5.6	0.6
Hydrogen	3	4.6	4.1	3.7	5.9	1.2
Carbon	3	78.0	84.1	62.8	87.0	13.2
Nitrogen	3	1.8	1.7	1.6	2.0	0.2
Oxygen	3	10.0	3.8	2.6	23.6	11.8
Sulfur	3	0.6	0.6	0.5	0.6	0.1
Calorific value						
Btu/lb	3	13,280	14,310	11,080	14,440	1,900
Forms of sulfur						
Sulfate	3	0.01	0.01	0.01	0.01	0.00
Pyritic	3	0.05	0.05	0.04	0.06	0.01
Organic	3	0.51	0.55	0.40	0.57	0.09
Ash-fusion temperatures (˚F)						
Initial deformation	3	2,125	2,100	2,060	2,210	78
Softening temperature	3	2,230	2,210	2,150	2,320	86
Fluid temperature	3	2,325	2,300	2,260	2,420	83

Table A1-5. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Danforth Hills coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F)]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	47	14.8	15.2	2.9	23.8	3.3
Volatile matter	47	30.9	32.2	11.3	34.9	4.1
Fixed carbon	47	42.8	44.8	22.5	50.9	6.2
Ash	47	11.5	6.5	2.6	45.8	10.3
Hydrogen	47	5.5	5.7	2.5	6.2	0.7
Carbon	47	55.9	57.9	33.5	64.4	7.5
Nitrogen	47	1.3	1.4	0.6	1.6	0.2
Oxygen	47	25.4	25.7	6.4	30.6	3.7
Sulfur	47	0.5	0.4	0.3	1.1	0.2
Calorific value						
Btu/lb	47	9,650	10,010	5,780	11,200	1,320
Forms of sulfur						
Sulfate	41	0.01	0.01	0.01	0.04	0.01
Pyritic	47	0.09	0.05	0.01	0.41	0.10
Organic	47	0.37	0.34	0.12	0.76	0.13
Ash-fusion temperatures (˚F)						
Initial deformation	47	2,420	2,410	2,030	2,910	220
Softening temperature	47	2,520	2,500	2,090	2,910	220
Fluid temperature	47	2,585	2,570	2,140	2,910	206

Table A1-6. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Durango coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F). G, greater than value shown]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	27	2.2	1.5	0.5	8.1	1.6
Volatile matter	27	28.2	30.1	13.7	37.9	6.6
Fixed carbon	27	50.9	53.8	32.6	59.8	7.1
Ash	27	18.7	13.2	3.6	46.3	13.1
Hydrogen	27	4.7	5.1	2.8	5.7	0.9
Carbon	27	66.5	71.1	42.2	78.1	11.0
Nitrogen	27	1.4	1.5	0.8	1.8	0.3
Oxygen	27	7.7	6.1	3.1	20.4	4.0
Sulfur	27	1.0	0.8	0.4	3.3	0.6
Calorific value						
Btu/lb	27	11,850	12,760	7,620	13,960	2,080
Forms of sulfur						
Sulfate	26	0.04	0.02	0.01	0.2	0.04
Pyritic	27	0.30	0.12	0.01	2.56	0.55
Organic	27	0.60	0.63	0.33	0.77	0.12
Ash-fusion temperatures (˚F)						
Initial deformation	27	2,740	2,800	2,310	2,910G	148
Softening temperature	27	2,795	2,800	2,420	2,910G	102
Fluid temperature	27	2,815	2,800	2,510	2,910G	80

Table A1-7. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Grand Hogback coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (°F). G, greater than value shown]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	5	4.5	4.5	4.0	4.8	0.3
Volatile matter	5	38.9	39.2	37.2	39.8	1.0
Fixed carbon	5	48.4	48.3	46.1	50.0	1.6
Ash	5	8.2	8.2	6.1	10.4	2.0
Hydrogen	5	5.5	5.5	5.4	5.6	0.1
Carbon	6	69.5	69.1	68.0	71.4	1.5
Nitrogen	5	1.3	1.4	0.9	1.4	0.2
Oxygen	5	14.7	14.5	14.1	15.3	0.6
Sulfur	6	0.5	0.6	0.3	0.7	0.1
Calorific value						
Btu/lb	5	12,340	12,350	12,060	12,580	240
Forms of sulfur						
Sulfate	4	0.02	0.02	0.01	0.02	0.01
Pyritic	5	0.06	0.07	0.03	0.09	0.03
Organic	5	0.50	0.53	0.38	0.56	0.07
Ash-fusion temperatures (°F)						
Initial deformation	5	2,680	2,910	2,230	2,910	325
Softening temperature	5	2,700	2,910	2,280	2,910G	299
Fluid temperature	5	2,730	2,910	2,400	2,910G	248

Table A1-8. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Grand Mesa coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F). G, greater than value shown]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	50	13.7	13.6	2.5	23.8	4.8
Volatile matter	50	33.0	33.2	22.0	38.7	3.2
Fixed carbon	50	41.6	42.6	24.6	51.5	5.1
Ash	50	11.7	9.8	3.2	41.4	7.2
Hydrogen	50	5.6	5.7	4.1	6.3	0.4
Carbon	50	57.2	58.0	35.5	74.2	7.2
Nitrogen	50	1.3	1.3	0.8	1.8	0.2
Oxygen	50	23.5	23.6	8.7	38.8	5.5
Sulfur	50	0.7	0.6	0.3	2.2	0.3
Calorific value						
Btu/lb	50	10,030	10,190	6,170	13,490	1,380
Forms of sulfur						
Sulfate	49	0.02	0.01	0.01	0.09	0.02
Pyritic	50	0.13	0.05	0.01	1.55	0.25
Organic	50	0.54	0.51	0.09	1.26	0.21
Ash-fusion temperatures (˚F)						
Initial deformation	50	2,650	2,800	2,055	2,910G	297
Softening temperature	50	2,695	2,800	2,155	2,910G	258
Fluid temperature	50	2,735	2,800	2,250	2,910G	218

Table A1-9. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Lower White River coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F). G, greater than value shown]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	13	12.0	10.2	6.7	22.3	5.2
Volatile matter	13	33.4	33.6	29.6	36.8	2.2
Fixed carbon	13	42.9	42.7	35.6	51.1	5.7
Ash	13	11.6	10.0	4.1	23.9	5.3
Hydrogen	13	5.3	5.4	4.5	5.6	0.3
Carbon	13	58.2	62.0	44.8	66.9	7.4
Nitrogen	13	1.3	1.3	1.0	1.4	0.1
Oxygen	13	23.0	20.1	17.7	36.6	6.3
Sulfur	13	0.5	0.5	0.4	1.1	0.2
Calorific value						
Btu/lb	13	10,090	10,830	7,240	11,720	1,490
Forms of sulfur						
Sulfate	12	0.02	0.02	0.01	0.05	0.01
Pyritic	13	0.18	0.17	0.01	0.43	0.13
Organic	13	0.34	0.34	0.11	0.63	0.15
Ash-fusion temperatures (˚F)						
Initial deformation	13	2,595	2,605	2,215	2,855G	234
Softening temperature	13	2,660	2,705	2,305	2,910G	204
Fluid temperature	13	2,705	2,800	2,415	2,910G	168

Table A1-10. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Somerset coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F). G, greater than value shown]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	43	4.5	4.3	1.8	8.6	1.7
Volatile matter	43	35.5	35.7	30.4	40.0	2.4
Fixed carbon	43	48.1	48.8	37.6	54.5	4.4
Ash	43	11.9	10.6	2.7	29.2	6.6
Hydrogen	43	5.3	5.4	4.4	5.8	0.3
Carbon	44	65.9	67.2	49.7	76.3	6.3
Nitrogen	43	1.4	1.5	0.8	2.1	0.4
Oxygen	43	14.2	14.7	0.7	20.7	3.8
Sulfur	44	0.7	0.6	0.4	1.3	0.2
Calorific value						
Btu/lb	43	11,770	11,730	9,220	13,670	1,100
Forms of sulfur						
Sulfate	42	0.02	0.02	0.01	0.08	0.01
Pyritic	43	0.11	0.07	0.02	0.45	0.10
Organic	43	0.54	0.51	0.38	0.97	0.11
Ash-fusion temperatures (˚F)						
Initial deformation	43	2,560	2,650	2,000	2,910G	252
Softening temperature	43	2,630	2,740	2,075	2,910G	224
Fluid temperature	43	2,685	2,800	2,165	2,910G	196

Table A1-11. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Yampa coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F). L, less than value shown. A common problem in statistical summaries of data arises when values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. G, greater than value shown]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	179	10.0	9.6	2.9	29.1	3.6
Volatile matter	148	35.8	36.0	24.7	42.1	3.0
Fixed carbon	148	45.1	46.1	23.2	52.4	4.4
Ash	148	8.5	7.3	2.2	37.0	5.6
Hydrogen	148	5.6	5.7	3.8	7.1	0.4
Carbon	154	61.7	62.9	32.3	75.3	6.7
Nitrogen	148	1.5	1.6	0.5	2.0	0.3
Oxygen	148	21.5	21.0	14.7	40.7	3.3
Sulfur	246	0.8	0.5	0.1	9.2	0.9
Calorific value						
Btu/lb	148	10,930	11,190	5,070	12,440	1,150
Forms of sulfur						
Sulfate	222	0.03	0.01	0.01L	0.66	0.06
Pyritic	240	0.28	0.08	0.01L	6.34	0.64
Organic	208	0.54	0.44	0.06	2.37	0.37
Ash-fusion temperatures (˚F)						
Initial deformation	148	2,435	2,450	1,850	2,910G	320
Softening temperature	148	2,510	2,560	1,880	2,910G	300
Fluid temperature	148	2,585	2,700	1,990	2,910G	260

Table A1-12. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Bisti coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (°F). G, greater than value shown]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	63	17.4	17.2	8.0	28.1	3.9
Volatile matter	63	28.2	28.3	16.5	34.5	3.5
Fixed carbon	63	30.2	31.6	13.2	41.3	6.2
Ash	63	24.2	22.9	9.3	46.5	9.4
Hydrogen	63	5.3	5.4	3.6	6.3	0.6
Carbon	63	43.7	46.3	19.6	59.4	8.5
Nitrogen	63	0.9	0.9	0.4	1.2	0.2
Oxygen	63	25.4	24.4	16.1	37.4	4.2
Sulfur	63	0.5	0.5	0.2	1.3	0.2
Calorific value						
Btu/lb	63	7,610	8,130	3,270	10,410	1,600
Forms of sulfur						
Sulfate	63	0.03	0.02	0.01	0.13	0.03
Pyritic	63	0.10	0.07	0.02	0.92	0.12
Organic	63	0.37	0.37	0.17	0.62	0.09
Ash-fusion temperatures (°F)						
Initial deformation	62	2,660	2,650	2,250	2,910G	174
Softening temperature	62	2,715	2,755	2,350	2,910G	147
Fluid temperature	62	2,770	2,800	2,500	2,910G	100

Table A1-13. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Fruitland coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F)]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	11	6.1	5.7	4.3	9.8	1.6
Volatile matter	11	36.9	37.3	31.2	40.1	2.5
Fixed carbon	11	40.9	41.2	34.8	44.8	2.6
Ash	11	16.2	16.1	7.5	24.3	4.9
Hydrogen	8	5.1	5.2	4.5	5.8	0.4
Carbon	8	59.1	60.1	52.5	64.3	4.0
Nitrogen	8	1.3	1.3	1.0	1.5	0.2
Oxygen	8	16.8	16.0	15.1	20.2	1.7
Sulfur	11	0.9	0.7	0.1	1.7	0.5
Calorific value						
Btu/lb	11	10,620	10,730	8,980	11,400	790
Forms of sulfur						
Sulfate	7	0.05	0.02	0.01	0.24	0.08
Pyritic	8	0.44	0.23	0.13	1.12	0.37
Organic	8	0.55	0.54	0.43	0.69	0.09
Ash-fusion temperatures (˚F)						
Initial deformation	3	2,280	2,250	2,110	2,480	187
Softening temperature	3	2,365	2,360	2,200	2,530	165
Fluid temperature	3	2,460	2,450	2,310	2,630	160

Table A1-14. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Monero coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (°F). G, greater than value shown]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	8	3.6	2.6	1.8	11.3	3.1
Volatile Matter	8	36.1	36.5	30.9	39.6	2.8
Fixed Carbon	8	46.7	45.5	38.2	54.7	5.5
Ash	8	13.6	13.5	3.4	23.9	7.6
Hydrogen	8	5.2	5.2	4.6	5.7	0.4
Carbon	8	67.9	68.3	57.7	79.3	7.8
Nitrogen	8	1.4	1.4	1.2	1.6	0.2
Oxygen	8	11.2	8.7	7.9	29.0	7.2
Sulfur	8	0.7	0.6	0.6	1.4	0.3
Calorific value						
Btu/lb	8	12,100	12,300	9,470	14,270	1,590
Forms of sulfur						
Sulfate	7	0.02	0.02	0.01	0.03	0.01
Pyritic	8	0.18	0.08	0.03	0.79	0.26
Organic	8	0.51	0.55	0.30	0.62	0.11
Ash-fusion temperatures (°F)						
Initial deformation	8	2,715	2,745	2,520	2,910G	134
Softening temperature	8	2,770	2,780	2,660	2,910G	79
Fluid temperature	8	2,810	2,800	2,750	2,910G	45

Table A1-15. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Navajo coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F). G, greater than value shown]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	5	8.3	8.8	4.1	11.5	2.7
Volatile matter	5	33.5	33.1	30.3	37.3	3.3
Fixed carbon	5	39.0	40.1	33.1	41.7	3.4
Ash	5	19.1	18.7	13.8	25.8	4.4
Hydrogen	4	5.0	5.0	4.6	5.3	0.3
Carbon	4	55.1	55.2	50.8	59.4	3.5
Nitrogen	4	1.3	1.2	1.2	1.4	0.1
Oxygen	4	17.6	17.9	13.6	21.1	3.2
Sulfur	4	0.6	0.6	0.5	0.7	0.1
Calorific value						
Btu/lb	5	9,220	9,570	7,390	10,630	1,210
Forms of sulfur						
Sulfate	4	0.02	0.02	0.01	0.02	0.01
Pyritic	4	0.14	0.14	0.08	0.18	0.04
Organic	4	0.45	0.46	0.37	0.50	0.06
Ash-fusion temperatures (˚F)						
Initial deformation	4	2,740	2,805	2,430	2,910	228
Softening temperature	4	2,815	2,910	2,530	2,910G	190
Fluid temperature	4	2,855	2,910	2,680	2,910G	115

Table A1-16. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Star Lake coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (°F). G, greater than value shown]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	46	13.2	12.8	10.0	18.5	1.9
Volatile matter	46	30.9	31.1	22.2	37.6	3.0
Fixed carbon	46	34.1	34.3	21.1	41.8	4.6
Ash	46	21.9	21.4	11.6	44.7	7.3
Hydrogen	46	5.3	5.4	4.0	5.9	0.4
Carbon	46	49.7	50.2	32.4	59.2	6.0
Nitrogen	46	1.0	1.0	0.7	1.2	0.1
Oxygen	46	21.8	21.2	17.6	34.8	2.7
Sulfur	46	0.6	0.6	0.4	1.9	0.2
Calorific value						
Btu/lb	46	8,830	8,940	5,780	10,470	1,060
Forms of sulfur						
Sulfate	40	0.01	0.01	0.01	0.01	0.00
Pyritic	46	0.14	0.09	0.01	1.25	0.20
Organic	46	0.46	0.47	0.28	0.65	0.08
Ash-fusion temperatures (°F)						
Initial deformation	46	2,730	2,800	2,260	2,910G	155
Softening temperature	46	2,770	2,800	2,380	2,910G	114
Fluid temperature	46	2,805	2,800	2,640	2,910G	69

Table A1-17. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Henry Mountains coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F). G, greater than value shown]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	18	11.3	11.6	4.9	14.7	2.3
Volatile matter	18	34.6	35.0	27.4	38.2	2.4
Fixed carbon	18	39.5	39.8	30.6	48.7	5.0
Ash	18	14.6	13.7	7.1	27.3	5.9
Hydrogen	18	5.4	5.4	4.7	5.8	0.3
Carbon	18	56.2	57.5	44.0	62.3	5.3
Nitrogen	18	1.1	1.1	0.7	1.2	0.1
Oxygen	18	21.7	22.4	16.0	25.6	2.3
Sulfur	18	1.1	0.7	0.4	3.2	0.9
Calorific value						
Btu/lb	18	9,840	10,050	7,710	10,920	910
Forms of sulfur						
Sulfate	18	0.04	0.01	0.01	0.17	0.05
Pyritic	18	0.58	0.29	0.06	2.10	0.62
Organic	18	0.52	0.42	0.18	1.09	0.31
Ash-fusion temperatures (˚F)						
Initial deformation	18	2,325	2,280	2,055	2,800G	238
Softening temperature	18	2,405	2,375	2,120	2,800G	223
Fluid temperature	18	2,500	2,510	2,150	2,800G	203

Table A1-18. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Kaiparowits Plateau coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (°F). G, greater than value shown]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	10	20.3	19.9	15.6	25.9	3.1
Volatile Matter	10	32.5	34.0	26.7	35.1	3.2
Fixed Carbon	10	36.3	37.1	29.7	40.9	3.9
Ash	10	11.0	9.2	4.4	24.9	6.5
Hydrogen	10	6.0	6.1	5.0	6.3	0.4
Carbon	10	52.0	54.1	42.9	56.8	5.1
Nitrogen	10	0.9	0.9	0.8	1.0	0.1
Oxygen	10	29.4	30.1	24.5	32.3	2.4
Sulfur	10	0.8	0.7	0.5	1.6	0.3
Calorific value						
Btu/lb	10	9,030	9,360	7,430	9,860	900
Forms of sulfur						
Sulfate	10	0.01	0.01	0.01	0.02	0.00
Pyritic	10	0.34	0.21	0.07	1.07	0.31
Organic	10	0.43	0.44	0.36	0.54	0.06
Ash-fusion temperatures (°F)						
Initial deformation	10	2,185	2,120	1,960	2,800G	250
Softening temperature	10	2,285	2,220	2,060	2,800G	216
Fluid temperature	10	2,375	2,320	2,170	2,800G	193

Table A1-19. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion-temperatures of coal from the Wasatch Plateau coal field.

[All values are reported on the as-received basis and are in percent except calorific value (Btu/lb) and ash-fusion-temperatures (˚F). G, greater than value shown]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	73	5.9	6.1	1.9	13.7	2.7
Volatile matter	73	40.9	41.8	25.6	47.2	4.3
Fixed carbon	73	43.9	44.8	26.3	50.8	4.4
Ash	73	9.3	8.1	2.2	34.4	6.2
Hydrogen	73	5.8	5.8	4.3	6.5	0.4
Carbon	73	67.1	69.4	37.6	74.5	6.8
Nitrogen	73	1.2	1.3	0.3	1.6	0.3
Oxygen	73	16.0	16.0	11.4	22.9	2.7
Sulfur	73	0.6	0.6	0.4	2.3	0.3
Calorific value						
Btu/lb	73	12,020	12,480	6,440	13,470	1,310
Forms of sulfur						
Sulfate	66	0.02	0.01	0.01	0.11	0.02
Pyritic	73	0.19	0.12	0.02	1.61	0.22
Organic	73	0.43	0.41	0.17	0.79	0.12
Ash-fusion temperatures (˚F)						
Initial deformation	72	2,315	2,300	1,780	2,910G	242
Softening temperature	72	2,400	2,370	1,880	2,910G	230
Fluid temperature	72	2,515	2,520	1,980	2,910G	235

Appendix 2—Number of Samples, Mean, Median, Range, and Standard Deviation of Ash and 38 Elements for High-Priority Coal Fields in the Colorado Plateau Coal Assessment Area

Table A2-1. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Black Mesa coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to an insufficient number of analyses above the lower detection limit]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	31	7.6	6.7	3.2	22	3.7
Si	31	1.5	1.2	0.28	5.4	1.1
Al	31	0.7	0.54	0.21	2.8	0.53
Ca	31	0.56	0.44	0.24	1.3	0.31
Mg	31	0.1	0.094	0.045	0.25	0.038
Na	31	0.099	0.11	0.014	0.24	0.054
K	31	0.042	0.023	0.002	0.23	0.048
Fe	31	0.27	0.26	0.13	0.49	0.078
Ti	28	0.05	0.044	0.019	0.14	0.026
Parts per million						
As	31	1.3	1.0	0.5L	10	1.7
B	31	27	26	14	60	10
Ba	31	330	310	170	650	110
Be	25	0.76	0.48	0.1	3.1	0.74
Cd	---	---	---	---	---	---
Co	31	1.0	0.77	0.74L	4.3	0.82
Cr	31	4.0	3.2	0.96	15	2.8
Cu	31	5.4	4.6	2.3	14	2.5
F	31	33	30	20L	85	20
Ga	31	3.0	1.8	0.64	11	2.3
Hg	31	0.04	0.04	0.02	0.13	0.02
La	17	6.1	5.4	3.5L	22	4.7
Li	31	3.8	2.7	1.1	19	3.3
Mn	31	9.6	7.8	3.0	48	8.1
Mo	29	0.95	0.87	0.3	2.2	0.49
Nb	29	1.9	1.5	0.68	11	1.8
Ni	31	2.3	1.8	0.67	6.5	1.5
P	---	---	---	---	---	---
Pb	31	2.6	2.0	1.1L	12	2.1
Sb	31	0.3	0.3	0.1L	0.9	0.2
Sc	31	1.3	1.0	0.46	3.2	0.72
Se	31	1.4	1.4	0.7	2.2	0.4
Sr	31	150	140	49	280	64
Th	---	---	---	---	---	---
U	31	0.74	0.62	0.24L	2.5	0.48
V	31	9.7	7.6	3.2	32	6.8
Y	31	3.7	2.9	1.0	11	2.5
Yb	26	0.43	0.32	0.12	1.5	0.33
Zn	31	6.7	3.5	1.1	70	12
Zr	31	16	13	3.2	43	9.6

Table A2-2. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Book Cliffs coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	22	17	16	5.1	45	10
Si	22	5.0	4.4	1.4	12	2.9
Al	22	2.3	1.9	0.82	8.3	1.8
Ca	22	0.38	0.059	0.022	3.9	0.89
Mg	22	0.077	0.029	0.01	0.43	0.11
Na	22	0.083	0.076	0.048	0.19	0.037
K	22	0.12	0.098	0.017	0.51	0.12
Fe	22	0.28	0.13	0.045	1.2	0.32
Ti	22	0.096	0.086	0.042	0.21	0.046
			Parts per million			
As	22	1.5	0.49	0.1L	7.0	2.1
B	22	84	86	52	110	16
Ba	22	120	77	30	380	94
Be	22	2.9	2.7	0.61	8.2	1.7
Cd	22	0.13	0.1	0.07L	0.34	0.1
Co	21	2.1	1.9	0.77L	5.1	1.1
Cr	20	10	9.2	2.8	40	7.8
Cu	22	11	8.6	5.4	35	6.2
F	22	93	58	25	300	75
Ga	22	5.8	5.1	2.2	15	3.3
Hg	22	0.07	0.04	0.01	0.33	0.09
La	22	12	8.3	7.2L	67	14
Li	22	19	14	5.7	75	17
Mn	22	5.6	3.1	1.5L	19	5.4
Mo	21	0.69	0.52	0.16	2.4	0.53
Nb	22	6.2	5.4	3.6	11	2.2
Ni	22	6.7	5.6	2.0L	28	5.4
P	22	270	87	44L	1200	340
Pb	22	9.6	7.5	2.6L	38	8
Sb	21	1.7	1.2	0.4	5.9	1.4
Sc	22	3.5	3.1	1.4	9.7	1.7
Se	22	1.5	1.2	0.1L	5.3	1.1
Sr	22	51	32	11	180	46
Th	22	4.6	3.5	1.8	15	3.2
U	22	2.5	2.0	0.69	6.8	1.6
V	22	21	17	9.8	78	14
Y	22	11	10	6.6	23	4.2
Yb	22	1.1	0.87	0.5	2.5	0.53
Zn	22	19	12	3.9	89	19
Zr	22	61	54	36	130	23

Table A2-3. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Carbondale coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Percent						
Ash	10	7.7	7.7	4.1	12	2.2
Si	10	1.6	1.6	0.66	2.9	0.73
Al	10	0.92	0.82	0.41	2.1	0.46
Ca	10	0.4	0.4	0.16	0.73	0.18
Mg	10	0.074	0.087	0.013	0.1	0.028
Na	10	0.14	0.16	0.001	0.25	0.09
K	10	0.027	0.024	0.01	0.048	0.012
Fe	10	0.41	0.31	0.19	0.94	0.25
Ti	10	0.045	0.044	0.027	0.07	0.014
Parts per million						
As	9	1.0	0.46	0.13	3.1	1.1
B	10	57	55	20	130	33
Ba	10	260	240	190	380	67
Be	10	0.39	0.32	0.18	1.0	0.25
Cd	10	0.06	0.04	0.06L	0.12	0.03
Co	10	1.0	0.98	0.78	1.4	0.23
Cr	10	1.9	1.7	0.1L	3.8	1.0
Cu	10	4.6	4.5	3.5	6.0	0.9
F	10	120	80	40	450	120
Ga	10	3.5	2.6	1.8	8.2	2.1
Hg	10	0.07	0.02	0.01	0.31	0.1
La	9	7.0	6.2	6.2L	12	3.2
Li	10	8.8	8.1	5.2	20	4.4
Mn	10	12	8.2	4.8	40	11
Mo	10	0.62	0.5	0.55L	1.5	0.37
Nb	10	1.8	1.8	2.3L	2.8	0.57
Ni	10	1.9	1.6	0.79	5.1	1.2
P	10	570	310	170L	2300	660
Pb	10	2.8	2.8	1.6L	4.7	1.1
Sb	10	0.2	0.2	0.1L	0.3	0.1
Sc	10	1.0	0.92	0.64	1.8	0.35
Se	10	1.0	1.1	0.1L	1.5	0.4
Sr	10	190	170	79	380	98
Th	10	2.0	2.0	0.72	3.8	0.9
U	10	0.6	0.48	0.23L	1.4	0.51
V	10	5.2	4.8	3.2	8.2	1.6
Y	10	4.1	3.9	1.8	8.2	2.1
Yb	10	0.39	0.39	0.18	0.71	0.17
Zn	10	4.5	3.9	1.2L	9.8	2.8
Zr	10	18	15	8.2	35	9.5

Table A2-4. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Crested Butte coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. Leaders (---) indicate statistics could not be calculated owing to an insufficient number of analyses above the lower detection limit]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
			Percent			
Ash	3	4.9	4.8	4.6	5.3	0.36
Si	3	0.79	0.78	0.67	0.9	0.11
Al	3	0.62	0.6	0.58	0.69	0.06
Ca	3	0.3	0.31	0.23	0.37	0.073
Mg	3	0.064	0.072	0.047	0.074	0.015
Na	3	0.031	0.034	0.005	0.055	0.025
K	3	0.017	0.017	0.011	0.024	0.0065
Fe	3	0.67	0.69	0.49	0.82	0.16
Ti	3	0.027	0.027	0.025	0.029	0.002
			Parts per million			
As	3	0.39	0.43	0.31	0.44	0.072
B	3	20	4.6	3.4	53	28
Ba	3	80	92	53	96	24
Be	3	0.33	0.24	0.23	0.53	0.17
Cd	3	0.07	0.05	0.05	0.11	0.03
Co	3	1.3	1.1	1.1	1.6	0.27
Cr	3	2.1	2.0	1.7	2.7	0.51
Cu	3	3.9	3.9	3.7	4.1	0.21
F	3	95	120	35	130	52
Ga	3	2.1	2.3	1.4	2.7	0.62
Hg	3	0.06	0.06	0.06	0.07	0.01
La	---	---	---	---	---	---
Li	3	6.1	5.9	5.3	7.0	0.9
Mn	3	31	31	25	38	6.5
Mo	3	0.4	0.34	0.32	0.53	0.12
Nb	---	---	---	---	---	---
Ni	3	2.8	2.7	2.3	3.4	0.54
P	3	450	610	130	610	280
Pb	---	---	---	---	---	---
Sb	---	---	----	---	---	---
Sc	3	0.89	0.92	0.8	0.96	0.086
Se	3	1.0	0.9	0.7	1.4	0.4
Sr	3	81	80	72	92	10
Th	3	1.4	1.5	0.8	1.9	0.57
U	3	1.1	1.1	0.28	2.1	0.89
V	3	3.9	3.7	3.4	4.6	0.64
Y	3	3.4	3.4	3.2	3.7	0.25
Yb	3	0.28	0.24	0.23	0.37	0.079
Zn	3	2.5	2.9	1.4	3.2	0.97
Zr	3	9.8	9.6	9.2	11	0.72

Table A2-5. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Danforth Hills coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
			Percent			
Ash	50	13	8.0	2.4	45	11
Si	49	3.3	1.6	0.32	15	3.6
Al	49	1.3	1.0	0.18	4.2	0.96
Ca	49	0.49	0.37	0.16	2.2	0.35
Mg	50	0.1	0.1	0.009	0.36	0.068
Na	50	0.078	0.04	0.003	1.1	0.15
K	49	0.12	0.044	0.002	0.65	0.16
Fe	49	0.31	0.22	0.084	1.0	0.24
Ti	49	0.058	0.04	0.009	0.2	0.045
			Parts per million			
As	50	1.5	0.72	0.35	11	1.9
B	50	48	45	21	83	15
Ba	50	240	190	81	940	170
Be	46	1.2	1.0	0.14L	4.4	1.0
Cd	50	0.08	0.04	0.01L	0.45	0.11
Co	50	2.3	2.0	0.33	8.8	1.8
Cr	48	7.5	4.2	0.1L	47	8.7
Cu	50	6.4	4.1	1.3	33	5.9
F	50	120	90	20L	510	100
Ga	50	3.2	2.3	0.62	14	2.9
Hg	50	0.05	0.02	0.01L	0.39	0.07
La	44	6.8	5.6	1.2L	22	5.3
Li	50	6.5	3.3	0.28	63	10
Mn	50	21	8.9	1.6L	150	31
Mo	46	0.68	0.5	0.071L	3.1	0.65
Nb	47	2.2	1.4	0.34	13	2.8
Ni	50	7.0	4.7	0.86	33	7.3
P	50	520	320	44L	3700	700
Pb	50	4.8	2.3	0.72L	57	8.6
Sb	50	0.8	0.5	0.1L	4.4	0.9
Sc	50	1.8	1.3	0.77L	8.8	1.6
Se	44	0.7	0.6	0.3	1.9	0.3
Sr	50	120	87	11	520	110
Th	50	2.4	2.1	0.3	10	1.8
U	50	1.4	1.1	0.2L	6.3	1.2
V	50	15	8.2	2.1	88	16
Y	50	5.9	4.2	1.0	22	5.1
Yb	50	0.53	0.41	0.1	2.2	0.45
Zn	50	15	6.8	1.2	100	21
Zr	50	28	20	2.4	110	25

Table A2-6. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Durango coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	31	21	16	3.5	49	13
Si	31	6.1	4.3	1.1	16	4.3
Al	31	2.6	2.0	0.46	5.8	1.6
Ca	31	0.14	0.11	0.021	0.61	0.13
Mg	31	0.085	0.067	0.006	0.31	0.068
Na	31	0.075	0.037	0.012	0.33	0.083
K	31	0.14	0.068	0.004	0.75	0.18
Fe	31	0.56	0.34	0.056	2.8	0.62
Ti	31	0.11	0.091	0.027	0.26	0.061
			Parts per million			
As	31	4.8	0.42	0.1L	85	15
B	31	22	17	7.6	83	16
Ba	31	260	210	7.9	970	240
Be	29	1.2	0.66	0.29	6.1	1.2
Cd	31	0.15	0.08	0.04L	1.4	0.26
Co	29	2.5	2.1	0.62	5.6	1.4
Cr	29	4.4	3.8	1.5	12	2.9
Cu	31	12	9.7	6.0L	51	9.5
F	31	140	130	20L	430	100
Ga	31	5.9	4.8	1.5	16	3.6
Hg	31	0.08	0.03	0.01L	0.49	0.11
La	31	11	8.3	3.3L	26	6.0
Li	31	22	18	4.5	110	18
Mn	31	15	11	1.7L	80	16
Mo	29	2.2	1.1	0.21	26	4.7
Nb	31	4.6	3.9	1.4L	9.4	2.3
Ni	30	4.9	3.4	1.6	19	3.7
P	30	190	90	44L	700	200
Pb	31	6.6	5.2	2.7L	18	4.0
Sb	31	0.7	0.3	0.1	8.2	1.5
Sc	29	2.7	2.4	1.1	5.8	1.2
Se	31	1.7	1.6	0.6	3.5	0.7
Sr	31	93	53	10	1100	200
Th	30	3.8	2.7	0.88	15	3.1
U	31	2	1.2	0.46	8.5	1.8
V	31	18	14	2.8	65	14
Y	31	6.9	5.7	2.5L	13	3.1
Yb	31	0.66	0.5	0.21	2.0	0.45
Zn	31	14	11	2.0	51	12
Zr	31	48	42	17	110	25

