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COAL ATLAS OF THE MATANUSKA VALLEY, ALASKA

By

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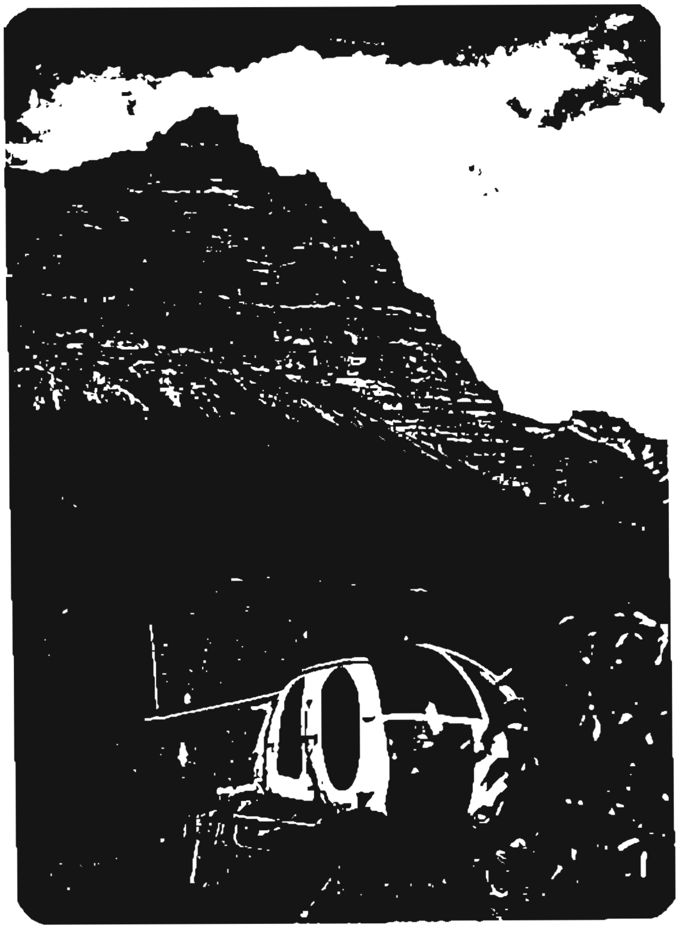

Castle Mountain of central Matanuska Valley overlooks Castle Mountain coal field. The mountain is composed predominantly of massive conglomerate of the Tertiary Wishbone Formation. Chickaloon Formation coal-bearing strata underlies the lower, vegetation-covered section of the mountain.

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FOREWORD

Alaska contains vast resources of bituminous and subbituminous coal, and minor deposits of lignite and anthracite. The high cost of petroleum fuels and uncertainty of long-term supply have created a strong interest by industry, government, and the public in Alaska's coal resources and the feasibility of producing them for local use, export, and the generation of synthetic fuels.

The Alaska Division of Geological and Geophysical Surveys (DGGS) has initiated a program to investigate various coal fields and to assess the coal resources of the state. DGGS is compiling a separate coal atlas for each important coal field. These reports synthesize and summarize all available geological and resource information pertinent to coal development. The Matanuska Valley is the third area selected for study by DGGS.

The purposes of these investigations are: 1) to aid land classification and management as well as in issuing coal prospecting permits and coal leases; 2) to more accurately assess coal resources and reserves and the potential for coal development; 3) to address the numerous inquiries of industry interested in developing the coal resources and of Pacific-rim countries seeking coal supplies; and 4) to provide a single source of information on the coal deposits of an area.

The present report summarizes the results of field studies, laboratory work, and compilation efforts during the 1983-84 fiscal year. It is hoped that this report will serve the interests and needs of a broad spectrum of individuals and agencies within and outside Alaska.

ABSTRACT

The Matanuska Valley of south-central Alaska contains relatively small but important reserves of mainly bituminous coals within the Chickaloon Formation of Early Tertiary age. Identified resources amount to about 100 million short tons, and hypothetical-resource estimates range to 500 million short tons. Most of the potentially minable resources are concentrated in the Eska-Moose (Wishbone Hill area) and Chickaloon fields.

Coals of the Chickaloon Formation formed in paludal swamps of continental alluvial plains. Coal beds have locally been named and correlated between mines in the Wishbone Hill and Chickaloon districts. The average maximum thickness of coal beds of the Matanuska Valley is 8 ft but locally range to over 30 ft. The relative complexity of structure increases eastward in the region. Coals of the Anthracite Ridge field are highly folded and faulted and contain abundant igneous intrusions. The rank of coals increases from subbituminous and high-volatile bituminous in the lower Matanuska Valley, to medium- and low-volatile bituminous in the central Matanuska Valley, and finally to low-volatile bituminous, semianthracite, and anthracite coals of the upper Matanuska Valley.

The quality of Matanuska Valley coals is high compared to other Alaskan coals, and is generally similar to those of the Bering River field. Sulfur

contents are uniformly low (less 1 percent) but ash contents are typically relatively high (mean of 20 percent). Mean heating values are about 10,700 Btu per pound on an as-received basis. Matanuska Valley coals generallv have lower contents of Mn, Zn, B, As, Ni, Pb, Zr, Cu, Sn, Co, Cr, La, Y, Ga, and Be than other coals, but show higher contents of F, Sc, V, Br, I, Cs, Ce, Sm, Eu, and Th than other U.S. coals.

Coal overburdens of the Matanuska Valley are very low in pyritic sulfur (mean content 0.02 percent). Problems with acidic, sodic, or saline minesoils are not anticipated based on recent research. Future mine reclamation programs should be very successful.

The near-term coal-development potential in the Matanuska Valley is high, particularly in the Wishbone Hill district. Because of the relatively small coal-resource base of the region, mine size will be limited to less than 1 million short tons per year.

ACKNOWLEDGMENTS

The author would like to recognize the contributions of M.A. Belowich, who served as a student-intern assistant during field investigations in the Matanuska Valley. He particularly helped in compiling information, drafting plates and figures for the report, and in laboratory petrologic analysis.

Analytical work on coals and overburdens were performed by P.D. Rao of the University of Alaska Mineral Industry Research Laboratory (Fairbanks), Commercial Testing and Engineering, Inc. (Denver, Colorado), and CDS Laboratories (Durango, Colorado). Soloy Helicopters, Inc. of Palmer and Wasilla served as logistical-support contractor.

INTRODUCTION

Location and Accessibility

The Matanuska coal field is located in the Matanuska Valley of south-central Alaska (fig. 1). It is an area immediately adjacent to the Matanuska River and containing mainly Mesozoic sedimentary rocks and the Tertiary coal-bearing rocks that are described in this report (fig. 2). The Matanuska Valley extends eastward from the head of Cook Inlet and separates the Chugach Mountains on the south from the Talkeetna Mountains on the north. The Matanuska coal field lies east of the Little Susitna field and west of the Copper River lowland. It is one of the two major historic coal-producing fields of Alaska, and has been subdivided into three major districts---Wishbone Hill, Chickaloon, and Anthracite Ridge (Barnes and Payne, 1956). The field is 6 to 8 mi wide, 50 mi long, has an area of at least 200 mi^2, and lies 50 to 100 mi northeast of Anchorage. Its western end is 25 to 50 mi northeast of tidewater, and the center of the coal field is 150 mi from Seward by rail. The general trend of the coal field is N. 70° E, and it is located at 61° latitude (Martin and Katz, 1912; Tuck, 1937a, Apell, 1944; and Krieg and Associates, 1983).

The lower Matanuska Valley is traversed by the Alaska Railroad, and at one time a 22-mi segment connected Matanuska station to Palmer, Sutton, Eska, and Jonesville in the eastern part of the district. However, the rails along this line were pulled after closure of the Evan Jones mine. In addition, a spur line was constructed along Moose Creek at the west end of the Wishbone Hill district, but this tract was abandoned after a 1942 flood. Subsequently, coal from the Premier and Moose Creek mines was transported by trucks. The Glenn Highway transects the Matanuska Valley passing 2 mi south of Wishbone Hill and connects the Anchorage-Palmer Highway with the Richardson Highway and interior Alaska. Palmer is 12 mi south of the old Premier and Buffalo mines, and Anchorage is 50 mi south of Palmer. Secondary gravelled roads connect the Eska and Jonesville mines on Eska Creek, and the Premier and Buffalo mines on Moose Creek to the Glenn Highway (Barnes and Payne, 1956).