Table A2-7. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Grand Hogback coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to an insufficient number of analyses above the lower detection limit]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	6	9.4	9.6	6.7	12	2.3
Si	6	2.0	1.6	1.3	3.2	0.8
Al	6	1.4	1.0	0.98	2.2	0.57
Ca	6	0.49	0.28	0.17	1.1	0.4
Mg	6	0.041	0.029	0.026	0.088	0.024
Na	6	0.057	0.061	0.043	0.072	0.011
K	6	0.038	0.031	0.022	0.071	0.019
Fe	6	0.14	0.12	0.051	0.34	0.1
Ti	6	0.061	0.053	0.044	0.088	0.019
Parts per million						
As	6	1.3	1.5	0.41	2.1	0.59
B	6	120	130	66	150	29
Ba	6	220	220	150	280	46
Be	6	0.56	0.47	0.29	1.2	0.34
Cd	---	---	---	---	---	---
Co	5	1.5	1.4	1.3	2.3	0.41
Cr	5	2.4	2.3	1.5	3.5	0.74
Cu	6	6.7	6.7	3.9	10	2.2
F	6	44	38	25	85	23
Ga	6	6.6	5.7	2.9	12	3.3
Hg	6	0.04	0.03	0.01L	0.1	0.03
La	4	11	9.1	6.6	18	5.2
Li	6	11	10	7.8	15	2.8
Mn	6	32	12	7.2	110	40
Mo	5	1.9	1.9	1.7	2.1	0.13
Nb	5	2.8	1.9	1.3	6.1	2.0
Ni	6	2.1	2.0	1.3	2.8	0.52
P	6	130	50	44L	440	160
Pb	6	5.5	4.6	3.0	9.2	2.5
Sb	6	0.3	0.2	0.1L	1.1	0.4
Sc	6	1.7	1.4	1.0	3.7	0.99
Se	6	1.2	1.2	0.8	1.9	0.5
Sr	6	130	130	68	190	39
Th	6	2.5	2.2	1.0L	4.6	1.4
U	6	1.0	0.92	0.36	2.3	0.71
V	6	8.8	7.5	4.7	15	3.8
Y	6	4.8	4.1	2.9	8.5	2.1
Yb	6	0.48	0.41	0.29	0.85	0.21
Zn	6	5.3	4.2	3.2	11	2.9
Zr	6	29	24	13	61	18

Table A2-8. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Grand Mesa coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	51	13	11	3.7	43	7.4
Si	51	3.3	2.8	0.63	14	2.5
Al	51	1.8	1.8	0.42	3.9	0.82
Ca	51	0.35	0.2	0.065	3.4	0.49
Mg	51	0.091	0.08	0.012	0.33	0.08
Na	51	0.13	0.12	0.022	0.4	0.095
K	51	0.086	0.041	0.001	0.69	0.14
Fe	51	0.36	0.26	0.064	1.3	0.29
Ti	51	0.075	0.075	0.022	0.18	0.03
			Parts per million			
As	50	1.3	0.73	0.1L	5.9	1.4
B	51	130	130	45	290	43
Ba	51	300	260	24	880	180
Be	49	0.71	0.62	0.11	2.0	0.4
Cd	51	0.09	0.08	0.06L	0.22	0.04
Co	51	1.5	1.5	0.63	3.7	0.61
Cr	51	3.5	3.0	0.1L	13	2.7
Cu	51	8.2	8.5	3.7	15	2.6
F	51	71	60	20L	230	46
Ga	51	6.6	6.1	1.9	14	2.7
Hg	50	0.05	0.04	0.01	0.19	0.04
La	45	7.9	6.6	3.7L	22	4.6
Li	51	14	13	2.2	32	7.1
Mn	51	34	15	1.8	370	57
Mo	43	1.0	0.92	0.37L	2.0	0.4
Nb	43	3.3	3.1	0.74	8.7	1.6
Ni	51	2.8	2.5	1.6L	6.5	1.4
P	51	220	130	44L	1700	280
Pb	51	7.5	6.6	1.7	30	4.3
Sb	51	0.5	0.5	0.1	1.3	0.3
Sc	51	1.8	1.8	1.1L	4.3	0.74
Se	51	1.1	1.1	0.1L	2	0.4
Sr	51	110	89	28	270	64
Th	51	3.1	2.8	0.64	7.5	1.7
U	51	1.4	1.3	0.2L	3.1	0.78
V	51	12	11	4.4	30	6.3
Y	51	5.4	5.0	1.9	13	2.8
Yb	51	0.51	0.45	0.19	1.3	0.27
Zn	51	13	9.7	2.2	39	8.5
Zr	51	34	32	7.6	87	17

Table A2-9. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Lower White River coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to an insufficient number of analyses above the lower detection limit]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	17	13	11	4.8	25	5.7
Si	17	3.3	2.7	0.19	7.1	1.9
Al	17	1.5	1.4	0.34	2.6	0.62
Ca	17	0.56	0.43	0.17	1.4	0.37
Mg	17	0.12	0.1	0.046	0.23	0.061
Na	17	0.12	0.12	0.077	0.17	0.023
K	17	0.069	0.042	0.005	0.21	0.065
Fe	17	0.38	0.3	0.094	1.9	0.42
Ti	17	0.079	0.081	0.006	0.13	0.03
			Parts per million			
As	16	0.47	0.38	0.25	0.93	0.22
B	17	53	54	30	84	14
Ba	17	360	360	110	680	170
Be	17	0.66	0.7	0.26L	1.2	0.32
Cd	---	---	---	---	---	---
Co	17	1.6	1.3	0.58	4.9	1.0
Cr	14	7.5	5.3	1.4	21	5.4
Cu	17	7.2	6.3	2.0	16	3.3
F	17	110	110	50	210	42
Ga	17	3.7	3.6	0.72	7.7	1.8
Hg	17	0.04	0.03	0.01	0.1	0.03
La	16	9.0	8.5	6.8L	17	3.9
Li	17	11	10	1.7	26	5.7
Mn	17	40	7.3	2.2	540	130
Mo	14	1.1	0.85	0.48	2.3	0.6
Nb	17	5.0	4.9	0.72	13	2.7
Ni	17	4.2	2.9	1.3	11	2.9
P	17	560	520	130L	1400	310
Pb	17	7.5	5.4	0.72	41	9.1
Sb	16	0.3	0.2	0.1	0.6	0.2
Sc	17	2.0	1.6	0.58	3.8	0.87
Se	17	1.1	1.1	0.4	2.3	0.4
Sr	17	170	170	30	270	67
Th	17	3.3	2.7	0.24	7.7	2.2
U	17	1.6	1.3	0.26L	3.4	0.99
V	17	15	13	2.1	34	8.0
Y	17	8.6	7.5	4.3	18	3.8
Yb	17	0.78	0.69	0.21	1.8	0.43
Zn	17	13	12	2.9	30	8.5
Zr	17	27	29	3.7	50	11

Table A2-10. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Somerset coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	58	13	12	1.8	37	8.7
Si	58	3.6	2.8	0.37	12	2.9
Al	58	1.6	1.5	0.25	4.2	1.0
Ca	58	0.21	0.16	0.025	1.2	0.18
Mg	58	0.078	0.066	0.013	0.41	0.06
Na	58	0.12	0.11	0.014	0.39	0.081
K	58	0.15	0.084	0.005	0.73	0.17
Fe	58	0.41	0.37	0.11	1.0	0.23
Ti	58	0.061	0.048	0.009	0.16	0.039
Parts per million						
As	57	2.2	1.0	0.14L	20	3.3
B	58	110	100	27	200	39
Ba	58	190	170	54	560	99
Be	54	1.3	1.0	0.078	4.7	0.98
Cd	58	0.07	0.06	0.02L	0.49	0.07
Co	57	1.6	1.3	0.27L	5.0	1.1
Cr	55	5.5	3.1	0.54	19	5.2
Cu	58	8.7	6.7	1.5	29	5.6
F	58	100	88	20L	310	60
Ga	58	3.9	3.2	0.52	11	2.5
Hg	58	0.07	0.04	0.01	0.41	0.07
La	57	9.6	8.0	2.6L	34	6.8
Li	58	10	8.0	1.4	28	6.7
Mn	58	15	7.7	0.35	160	28
Mo	48	0.85	0.68	0.13L	2.4	0.5
Nb	58	4.0	3.6	0.54	11	2.6
Ni	58	3.6	2.9	0.54	19	3.1
P	58	230	170	22L	1800	270
Pb	58	5.3	4.9	0.54L	17	3.7
Sb	58	0.7	0.6	0.1	4.9	0.8
Sc	58	2.1	1.7	0.27L	6.6	1.4
Se	58	1.0	1.0	0.4	3.8	0.6
Sr	58	130	110	36	840	110
Th	40	4.0	4.3	0.5	8.9	2.3
U	58	1.5	1.3	0.25	5.5	1.1
V	58	16	12	1.8	60	13
Y	58	7.1	6.0	1.3	20	4.6
Yb	58	0.62	0.49	0.09	1.6	0.37
Zn	58	14	8.4	1.1	47	12
Zr	58	43	37	3.3	140	32

Table A2-11. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Yampa coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
			Percent			
Ash	349	11	7.5	1.7	50	9.3
Si	349	2.7	1.5	0.15	18	3.3
Al	349	1.3	0.99	0.2	9.3	1.1
Ca	349	0.33	0.24	0.048	5.0	0.38
Mg	349	0.072	0.047	0.006	0.98	0.09
Na	349	0.059	0.037	0.003	0.88	0.077
K	349	0.088	0.036	0.002	1.1	0.15
Fe	349	0.52	0.19	0.037	7.1	0.79
Ti	349	0.052	0.042	0.006	0.3	0.042
			Parts per million			
As	349	1.8	0.55	0.13L	39	3.9
B	349	67	61	6.7	310	40
Ba	349	200	160	21	1100	130
Be	338	1.2	0.65	0.038L	14	1.6
Cd	349	0.06	0.03	0.01L	0.6	0.08
Co	346	1.3	0.94	0.1L	30	1.8
Cr	341	4.3	2.4	0.1L	36	5.7
Cu	349	6.5	5.0	1.3	120	7.8
F	349	110	80	20L	1500	140
Ga	341	4.0	3.1	0.26	24	3.3
Hg	349	0.06	0.02	0.01L	0.42	0.08
La	335	7.3	5.9	0.25L	35	5.7
Li	349	8.2	6.4	0.48	56	7.8
Mn	349	23	7.7	1.2	1100	80
Mo	314	1.0	0.72	0.21L	11	1.1
Nb	348	3.1	2.3	0.29L	20	3.1
Ni	349	3.8	2.5	0.64L	65	4.5
P	349	340	150	44L	5700	530
Pb	349	5.2	3.9	1.2L	33	4.4
Sb	347	0.3	0.2	0.1L	4.0	0.4
Sc	347	1.8	1.3	0.26L	12	1.6
Se	346	1.0	0.9	0.1L	6.4	0.7
Sr	349	170	110	15	2100	190
Th	324	2.6	1.8	0.2	15	2.3
U	349	1.0	0.73	0.18L	34	2.0
V	349	11	6.8	1.1	160	14
Y	349	6	4.7	0.72	62	5.3
Yb	342	0.59	0.47	0.06L	6.2	0.51
Zn	349	9.2	4.2	0.86	290	20
Zr	349	47	26	4.7	1000	77

Table A2-12. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Bisti coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	68	28	28	6.4	47	9.7
Si	68	7.6	7.7	1.8	13	2.8
Al	68	3.5	3.5	0.68	6.6	1.3
Ca	68	0.38	0.31	0.024	1.2	0.2
Mg	68	0.12	0.1	0.035	0.29	0.062
Na	68	0.32	0.29	0.043	0.8	0.12
K	68	0.21	0.18	0.019	0.74	0.17
Fe	68	0.59	0.47	0.11	3.6	0.45
Ti	68	0.15	0.15	0.025	0.29	0.047
Parts per million						
As	66	2.7	1.0	0.5	34	5.8
B	68	73	72	6.4	150	26
Ba	68	340	220	99	1700	330
Be	68	4.0	3.3	0.32	15	2.8
Cd	68	0.15	0.15	0.06L	0.43	0.06
Co	67	3.2	2.4	1.4	8.3	1.7
Cr	68	8.5	6.7	0.1L	70	8.5
Cu	68	16	14	1.9	36	7.2
F	68	72	70	20L	190	45
Ga	68	14	13	1.9	47	6.6
Hg	68	0.08	0.06	0.01	0.26	0.06
La	39	16	14	14L	47	8.4
Li	68	22	21	2.5	40	7.8
Mn	68	89	27	4.2	3500	420
Mo	51	2.1	1.8	0.32L	7.0	1.1
Nb	67	7.0	6.5	1.3L	21	3.0
Ni	68	4.9	3.7	0.45	23	3.5
P	68	470	430	44L	1000	300
Pb	68	13	13	2.2	26	4.5
Sb	68	1.3	0.9	0.3	6.5	1.0
Sc	68	4.2	3.7	0.45	23	2.8
Se	67	1.8	1.8	0.6	3.2	0.6
Sr	68	120	82	9.6	2100	250
Th	56	8.2	7.1	2.4	25	3.9
U	68	3.3	3.0	1.0	9.4	1.4
V	68	33	27	4.5	140	22
Y	68	15	14	1.9	34	7.8
Yb	68	1.5	1.3	0.19	3.4	0.74
Zn	68	19	15	4.5	50	12
Zr	68	69	64	9.6	240	35

Table A2-13. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Fruitland coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	32	19	19	8.2	34	6.0
Si	32	4.9	4.8	1.4	9.6	1.9
Al	32	2.4	2.2	0.62	4.1	0.85
Ca	32	0.78	0.52	0.11	3.7	0.87
Mg	32	0.1	0.099	0.054	0.24	0.036
Na	32	0.21	0.21	0.11	0.37	0.069
K	32	0.078	0.077	0.002	0.19	0.049
Fe	32	0.52	0.32	0.17	1.7	0.41
Ti	9	0.11	0.078	0.061	0.19	0.051
Parts per million						
As	32	4.6	1.0	0.32L	40	8.6
B	32	89	87	50	140	24
Ba	32	280	260	120	570	120
Be	31	0.97	0.76	0.36	3.5	0.63
Cd	32	0.14	0.1	0.04L	0.55	0.12
Co	28	1.5	1.3	0.85L	3.4	0.56
Cr	32	3.7	3.5	2.2	8.0	1.2
Cu	32	23	13	4.5	180	39
F	32	65	60	10L	190	46
Ga	32	7.0	6	2.8	17	3.3
Hg	32	0.13	0.06	0.02	0.75	0.17
La	29	14	13	5.8L	26	4.7
Li	32	20	21	8.4	33	6.6
Mn	32	45	24	5.0	400	74
Mo	22	2.3	1.5	0.74	6.1	1.7
Nb	30	4.5	4.0	1.8	8.9	1.7
Ni	31	2.6	1.9	0.71L	6.8	1.5
P	32	150	30	18L	500	190
Pb	32	130	12	3.4	1900	450
Sb	32	0.4	0.3	0.1	1.2	0.3
Sc	32	3.0	2.9	0.95	5.1	0.91
Se	32	2.0	2.0	1.1	3.5	0.6
Sr	32	130	100	40	350	70
Th	30	7.0	6.4	1.7	17	3.0
U	32	2.8	2.7	0.98	8.2	1.6
V	32	20	18	5.8	34	7.8
Y	32	6.6	6.6	2.7	13	2.7
Yb	32	0.69	0.71	0.27	1.2	0.24
Zn	32	61	8.4	3.1	830	200
Zr	32	39	38	14	76	14

Table A2-14. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Monero coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to an insufficient number of analyses above the lower detection limit]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	8	13	12	0.7	26	9.9
Si	8	4.0	3.9	0.2	7.6	3.2
Al	8	1.5	0.79	0.099	4.1	1.5
Ca	8	0.059	0.059	0.002	0.11	0.038
Mg	8	0.039	0.029	0.002	0.1	0.035
Na	8	0.038	0.024	0.001	0.11	0.038
K	8	0.11	0.05	0.004	0.35	0.12
Fe	8	0.33	0.21	0.011	1.2	0.39
Ti	8	0.096	0.086	0.006	0.22	0.077
			Parts per million			
As	8	3.0	1.2	0.33	12	4.2
B	8	33	35	3.4	60	22
Ba	8	100	85	3.2	280	99
Be	8	5.8	4.9	0.13	16	5.2
Cd	8	0.09	0.06	0.01	0.33	0.11
Co	8	7.6	6.4	2.6	13	3.5
Cr	8	12	9.9	3.1	36	10
Cu	8	5.6	5.6	0.54	9.3	2.9
F	8	64	60	40	100	21
Ga	8	6.1	4.5	0.38	16	5.5
Hg	8	0.19	0.2	0.04	0.28	0.07
La	8	11	10	6.1	17	4.9
Li	8	5.2	2.4	0.22	17	6.4
Mn	8	11	6.7	0.26	30	11
Mo	8	1.2	1.1	0.084	2.5	0.86
Nb	8	4.4	3.5	0.28L	11	3.9
Ni	8	14	14	0.61	26	7.9
P	---	---	---	---	---	---
Pb	8	4.6	3.1	0.31	12	4.0
Sb	8	2.7	2.2	0.5	6.4	2.0
Sc	8	3.6	3.9	1.1	6.2	1.8
Se	8	2.3	2.1	1.4	3.7	0.8
Sr	8	58	55	3.1	130	42
Th	8	4.5	3.7	0.91	9.8	3.4
U	8	2.1	1.7	0.4	4.9	1.6
V	8	23	27	1.5	47	17
Y	8	20	20	0.68	50	16
Yb	8	1.7	1.7	0.29	3.6	1.1
Zn	8	15	14	0.14	31	12
Zr	8	56	56	3.4	120	47

Table A2-15. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Navajo coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to an insufficient number of analyses above the lower detection limit]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	9	22	20	10	38	8.5
Si	9	5.8	4.9	2.6	11	2.8
Al	9	2.7	2.9	1.0	4.0	0.94
Ca	9	0.44	0.37	0.18	1.2	0.32
Mg	9	0.092	0.079	0.047	0.16	0.036
Na	9	0.31	0.29	0.12	0.67	0.15
K	9	0.12	0.11	0.03	0.31	0.091
Fe	9	0.6	0.49	0.28	1.2	0.32
Ti	9	0.12	0.11	0.054	0.15	0.029
			Parts per million			
As	9	4.3	1.0	1.0L	25	8.1
B	9	85	87	63	100	14
Ba	9	150	140	30	260	70
Be	9	1.4	1.3	0.63	2.3	0.59
Cd	---	---	---	---	---	---
Co	9	1.6	1.0	1.7L	3.8	1.1
Cr	9	4.7	3.9	2.7	9.7	2.2
Cu	9	12	10	6.9	20	5.7
F	9	110	80	65	220	61
Ga	9	8.3	9.7	5.2	11	2.6
Hg	9	0.08	0.04	0.02	0.33	0.1
La	---	---	---	---	---	---
Li	9	19	18	8.0	25	5.4
Mn	9	33	28	7.2	83	26
Mo	6	2.3	1.9	0.72	4.9	1.6
Nb	9	6.6	6.1	3.0	11	2.5
Ni	9	4.2	3.0	1.5L	11	3.8
P	9	430	390	90L	820	230
Pb	9	11	12	5.2	19	4.6
Sb	9	0.6	0.5	0.2	1.2	0.3
Sc	9	3.2	3.0	1.5	5.6	1.4
Se	9	1.6	1.5	1.1	2.2	0.4
Sr	9	83	69	49	210	51
Th	7	8.1	9.1	4.1	12	2.7
U	9	2.4	2.2	1.3	3.7	0.82
V	9	18	16	10	32	7.0
Y	9	7.8	7.2	4.5	11	2.3
Yb	9	0.67	0.61	0.45	1.1	0.23
Zn	9	14	8.4	4.5	45	14
Zr	9	49	46	21	75	17

Table A2-16. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Star Lake coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	46	25	24	14	46	7.3
Si	46	6.7	6.2	3.0	14	2.3
Al	46	3.6	3.8	1.4	6.0	1.2
Ca	46	0.49	0.35	0.14	1.8	0.36
Mg	46	0.093	0.077	0.042	0.4	0.058
Na	46	0.24	0.22	0.091	0.59	0.1
K	46	0.16	0.12	0.028	0.73	0.15
Fe	46	0.56	0.45	0.24	1.9	0.36
Ti	46	0.17	0.16	0.069	0.29	0.048
			Parts per million			
As	46	2.2	0.9	0.6L	19	3.7
B	46	66	66	27	140	22
Ba	46	91	77	32	230	49
Be	41	2.5	1.8	0.48	8.1	2.0
Cd	46	0.13	0.11	0.03L	0.53	0.12
Co	46	2.8	2.1	1.1	8.4	1.7
Cr	46	6.4	5.9	0.1L	18	2.7
Cu	46	17	16	5.4	34	4.9
F	46	87	70	20L	340	63
Ga	46	14	13	5.0	21	4.1
Hg	46	0.07	0.05	0.01L	0.72	0.11
La	28	16	16	6.8L	27	4.8
Li	46	23	20	6.5	42	9.5
Mn	46	57	33	8.0	320	70
Mo	31	2.2	1.9	0.95	5.8	0.98
Nb	31	7.2	6.4	3.5	19	3.4
Ni	42	5.6	5.3	2.5L	14	3.0
P	46	100	30	44L	440	120
Pb	46	13	13	6.2	30	4.7
Sb	46	1.3	0.9	0.3	4.3	1.0
Sc	45	3.4	3.3	1.6	6.1	1.0
Se	46	2.3	2.2	1.0	3.7	0.7
Sr	46	100	98	42	230	41
Th	46	7.4	7.4	0.1L	16	3.4
U	46	3.7	3.4	1.8	8.0	1.3
V	46	25	24	11	43	8.3
Y	46	11	9.2	3.0	27	5.9
Yb	46	1.2	1.0	0.48	2.7	0.56
Zn	46	16	13	4.1	52	11
Zr	46	65	67	25	160	27

Table A2-17. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Henry Mountains coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to an insufficient number of analyses above the lower detection limit]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
			Percent			
Ash	18	15	14	7.9	26	5.2
Si	18	3.7	3.6	1.2	8.3	1.7
Al	18	1.3	1.3	0.39	2.8	0.71
Ca	18	0.9	0.91	0.28	2.0	0.44
Mg	18	0.14	0.15	0.038	0.19	0.044
Na	18	0.085	0.072	0.014	0.2	0.057
K	18	0.087	0.065	0.002	0.26	0.078
Fe	18	0.55	0.32	0.14	2.3	0.61
Ti	18	0.089	0.08	0.03	0.17	0.038
			Parts per million			
As	18	1.6	1.1	0.47	9.4	2.0
B	18	160	150	71	300	72
Ba	18	97	81	22	220	62
Be	16	1.2	0.95	0.25	2.9	0.81
Cd	18	0.09	0.08	0.08L	0.26	0.05
Co	18	1.8	1.6	0.49	4.7	1.2
Cr	17	9.8	9.0	1.4	26	6.4
Cu	18	10	10	4.8	20	4.5
F	18	42	33	20L	150	37
Ga	18	5.1	4.5	1.2	14	3.0
Hg	18	0.09	0.06	0.02	0.27	0.07
La	9	9.8	10	7.9L	14	3.9
Li	18	17	18	5.1	34	7.8
Mn	18	25	19	8.8	69	15
Mo	13	1.3	1.0	0.64	2.9	0.65
Nb	18	4.0	3.6	1.7	7.9	2.0
Ni	18	3.6	3.1	1.4	7.9	1.8
P	---	---	---	---	---	---
Pb	18	5.5	4.8	3.9L	12	2.9
Sb	18	0.6	0.4	0.1	1.9	0.5
Sc	18	2.2	1.7	0.64	4.6	1.2
Se	18	1.6	1.6	0.6	2.2	0.5
Sr	18	66	60	15	140	34
Th	17	3.7	2.7	0.93	8.3	2.6
U	18	2.8	2.4	0.74	9.4	2.1
V	18	14	13	5.5	30	7.3
Y	18	11	11	2.4	22	5.2
Yb	18	0.96	0.95	0.24	2.0	0.5
Zn	18	11	9.3	3.0	41	9.0
Zr	18	30	29	8.3	79	18

Table A2-18. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Kaiparowits Plateau coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to an insufficient number of analyses above the lower detection limit]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	10	13	10	6.3	32	8.1
Si	10	3.1	2.2	1.1	9.8	2.7
Al	10	1.2	0.7	0.34	3.4	1.1
Ca	10	0.85	0.85	0.5	1.3	0.24
Mg	10	0.15	0.15	0.11	0.22	0.034
Na	10	0.069	0.011	0.003	0.33	0.12
K	10	0.071	0.022	0.008	0.38	0.11
Fe	10	0.34	0.31	0.094	0.6	0.17
Ti	10	0.077	0.047	0.022	0.23	0.069
			Parts per million			
As	10	4.2	2.1	0.52	27	8.1
B	10	120	120	78	170	30
Ba	10	150	73	26	810	230
Be	9	0.85	0.81	0.37	1.6	0.46
Cd	---	---	---	---	---	---
Co	10	1.3	1.1	0.41	3.6	0.92
Cr	10	9.4	6.9	2.3	34	9.5
Cu	10	9.1	7.1	3.5	23	6
F	10	76	55	40	240	61
Ga	10	3.6	2.4	1.3	11	3.0
Hg	10	0.06	0.07	0.01	0.13	0.04
La	---	---	---	---	---	---
Li	10	17	10	2.9	70	20
Mn	10	30	28	15	51	12
Mo	10	1.1	0.59	0.59L	4.3	1.2
Nb	4	4.5	3.3	1.6L	11	4.3
Ni	10	4.1	3.4	1.3	9.5	2.5
P	10	120	90	44L	130	140
Pb	10	5.6	4.1	2.4	11	3.2
Sb	10	0.4	0.3	0.1	1.0	0.3
Sc	10	2.1	1.6	0.63	4.7	1.4
Se	9	1.5	1.6	0.8	2.2	0.5
Sr	10	75	74	44	120	26
Th	10	2.1	1.2	0.49	7.7	2.3
U	10	1.3	1.0	0.16L	3.3	1.1
V	10	13	9.2	3.2	32	11
Y	10	6.6	6.0	1.9	15	3.8
Yb	10	0.52	0.41	0.19	1.1	0.32
Zn	10	16	12	4.8	48	13
Zr	10	24	17	9.5	64	18

Table A2-19. Number of samples, mean, median, range, and standard deviation of ash and 38 elements in coal from the Wasatch Plateau coal field.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Percent						
Ash	86	9.9	8.9	1.8	37	6.5
Si	86	2.6	2.1	0.39	14	2.2
Al	86	0.89	0.76	0.16	4.5	0.65
Ca	86	0.36	0.3	0.066	1.3	0.26
Mg	86	0.063	0.044	0.005	0.34	0.061
Na	86	0.15	0.13	0.014	0.42	0.12
K	86	0.059	0.035	0.001	0.41	0.076
Fe	86	0.24	0.21	0.05	0.94	0.14
Ti	86	0.056	0.05	0.013	0.2	0.033
Parts per million						
As	86	0.91	0.5	0.21L	14	1.5
B	86	86	85	23	170	38
Ba	86	63	52	2.7	610	71
Be	81	1.2	0.88	0.078L	5.4	1.2
Cd	86	0.07	0.05	0.01L	0.36	0.07
Co	86	1.4	1.0	0.25L	7.9	1.1
Cr	86	9.0	6.2	1.3	55	8.5
Cu	86	8.3	6.6	2.2	23	4.5
F	86	54	35	20L	240	52
Ga	86	3.7	2.9	0.38	26	3.5
Hg	86	0.05	0.04	0.01L	0.21	0.04
La	71	6.6	6.0	1.5L	18	3.9
Li	86	11	7.7	0.74	57	11
Mn	86	7.8	5.6	0.9	70	9.1
Mo	60	0.83	0.68	0.2	3.5	0.56
Nb	82	2.5	2.0	0.3L	11	2.1
Ni	86	4.6	3.7	0.35	13	3.1
P	86	250	180	17L	1200	250
Pb	86	10	3.8	0.88L	290	35
Sb	86	0.3	0.2	0.1L	3.2	0.4
Sc	86	1.8	1.5	0.35L	6.5	1.2
Se	86	1.5	1.3	0.8	5.7	0.7
Sr	86	110	80	15	460	94
Th	53	1.8	1.5	0.29	5.3	1.3
U	86	1.0	0.81	0.22L	3.5	0.72
V	86	12	9.8	2.0	55	9.0
Y	86	6.9	5.6	1.1	26	4.9
Yb	86	0.65	0.54	0.12	2.6	0.49
Zn	86	10	5.7	0.85	55	10
Zr	86	30	21	6.9	130	24

Appendix 3—Explanation of Data in the Coplateau.txt File Used to Create the ArcView Shapefile for Colorado Plateau Chemical Data

The digital files used for the Quality Characterization of Cretaceous coal from the Colorado Plateau Coal Assessment Area are presented as views in the ArcView project. The ArcView project and digital files are stored on both discs of this CD-ROM set. 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 Arc View 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.

The following information describes the data presented in coplateau.txt and is also included as chemterm.pdf in the ArcView project

Table A3 is a simplified data dictionary showing field name, value, and description for all the columns in the ASCII file "coplateau.txt." This file was created by R.H. Affolter of the U.S. Geological Survey from the USGS USCHEM database and was used to create the ArcView chemical data shapefile for the Colorado Plateau. Column definitions are modified from Bragg and others (1998). All column headings with a "_Q" suffix in the coplateau.txt file are used for the qualified data values and are indicated by L (less than), B (not determined), N (not detected), G (greater than). All columns except DLAT and DLONG are in text to preserve significant figures. For detailed descriptions of U.S. Geological Survey analytical methods, see Swanson and Huffman (1976); Baedecker (1987); and Golightly and Simon (1989). For limitations of the coal quality data see Finkelman and others (1994).

Table A3. Explanation of coplateau.txt file used to create the ArcView shapefile for Colorado Plateau chemical data.

Field name	Value	Description
SAMPID	TEXT	Analysis Identification Number.
STATE	TEXT	Name of State where sample was collected.
COUNTY	TEXT	Name of county in state where sample was collected.
DLAT	REAL	Decimal Latitude coordinate for point source location of coal sample.
DLONG	REAL	Decimal Longitude coordinate for point source location of coal sample.
CFIELD	TEXT	Coal Field Name.
CFORMATN	TEXT	Formation Name—Stratigraphic formation name specified by the collector of the sample.
CGROUP	TEXT	Group Name—Stratigraphic group name specified by the collector of the sample.
CBED	TEXT	Bed Name—Stratigraphic bed name specified by the collector of the sample.
DEPTH	TEXT	Depth from the surface of the earth to the top of the sample if the sample is part of a drill core. If samples are not drill cores, but samples are benched, then depth is a measure from the top of the uppermost bench to the top of the next sample in the benched series. (Depth is measured in inches).
SAMPTHK	TEXT	Thickness of the sample, measured in inches.
COMMENTS	TEXT	Used as a comment field to describe the mine name, the drill hole identified, or other miscellaneous information about the sample.
SYSTEM	TEXT	System designates a fundamental unit of the sample's geologic age.
POINTID	TEXT	The field number assigned by the collector or submitter of the sample.
MOISTR	TEXT	(as-received basis) Moisture content in percent as determined by ASTM method D-3173.
VOLMAT	TEXT	(as-received basis) Volatile matter content in percent as determined by ASTM method D-3175.

Table A3. Explanation of coplateau.txt file used to create the ArcView shapefile for Colorado Plateau chemical data—*Continued*.