History and Production

There are several major coal fields and many scattered coal occurrences throughout Alaska, where coal has been removed and used for local consumption. River steamers and ships plying the Bering Sea and Arctic Ocean also used Alaska coal. Prior to World War II, the Alaska Railroad was the chief consumer of coal mined in the state. During the war, Alaska was designated a military combat area, a large influx of military men and equipment was brought into the Territory, and the increased demand for coal greatly exceeded the pre-war requirements---from 200,000 to 500,000 or 600,000 tons per year. The U.S. Bureau of Mines (USBM) explored several coal areas in an attempt to locate and define adequate supplies of coal throughout the Territory. The USBM began exploring the Moose Creek area to encourage production of Alaska coal because of the high cost of imported fuel supplies (USBM War Minerals Report, 1944b). In 1932, they conducted a core-drilling program west of Moose Creek drilling 3,700 ft at five locations. A more ambitious core-drilling program was conducted in the Moose Creek area from

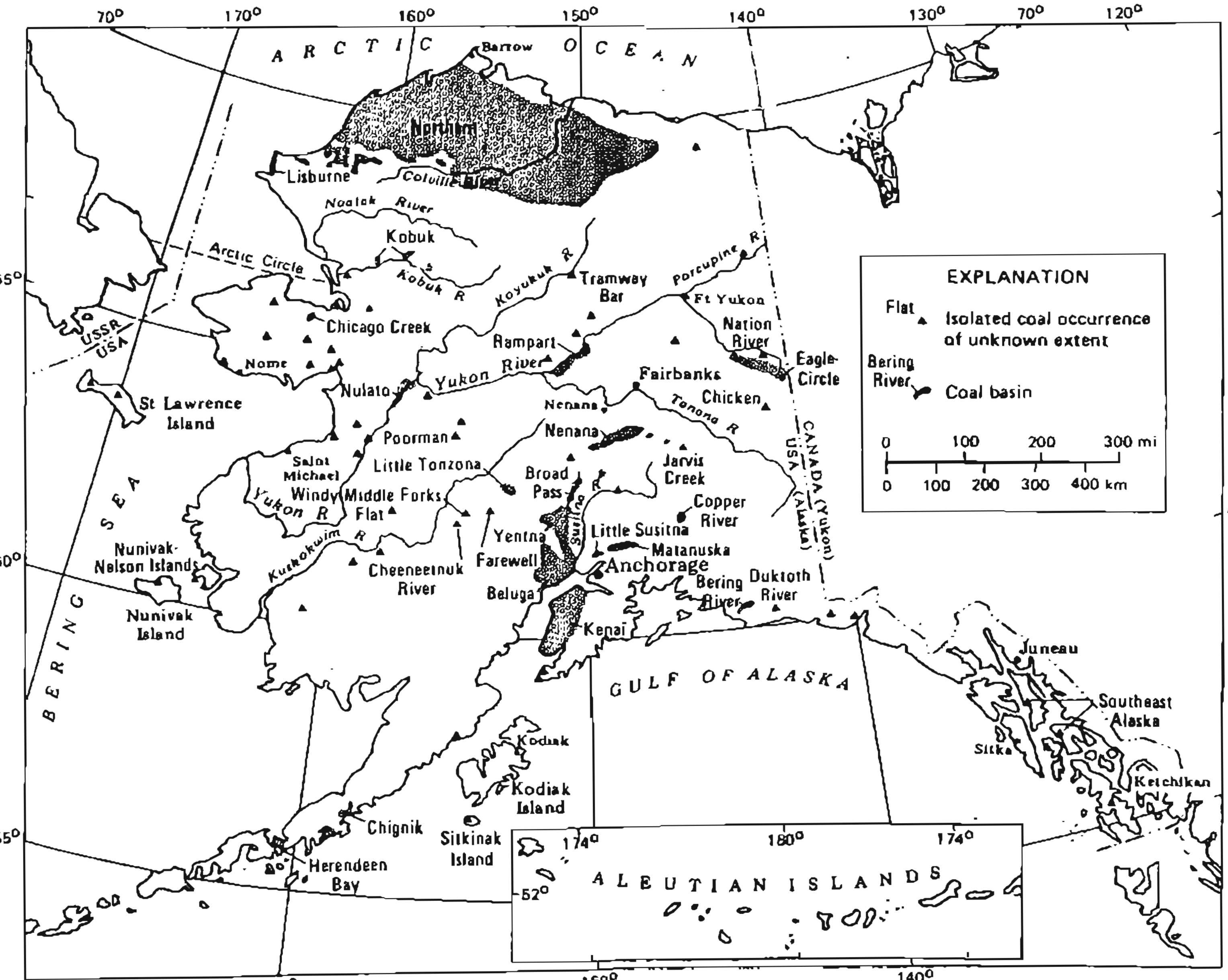
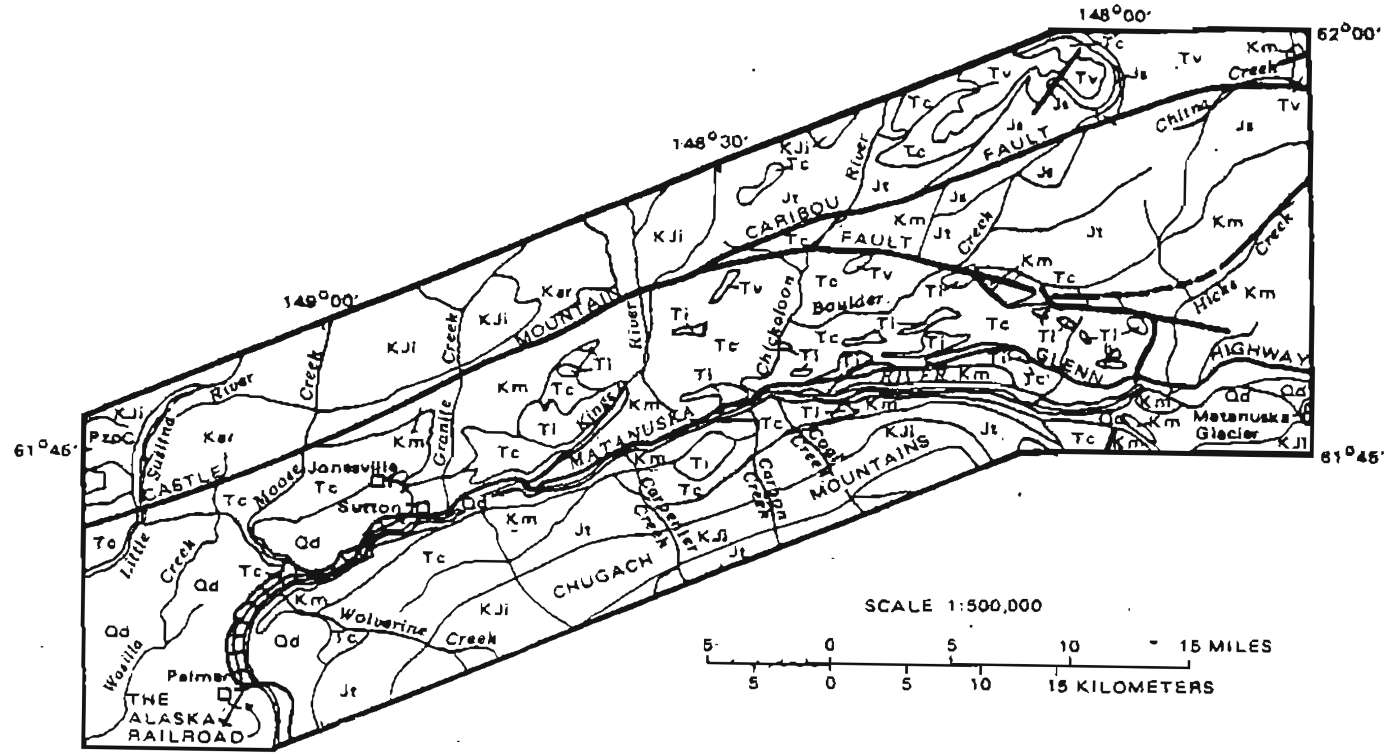


Figure 1. Alaska's coal basins, fields, and isolated occurrences.



CORRELATION OF MAP UNITS

Unit	Age	Period
Qd	Pleistocene and Recent	QUATERNARY
Tv	Oligocene	TERTIARY
Ti	Paleocene, Eocene, and Oligocene	TERTIARY
Tc	Paleocene, Eocene, and Oligocene	TERTIARY
Km	Lower and Upper(?) Cretaceous	CRETACEOUS
Kar	Lower and Upper(?) Cretaceous	CRETACEOUS
KJi	Middle Jurassic to Early Cretaceous	CRETACEOUS / JURASSIC
Js	Middle and Upper Jurassic	JURASSIC
Jt	Lower Jurassic	JURASSIC
PzpC		PRECAMBRIAN OR PALEOZOIC

DESCRIPTION OF MAP UNITS

Unit	Description
Qd	Surficial deposits
Tv	Volcanic rocks — Mainly basaltic lava flows
Ti	Hypabyssal intrusive rocks
Tc	Continental clastic sedimentary rocks — Includes Chickaloon, Wishbone, and Tsadaka Formations
Km	Matanuska Formation — Marine clastic sedimentary rocks
Kar	Arkose Ridge Formation — Nonmarine arkose, conglomerate, and siltstone
KJi	Plutonic intrusive rocks — Mainly quartz diorite and granodiorite
Js	Marine clastic sedimentary rocks — Consists of Tuxedni, Chinitna, and Naknek Formation
Jt	Talkeetna Formation — Dominantly marine, intermediate volcanic and sedimentary rocks
PzpC	Muscovite schist

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Major faults — Dashed where inferred.

Figure 2. Generalized geologic map of the Matanuska Valley. Modified from Grantz, 1964.

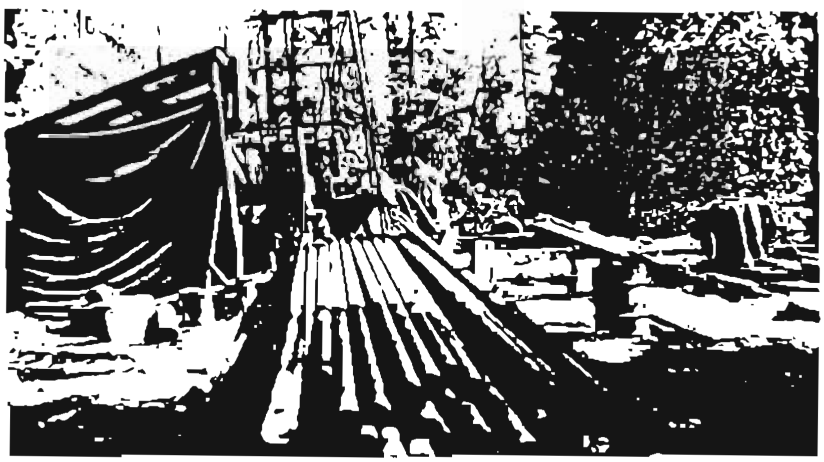
1948-1958 (fig. 3; Sanders, 1981). During the war years, much coal was imported by cargo ships en route to Alaska (Apell, 1944).

In assuring a supply of coal for the railroad and the Navy, the Alaska Engineering Commission and Navy Alaska Commission performed much of the early exploration and development in the Matanuska coal field. The first coal was mined in the Matanuska Valley in 1916, and thereafter production was fairly continuous with one to four mines being in operation at any one time (fig. 4; Barnes and Payne, 1956). The Matanuska Valley has been one of the two major historic coal-producting fields of Alaska, along with Nenana, and has been the principal productive bituminous coal field of Alaska (Smith, 1939). Coal was also mined intermittently from the Houston area since 1917; a short prospect tunnel was driven at the mouth of Coal Creek and produced some coal for use at the gold mines of the Willow Creek district. Coal production from the Wishbone Hill and Chickaloon districts during the first half of the century played an important part in the economic development of this region of Alaska (Tuck, 1937b).

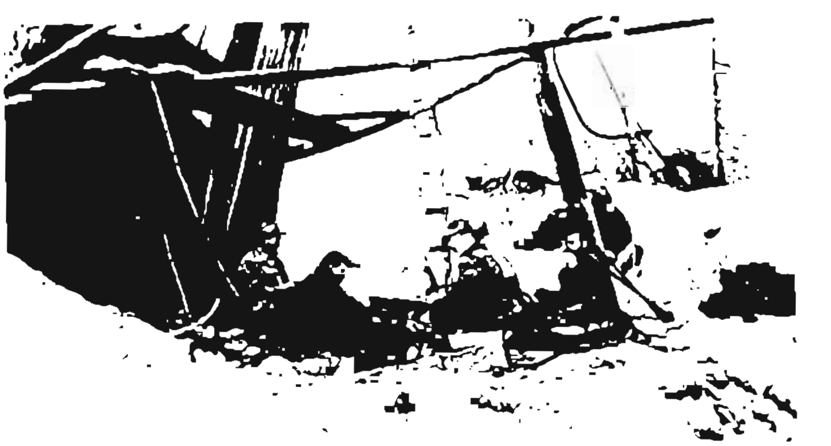
After the completion of the Matanuska branch of the Alaska Railroad to Chickaloon in 1917, the Chickaloon district was explored by the Federal Government---the Alaska Engineering Commission (later Alaska Railroad) on the Chickaloon River and the Navy Department on Coal Creek. A mine on the Chickaloon River was developed by a number of crosscut tunnels and connecting drifts driven along the best coal beds in 1917-18 (Chapin, 1920). The USBM conducted two favorable coking tests on samples of Chickaloon coal in 1918. The U.S. Navy built the coal mining town of Chickaloon in 1920 (fig. 5). It was later abandoned and dismantled when it was discovered that the coal was unminable and unsatisfactory for naval use. However, several thousand tons of coal were mined at Chickaloon and Coal Creek mines incidental to exploration and in 1922 a large sample was washed and shipped for a Navy steaming test. From 1925 to 1930, 1,650 tons of coal were produced by a private operator on the west side of Coal Creek (the Hecky mine) and sold to the railroad. The Chickaloon district was inactive from 1930 to 1958. From 1958 to 1960, the Castle Mountain mine, located on the south slope of Castle Mountain and 3 mi northwest of the earlier development on the Chickaloon River, produced 20,700 tons of coal which were sold to Anchorage military bases for power generation purposes (Warfield, 1967).

Two mines have accounted for the majority of coal production in the Wishbone Hill district---the Evan Jones and Eska mines. Coal was mined from nearly a dozen beds, and both mines required washeries to prepare marketable coal (Bain, 1946). The Evan Jones mine, named after the original prospector and first president, operated almost continuously from 1920 until 1968, producing over 6 million tons of coal. The mine was located about 60 rail miles northeast of Anchorage on a 2,560-acre lease 3 mi from the Glenn Highway. It was originally served by a 15-mi spur of the Alaska Railroad, but the tracks were later pulled after the mine closed. From 1920 until 1953, the mine was a room-and-pillar underground operation. Stripping with a dragline and two bulldozers was initiated in 1953 and by 1960 the underground operation was closed entirely (Geer and Fennessy, 1962). High-volatile B bituminous, noncoking to poor coking coal was mined from beds of the Premier series that varied from 1 to 17 ft in thickness and dipped 30° to 50°. The

a. Looking north at drill site of hole 5-20WH (project 826).