Field name	Value	Description
FIXEDC	TEXT	(as-received basis) Fixed Carbon content in percent as determined by ASTM method D-3172.
STDASH	TEXT	(as-received basis) Ash yield in percent as determined by ASTM method D-3174 (ash obtained at 750˚C).
HYDRGN	TEXT	(as-received basis) Hydrogen content in percent as determined by ASTM method D-3178.
CARBON	TEXT	(as-received basis) Carbon content in percent as determined by ASTM method D-3178 .
NITRGN	TEXT	(as-received basis) Nitrogen content in percent as determined by ASTM method D-3179.
OXYGEN	TEXT	(as-received basis) Oxygen content in percent as determined by ASTM method D-3176.
SULFUR	TEXT	(as-received basis) Sulfur content in percent as determined by ASTM method D-3177.
BTU	TEXT	(as-received basis) Gross calorific value of the coal sample expressed in British Thermal Units (BTU/lb) as determined by ASTM method D-2015.
SLFATE	TEXT	(as-received basis) Sulfate content in percent as determined by ASTM method D-2492.
SLFPYR	TEXT	(as-received basis) Pyritic Sulfur content in percent as determined by ASTM method D-2492.
SLFORG	TEXT	(as-received basis) Organic Sulfur content in percent as determined by ASTM method D-2492.
ASHDEF	TEXT	(as-received basis) Ash Deformation temperature in ˚F as determined by ASTM method D1857 in reducing atmosphere.
ASHSOF	TEXT	(as-received basis) Ash Softening temperature in ˚F as determined by ASTM method D1857 in reducing atmosphere.
ASHFLD	TEXT	(as-received basis) Ash Fluid temperature in ˚F as determined by ASTM method D1857 in reducing atmosphere.
FRESWL	TEXT	(as-received basis) Free-Swelling index as determined by ASTM method D-720.
ADLOSS	TEXT	(as-received basis) Air-Dried loss content in percent as determined by ASTM method D-2013.
GSASH	TEXT	Ash yield in percent as determined by USGS laboratories (ash obtained at 525˚C).
SI_E	TEXT	(as-received whole-coal basis) Silicon (Si) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525˚C)—May be converted from SiO_2 content in percent which was determined by the same method.
AL_E	TEXT	(as-received whole-coal basis) Aluminum (Al) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525˚C)—May be converted from Al_2O_3 content in percent which was determined by the same method.
CA_E	TEXT	(as-received whole-coal basis) Calcium (Ca) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525˚C)—May be converted from CaO content in percent which was determined by the same method.
MG_E	TEXT	(as-received whole-coal basis) Magnesium (Mg) content in percent converted from content as determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption: ash obtained at 525˚C)—May be converted from MgO content in percent which was determined by the same method.
NA_E	TEXT	(as-received whole-coal basis) Sodium (Na) content in percent converted from content as determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption: ash obtained at 525˚C)—May be converted from Na_2O content in percent which was determined by the same method.
K_E	TEXT	(as-received whole-coal basis) Potassium (K) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525˚C)—May be converted from K_2O content in percent which was determined by the same method.
FE_E	TEXT	(as-received whole-coal basis) Iron (Fe) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525˚C)—May be converted from Fe_2O_3 content in percent which was determined by the same method.
TI_E	TEXT	(as-received whole-coal basis) Titanium (Ti) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525˚C)—May be converted from TiO_2 content in percent which was determined by the same method.
AS_E	TEXT	(as-received whole-coal basis) Arsenic (As) content in parts-per-million as determined on whole-coal by USGS laboratories using either wet chemistry analysis or Instrumental Neutron Activation Analysis (INAA).
B_E	TEXT	(as-received whole-coal basis) Boron (B) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C).
BA_E	TEXT	(as-received whole-coal basis) Barium (Ba) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C).

Table A3. Explanation of coplateau.txt file used to create the ArcView shapefile for Colorado Plateau chemical data—*Continued*.

Field name	Value	Description
BE_E	TEXT	(as-received whole-coal basis) Beryllium (Be) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C).
CD_E	TEXT	(as-received whole-coal basis) Cadmium (Cd) content in parts-per-million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption—ash obtained at 525˚C).
CO_E	TEXT	(as-received whole-coal basis) Cobalt (Co) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either semi-quantitative 6-step emission spectrographic analysis or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C) or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
CR_E	TEXT	(as-received whole-coal basis) Chromium (Cr) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either semi-quantitative 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C) or on a whole-coal basis using Instrumental Neutron Activation Analysis.
CU_E	TEXT	(as-received whole-coal basis) Copper (Cu) content in parts-per-million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption—ash obtained at 525˚C).
F_E	TEXT	(as-received whole-coal basis) Fluorine (F) content in parts-per-million as determined on whole-coal by USGS laboratories using wet chemistry analysis (ion-selective electrode).
GA_E	TEXT	(as-received whole-coal basis) Gallium (Ga) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C).
GE_E	TEXT	(as-received whole-coal basis) Germanium (Ge) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C).
HG_E	TEXT	(as-received whole-coal basis) Mercury (Hg) content in parts-per-million as determined on whole-coal by USGS laboratories using wet chemistry analysis (cold-vapor atomic absorption).
LA_E	TEXT	(as-received whole-coal basis) Lanthanum (La) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C) or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
LI_E	TEXT	(as-received whole-coal basis) Lithium (Li) content in parts-per-million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption—ash obtained at 525˚C).
MN_E	TEXT	(as-received whole-coal basis) Manganese (Mn) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C) and later using wet chemistry analysis (atomic absorption on the ash).
MO_E	TEXT	(as-received whole-coal basis) Molybdenum (Mo) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centrigrade).
NB_E	TEXT	(as-received whole-coal basis) Niobium (Nb) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centrigrade).
NI_E	TEXT	(as-received whole-coal basis) Nickel (Ni) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centrigrade).
P_E	TEXT	(as-received whole-coal basis) Phosphorus (P) content in parts-per-million as determined on the coal ash or whole-coal by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525˚C)—May be converted from P_2O_5 content in percent which was determined by the same method.

Table A3. Explanation of coplateau.txt file used to create the ArcView shapefile for Colorado Plateau chemical data—*Continued*.

Field name	Value	Description
PB_E	TEXT	(as-received whole-coal basis) Lead (Pb) content in parts-per-million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption—ash obtained at 525˚C).
SB_E	TEXT	(as-received whole-coal basis) Antimony (Sb) content in parts-per-million as determined on whole-coal by USGS laboratories using wet chemistry analysis (Rhodamine B) or on Instrumental Neutron Activation Analysis (INAA).
SC_E	TEXT	(as-received whole-coal basis) Scandium (Sc) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C) or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
SE_E	TEXT	(as-received whole-coal basis) Selenium (Se) content in parts-per-million as determined on whole-coal basis by USGS laboratories using Xray-fluorescence or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
SR_E	TEXT	(as-received whole-coal basis) Strontium (Sr) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C).
TH_E	TEXT	(as-received whole-coal basis) Thorium (Th) content in parts-per-million as determined on whole-coal basis by USGS laboratories using Delayed Neutron Analysis (DNA) for older samples and Instrumental Neutron Activation analysis (INAA).
U_E	TEXT	(as-received whole-coal basis) Uranium (U) content in parts-per-million as determined on whole-coal basis by USGS laboratories using Delayed Neutron Analysis (DNA).
V_E	TEXT	(as-received whole-coal basis) Vanadium (V) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C).
Y_E	TEXT	(as-received whole-coal basis) Yttrium (Y) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C).
YB_E	TEXT	(as-received whole-coal basis) Ytterbium (Yb) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C) or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
ZN_E	TEXT	(as-received whole-coal basis) Zinc (Zn) content in parts-per-million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption ash obtained at 525˚C).
ZR_E	TEXT	(as-received whole-coal basis) Zirconium (Zr) content in parts-per-million converted from content determined on coal ash by USGS laboratories using either 6-step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525˚C).

Appendix 4—Supplemental Selected References on the Geology and Chemistry from the Colorado Plateau Coal Assessment Area and Surrounding Areas

Since the early 1970's, the U. S. Geological Survey, in cooperation with other federal agencies (e.g., Bureau of Mines, Bureau of Reclamation, Bureau of Indian Affairs), state geological surveys, industry, and academia, has collected, evaluated and published various data from many of the coal-bearing regions of the western U.S. These publications cover the principal mined or mineable Cretaceous age coals from the Rocky Mountain Province including those from the Black Mesa Field (Arizona), Green River Region (southwestern Wyoming and Northwestern Colorado), San Juan River Region (Northwestern New Mexico and southwestern Colorado), and the Uinta Region (eastern Utah and west-central Colorado). U. S. Geological Survey publications relevant to western coals can be grouped into six general overlapping categories: (1) reports summarizing exploratory drilling, (2) geologic maps, (3) EMRIA reports (Energy Mineral Rehabilitation Inventory and Analysis), (4) coal resource estimates, (5) coal chemical composition and utilization, and (6) geological studies.

These publications can be summarized as follows:

1. Reports summarizing exploratory drilling contain location maps, drilling logs, detailed lithologic descriptions of cored intervals, geophysical logs, coal bed correlations and in some cases, proximate and ultimate analyses of the coals, and the element compositions of selected coal and coal-associated rock samples.
2. Maps include: (a) geologic maps of coal-bearing rocks, (b) Coal Development Potential maps (also called Known Recoverable Coal Resource Areas; KRCRA's are compiled to support land-planning by the Bureau of Land Management) (c) Coal Investigation maps that characterize coal deposits with geologic maps and detailed coal sections; and (d) miscellaneous field studies maps.
3. EMRIA (Energy Mineral Rehabilitation Inventory and Analysis) reports (in cooperation with the Bureau of Reclamation) provide descriptions and analyses of coals, overburden and underburden rocks, vegetation patterns, and hydrology of selected areas in order to estimate area reclamation potential.
4. Coal resource publications include area maps, procedural summaries, and tabular information. Some of these reports include resources estimates generated from data stored within the National Coal Resources Data System (NCRDS).
5. Coal chemical composition and utilization reports include proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures. Also included are statistical summaries of the ash contents and major-, minor- and trace-element compositions of coals and coal-associated rock samples.
6. Geologic studies of depositional environments, stratigraphic frameworks, and geochemical and mineralogical compositions of coal and coal-bearing rocks.

This Information in the report is provided as a supplemental source of chemical and geological reference material for the Colorado Plateau Area Study and nearby areas. Key words for most of the references are at the end of each reference (not all references have key words) and are in uppercase and inclosed in brackets [ ]. These key words contain words, phrases, or location information (latitude N###### and Longtude W#######) that can be used to search the references.

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Dames and Moore, 1979s, Coal resource occurrence and coal development potential maps of the Alamo Mesa East quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-0603, 28 p. [ALAMO MESA EAST QUADRANGLE, COAL DEPOSIT MAPS, CRETACEOUS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MENEFEE FORMATION, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N361500 N362230 W1080000 W1080730]

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MENEFEE FORMATION, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS, WATERFLOW QUADRANGLE. N364500 N365230 W1082230 W1083000]

Dames and Moore, 1979v, Coal resource occurrence and coal development potential maps of the Alamo Mesa West quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-0602, 34 p. [ALAMO MESA WEST QUADRANGLE, COAL DEPOSIT MAPS, CRETACEOUS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, GEOCHEMISTRY, INVENTORY, ISOPACH-MAPS, MAPS, MENEFEE FORMATION, MESAVERDE GROUP, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, STRUCTURE CONTOUR MAPS, UPPER CRETACEOUS. N361500 N362230 W1080730 W1081500]

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Dames and Moore, 1979x, Coal resource occurrence and coal development potential maps of the Youngs Lake quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-1114, 25 p. [CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MENEFEE FORMATION, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS, YOUNGS LAKE QUADRANGLE. N364500 N365230 W1081500 W1082230]

Dames and Moore, 1979y, Coal resource occurrence and coal development potential maps of the Aztec NE quadrangle San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-1113, 19 p. [AZTEC NE QUADRANGLE, CHEMICAL COMPOSITION, CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N365230 N370000 W1074500 W1075230]

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Dames and Moore, 1979ab, Coal resource occurrence and coal development potential maps of the Aztec NW quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-1112, 21 p. [AZTEC NW QUADRANGLE, CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N365230 N370000 W1075230 W1080000]

Dames and Moore, 1979bb, Coal resource occurrence and coal development potential maps of the La Plata quadrangle, San Juan County, New Mexico, and La Plata County, Colorado: U.S. Geological Survey Open-File Report 79-1110, 30 p. [COAL DEPOSIT MAPS, COLORADO, CRETACEOUS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, LA PLATA COUNTY, LA PLATA QUADRANGLE, MAPS, MENEFEE FORMATION, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN, SAN JUAN COUNTY, UPPER CRETACEOUS. N365230 N370000 W1080730 W1081500]

Dames and Moore, 1979cb, Coal resource occurrence and coal development potential maps of the Aztec SE quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-1118, 23 p. [AZTEC SE QUADRANGLE, CHEMICAL COMPOSITION, CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N364500 N365230 W1074500 W1075230]

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Dames and Moore, 1979eb, Coal resource occurrence and coal development potential maps of the Aztec SW quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-1117, 23 p. [AZTEC SW QUADRANGLE, CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N364500 N365230 W1075230 W1080000]

Dames and Moore, 1979fb, Coal resource occurrence and coal development potential maps of the Lybrook NW quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-0107, 25 p. [COAL DEPOSIT MAPS, CRETACEOUS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, LYBROOK NW QUADRANGLE, MAPS, MENEFEE FORMATION, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N360730 N361500 W1073730 W1074500]

Dames and Moore, 1979gb, Coal resource occurrence and coal development potential maps of the Bisti Trading Post quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-0601, 27 p. [BISTI TRADING POST QUADRANGLE, COAL DEPOSIT MAPS, CRETACEOUS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, GEOCHEMISTRY, INVENTORY, ISOPACH-MAPS, MAPS, MESAVERDE GROUP, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, STRUCTURE CONTOUR MAPS, UPPER CRETACEOUS. N361500 N362230 W1081500 W1082230]

Dames and Moore, 1979hb, Coal resource occurrence and coal development potential maps of the Lybrook SE quadrangle, Sandoval, McKinley and San Juan counties, New Mexico: U.S. Geological Survey Open-File Report 79-0111, 27 p. [COAL DEPOSIT MAPS, CRETACEOUS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, LYBROOK SE QUADRANGLE, MAPS, MCKINLEY COUNTY, MENEFEE FORMATION, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, SANDOVAL COUNTY, UPPER CRETACEOUS. N360000 N360730 W1073000 W1073730]

Dames and Moore, 1979ib, Coal resource occurrence and coal development potential maps of the Blanco Trading Post quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-0153, 23 p. [BLANCO TRADING POST QUADRANGLE, CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MENEFEE FORMATION, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N361500 N362230 W1074500 W1075230]

Dames and Moore, 1979jb, Coal resource occurrence and coal development potential maps of the Mesa Portales quadrangle, Sandoval County, New Mexico: U.S. Geological Survey Open-File Report 79-809, 21 p. [COAL DEPOSIT MAPS, CRETACEOUS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MENEFEE FORMATION, MESA PORTALES QUADRANGLE, MESOZOIC, NEW MEXICO, RESOURCES, SANDOVAL COUNTY, UPPER CRETACEOUS. N355230 N360000 W1070000 W1070730]

Dames and Moore, 1979jb, Coal resource occurrence and coal development potential maps of the Bloomfield NW quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-0798, 21 p. [BLOOMFIELD NW QUADRANGLE, CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N363730 N364500 W1075230 W1080000]

Dames and Moore, 1979kb, Coal resource occurrence and coal development potential maps of the Moncisco Wash quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-0805, 28 p. [CENOZOIC, CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INVENTORY, MAPS, MENEFEE FORMATION, MESOZOIC, MONCISCO QUADRANGLE, NEW MEXICO, PALEOCENE, PALEOGENE, RESOURCES, SAN JUAN COUNTY, TERTIARY, UPPER CRETACEOUS. N362230 N363000 W1080730 W1081500]

Dames and Moore, 1979lb, Coal resource occurrence and coal development potential maps of the Huerfano Trading Post NW quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-0612, 27 p. [CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, HUERFANO TRADING POST NW QUADRANGLE, INVENTORY, MAPS, MENEFEE FORMATION, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N362230 N363000 W1075230 W1080000]

Dames and Moore, 1979mb, Coal resource occurrence and coal development potential maps of the Bloomfield SW quadrangle, San Juan County, New Mexico: U.S. Geological Survey Open-File Report 79-0611, 21 p. [BLOOMFIELD SW QUADRANGLE, CHEMICAL COMPOSITION, CRETACEOUS, ECONOMIC GEOLOGY MAPS, ECONOMIC GEOLOGY, EXPLORATORY TEXT, FRUITLAND FORMATION, INVENTORY, MAPS, MESOZOIC, NEW MEXICO, RESOURCES, SAN JUAN COUNTY, UPPER CRETACEOUS. N363000 N363730 W1075230 W1080000]

Dames and Moore, 1979nb, Coal resource occurrence and coal development potential maps of the Mule Dam quadrangle, Sandoval County, New Mexico: U.S. Geological Survey Open-File Report 79-0112, 26 p. [COAL DEPOSIT MAPS, CRETACEOUS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, GEOCHEMISTRY, INVENTORY, MAPS, MENEFEE FORMATION, MESAVERDE GROUP, MESOZOIC, MULE DAM QUADRANGLE, NEW MEXICO, RESOURCES, SANDOVAL COUNTY, STRUCTURE CONTOUR MAPS, UPPER CRETACEOUS. N360000 N360730 W1072230 W1073000]

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METALS, MICROFOSSILS, MUDSTONE, NEW MEXICO, PALYNOMORPHS, PLATINUM GROUP, PROTEACIDITES, RATON BASIN, RATON FORMATION, RATON REGION, SANDSTONE, SEDIMENTS, SHALE, SILTSTONE, SOUTHERN RATON BASIN, STRATIGRAPHY,, BIOSTRATIGRAPHY, SUGARITE, TERTIARY, TRINIDAD REGION, UPPER CRETACEOUS]

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Rice, D.D., Threlkeld, C.N., Vuletich, A.K., and Pawlewicz, M.J., 1988, Identification and significance of coal-bed gas, San Juan Basin, northwestern New Mexico and southwestern Colorado, *in* Fassett, J.E., ed., Geology and coal-bed methane resources of the northern San Juan Basin, Colorado and New Mexico, Publisher: Rocky Mt. Assoc. Geol., Denver, CO, United States, p. 51–59. [BITUMINOUS COAL, C 13/C 12, CARBON, COLORADO, CONDENSATES, CRETACEOUS, DAKOTA FORMATION, DEVOLATILIZATION, DRILLING, ECONOMIC GEOLOGY, ENERGY SOURCES, EXPLORATION, FRUITLAND FORMATION, GENESIS, ISOTOPES, KEROGEN, LEWIS SHALE, MACERALS, MANCOS SHALE, MESOZOIC, NATURAL GAS, NEW MEXICO, NORTHWESTERN NEW MEXICO, ORGANIC MATERIALS, PETROGRAPHY, PETROLEUM, PICTURE CLIFFS SANDSTONE, PRODUCTION, RANK, REFLECTANCE, RESERVOIR ROCKS, SAN JUAN BASIN, SANDSTONE, SOURCE ROCKS, SOUTHWESTERN COLORADO, STABLE-ISOTOPES, THERMAL-MATURITY, UPPER CRETACEOUS, VITRINITE]

Richter, D.H., Saltus, R.W., and Korzeb, S.L., 1987, Mineral resources of the Antelope Wilderness Study Area, Socorro County, New Mexico: U.S. Geological Survey Bulletin 1734-B, B1–B11 p. [CENTRAL NEW MEXICO, CRETACEOUS, ECONOMIC GEOLOGY, GEOPHYSICAL SURVEYS, GEOPHYSICS, APPLIED. ANTELOPE WILDERNESS STUDY AREA, GEOTHERMAL ENERGY, GRAVEL DEPOSITS, MESAVERDE GROUP, MESOZOIC, METAL ORES, MINERAL ASSESSMENT, MINERAL RESOURCES, NEW MEXICO, PROGRAMS, SOCORRO COUNTY, SURVEYS, UPPER CRETACEOUS, URANIUM ORES, WILDERNESS AREAS. N334500 N335000 W1064000 W1065000]

Roberts, L.N., 1989, Results of 1988 coal exploratory drilling in the Fruitland Formation, western part of the Southern Ute Indian Reservation, La Plata County, Colorado; lithologic descriptions, preliminary correlations, and proximate analyses of coal samples: U.S. Geological Survey Open-File Report 89-0487, 221 p. [COLORADO, CORES, CRETACEOUS, DRILLING, ECONOMIC GEOLOGY, ENERGY SOURCES, EXPLORATION, FRUITLAND FORMATION, INDIAN RESERVATIONS, INTERPRETATION, LA PLATA COUNTY COLORADO, MESOZOIC, NORTH AMERICA, PINKERTON MESA QUADRANGLE, ROCKY MOUNTAINS, SOUTHERN UTE INDIAN RESERVATION, SOUTHWESTERN COLORADO, UPPER CRETACEOUS, WELL LOGGING. N370000 N370800 W1080000 W1081500]

Roberts, L.N., 1991, Coal resources of the Fruitland Formation in part of the Ute Mountain Ute Indian Reservation, San Juan County, New Mexico: U.S. Geological Survey Bulletin 1938, 15 p. [APPLICATIONS, BITUMINOUS COAL, CRETACEOUS, ECONOMIC GEOLOGY, ELECTRICAL LOGGING, ENERGY SOURCES, EVALUATION, FRUITLAND FORMATION, GEOLOGIC MAPS, INDIAN RESERVATIONS, ISOPACH-MAPS, MAPS, MAPS AND CHARTS, AREAL GEOLOGY, MESOZOIC, MINING, MINING-GEOLOGY, NEW MEXICO, NORTHWESTERN NEW MEXICO, RADIOACTIVITY, RESOURCES, SAN JUAN BASIN, SAN JUAN COUNTY NEW MEXICO, SECTIONS, STRATIGRAPHY, STRUCTURE CONTOUR MAPS, SURFACE-MINING, THICKNESS, UPPER CRETACEOUS, UTE MOUNTAIN UTE INDIAN RESERVATION, WELL LOGGING. N385000 N385500 W1081500 W1082500]

Roberts, L.N., and Kirschbaum, M.A., 1992, Effects of subsidence rates on Cretaceous coal accumulation, Western Interior U.S, *in* Barker, C.E., and Coury, A.B., eds., Abstracts of the U.S. Geological Survey, central region, 1992 poster review, U.S. Geological Survey Open-File Report 92-0391, p. 12. [CAMPANIAN, CRETACEOUS, FRONTIER FORMATION, FRUITLAND FORMATION, LANCE FORMATION, MAASTRICHTIAN, MESOZOIC, MONTANA, NESLEN FORMATION, NORTH AMERICA, OKLAHOMA, SENONIAN, STRUCTURAL GEOLOGY, ALMOND FORMATION, SUBSIDENCE, TECTONICS, THICKNESS, UPPER CRETACEOUS, UTAH, WESTERN INTERIOR, WILLIAMS FORK FORMATION, WYOMING]

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MESOZOIC, PALUDAL SEDIMENTATION, PEAT, PROCESSES, SAN JUAN BASIN, SEDIMENTATION, SEDIMENTS, SOUTHERN COLORADO, UPPER CRETACEOUS]

Roberts, L.N., and Uptegrove, J., 1991, Coal geology and preliminary coal zone correlations in the Fruitland Formation, western part of the Southern Ute Indian Reservation, La Plata County, Colorado: U.S. Geological Survey Coal Investigations Map C-0138, scale 1:24,000. [COAL DEPOSIT MAPS, COLORADO, CORRELATION, CRETACEOUS, ECONOMIC GEOLOGY, FRUITLAND FORMATION, INDIAN RESERVATIONS, LA PLATA COUNTY COLORADO, LITHOSTRATIGRAPHY, MAPS, MESOZOIC, SOUTHERN UTE INDIAN RESERVATION, SOUTHWESTERN COLORADO, STRATIGRAPHY, UPPER CRETACEOUS. N370000 N370730 W1080000 W1080730]

Robinson, L.N., and Roehler, H.W., 1979, Hypothetical coal resources of the Almond Formation in the Rock Springs coal field, Wyoming: U.S. Geological Survey Open-File Report 79-0588, 11 p. [ALMOND FORMATION, CRETACEOUS, ECONOMIC GEOLOGY, MESOZOIC, PREDICTION, RESOURCES, ROCK SPRINGS FIELD, SWEETWATER COUNTY, UPPER CRETACEOUS, WYOMING. N413000 N414500 W1084000 W1093000]

Robson, S.G., and Stewart, M., 1990, Geohydrologic evaluation of the upper part of the Mesaverde Group, northwestern Colorado: Water-Resources Investigations 90-4020, 125 p. [AQUIFERS, CHARACTERIZATION, COLORADO, CRETACEOUS, DATA PROCESSING, DIGITAL SIMULATION, GEOLOGIC MAPS, GROUND WATER, HYDROCHEMISTRY, HYDROGEOLOGY, HYDROGEOLOGY AND HYDROLOGY, ILES FORMATION, IMPACT STATEMENTS, LEVELS, MAPS, MAPS AND CHARTS, AREAL GEOLOGY, MESAVERDE GROUP, MESOZOIC, MINES, MOFFAT COUNTY COLORADO, MOVEMENT, NORTHWESTERN-COLORADO, RECHARGE, ROUTT COUNTY COLORADO, SANDSTONE, SECTIONS, TROUT CREEK SANDSTONE MEMBER, TWENTYMILE SANDSTONE MEMBER, UPPER CRETACEOUS, WASTE DISPOSAL, WATER BALANCE, WATER MANAGEMENT, WATER QUALITY, WILLIAMS FORK FORMATION. N401500 N403200 W1065500 W1073500]

Roehler, H.W., 1978a, Correlations of coal beds in the Fort Union, Almond, and Rock Springs formations in measured sections of the west flank of the Rock Springs Uplift, Sweetwater County, Wyoming: U.S. Geological Survey Open-File Report 78-0395, 1 p. [CENOZOIC, CORRELATION, CRETACEOUS, FORT UNION FORMATION, LITHOSTRATIGRAPHY, MEASURED SECTIONS, MESOZOIC, ROCK SPRINGS FORMATION, ROCK SPRINGS UPLIFT, STRATIGRAPHY,, ALMOND FORMATION, SWEETWATER COUNTY, TERTIARY, UPPER CRETACEOUS, WYOMING. N410000 N420000 W1090000 W1100000]

Roehler, H.W., 1978b, Correlations of coal beds in the Fort Union, Lance, and Almond formations in measured sections on the east flank of the Rock Springs Uplift, Sweetwater County, Wyoming: U.S. Geological Survey Open-File Report 78-0248, 1 p. [CENOZOIC, CORRELATION, CRETACEOUS, FORT UNION FORMATION, LANCE FORMATION, LITHOSTRATIGRAPHY, MEASURED SECTIONS, MESOZOIC, PALEOGENE, ROCK SPRINGS UPLIFT, STRATIGRAPHY,, ALMOND FORMATION, SWEETWATER COUNTY, TERTIARY, UPPER CRETACEOUS, WYOMING. N410000 N420000 W1080000 W1100000]

Roehler, H.W., 1978c, Correlations of coal beds in the Rock Springs Formation in measured sections on the east flank of the Rock Springs Uplift, Sweetwater County, Wyoming: U.S. Geological Survey Open-File Report 78-0247, 1 p. [CORRELATION, CRETACEOUS, LITHOSTRATIGRAPHY, MEASURED SECTIONS, MESOZOIC, ROCK SPRINGS FORMATION, ROCK SPRINGS UPLIFT, STRATIGRAPHY, SWEETWATER COUNTY, UPPER CRETACEOUS, WYOMING. N410000 N420000 W1080000 W1100000]

Roehler, H.W., 1979a, Geology and energy resources of the Sand Butte Rim NW quadrangle, Sweetwater County, Wyoming: U.S. Geological Survey Professional Paper 1065-A, 54 p. [CENOZOIC, CRETACEOUS, ECONOMIC GEOLOGY, ENERGY SOURCES, EOCENE, FORT UNION FORMATION, FOX HILLS FORMATION, GREEN RIVER FORMATION, LANCE FORMATION, LEWIS SHALE, MESOZOIC, NORTH AMERICA, PALEOGENE, RESOURCES, ROCK SPRINGS UPLIFT, ROCKY MOUNTAINS, SAND BUTTE RIM NW QUADRANGLE, STRATIGRAPHY, SUBBITUMINOUS COAL, SWEETWATER COUNTY, TERTIARY, UPPER CRETACEOUS, WASATCH FORMATION, WYOMING. N411000 N420000 W1080000 W1093000]

Roehler, H.W., 1979b, Geology and mineral resources of the Mud Springs Ranch quadrangle, Sweetwater County, Wyoming: U.S. Geological Survey Professional Paper 1065-C, 35 p. [ALMOND FORMATION, CENOZOIC, CRETACEOUS, ECONOMIC GEOLOGY, FORT UNION FORMATION, MESOZOIC, MUD SPRINGS RANCH QUADRANGLE, PALEOCENE, PALEOGENE, RESERVES, RESOURCES, ROCK SPRINGS UPLIFT, SWEETWATER COUNTY, TERTIARY, UPPER CRETACEOUS, WYOMING. N410000 N414000 W1080000 W1091500]

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GORGE RESERVOIR, GLADES COAL BED, LAGOONAL ENVIRONMENT, MARINE ENVIRONMENT, MCCOURT SANDSTONE TONGUE, MESOZOIC, NORTH AMERICA, ROCK SPRINGS COAL FIELD, ROCK SPRINGS FORMATION, ROCKY MOUNTAINS, SANDSTONE, SEDIMENTARY PETROLOGY, SEDIMENTATION, U.S. ROCKY MOUNTAINS, UINTA-MOUNTAINS, UPPER CRETACEOUS, UTAH, WYOMING]

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WYOMING, UPPER CRETACEOUS, WESTERN INTERIOR, WESTERN INTERIOR SEAWAY, WYOMING. N411000 N420500 W1083500 W1091000]

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TAIN, CARBON COUNTY UTAH, CENTRAL UTAH, CORRELATION, CRETACEOUS, ECONOMIC GEOLOGY, EMERY COUNTY UTAH, LITHOSTRATIGRAPHY, MAPS, MESAVERDE GROUP, MESOZOIC, NEPHI QUADRANGLE, PALEOENVIRONMENT, STAR POINT SANDSTONE, STRATIGRAPHIC MAPS, STRATIGRAPHY, UPPER CRETACEOUS, UTAH, WASATCH PLATEAU, WATTIS UTAH. N393000 N393730 W1110000 W1111500]

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Appendix 5—Minimum, Maximum, and Mean Values for Ash Yield, Sulfur Content, Calorific Value, and Moist, Mineral-Matter-Free Btu, Grouped by High-Priority Coal Fields and Stratigraphic Units for the Colorado Plateau Coal Assessment Area

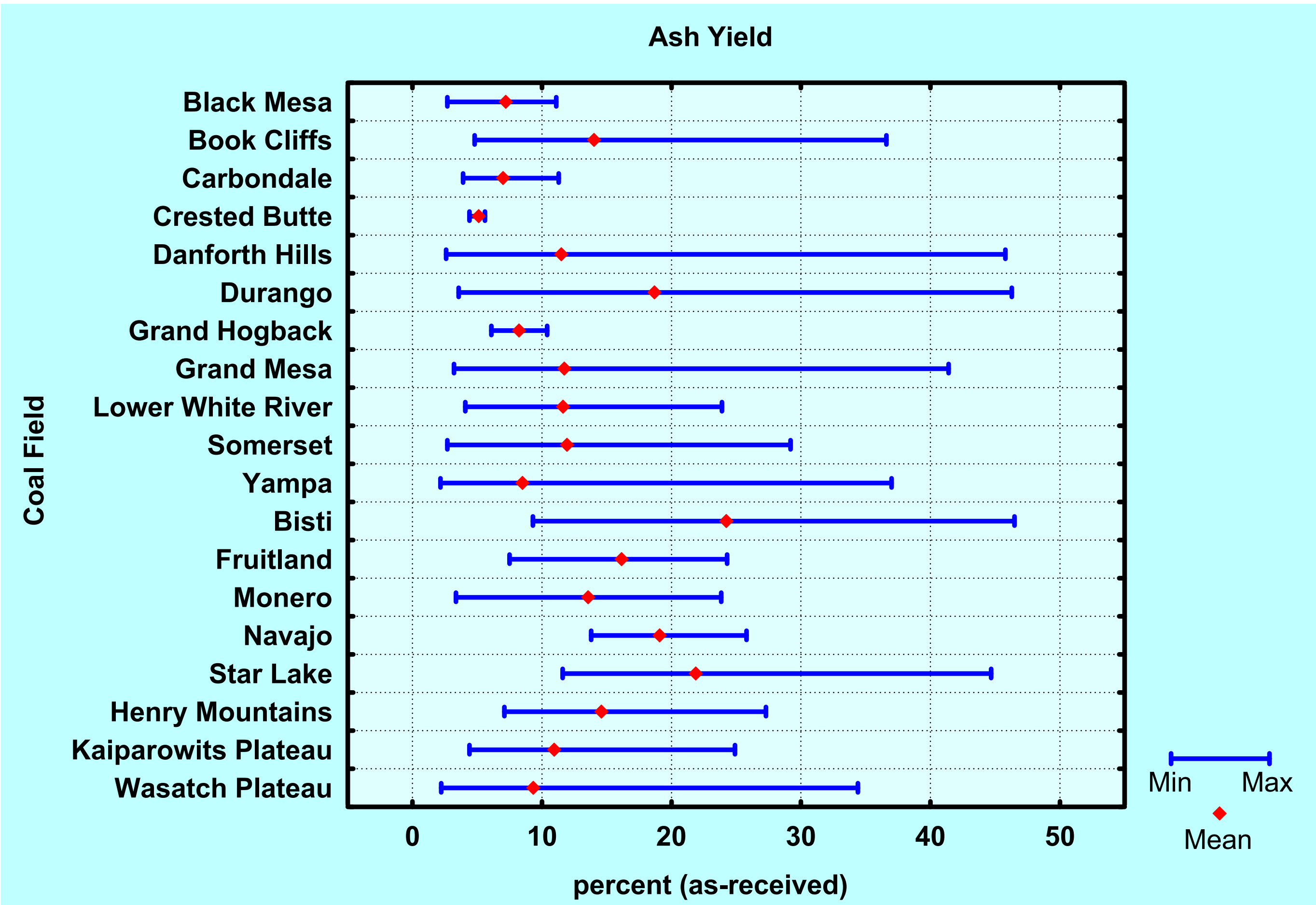


Figure A5-1. Minimum, maximum, and mean contents of ash yield for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

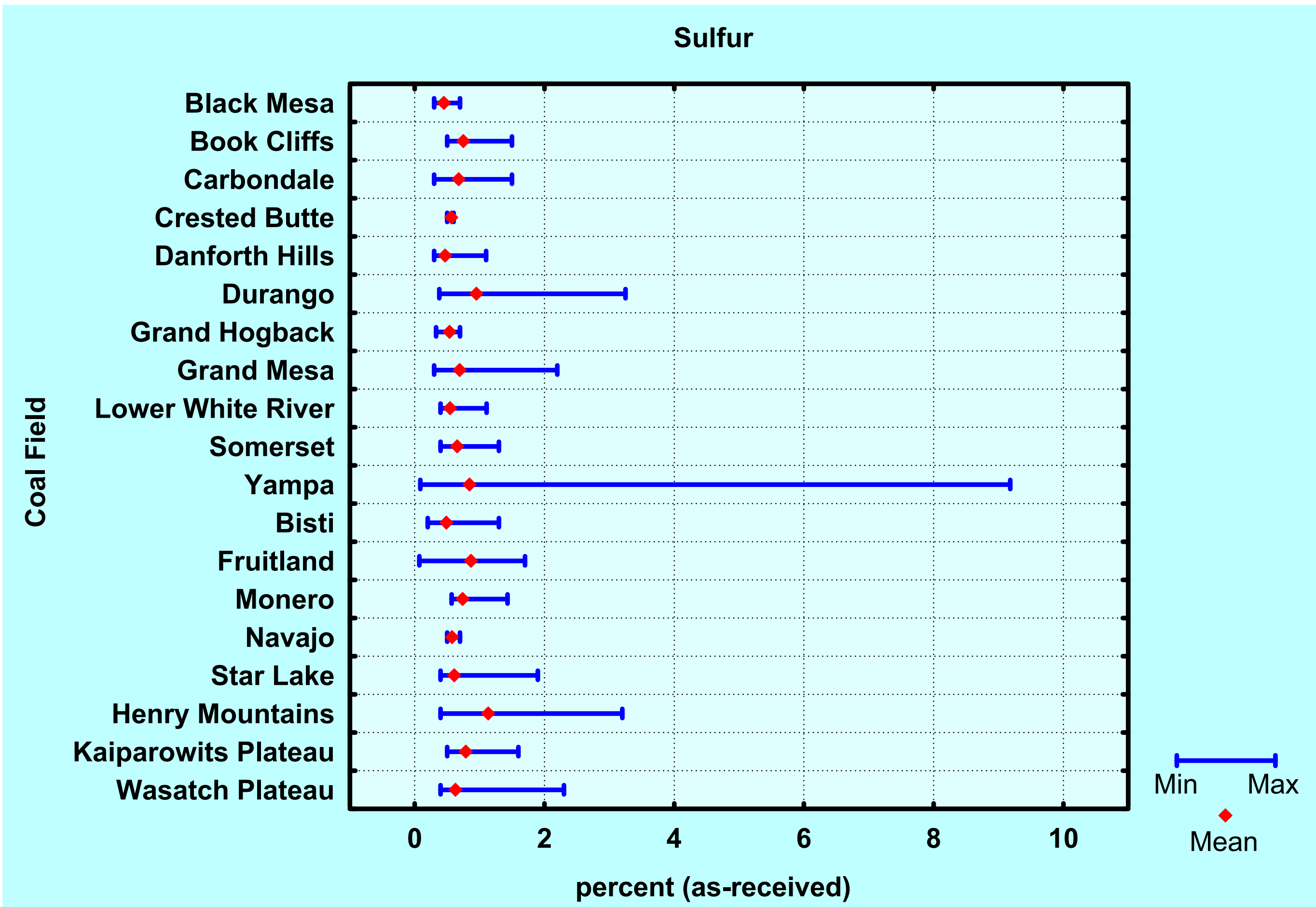


Figure A5-2. Minimum, maximum, and mean contents of sulfur content for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

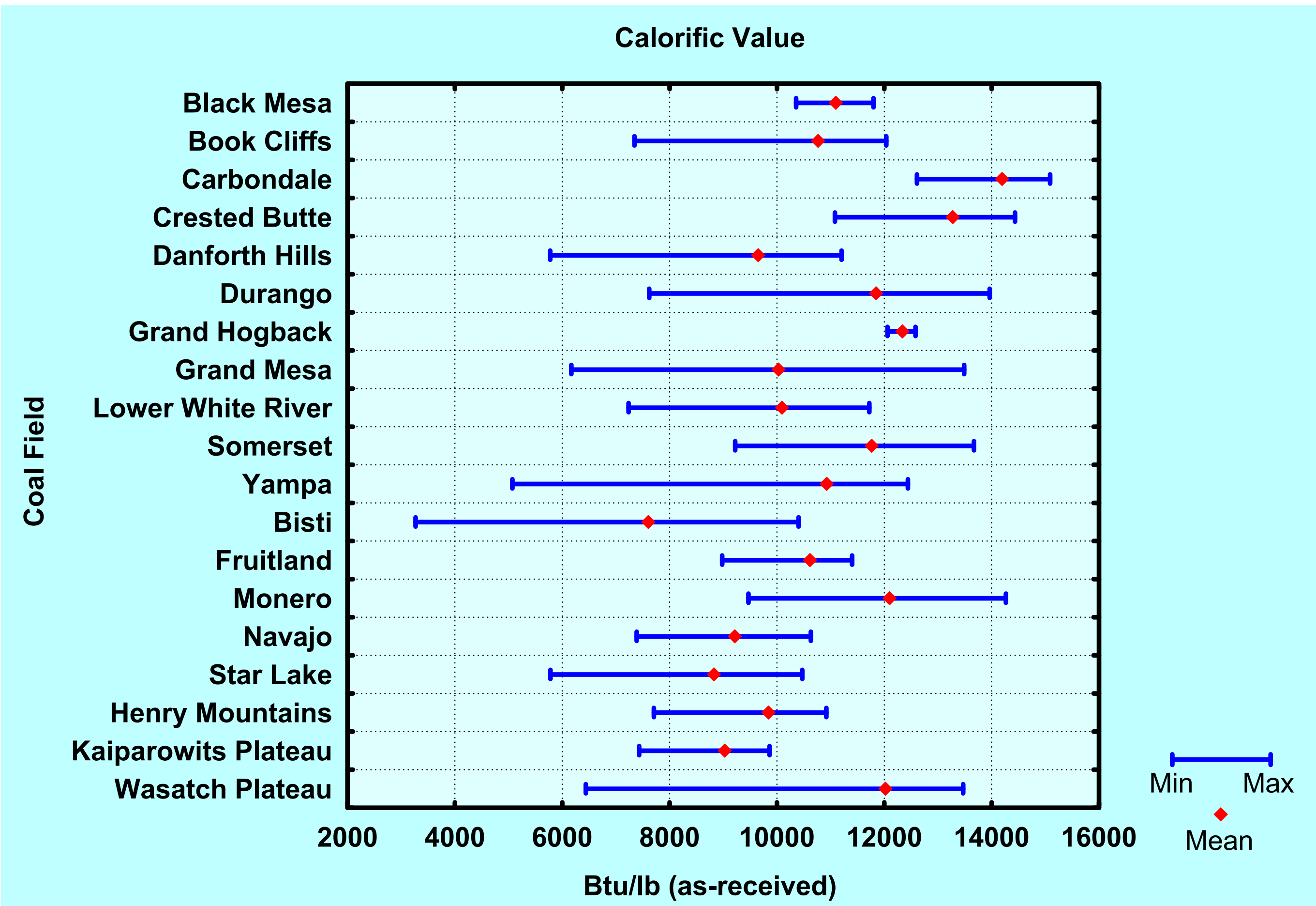


Figure A5-3. Minimum, maximum, and mean contents of calorific value for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

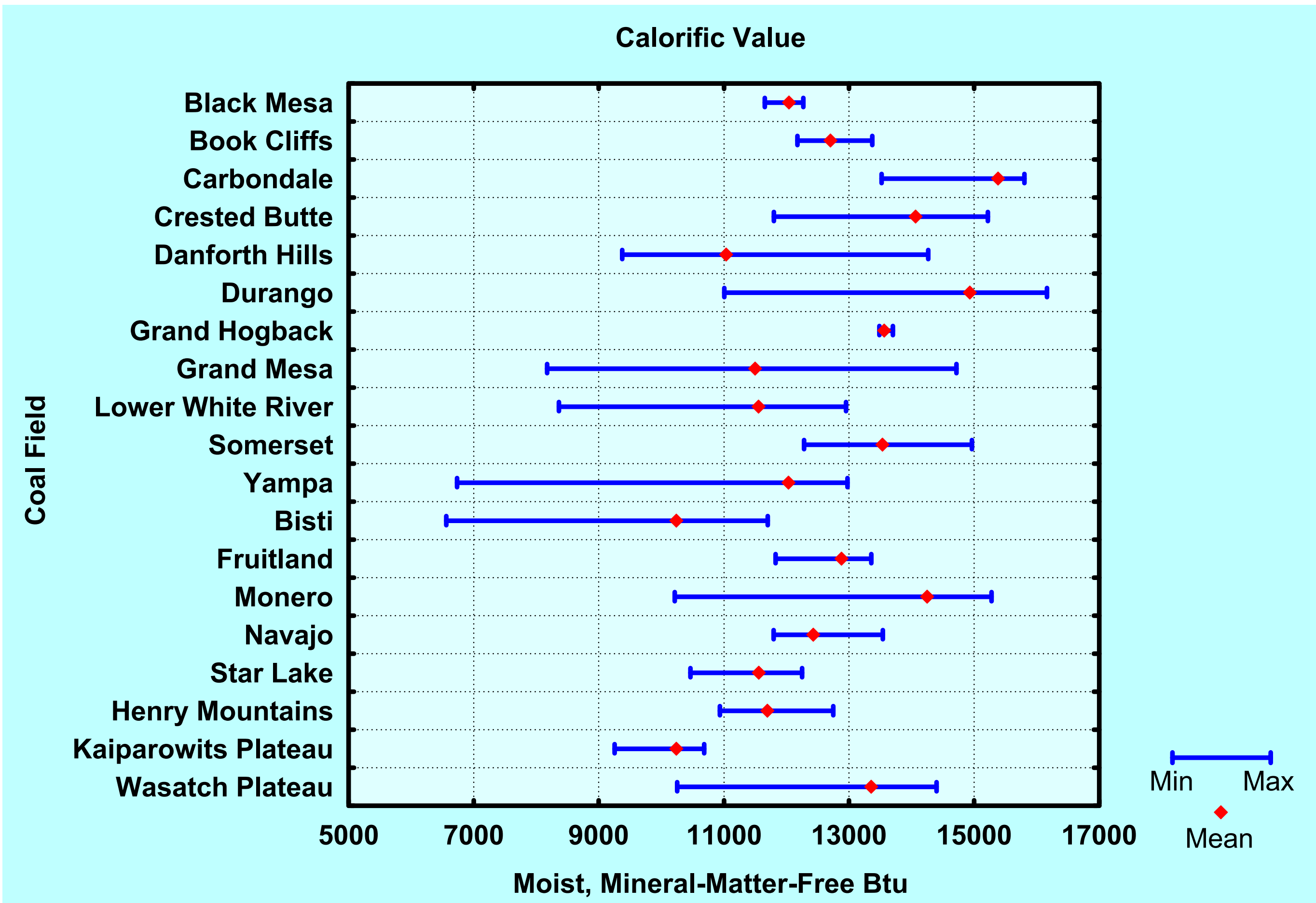


Figure A5-4. Minimum, maximum, and mean contents of moist, mineral-matter-free Btu for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

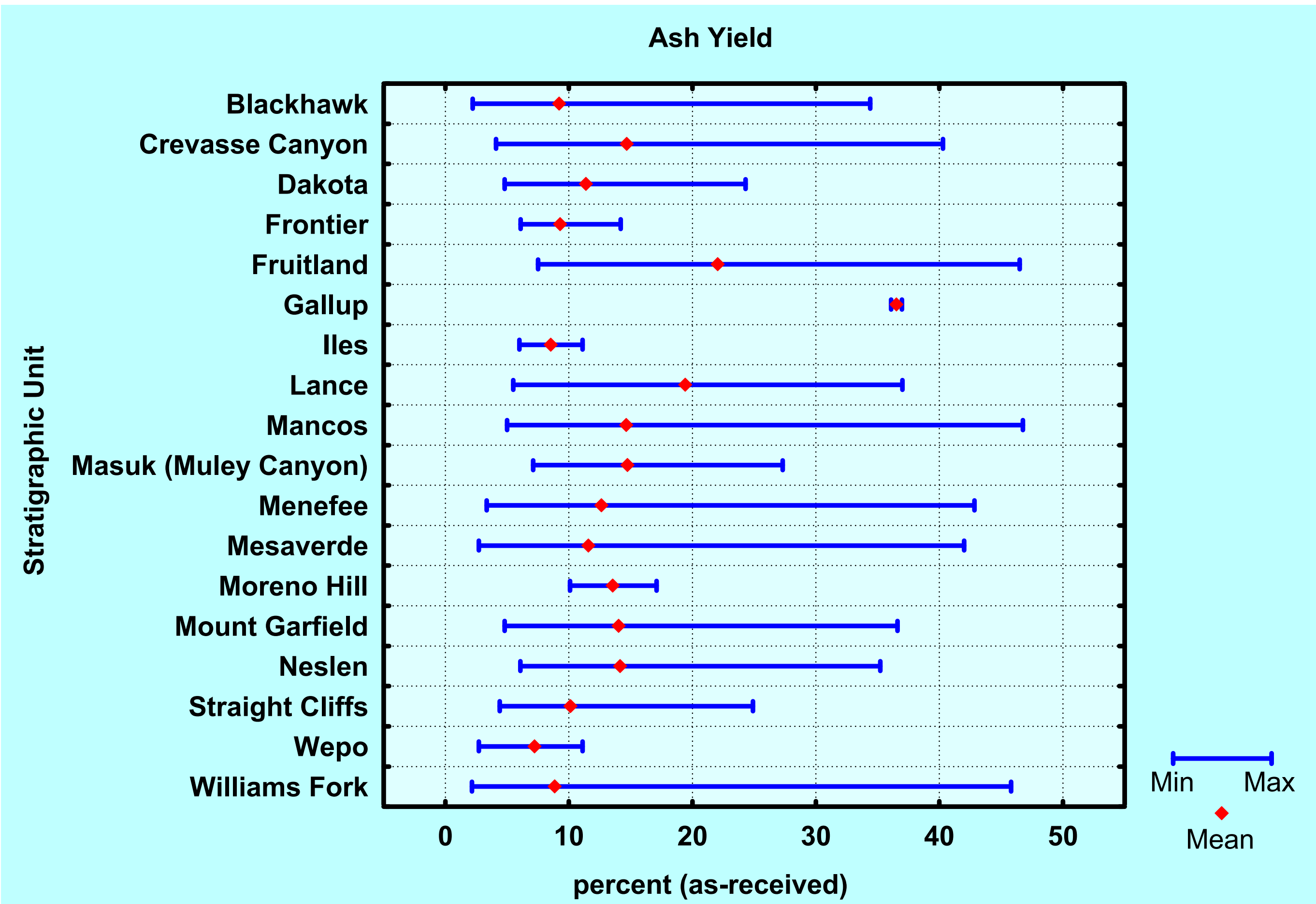


Figure A5-5. Minimum, maximum, and mean contents of ash yield for coal from all stratigraphic units in the Colorado Plateau coal assessment area.

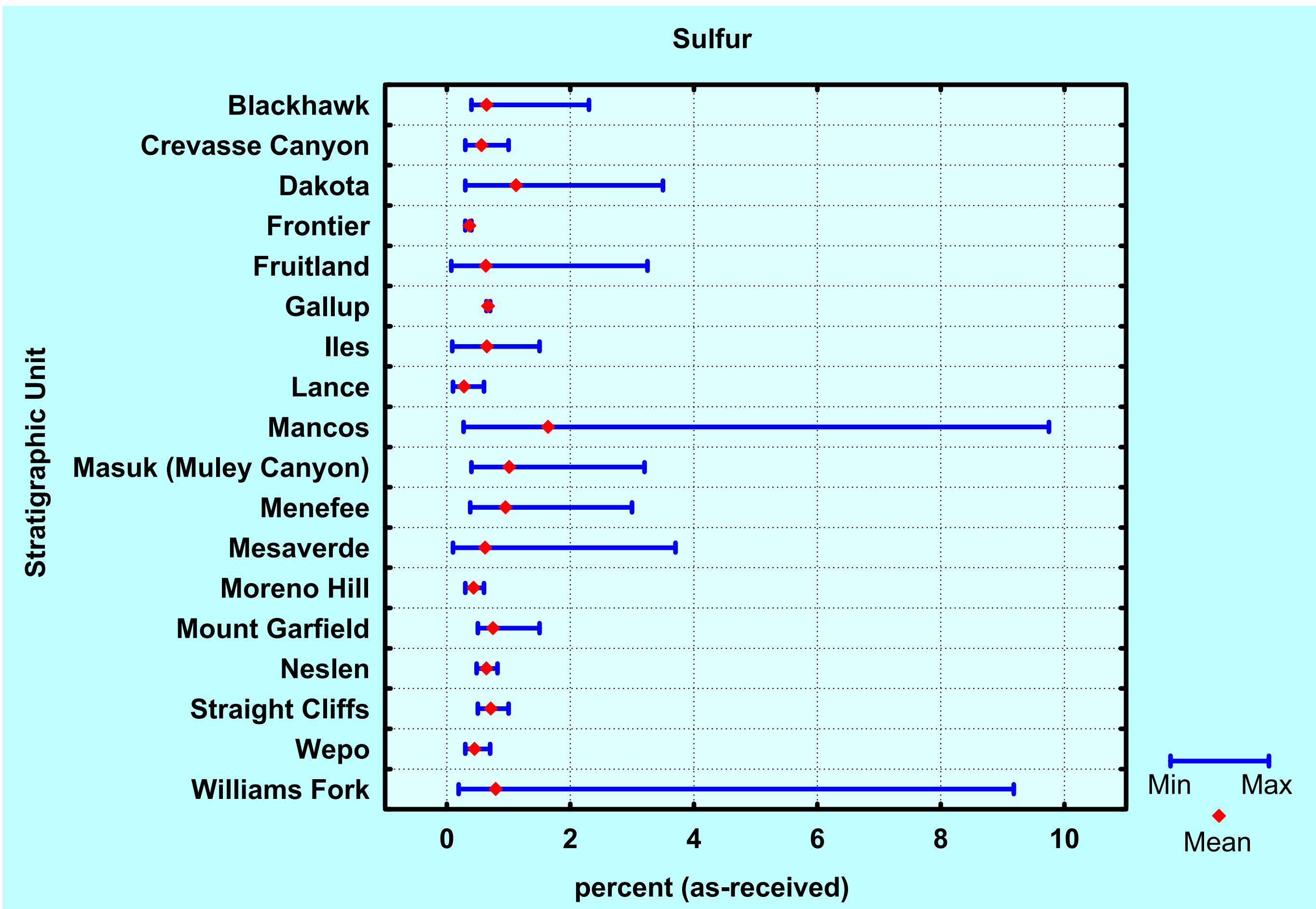


Figure A5-6. Minimum, maximum, and mean contents of sulfur content for coal from all stratigraphic units in the Colorado Plateau coal assessment area.

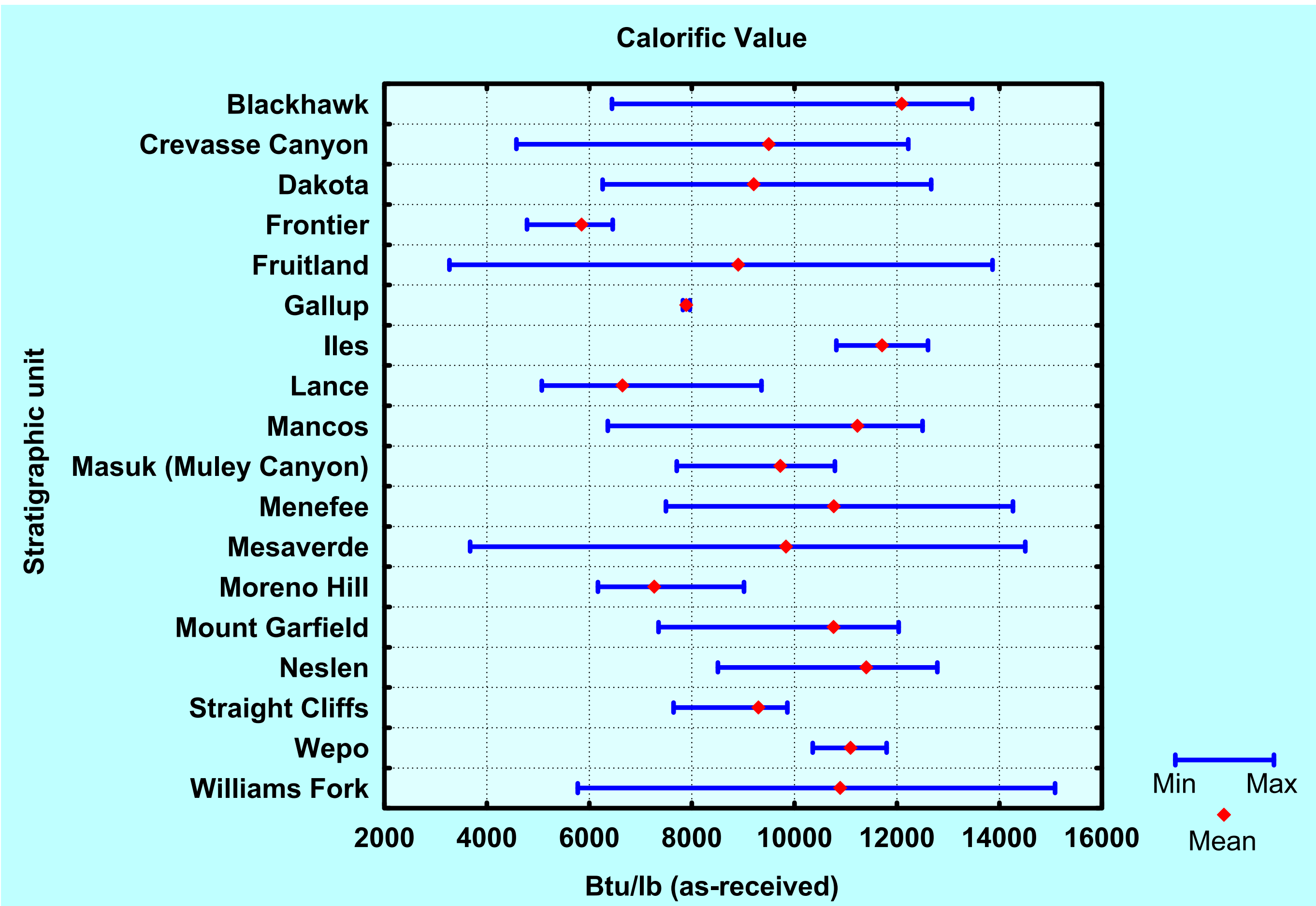


Figure A5-7. Minimum, maximum, and mean contents of calorific value for coal from all stratigraphic units in the Colorado Plateau coal assessment area.

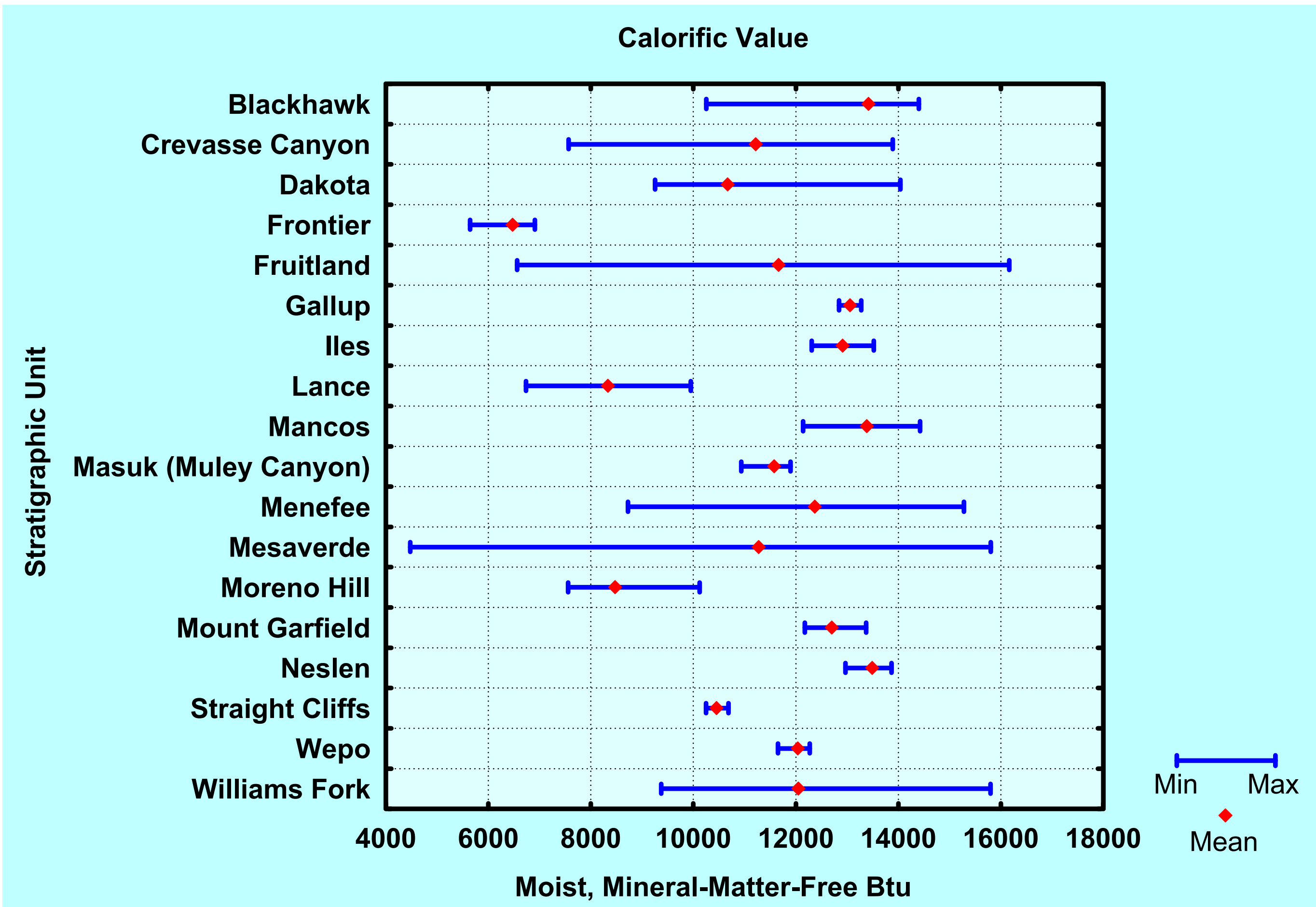


Figure A5-8. Minimum, maximum, and mean contents of moist, mineral-matter-free Btu for coal from all stratigraphic units in the Colorado Plateau coal assessment area.