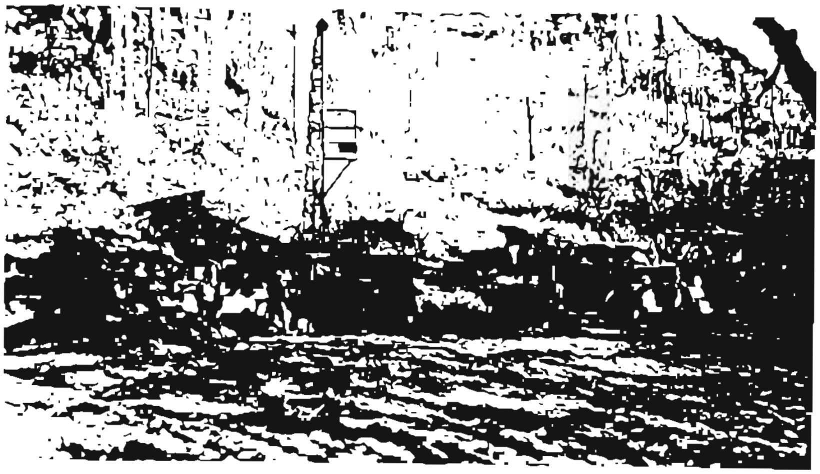


b. Looking east at drill hole site 4-19WH showing wedge used in offsetting (project 826).



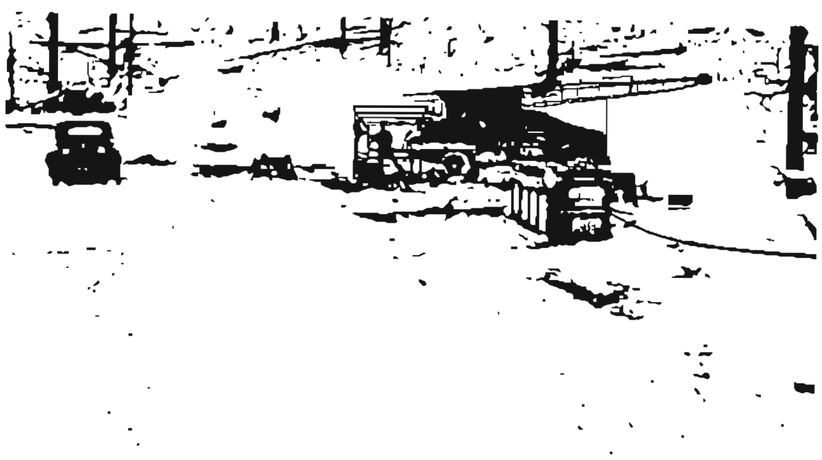
c. Drill hole 15 (project 814) in Eska-Jonesville area at lunchtime. Geologists (left to right) T.R.Jolley, J.H. Hulbert, Charles Hickock, F.F. Barnes, and Clyde Wahrhaftig are logging core after hole completion.

Figure 3. (con.)



a. Drill site at hole 1-20WH showing drill-rig set-up at base of slide rock adjacent to 'Eska Conglomerate' escarpment (project 826).

b. Looking northwest at drill site 2-20WH showing road in foreground leading to 'Eska Conglomerate' escarpment (project 826).



c. Drill site at hole 2-20WH showing lowered derrick and equipment covered for winter recess (project 826).

Figure 3. Historical photos from U.S. Bureau of Mines drilling projects at Wishbone Hill ca. 1948. Reproduced courtesy of R.S. Warfield.

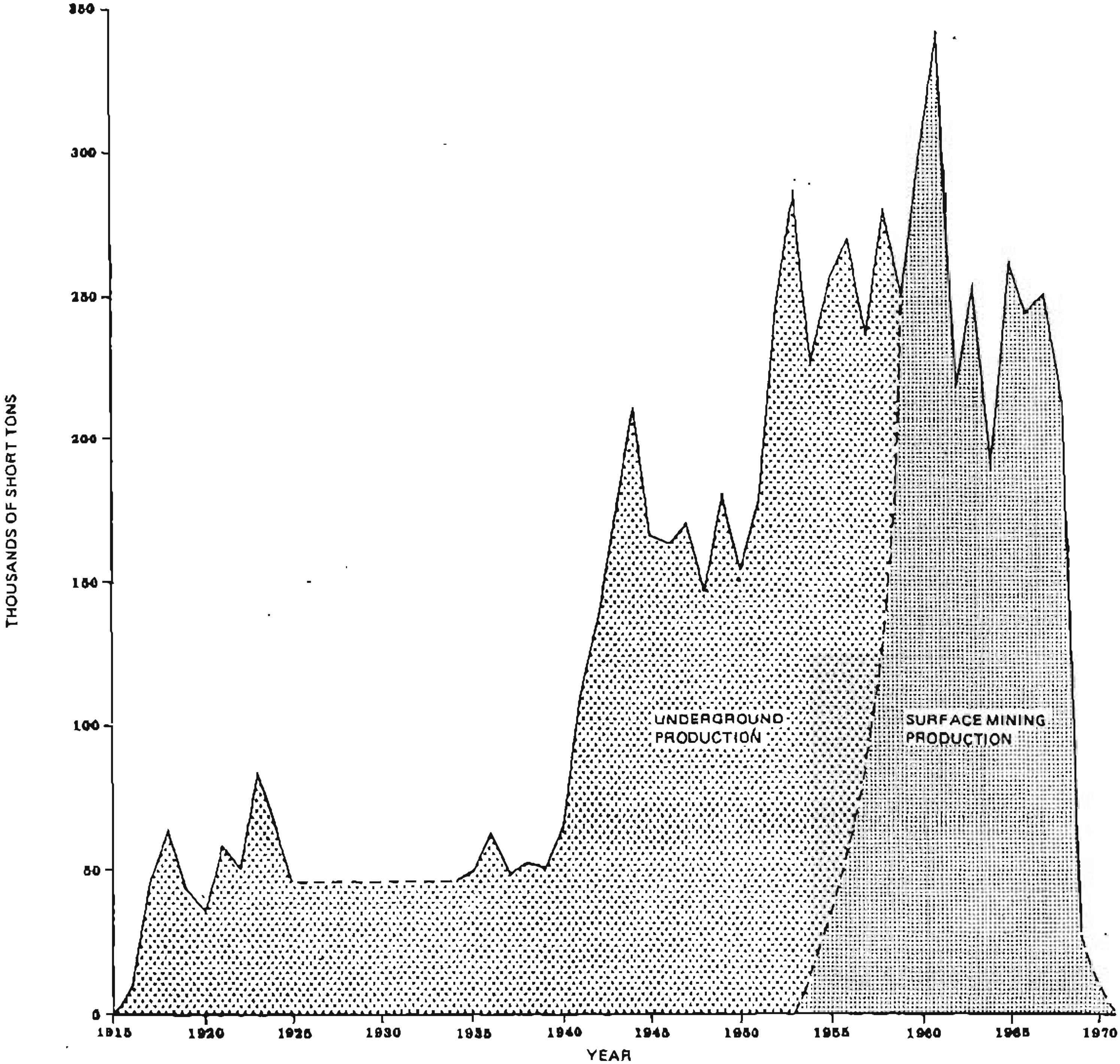


Figure 4. Coal production in Matanuska coal field, 1915-1971.

Figure 5. Coal-mine town at Chickaloon (ca. 1920) with filled coal cars of the Alaska Railroad in the foreground. The railroad was extended to Chickaloon in 1917. Photograph courtesy Lulu Fairbanks Collection, University of Alaska (Fairbanks) Archives.

seams were classified as clean, intermediate, and dirty for washability considerations with about one-third falling in each category (McFarland, 1961). The original screening and washing plant had a capacity over 200 tons per day (Tuck, 1937b).

Placer Amex, Inc., (now Placer U.S., Inc.) was the managing joint-venture partner of the Evan Jones mine from 1959 to its closure in 1968, and still controls the coal lease which is estimated to hold about half of the remaining underground coal reserves of the Wishbone Hill district. The company has completed a preliminary economic analysis of opening a new mine on the property when a market for the coal develops. The 30 to 50 million ton recoverable reserve of coal could support a small mine for about 50 yr. The mine would produce 500,000 tons per year using hydraulic methods and transport to the surface. It is estimated that a $50 million investment would be required to produce coal at a little over $2 per million Btu. Although a new coal washery would be needed, the mine would have established highway and railbed access and an existing power network. The steam coal could be shipped to the Seward terminal for export (Patsch, 1981).

The Eska mine was operated on the south limb of Wishbone Hill by the Alaska Railroad intermittently from 1919 through World War II (figs. 6 and 7). At one time the mine employed as many as 85 men. Coal at the mine was removed from six productive beds——Martin, Shaw, Eska, Maitland, David, and Emery——occupying the eastern portion of the Wishbone Hill syncline (Chapin, 1921). The facilities at the mine included a cleaning plant and washery. Barnes (1951) performed field mapping and exploratory drilling in the northwest part of the Eska coal reserve in 1944-46 and found the presence of at least 11 coal beds with three composing the Eska series developed at the Eska mine. Identified coal resources of 600,000 tons remain in the vicinity of the abandoned mine.