Appendix 6—Graduated Symbol Maps for Each Element of Environmental Concern from the Colorado Plateau Coal Assessment Area

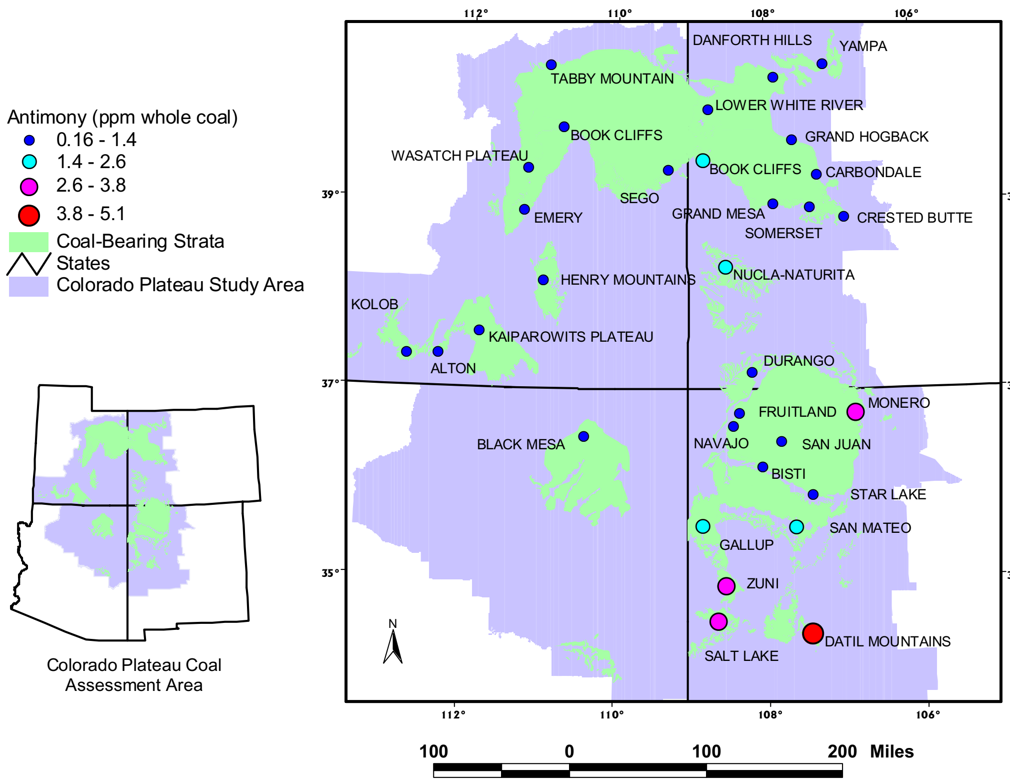


Figure A6-1. Graduated symbol map of the mean content of antimony for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

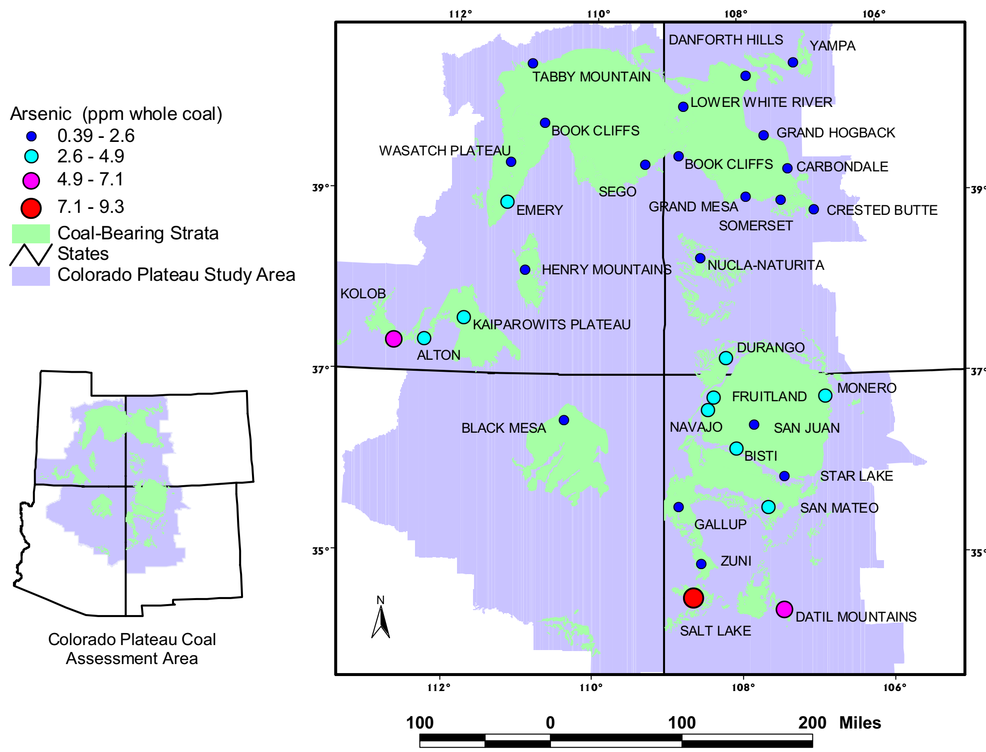


Figure A6-2. Graduated symbol map of the mean content of arsenic for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

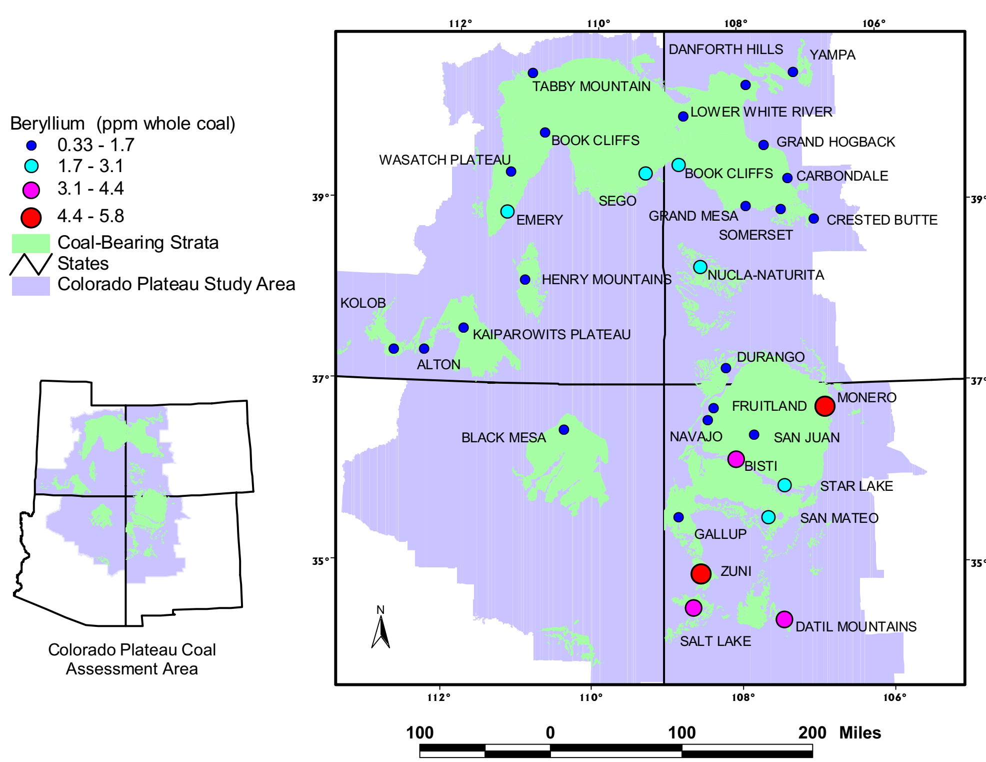


Figure A6-3. Graduated symbol map of the mean content of beryllium for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

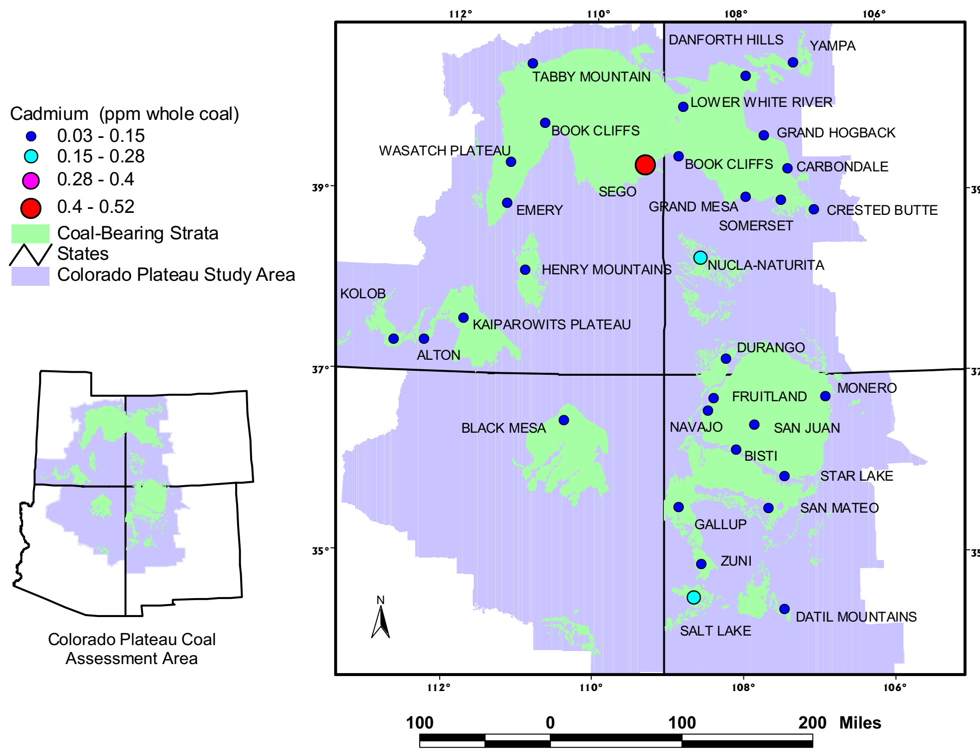


Figure A6-4. Graduated symbol map of the mean content of cadmium for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

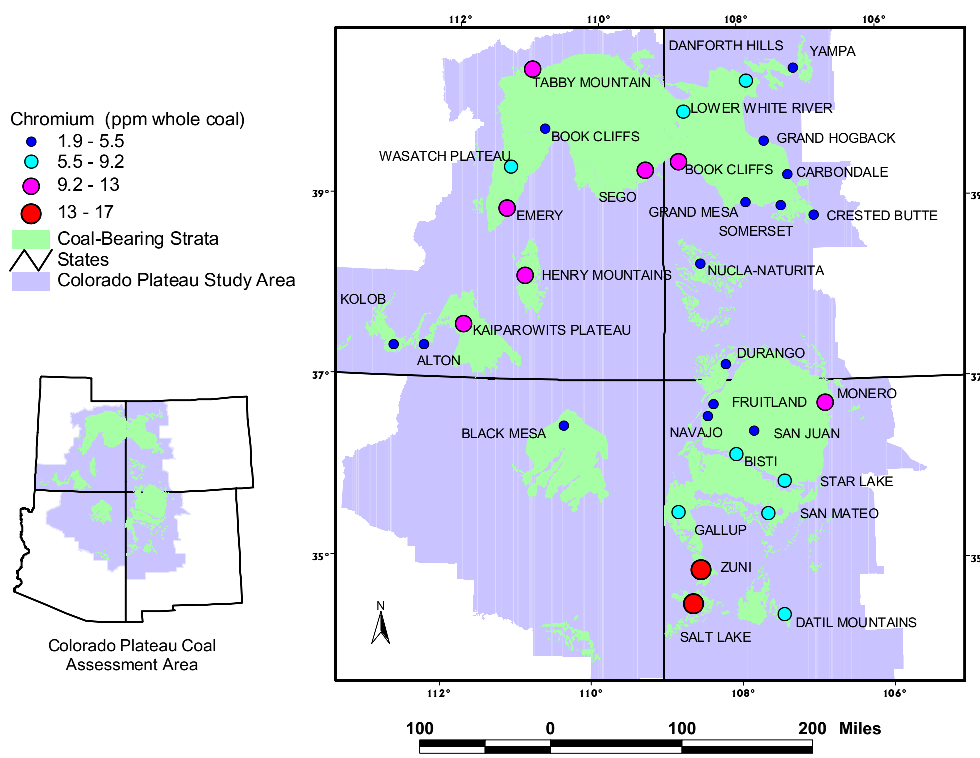


Figure A6-5. Graduated symbol map of the mean content of chromium for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

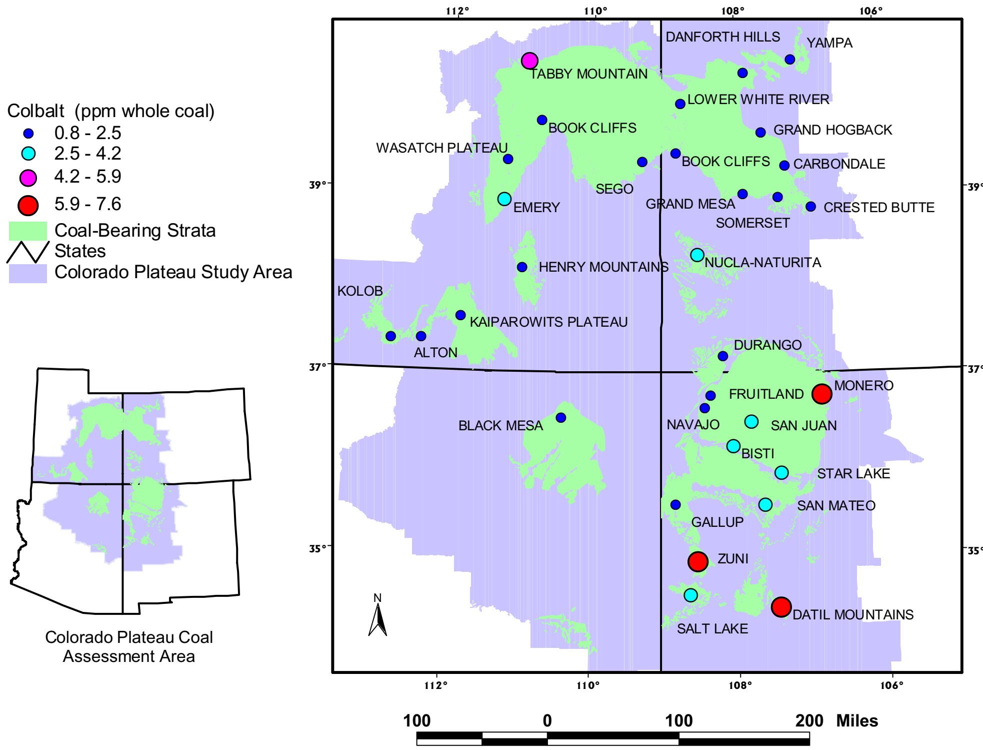


Figure A6-6. Graduated symbol map of the mean content of cobalt for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

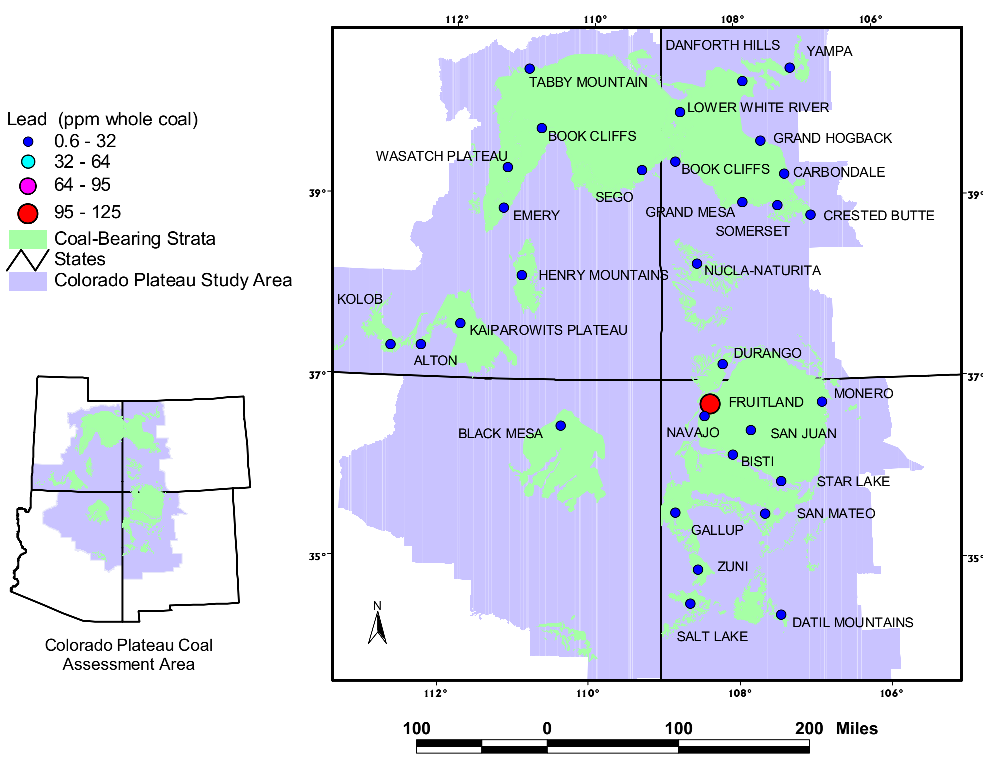


Figure A6-7. Graduated symbol map of the mean content of lead for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

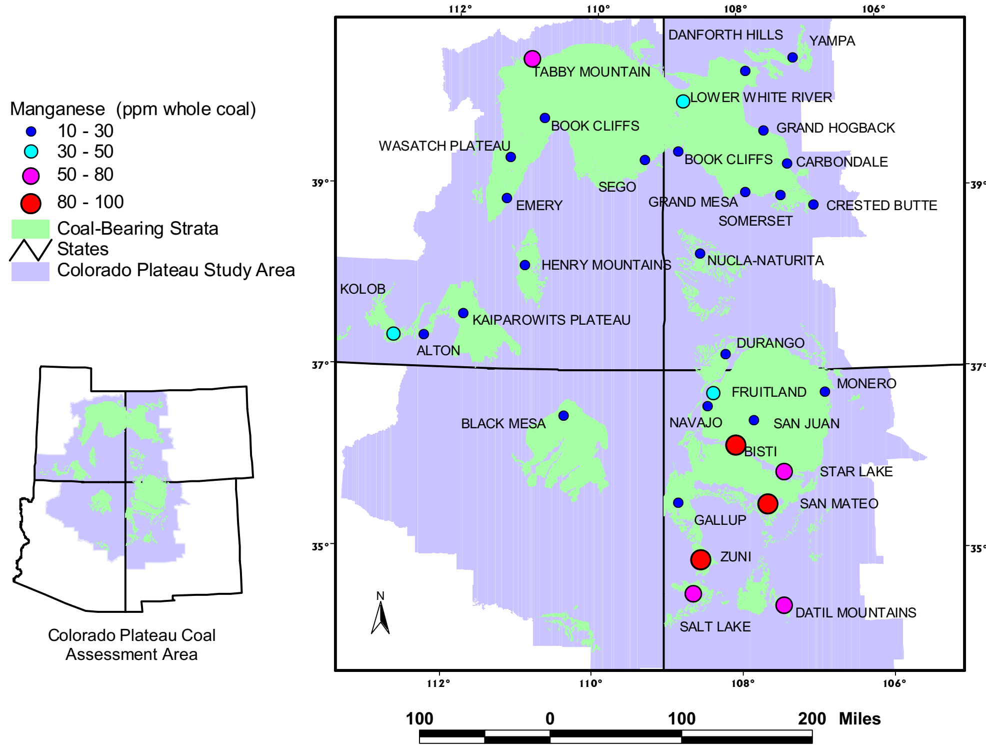


Figure A6-8. Graduated symbol map of the mean content of manganese for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

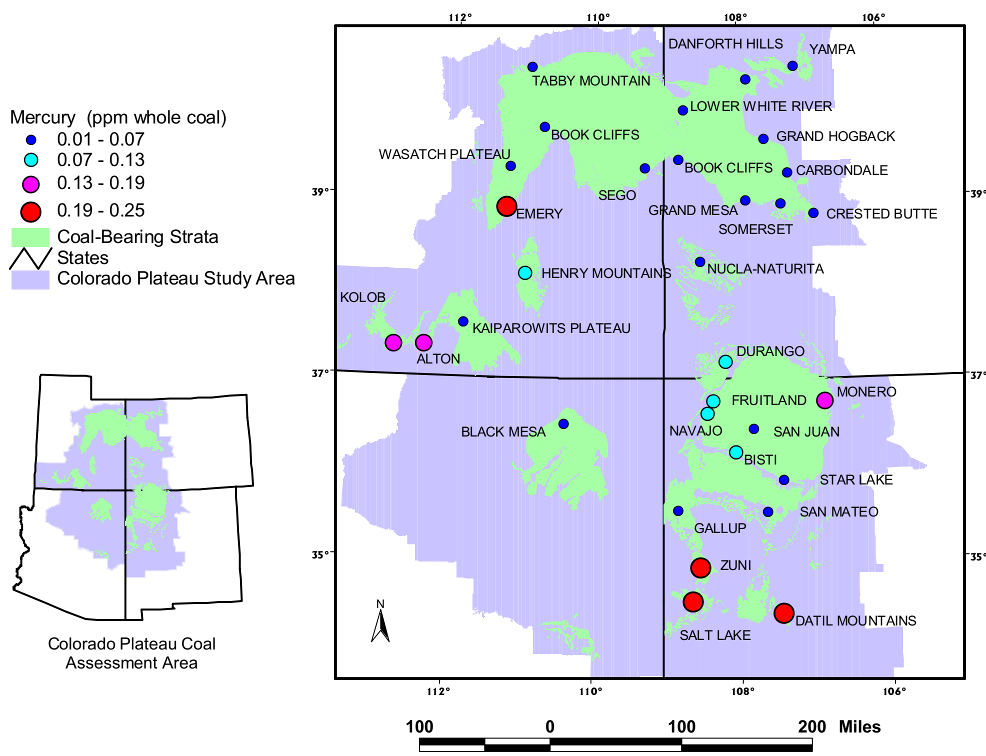


Figure A6-9. Graduated symbol map of the mean content of mercury for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

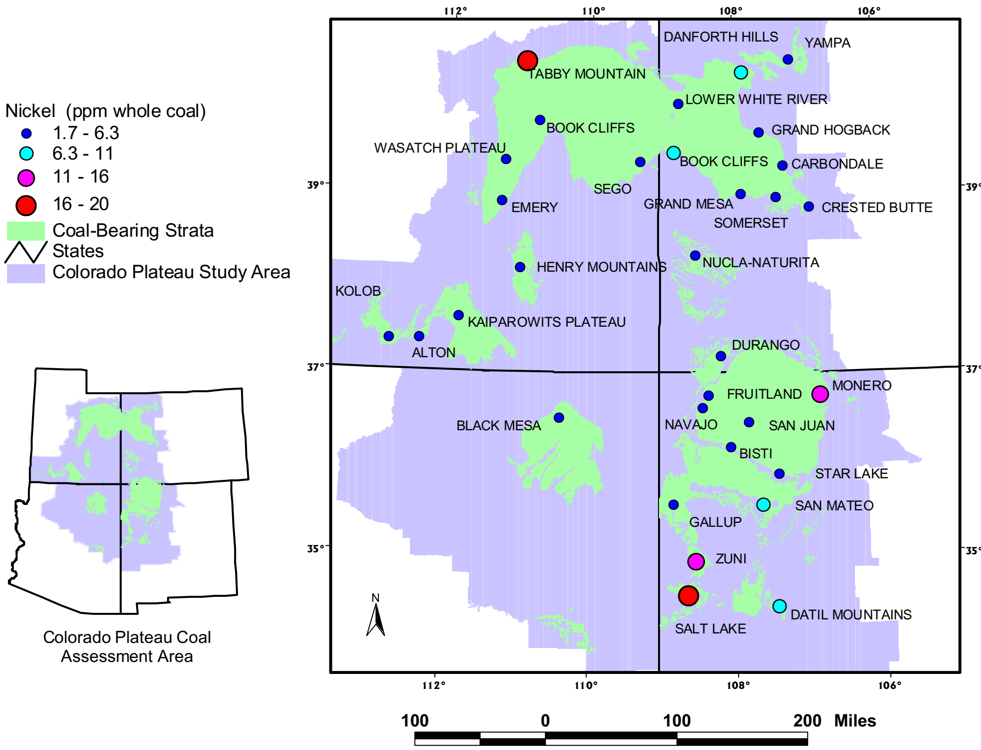


Figure A6-10. Graduated symbol map of the mean content of nickel for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

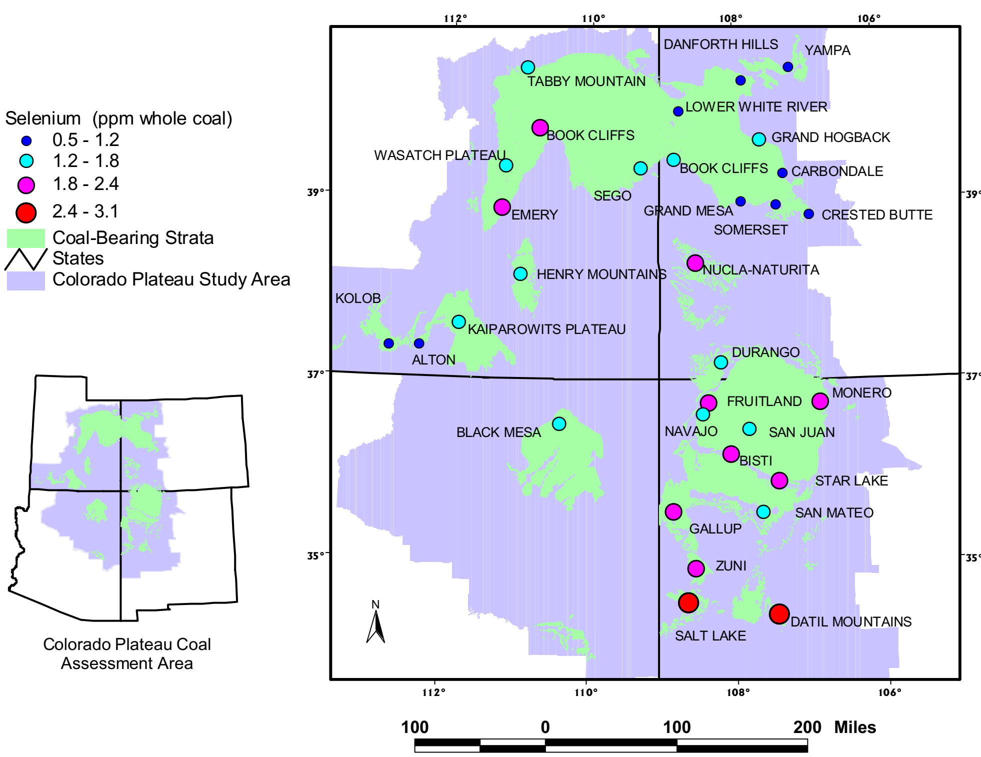


Figure A6-11. Graduated symbol map of the mean content of selenium for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

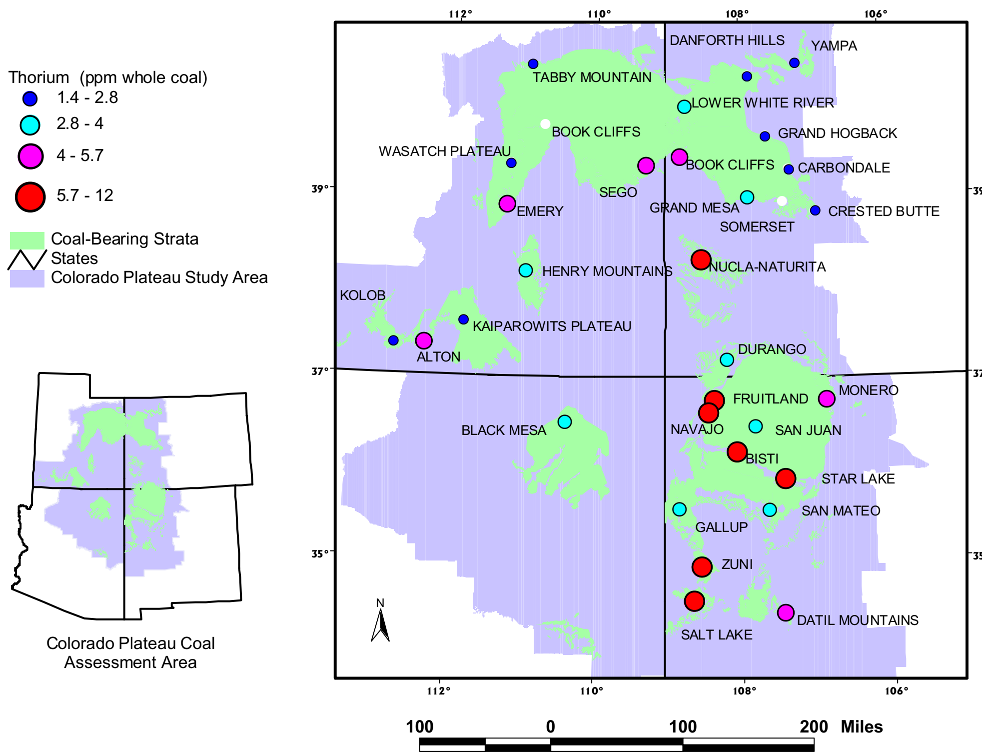


Figure A6-12. Graduated symbol map of the mean content of thorium for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

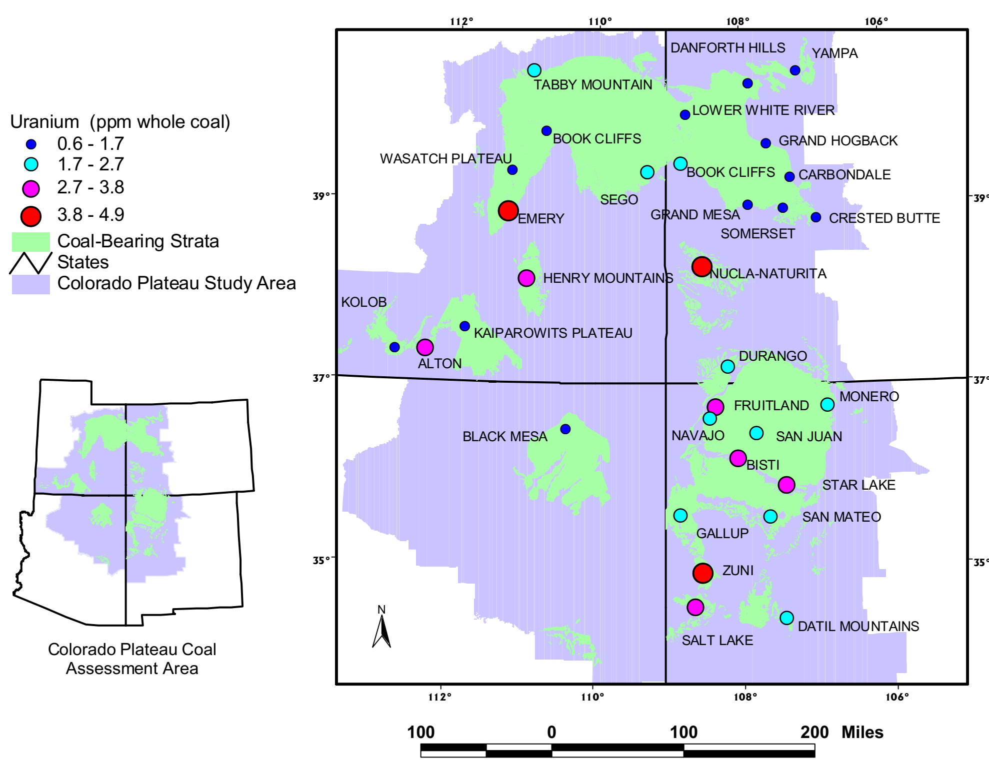


Figure A6-13. Graduated symbol map of the mean content of uranium for all coal fields studied (including high and low priority coal fields) in the Colorado Plateau coal assessment area.

Appendix 7—Minimum, Maximum, and Mean Contents of Elements of Environmental Concern shown by High-Priority Coal Field and Stratigraphic Unit from the Colorado Plateau Coal Assessment Area

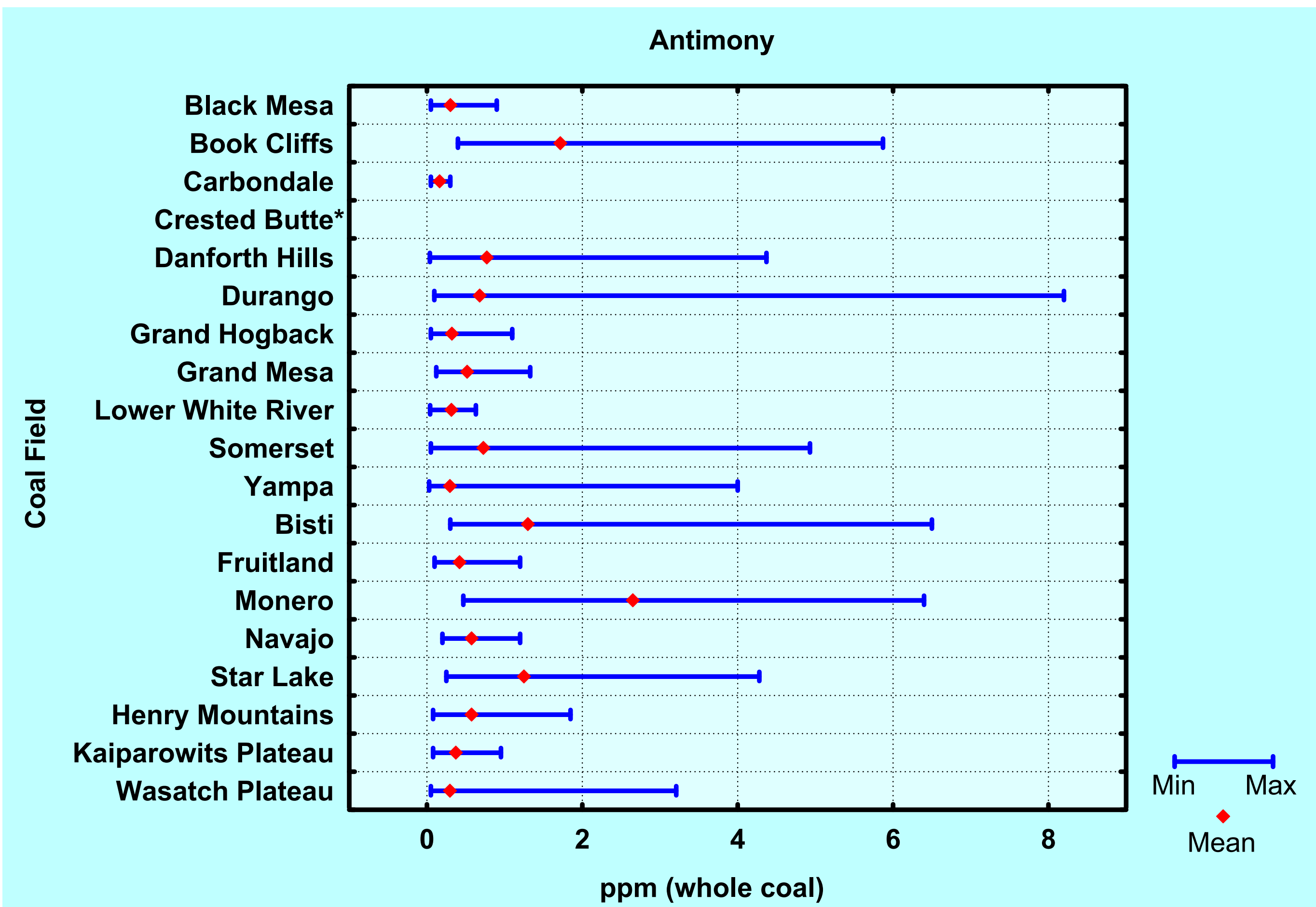


Figure A7-1. Minimum, maximum, and mean content of antimony for coal from high-priority coal fields in the Colorado Plateau coal assessment area (* indicates insufficient data).