The Eska mine surface installations and washing plant were sold to Mrak Coal Company, who used the facilities and modern stripping methods to become a relatively large-scale producer in the region (Race, 1962). The Mrak mine was a strip operation that produced in the late 1950's and early 1960's from a number of relatively small pits at the former site of the Eska mine (Geer and Fennessy, 1962).

Some coal mines have operated intermittently and produced some coal on the north slope of Wishbone Hill since the early 20th century. These have included the Buffalo, Baxter, Premier, New Black Diamond, Wishbone Hill, and Matanuska Center (Howard and Jesson) mines. These mines occupied an area of only about 2 mi^2. Of the 112 million tons of identified coal resources in the Wishbone Hill district (Barnes, 1967) only about 7.5 million tons of the most readily exploitable coal have been removed. The chronological history of this development is summarized in Appendix A.

Valley Coal Company has been involved in an extensive exploration drilling program and premine feasibility study on state coal leases west and southwest of Wishbone Hill over the past several years (figs. 8 and 9). Evan Jones Coal Company (subsidiary of Placer, U.S., Inc.) has performed a preliminary feasibility study to determine if the Evan Jones coal mine can be

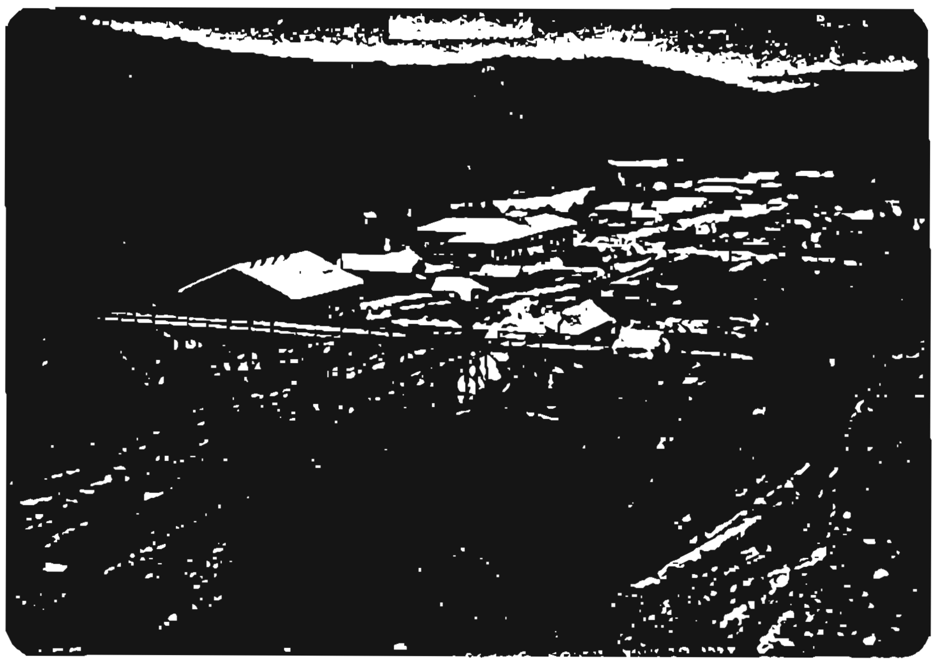


Figure 6. Eska coal mine town ca. 1921. Courtesy of Bunnell Collection, University of Alaska Archives.

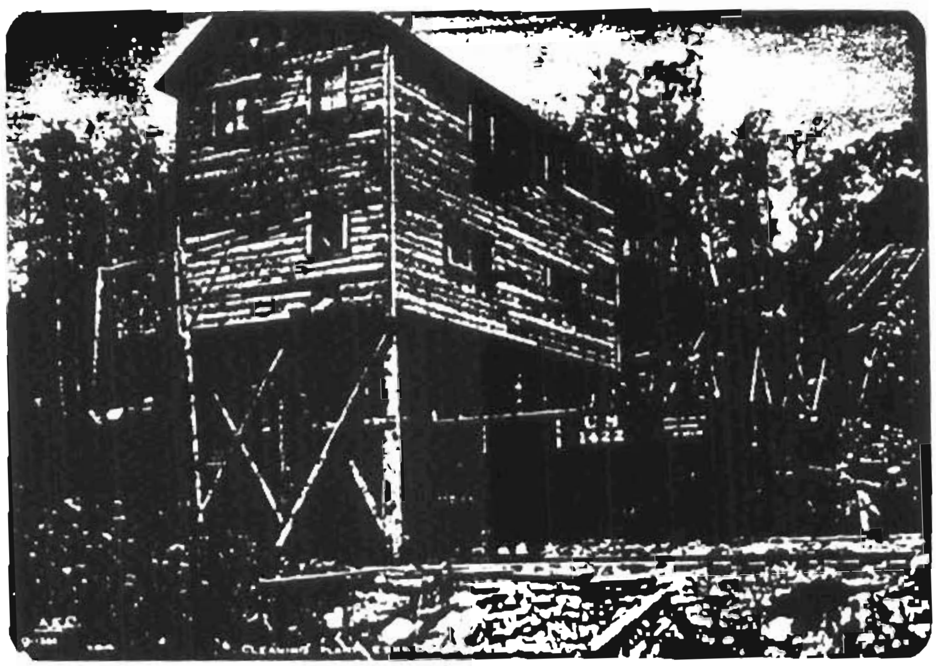


Figure 7. Coal cleaning plant at Eska, Matanuska Valley ca. 1919. Courtesy of Bunnell Collection, University of Alaska Archives.

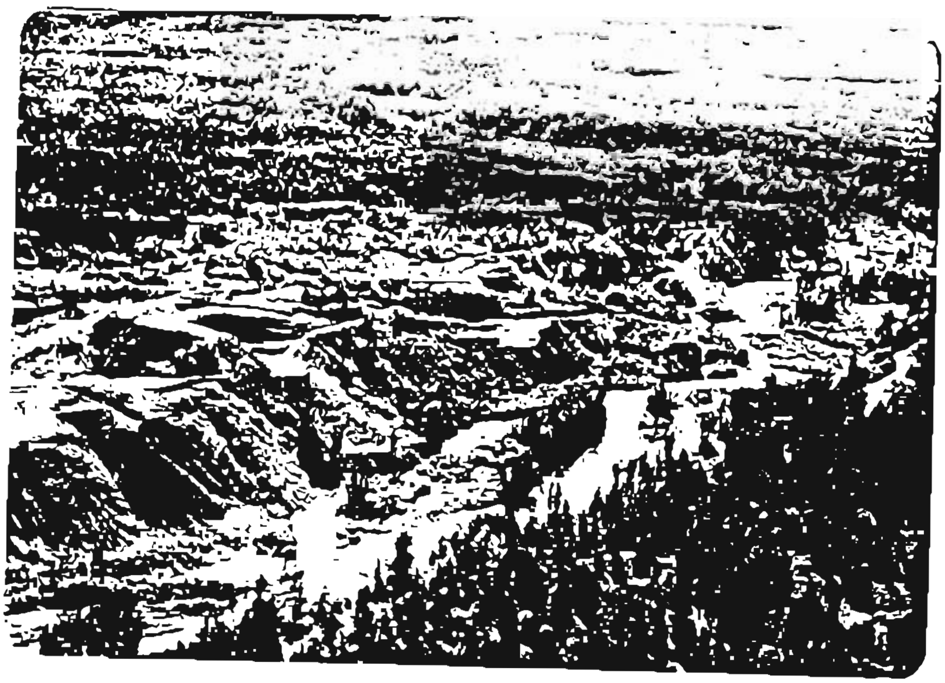


Figure 8. Looking southwest at mine spoils, cuts, and haul roads adjacent to Moose Creek, Premier mine area, western Wishbone Hill district. Near center of photo is 1983 drilling camp of Valley Coal Company.