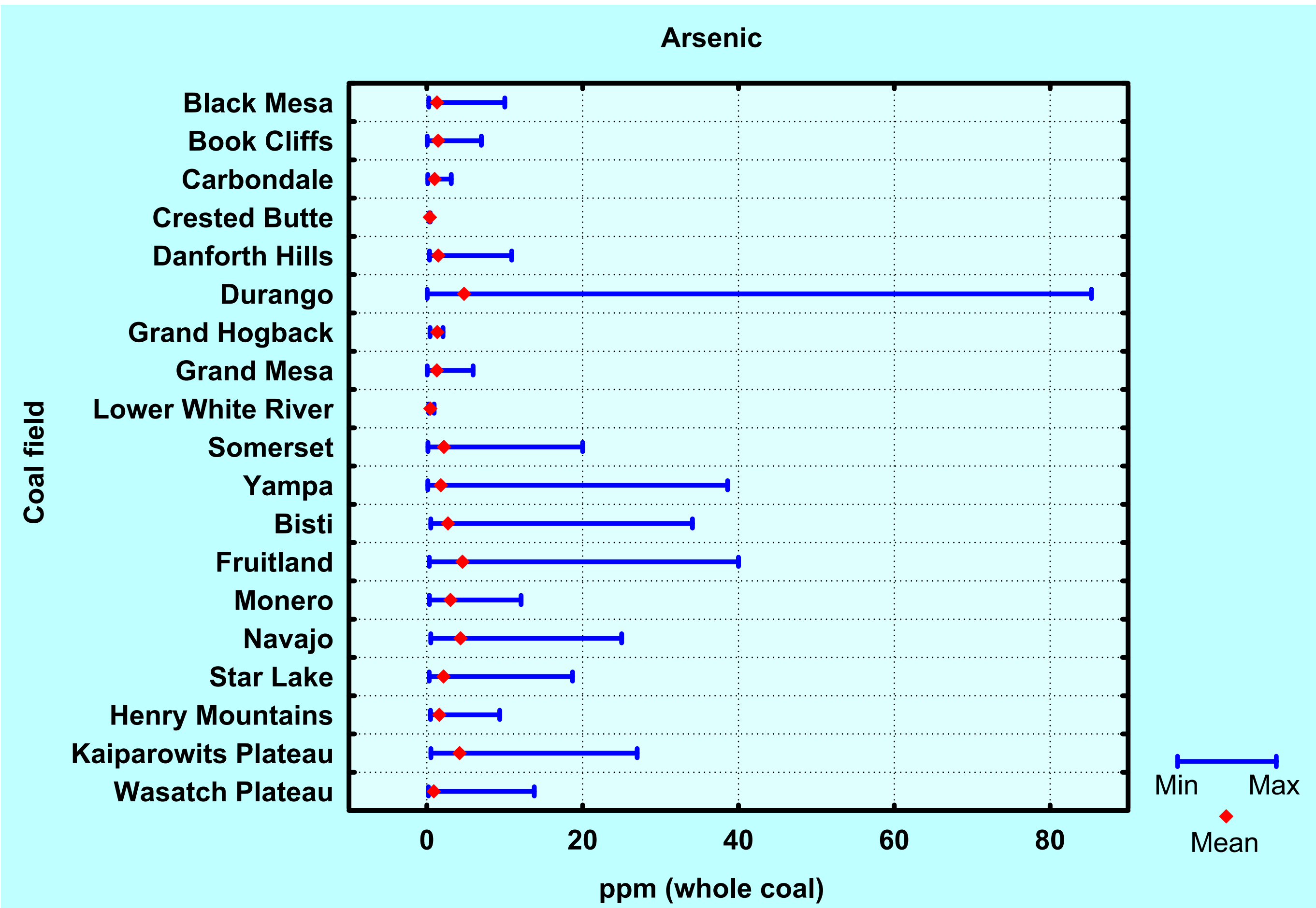


Figure A7-2. Minimum, maximum, and mean content of arsenic for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

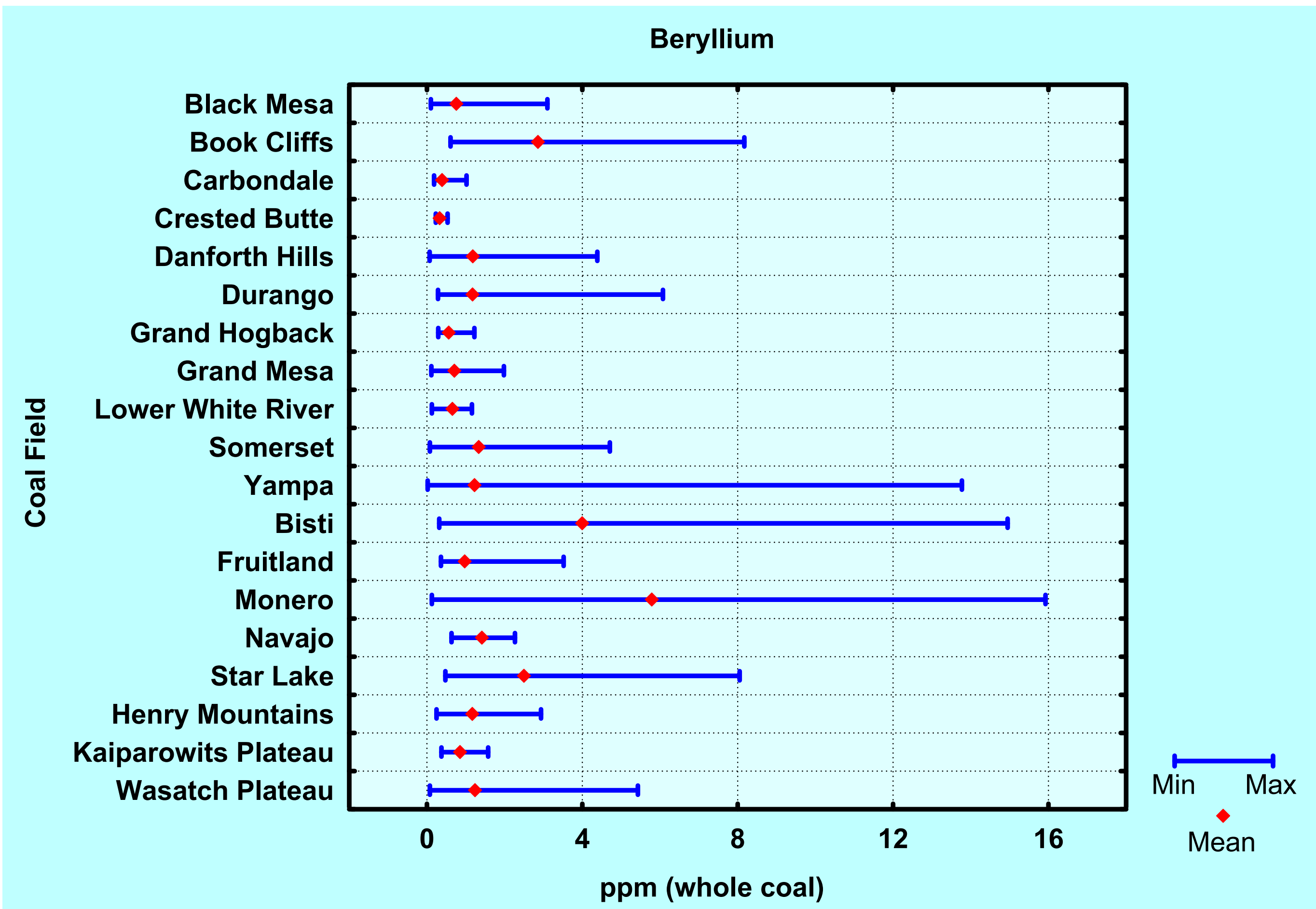


Figure A7-3. Minimum, maximum, and mean content of beryllium for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

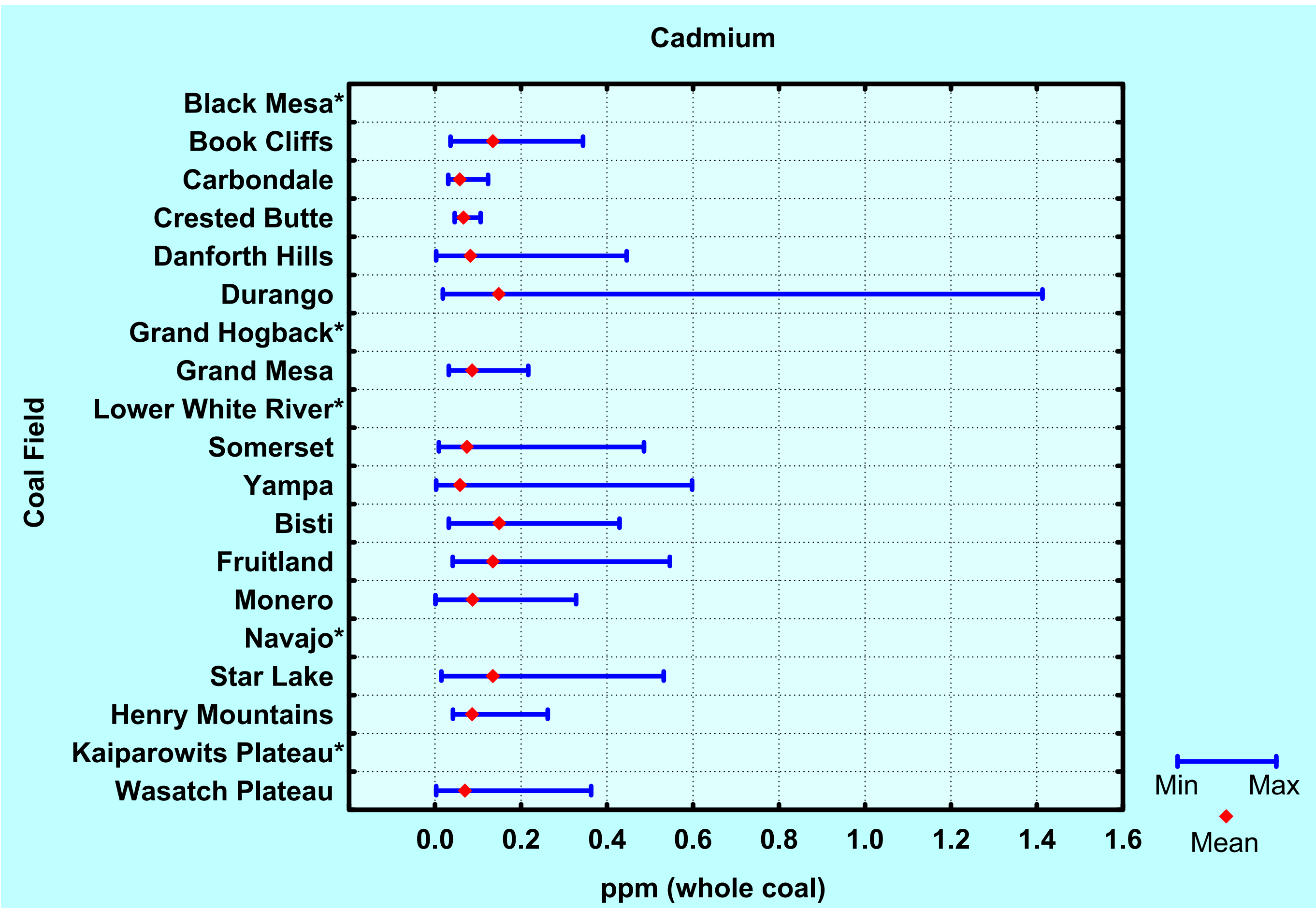


Figure A7-4. Minimum, maximum, and mean content of cadmium for coal from high-priority coal fields in the Colorado Plateau coal assessment area (* indicates insufficient data).

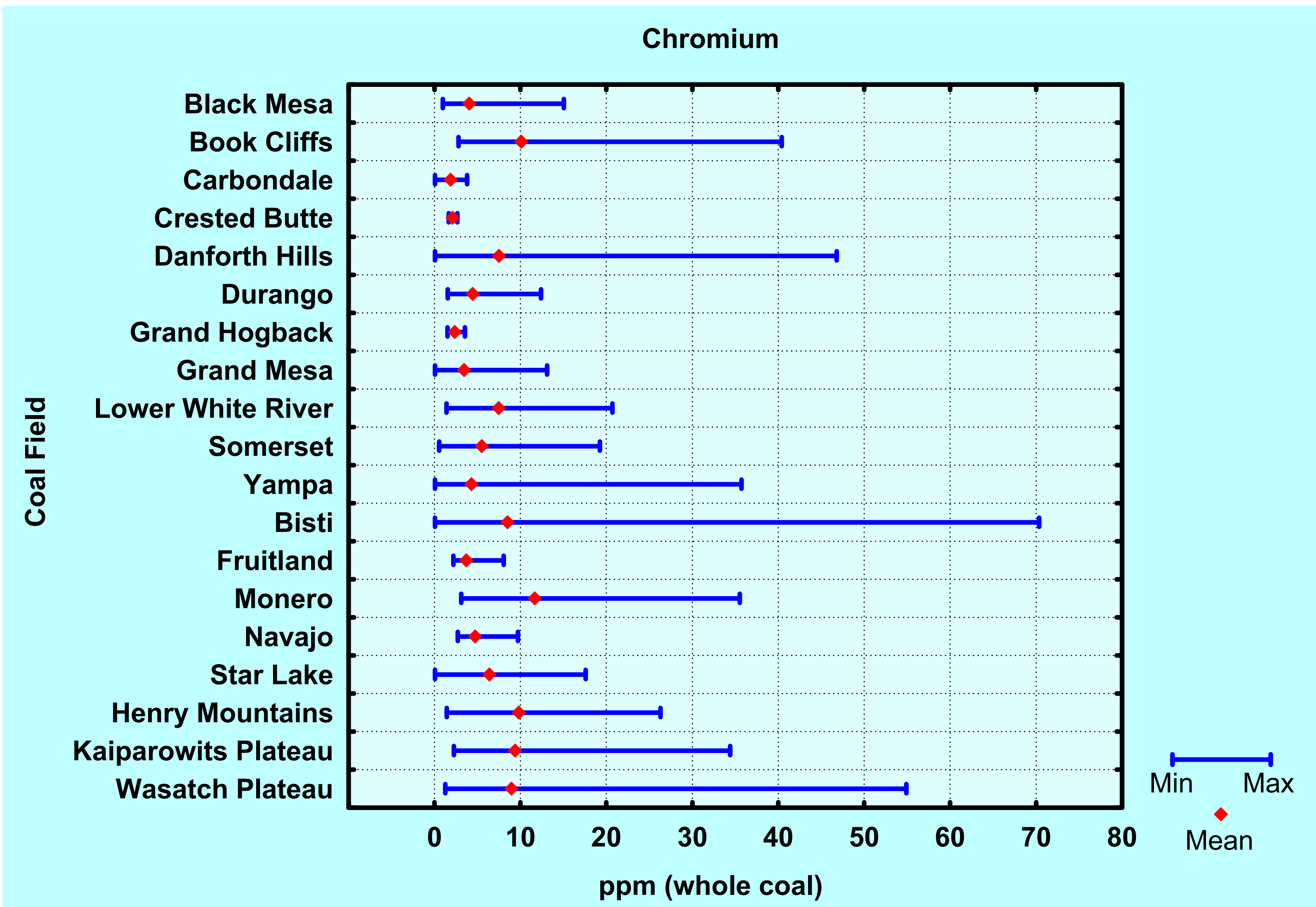


Figure A7-5. Minimum, maximum, and mean content of chromium for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

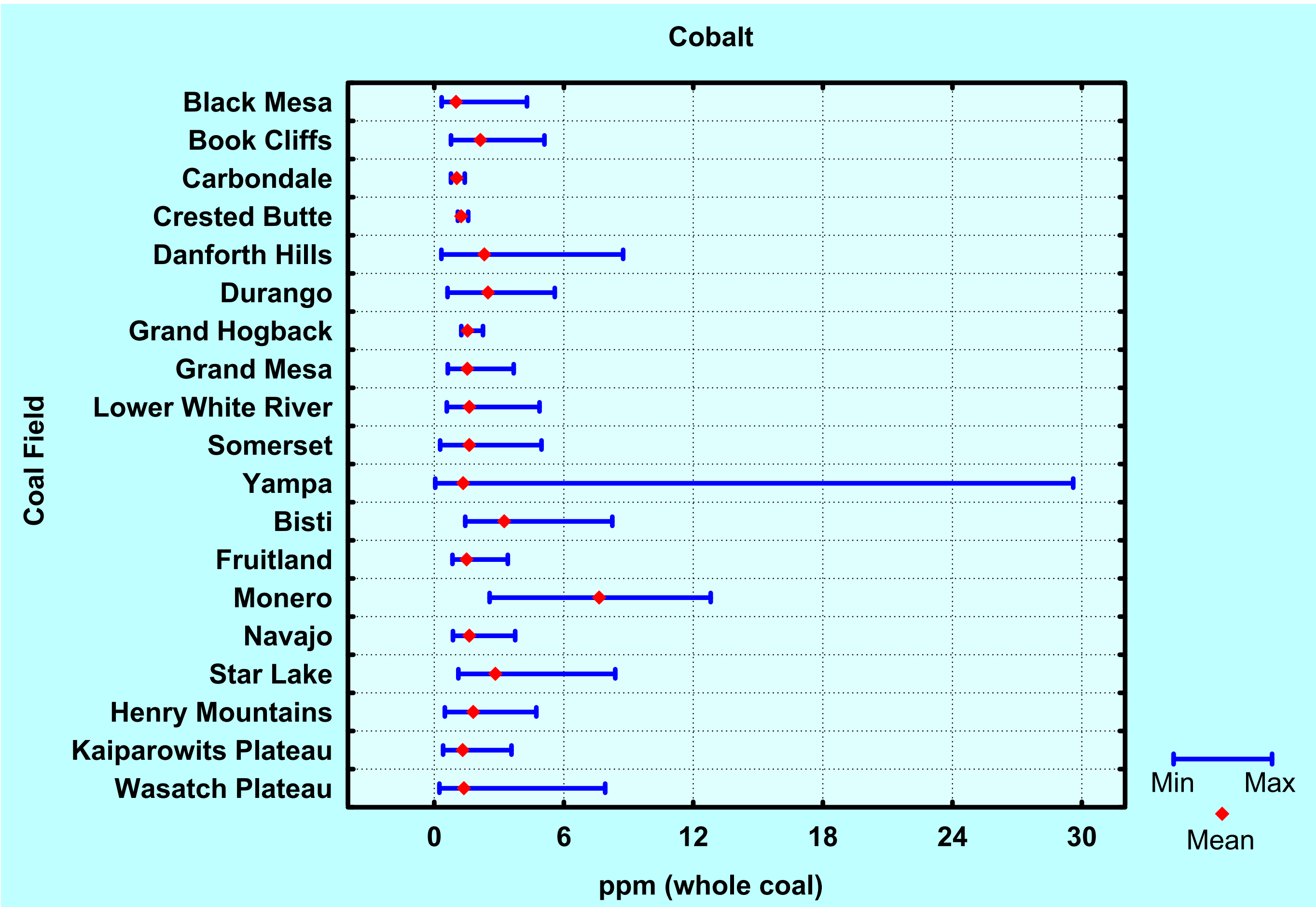


Figure A7-6. Minimum, maximum, and mean content of cobalt for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

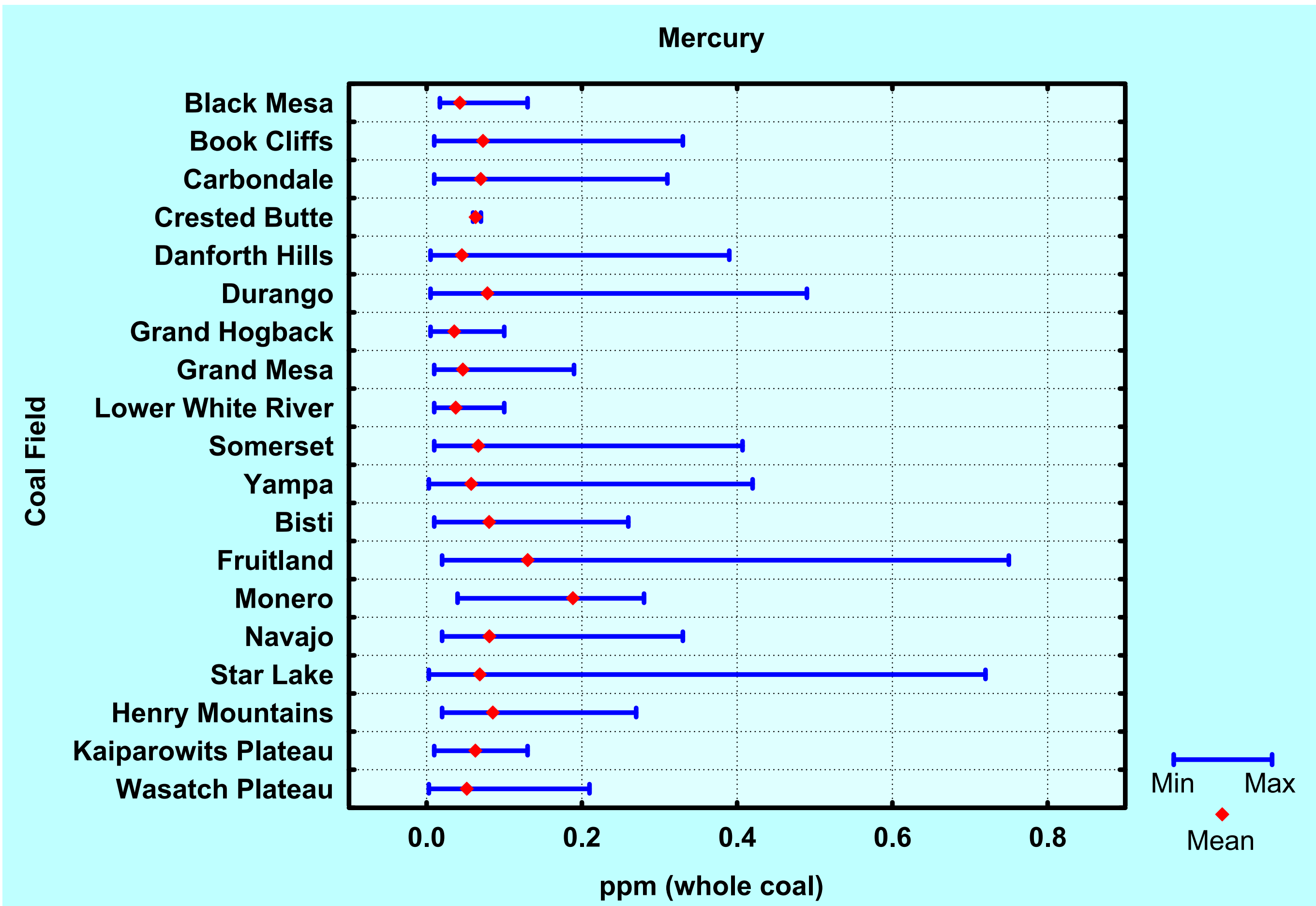


Figure A7-7. Minimum, maximum, and mean content of mercury for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

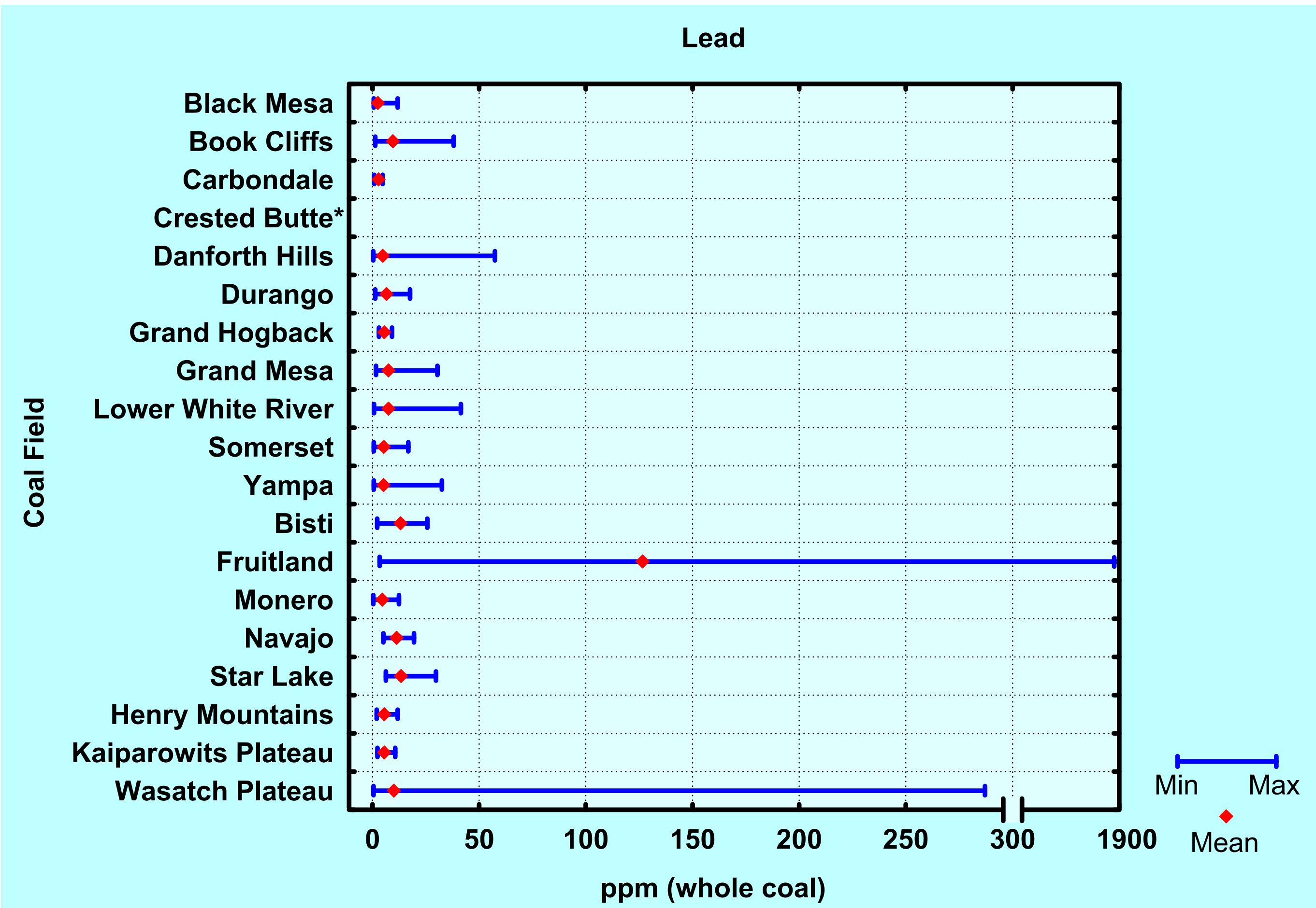


Figure A7-8. Minimum, maximum, and mean content of lead for coal from high-priority coal fields in the Colorado Plateau coal assessment area (* indicates insufficient data).

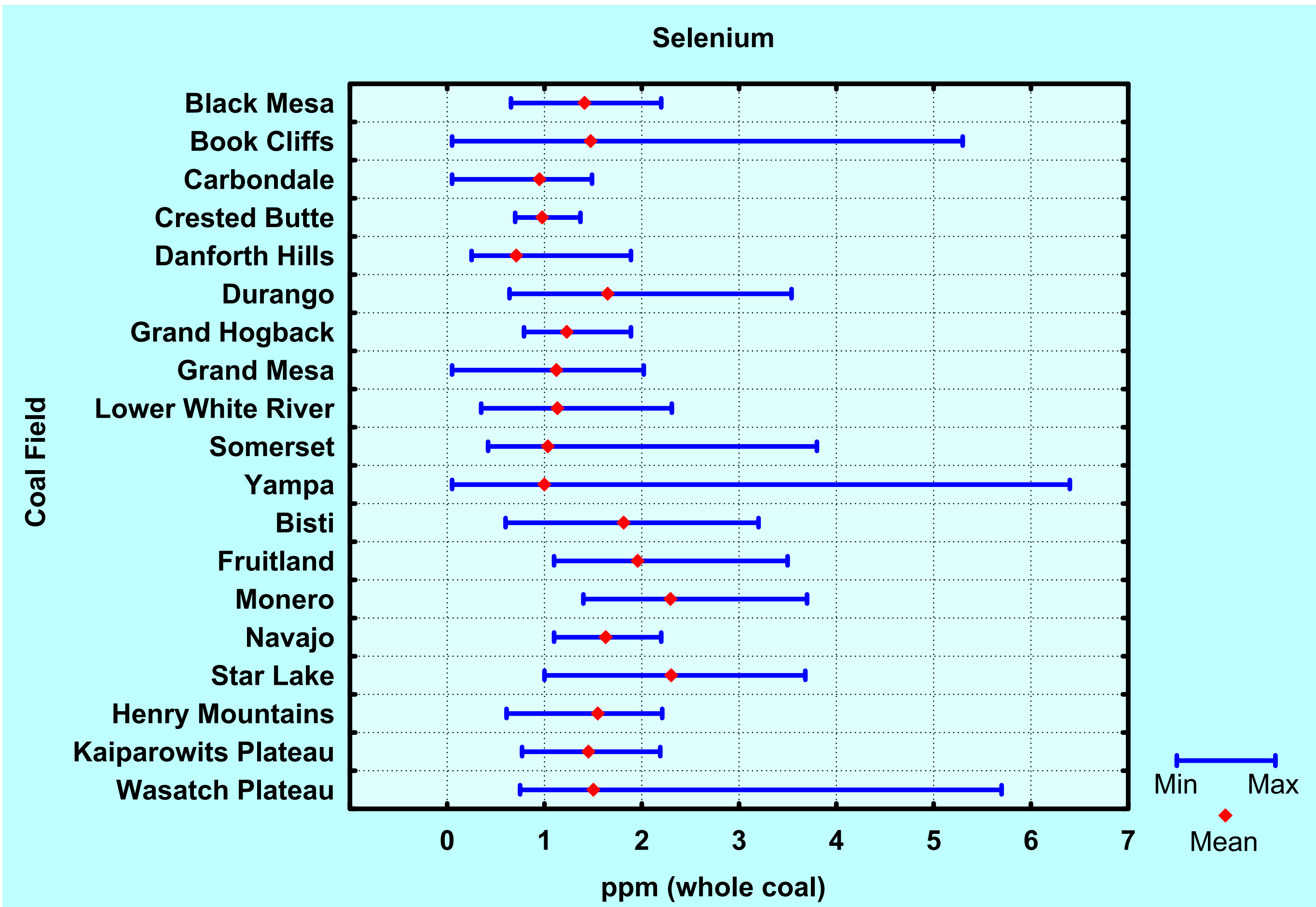


Figure A7-9. Minimum, maximum, and mean content of selenium for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

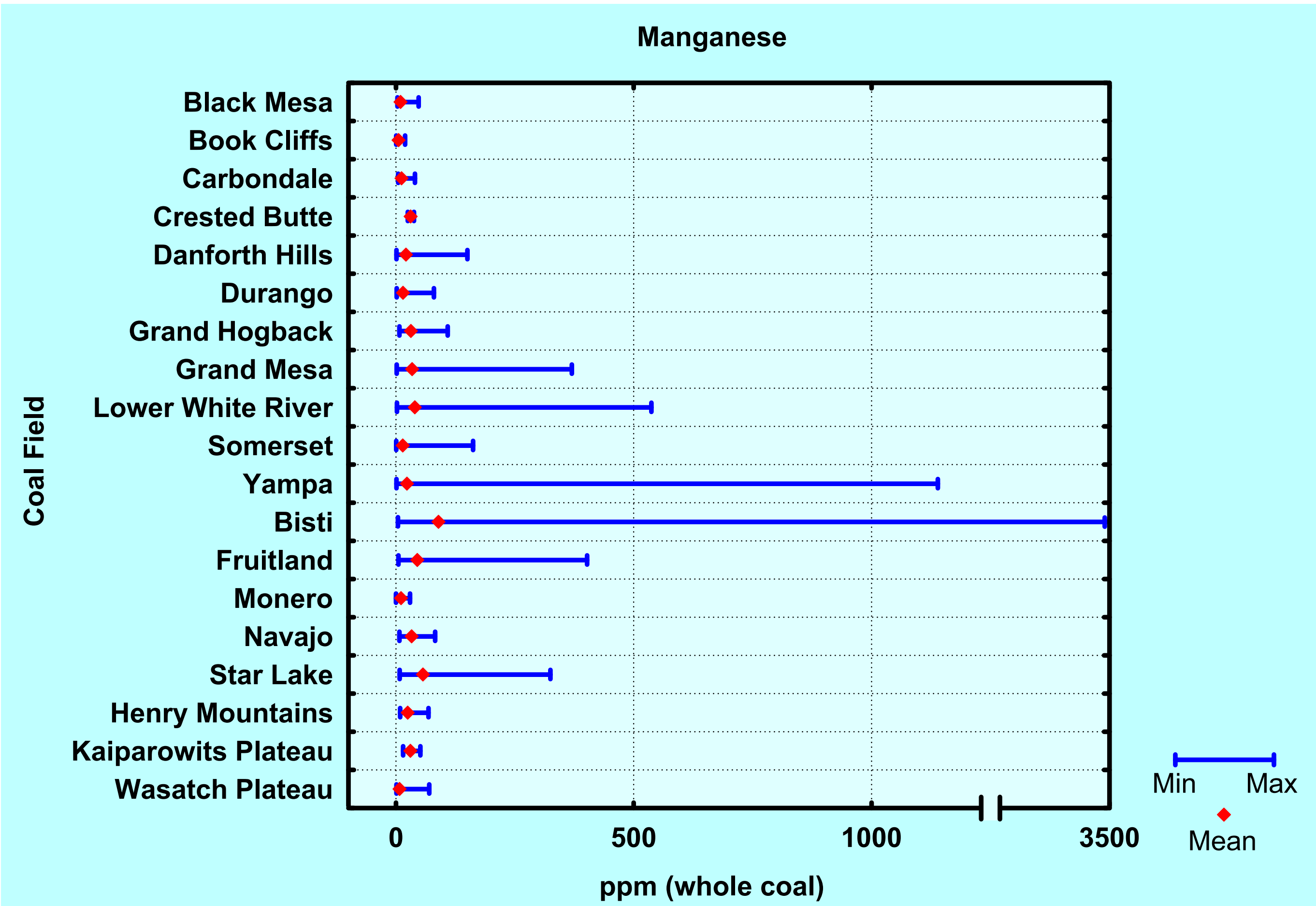


Figure A7-10. Minimum, maximum, and mean content of manganese for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

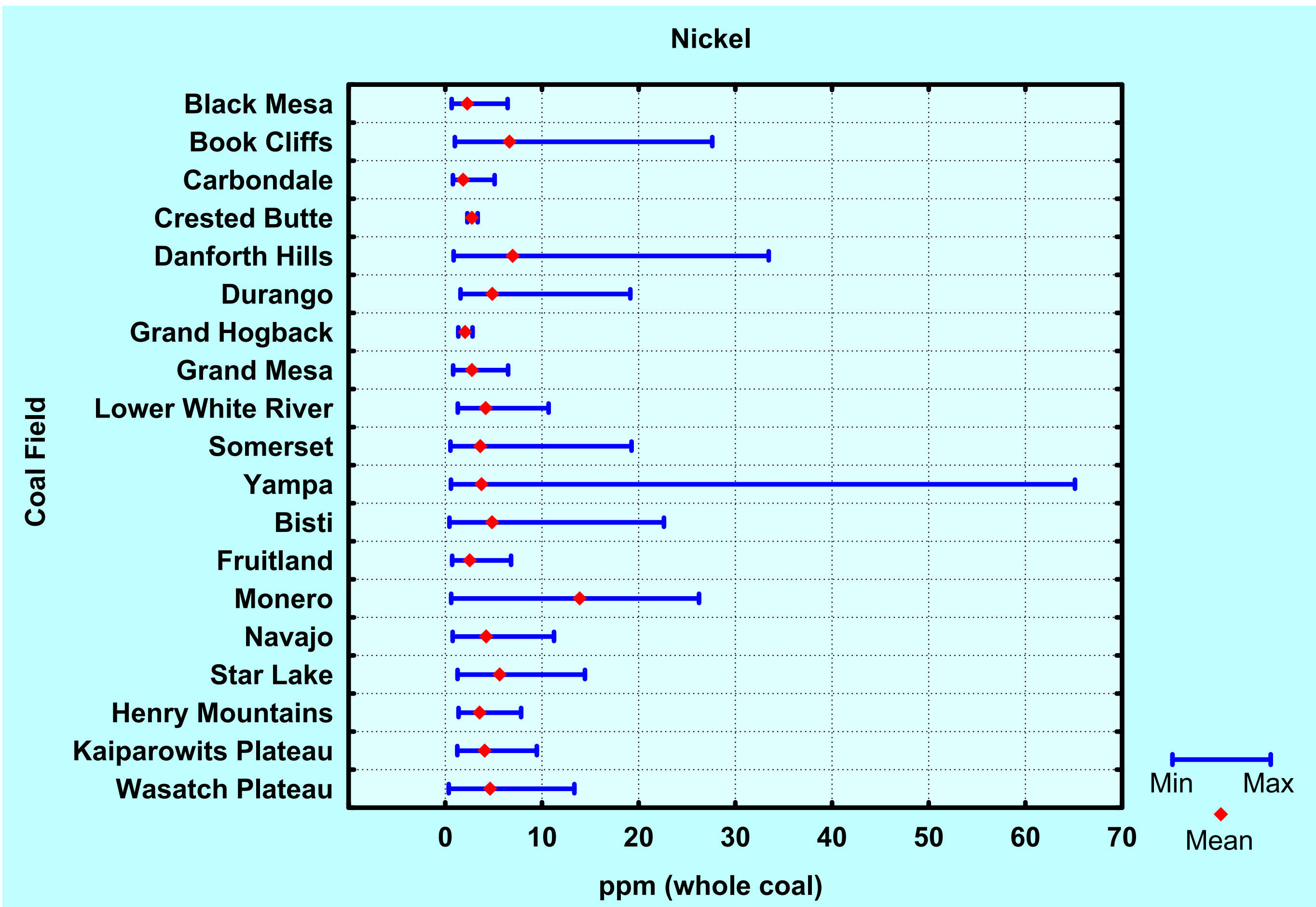


Figure A7-11. Minimum, maximum, and mean content of nickel for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

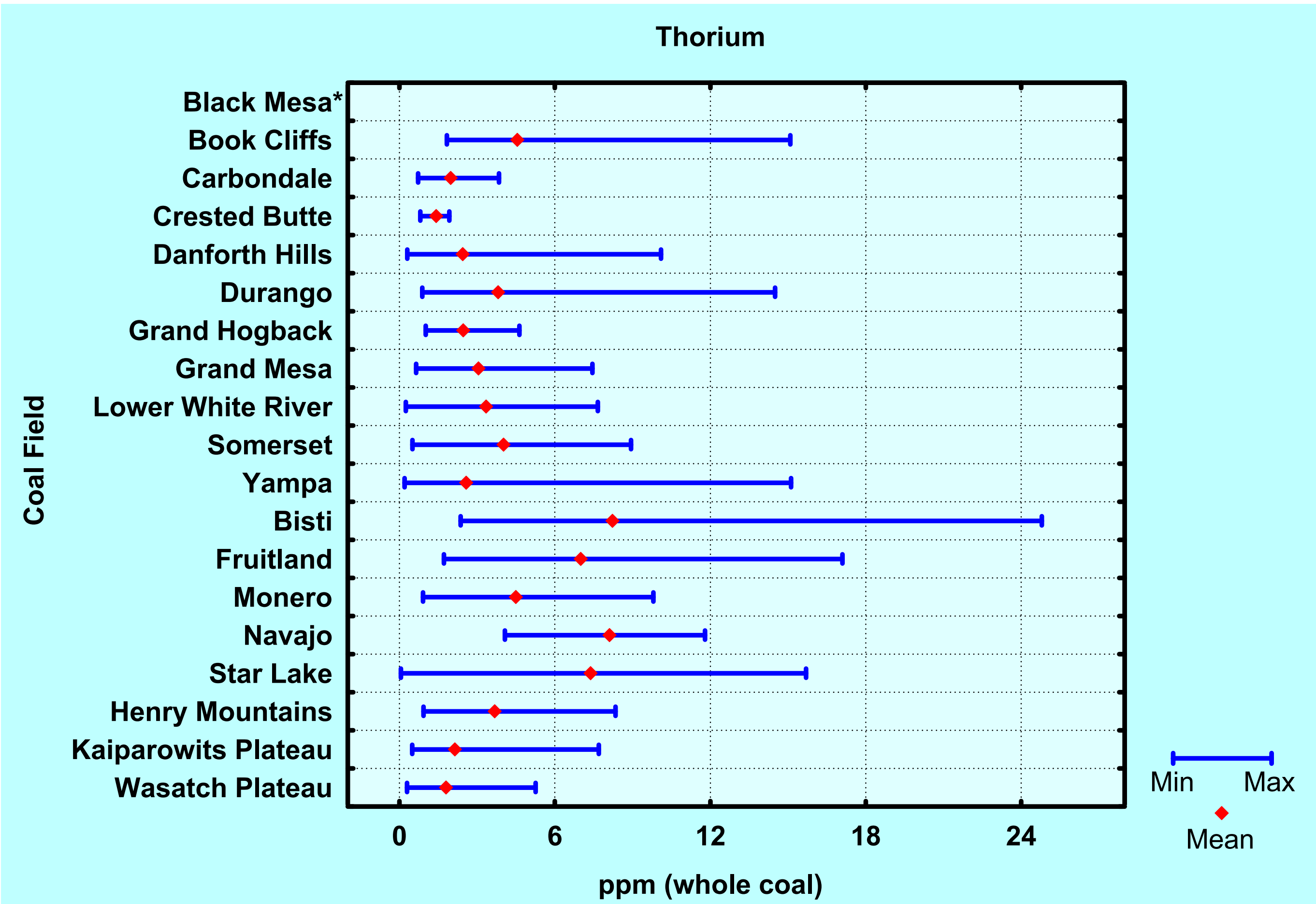


Figure A7-12. Minimum, maximum, and mean content of thorium for coal from high-priority coal fields in the Colorado Plateau coal assessment area (* indicates insufficient data).

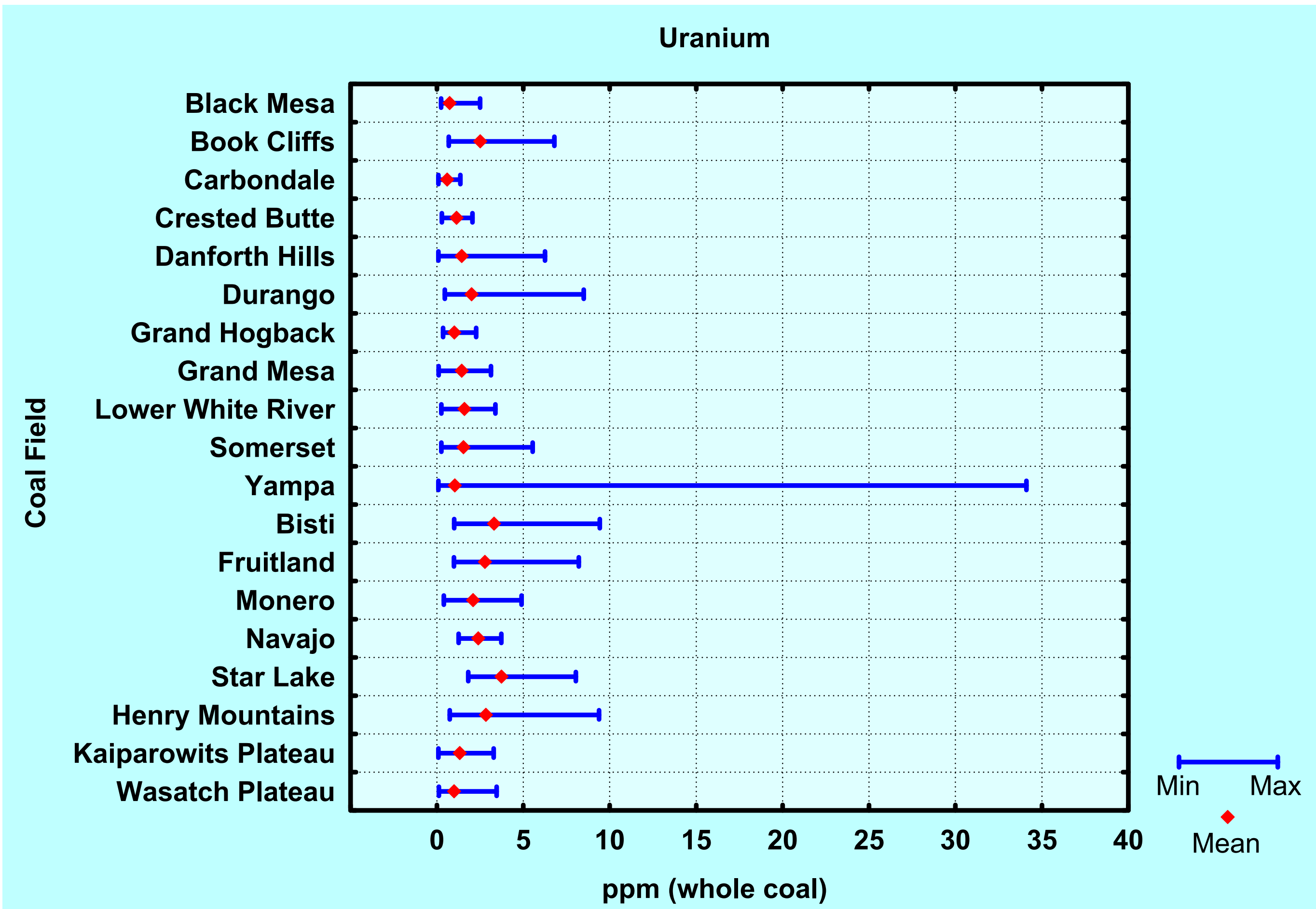


Figure A7-13. Minimum, maximum, and mean content of uranium for coal from high-priority coal fields in the Colorado Plateau coal assessment area.

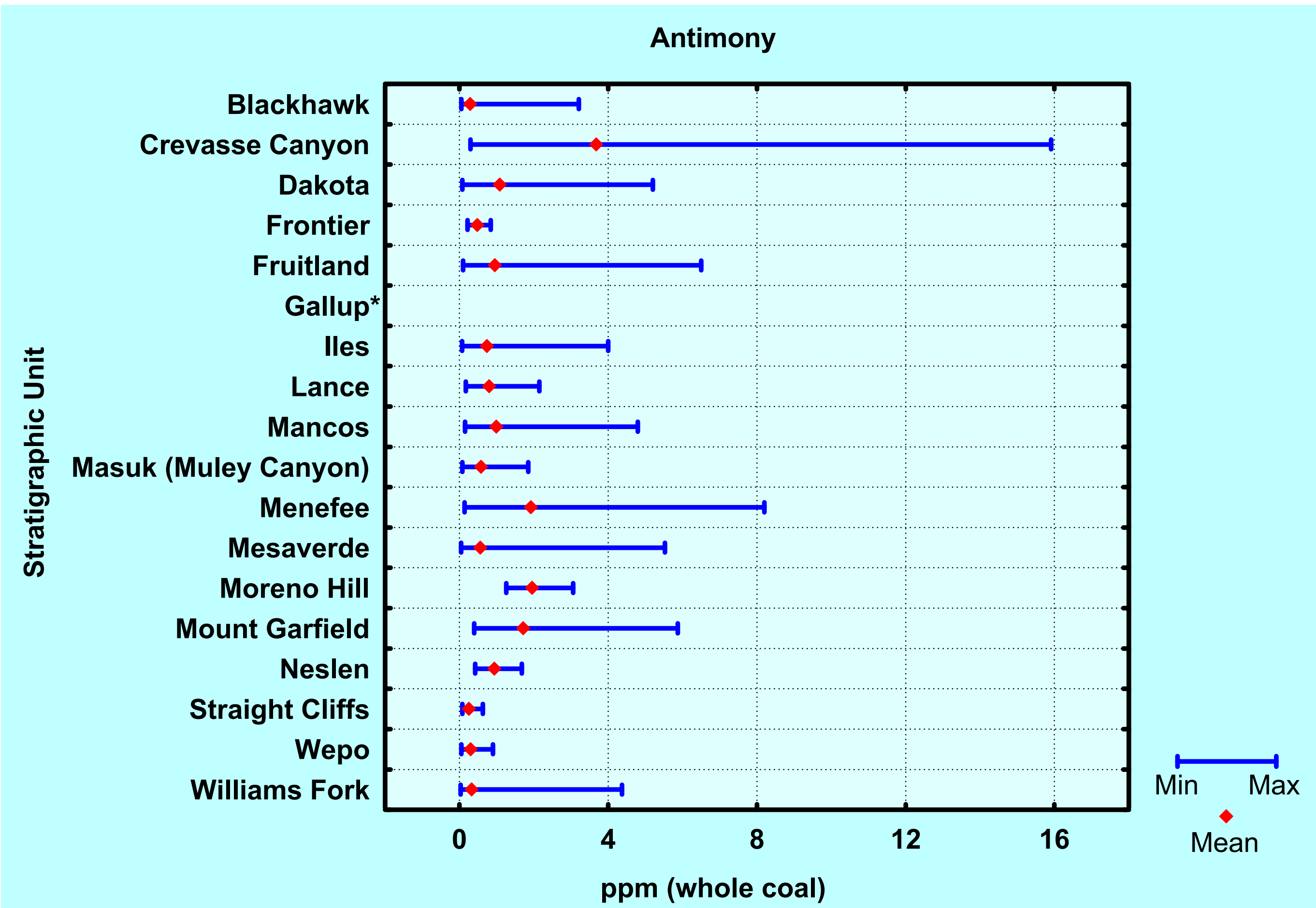


Figure A7-14. Minimum, maximum, and mean content of antimony for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

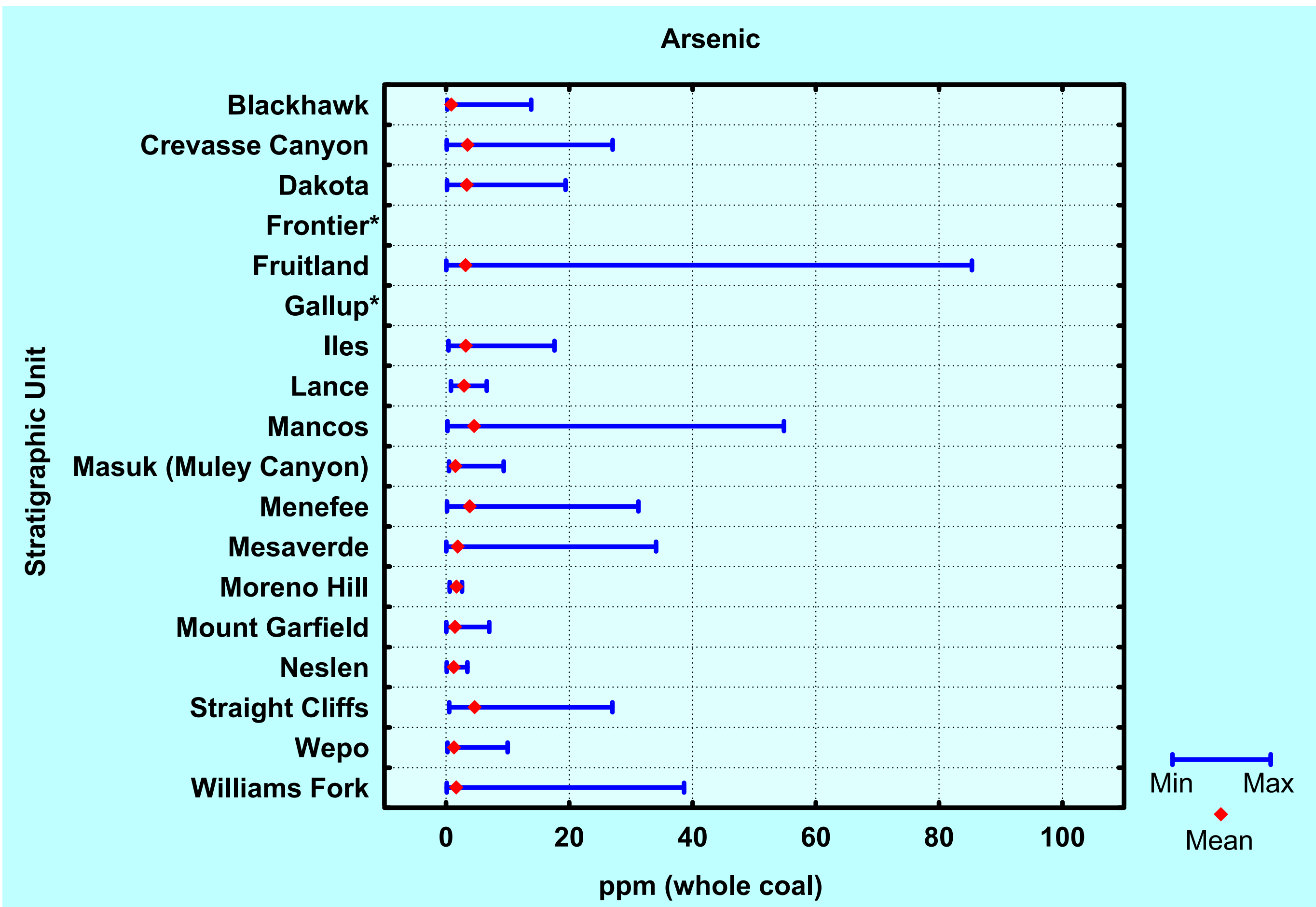


Figure A7-15. Minimum, maximum, and mean content of arsenic for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

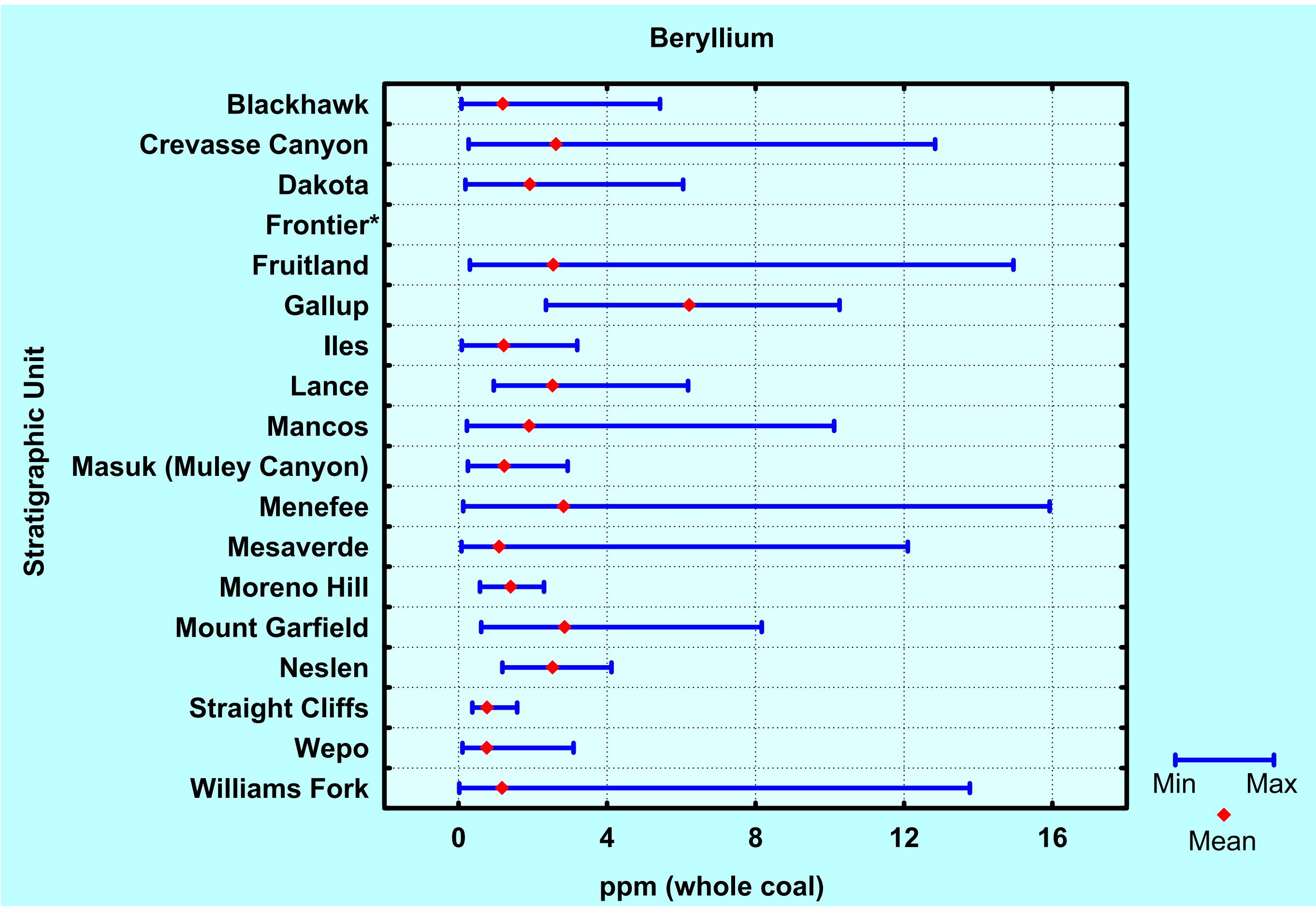


Figure A7-16. Minimum, maximum, and mean content of beryllium for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

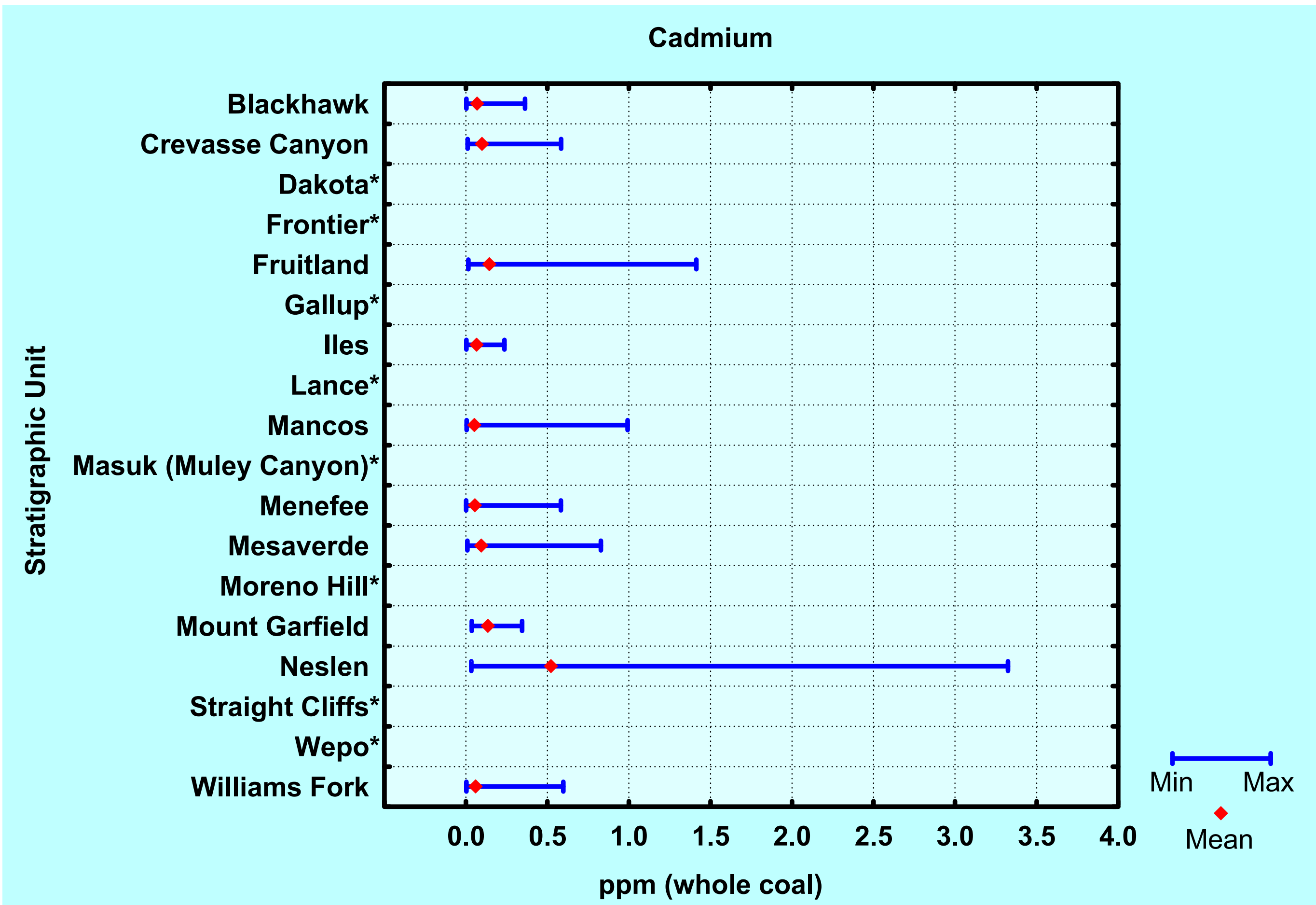


Figure A7-17. Minimum, maximum, and mean content of cadmium for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

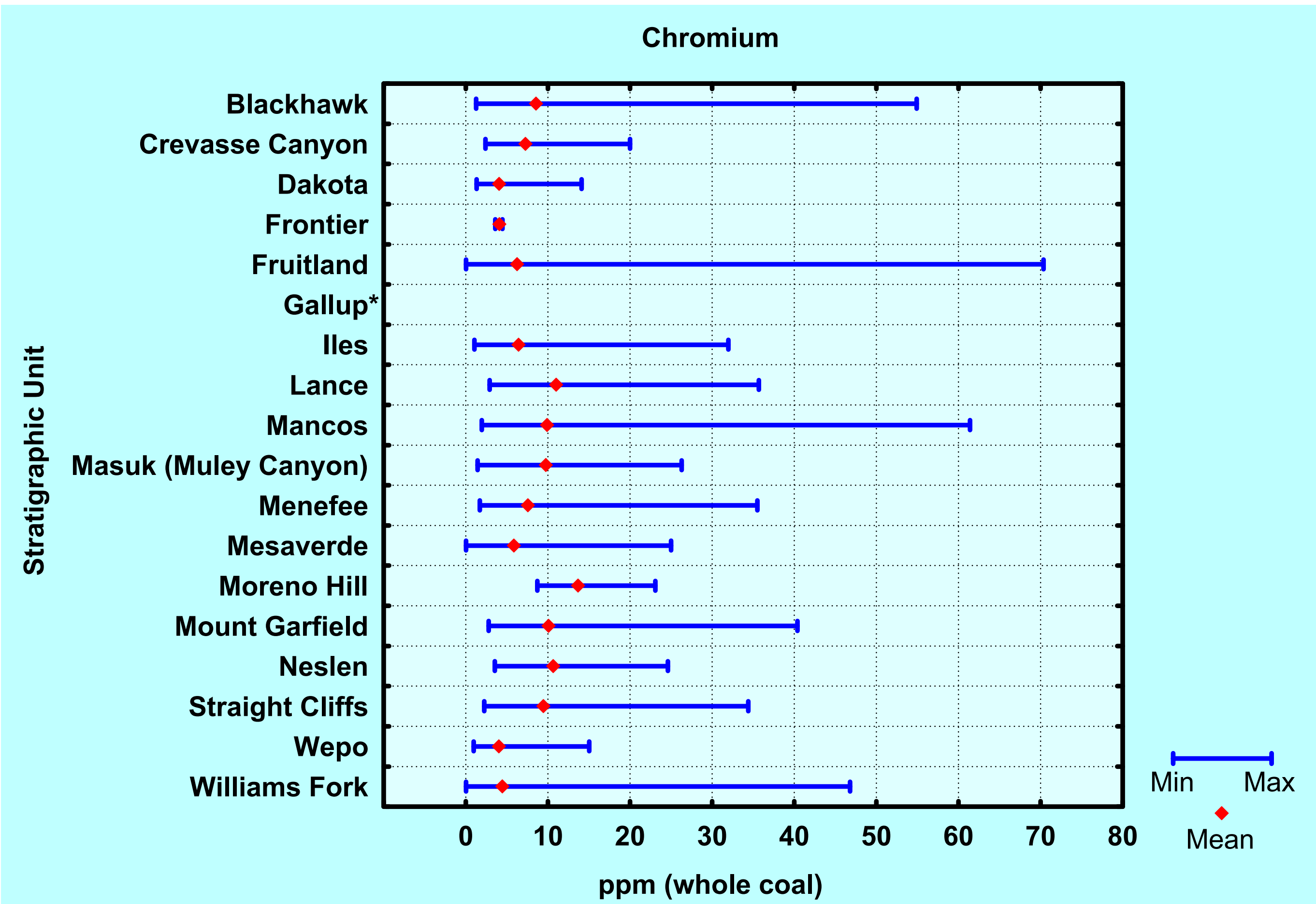


Figure A7-18. Minimum, maximum, and mean content of chromium for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