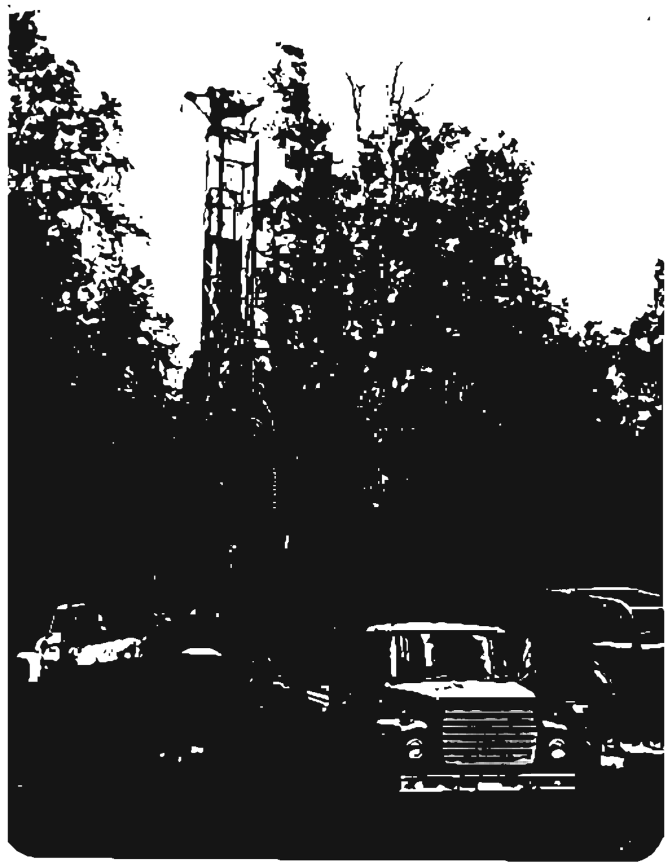


Figure 9. Valley Coal Company drilling site, Wishbone Hill area, Matanuska Valley (summer 1983).

reopened as an underground operation producing some 500,000 tons of coal per year.

It is likely that coal mining will again become a small-scale, fixed industry in the Matanuska Valley.

Climate

The Matanuska coal field is located in the transitional climatic zone between the continental climate of the northern interior and the maritime climate to the south in the vicinity of Prince William Sound. The Talkeetna Mountains serve as a barrier to cold interior air masses from moving southward into the valley, and the Chugach Mountains shelter the area from warm moist air moving northward from the Gulf of Alaska. Winter lasts from mid-October to mid-April with mean monthly temperatures between 10°F and 32°F, and the lowest expected temperature being -40°F. December is the coldest month and commonly has the heaviest snowfall. The total winter season average snowfall is about 95 in. Late April and May are typically drier with average temperatures from 35°F to 50°F; this is the thaw and break-up season for streams and lakes. Precipitation increases during the summer months, June through August. Falls are cool with heavy rains and occasional storms. The total average annual precipitation is about 15 in. Strong southwesterly winds are prevalent during spring and fall, and fog is common in fall and winter months. Daylight hours range from 5.5 on December 21 to 19.5 on June 21. The region is generally free of permafrost (Selkregg, 1974; Kreig and Associates, 1983).

Physiography

The Matanuska Valley is a narrow lowland area 5 to 10 mi wide (averages about 6 mi) and 100 mi long. It extends northeast-southwest from a point near the southwest corner of Copper River Plateau. The valley is 1 mi wide at its head where it merges into the flats of the Copper River basin. The western or lower end of the valley (in this report) is considered to be near the mouth of Moose Creek (Tsadaka Canyon) where it widens into the Susitna or Cook Inlet flats, a gravel-covered lowland, locally marshy, with irregular hills and ridges that seldom exceed 200 to 300 ft high. The Tertiary sedimentary rocks are weathered into low divides because of their relative less resistance. The Matanuska Valley is bounded on the north by the Talkeetna Mountains and on the south by a section of the Chugach Mountains trending northwestward from Mt. St. Elias. The Talkeetna Mountains east and west of the Chickaloon River are physiographically and geologically dissimilar. The mountains east of the Chickaloon River are higher and more rugged than those to the east, generally 6,000 to 8,000 ft west vs. 5,000 to 7,000 ft east. The fronts of both the Talkeetna and Chugach Mountains rise rather abruptly from the deep depression of Matanuska Valley and generally run parallel to the course of the Matanuska River. The general maximum elevation of the Chugach Mountains range from 5,000 to 6,000 ft, with local summits from 7,000 to 10,000 ft. In the valley itself are a series of undulating low ridges and knolls with interspersed kettles. The rounded hills range from 2,300 to 3,500 ft and the gravel-covered flats to about 1,200 ft. Most of the coal deposits are located from 1,000 to 2,000 ft elevation (Martin, 1906b, Paige and Knopf, 1907; Martin and Katz, 1912; and Capps, 1927).

The Matanuska River is the second largest river in south-central Alaska with a drainage basin of approximately 1,000 mi^2. It flows through the Matanuska valley or trough near the south side of the coal field for some 80 mi on a general course of S. 70° W., eventually emptying into the eastern end of Knik Arm, which is the northeasternmost branch of Cook Inlet. The river is braided, flat-bottomed, gravel-strewn, and ranges from 0.5 to 1 mi in width. This area includes the flood plain of the river and the benches on both sides. Flooding results in relative frequent changes in channels. There are several principal streams that enter the Matanuska River from the north and form the larger tributaries; from west to east, these include Tsadaka, Eska, Granite, Kings, Chickaloon, Hicks, and Caribou. The latter drains a considerable area of the Talkeetna Mountains (Paige and Knopf, 1907). The Chickaloon River is about 30 mi long. Other streams drain the Anthracite Ridge district including Sawmill (west), Purinton, Cascade, Winding, Muddy, and Packsaddle (east). Major tributaries on the south side of the river from west to east are Wolverine, Carpenter, Carbon, Coal, Monument, and Gravel Creeks. Some smaller streams occupy narrow tributary valleys or box canyons. The terminus of the Matanuska Glacier is near the eastern margin of the valley. Other smaller glaciers head in the Chugach Mountains and flow northward toward the Matanuska River (Martin, 1905b; Paige and Knopf, 1907; Waring, 1936; Apell, 1944).

The conglomerate-capped synclinal ridge of Wishbone Hill is the chief topographic feature and principal landmark of the lower Matanuska Valley (fig. 10). The hill is 6 mi long from Moose Creek northeast to Eska Creek, the two main areas of mining activity in the past, and occupies an area of about 15 mi^2 (Tuck, 1937b; Apell, 1944). It is a mesa-topped isolated fault block that has been elevated and tilted with its apex at the east and generally sloping southwestward. The altitude of Wishbone Hill ranges from about 900 ft on the southwest side near the Premier mine to over 2,300 ft on the ridge northeast of Jonesville. Bold conglomerate cliffs to 300 ft high cap the northern and southeast slopes of Wishbone Hill and converge to the northeast around the summit peak forming the diagnostic morphology---the 'wishbone pattern'---from which it takes its name. Several concentric lines of hogback ridges, ledges, and dip slopes within the outer cliffs reflect the general southwest-plunging synclinal structure of Wishbone Hill (Tuck, 1937b; Apell, 1944; Barnes and Payne, 1956). Bedrock on the north side of Wishbone Hill is covered by thin basal and ablation till and locally by thicker colluvial fan deposits. On the south, the bedrock is covered by thick glaciofluvial deposits including eskers, kames, and crevasse fillings that form an area of ridge-and-knob topography extending from west of Moose Creek to Eska Creek (Kreig and Associates, 1983). Both the north slope of Wishbone Hill and the basin occupied by Wishbone Lake drain southwestward into Moose Creek which subsequently joints the Matanuska River. That portion of the district east of Jonesville drains into Eska Creek, which has its head in the Talkeetna Mountains, whose southern front is only about a mile north of Wishbone Hill. The south slope of Wishbone Hill is drained by small streams entering morainic swamps and lakes with no surface outlet (Barnes and Payne, 1956).

Figure 10. Eastern end of Wishbone Hill looking toward the west-southwest and the Susitna lowland. Unreclaimed spoil banks of Eska mine are observable in the foreground and mine excavations near Jonesville in the intervening area.