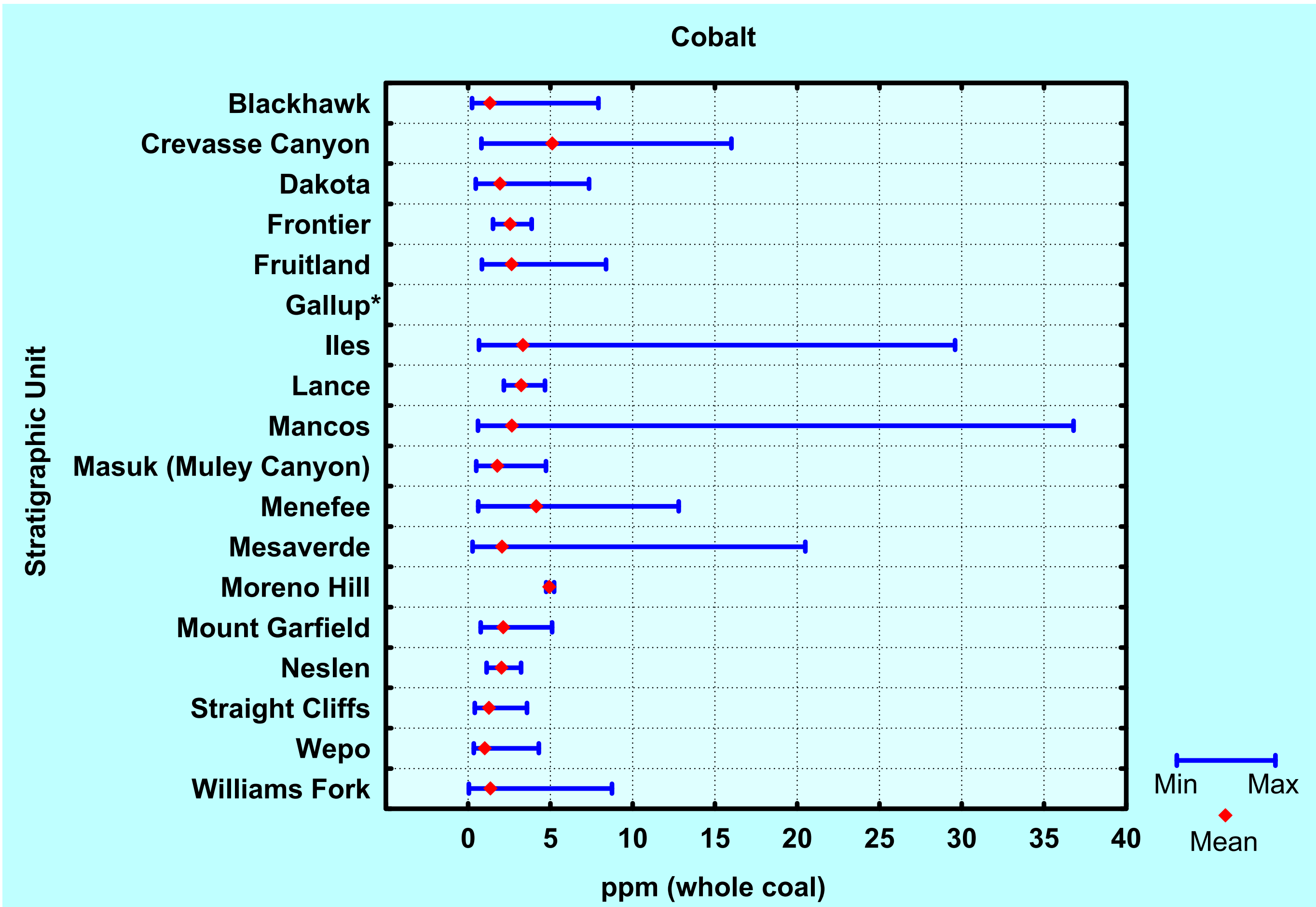


Figure A7-19. Minimum, maximum, and mean content of cobalt for coal from all stratigraphic units in the Colorado Plateau coal assessment area.

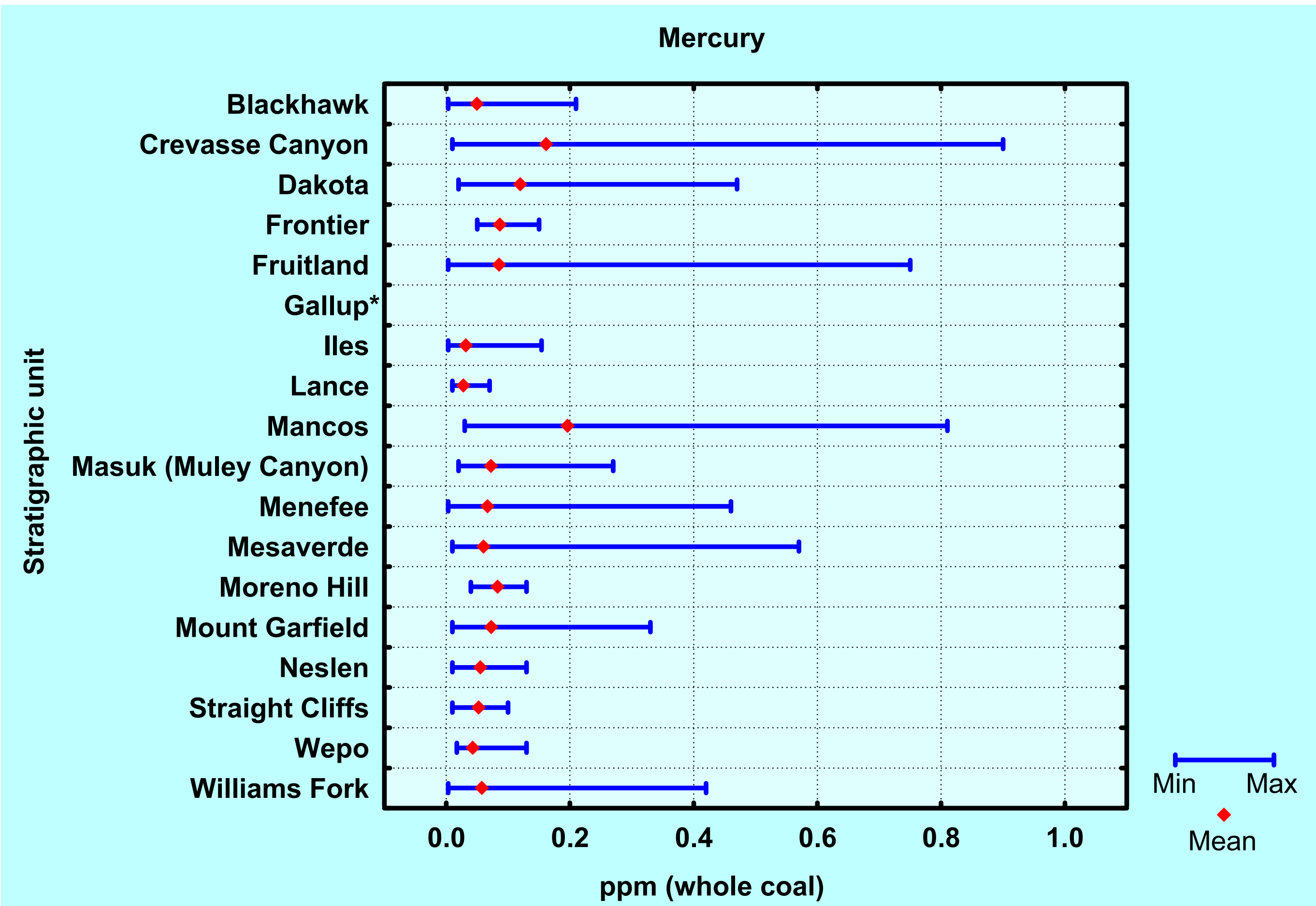


Figure A7-20. Minimum, maximum, and mean content of mercury for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

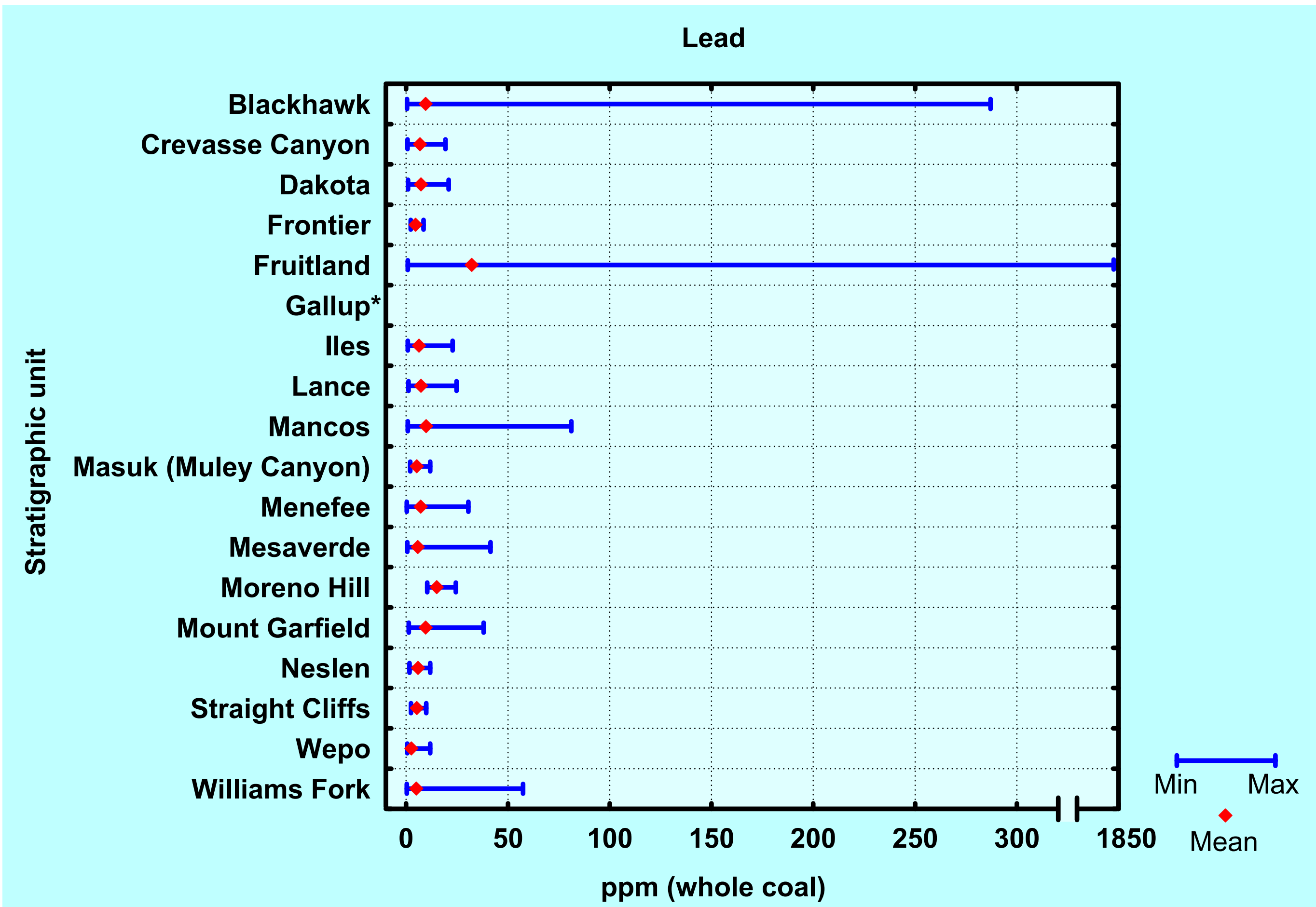


Figure A7-21. Minimum, maximum, and mean content of lead for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

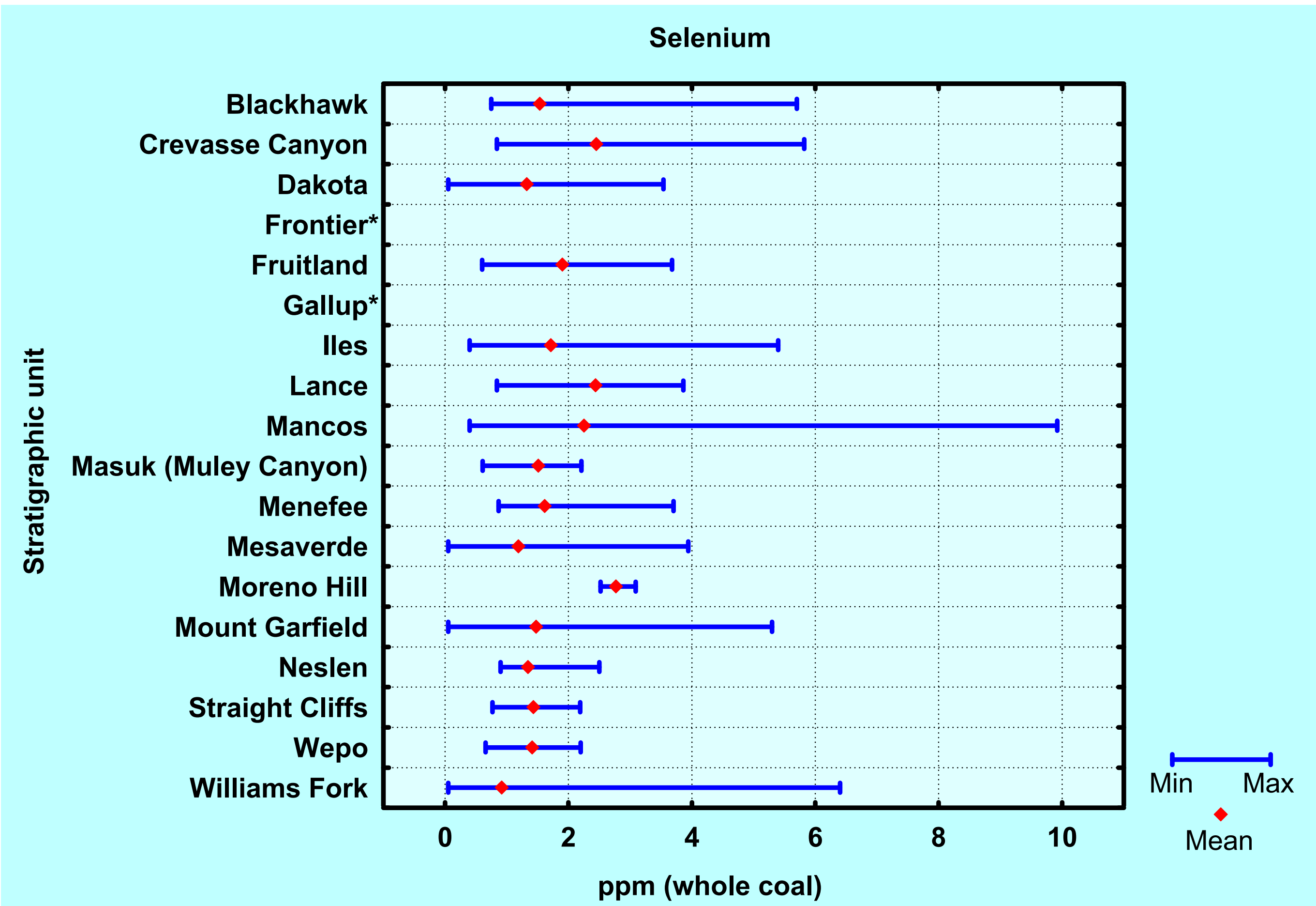


Figure A7-22. Minimum, maximum, and mean content of selenium for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

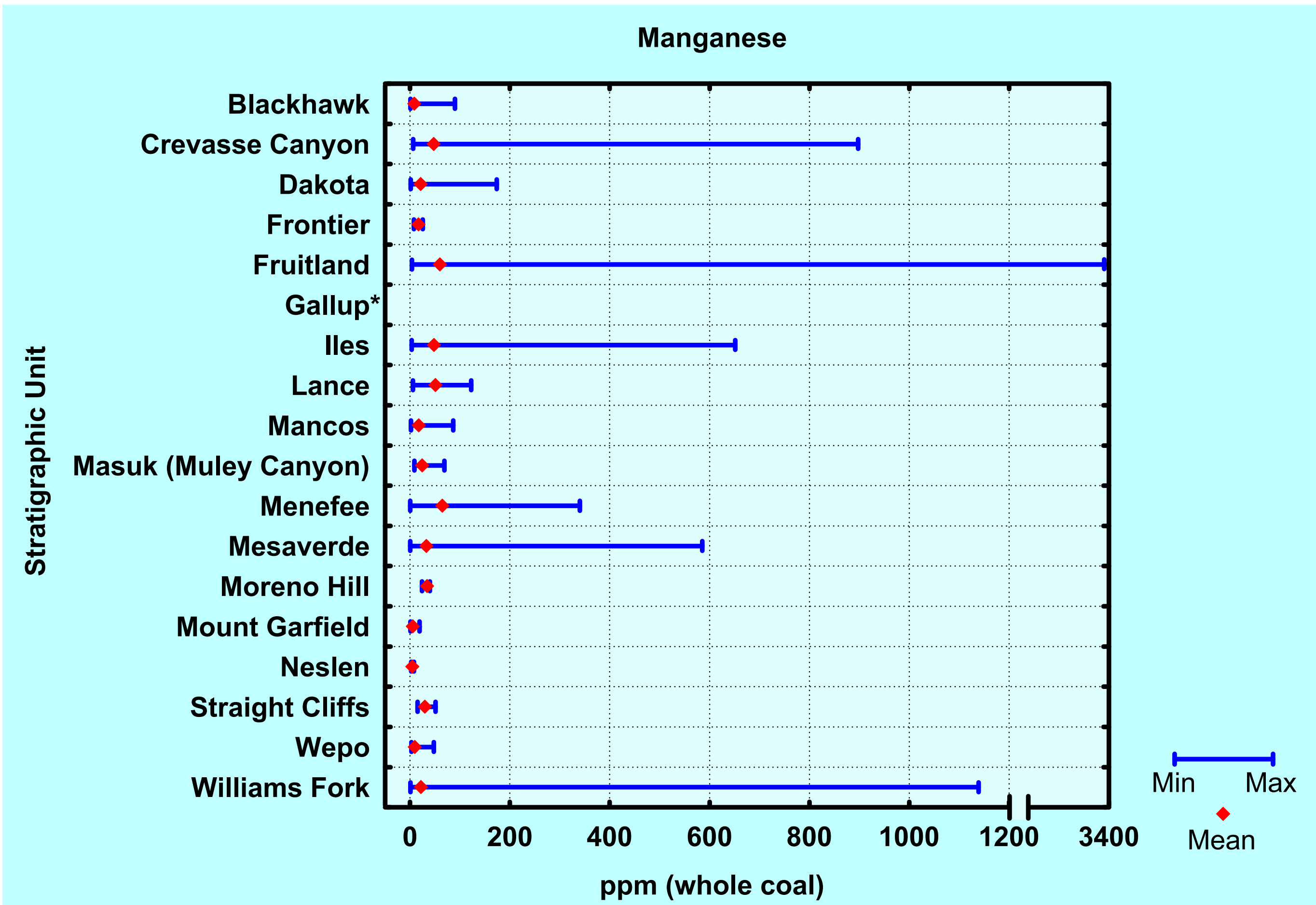


Figure A7-23. Minimum, maximum, and mean content of manganese for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

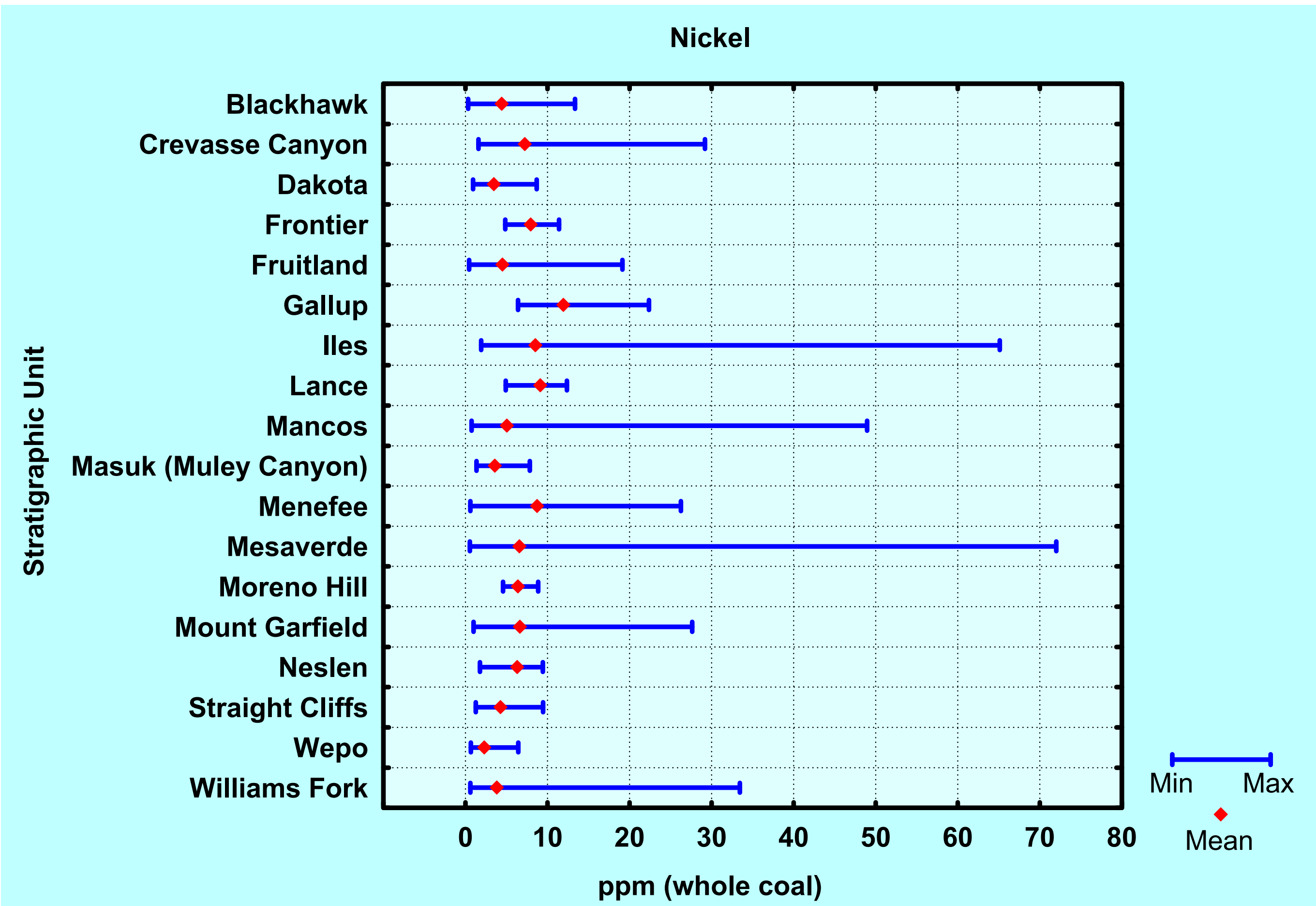


Figure A7-24. Minimum, maximum, and mean content of nickel for coal from all stratigraphic units in the Colorado Plateau coal assessment area.

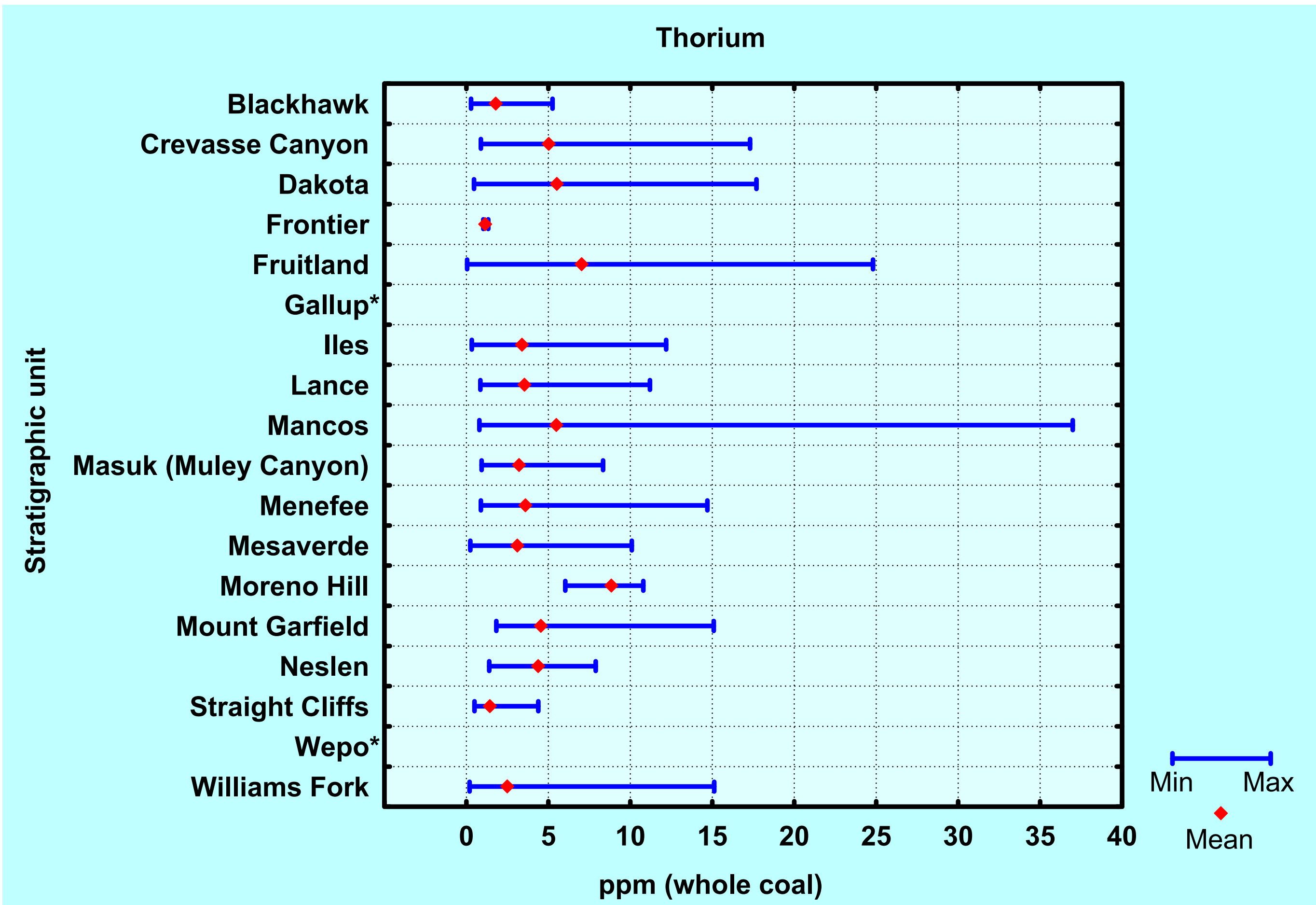


Figure A7-25. Minimum, maximum, and mean content of thorium for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).

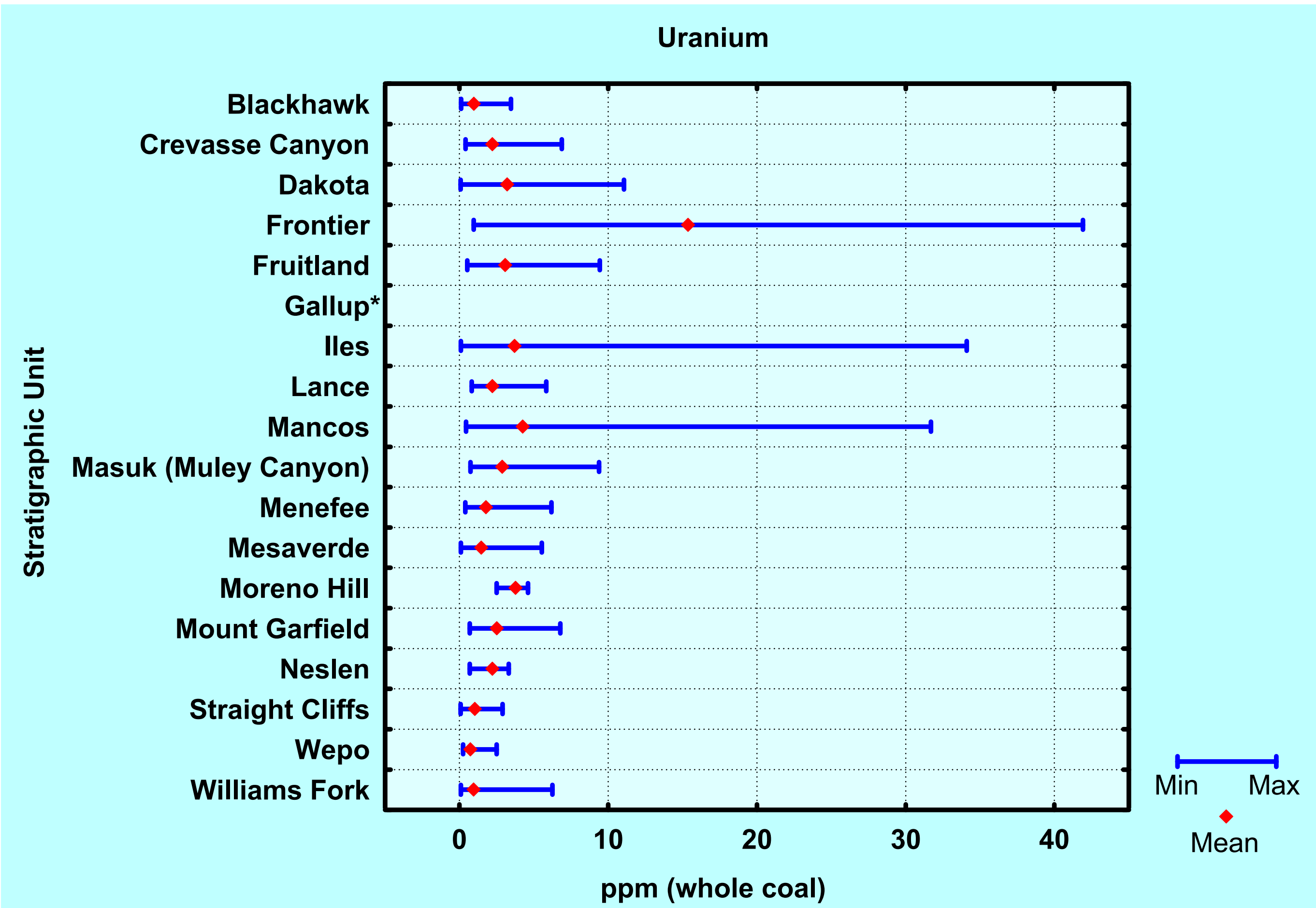
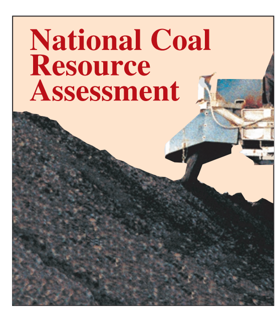


Figure A7-26. Minimum, maximum, and mean content of uranium for coal from all stratigraphic units in the Colorado Plateau coal assessment area (* indicates insufficient data).



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