There are several other important prominences that serve as useful landmarks in the Matanuska Valley. Along the north side of the valley from west to east are Arkose Ridge, Eska Mountain, Granite Peak, Red Mountain, Castle Mountain, Puddingstone Hill, and Anthracite Ridge. Lazy Mountain, Pinnacle Mountain, and Kings Mountain are important peaks on the south side of the valley.

DISTRIBUTION OF COAL-BEARING ROCKS

The Matanuska Valley contains a number of distinct coal-bearing areas or isolated fields. Merritt and Belowich (1984) identified five major subfields---Eska-Moose, Young Creek, Castle Mountain, Chickaloon, and Anthracite Ridge (fig. 11). All areas occupied by the coal-bearing Chickaloon Formation rocks should not be assumed to contain coal beds of workable character and thickness. However, it is generally the first cull since all coal beds of the region belong to this formation. The Chickaloon Formation covers up to 400 mi^2 of the valley from Moose Creek to Packsaddle Gulch, but probably less than a quarter of this is underlain by potentially minable coal deposits (Martin and Katz, 1912; Capps, 1927). West of Moose Creek, the Chickaloon Formation is covered by thick deposits of gravel and coals are not exposed (Waring, 1936). The Chickaloon Formation strata south of Arkose Ridge contain only scattered thin stringers of coal. There are a few thin coaly lenses on Wolverine Creek (Barnes, 1962a).

Tsadaka Canyon or lower Moose Creek contains the first significant coal exposures of the valley and are located about 18 mi from the mouth of the Matanuska River (Martin, 1906b). The Eska-Moose subfield is situated from Moose Creek eastward to the valley of Eska Creek (Martin and Katz, 1912). An area of about 4 mi^2 east of lower Granite Creek, including the Little Granite Creek basin and extending to the mouth of Young Creek, is probably underlain by coal-bearing rocks, although much of the area is covered by thick Quaternary deposits. However the only exposure is a few inches of clean coal in a dirty coal bed opposite the mouth of Little Granite Creek (Barnes, 1962a).

The Young Creek subfield is located about 7 to 8 mi east of Eska Creek, mainly in the upper part of the Young Creek valley. It is intermediate in position between Eska-Moose and Chickaloon subfields. Exposures along lower Young Creek---about 3.5 mi above juncture of creek with Kings River---contain at least two thin beds of coal, but shallow trenching in the western part of this area is reported to have indicated the presence of coal beds several feet thick. Other than the deposits on the north flank of Red Mountain, the coal occurrences of the Young Creek subfield are too small to warrant detailed examination (Barnes, 1962a).

Coal-bearing outcrops along the eastern bank of the Kings River are located about 8 mi above its mouth and about 34 mi from the mouth of the Matanuska River (Martin, 1906b; Hill, 1923). Several coal beds 1 to 3 ft thick are exposed for 0.25 mi, with two beds somewhat thicker. Early prospectors in the region found the coal crushed and intruded by igneous rocks. These coal occurrences are of small extent, and in general probably do not warrant detailed examination (Waring, 1936; Barnes, 1962a).

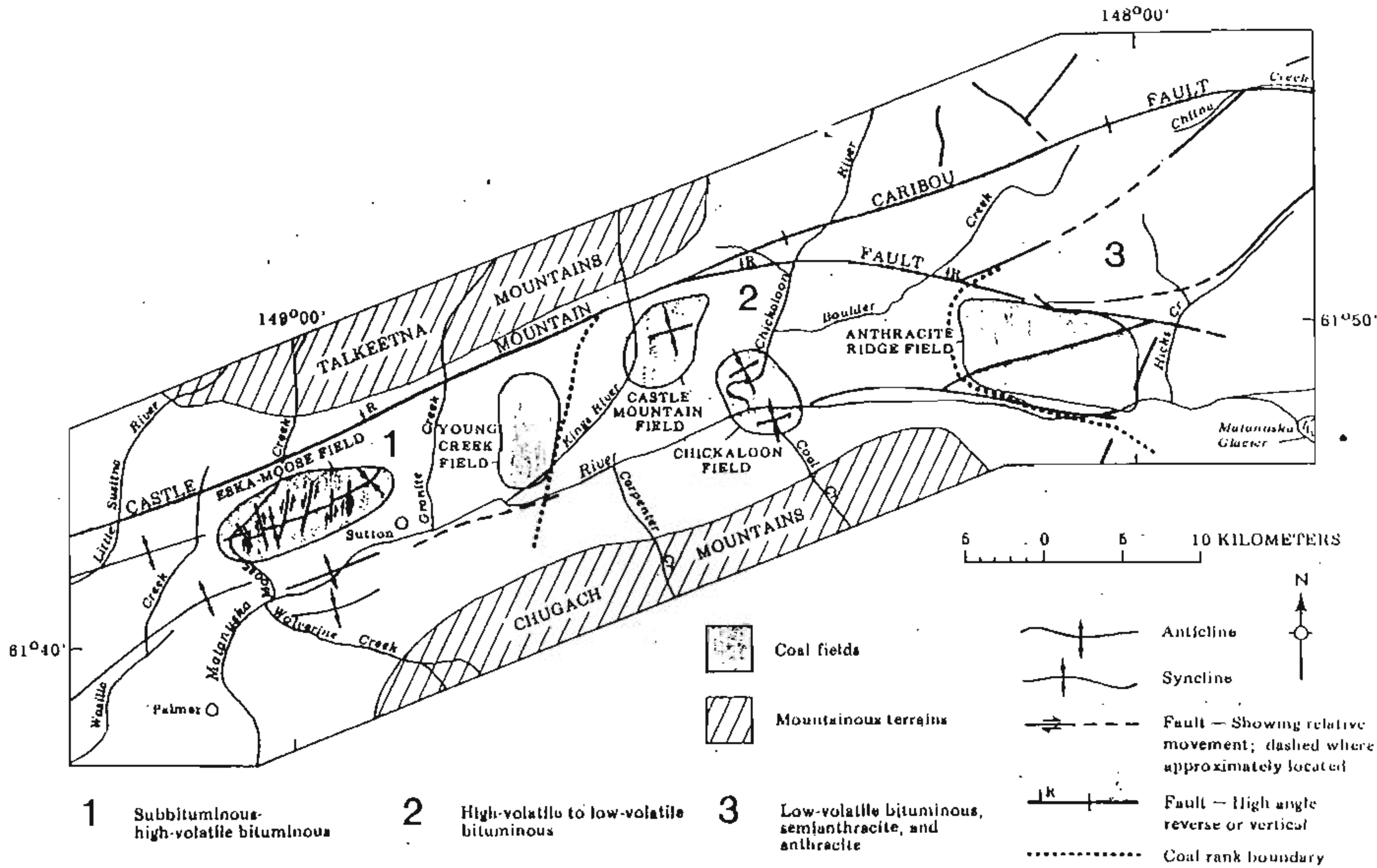


Figure 11. Major coal field subdivisions, rank, and geologic structure in the Matanuska Valley. Modified from Merritt and Belowich, 1984.

The Castle Mountain subfield is located south of Castle Mountain, westward to Kings River and northward to Edwardson's Gulch. Southeast of this subfield is the Chickaloon subfield, which is situated both north and south of the Matanuska River and includes a large part of the valley of the Chickaloon River several miles south of Castle Mountain and Puddingstone Hill (Capps, 1927). The Chickaloon River coal outcrops are about 38 mi from the mouth of the Matanuska River. The Chickaloon Formation extends south of the Matanuska River from a point 2.5 mi below the mouth of the Chickaloon River to at least 4 mi above its mouth (Hill, 1923). The deposits of lower Coal Creek are also included in the Chickaloon subfield, which contains the only coal of the Matanuska Valley originally found to be suitable for naval use. East of the Chickaloon-Coal Creek area, no further evidences of coal are found until reaching the Anthracite Ridge district (Waring, 1936).

There are several extensions of the Chickaloon Formation south of the Matanuska River, including the Coal Creek-Carbon Creek area, lower Monument and O'Brien Creeks, and on isolated patch in the basin of the first large tributary of Matanuska River west of Monument Creek (Capps, 1927). A 2-ft bed of bright coal is exposed on Carpenter Creek for a short distance on the west bank about 1.5 mi above its mouth (Barnes, 1962a). The Coal Creek exposures are 38 mi from the mouth of the Matanuska River (Martin, 1906b). Minor coal outcrops are also found in an area on both sides of the Matanuska River near the mouth of Gravel Creek and include the exposures along O'Brien Creek (Capps, 1927).

Coal outcrops cover several small areas on the south flank of Anthracite Ridge about 50 mi from the mouth of the Matanuska River. These deposits contain predominantly anthracite and high-grade bituminous coal (Capps, 1927). At several locations the coal beds are found in rather thick lenses (to 40 ft) but are of slight extent. The beds continue along the outcrops for no more than a few hundred feet before pinching out or grading into coaly shale and shale (Waring, 1936). The thin coals reported from Hicks Creek are predominantly black shales and coaly claystones. Outcrops of thin coal beds have also been reported on Billy Creek (Paige and Knopf, 1907), but the author was unable to locate them during recent reconnaissance.

STRUCTURAL GEOLOGY AND REGIONAL TECTONISM

Matanuska Valley is considered a northeastern arm of the larger Cook Inlet basin. The valley forms a structural trough 5 to 10 mi wide and 50 mi long, and narrows toward the northeast. This trough was named the Matanuska geosyncline by Payne (1955; fig. 12). The Talkeetna and Seldovia geanticlines flank the Matanuska geosyncline on the north and south respectively (Grantz, 1964). The general trend of major structural elements is northeast and east. This can be seen from the generalized aeromagnetic map of figure 13. Several major synclines have been recognized including Wishbone Hill, one at the east end of Castle Mountain, one just north of Chickaloon, and one on Coal Creek (Barnes, 1962). The Matanuska Valley is part erosional as well as structural. The present valley has been excavated by the Matanuska Glacier during repeated advances in the Pleistocene and later by the Matanuska River (Grantz, 1964).

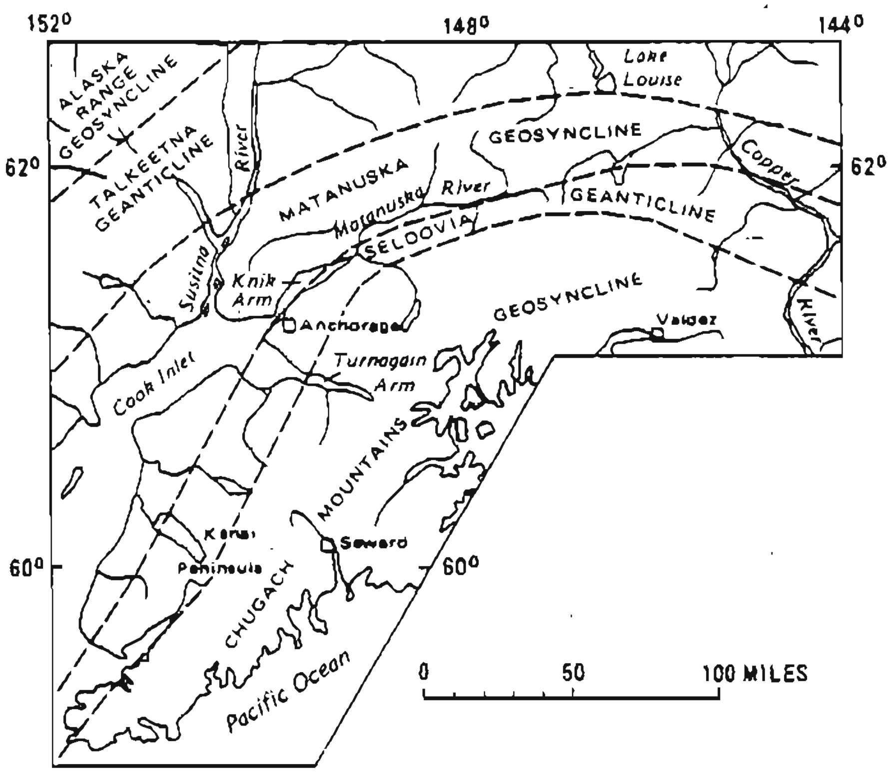


Figure 12. Major Mesozoic tectonic elements in south-central Alaska. From Payne, 1955.

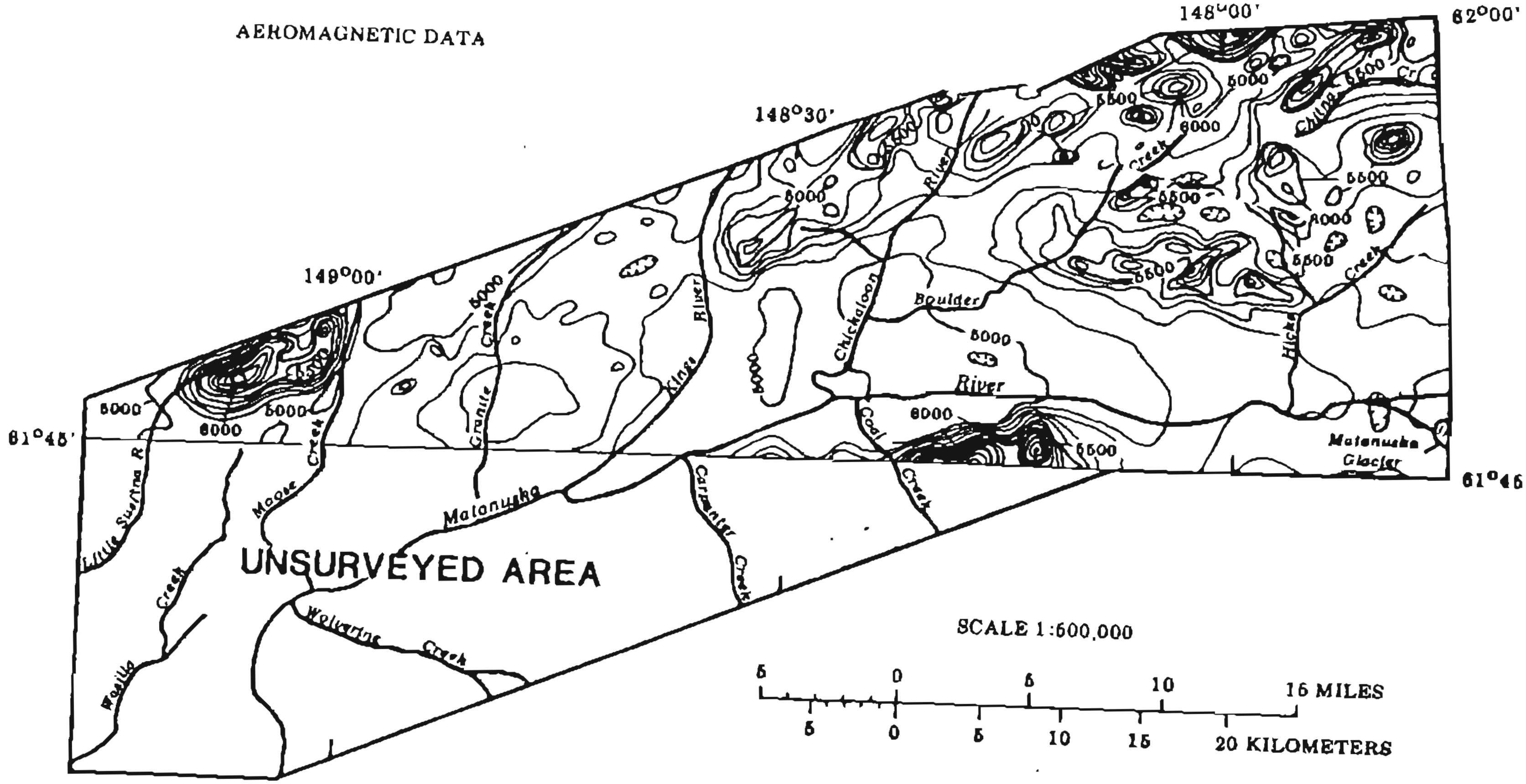


Figure 13. Highly generalized aeromagnetic map of the northern portions of the Matanuska Valley. Tertiary coal-bearing and Cretaceous sedimentary rocks occupy basinal areas of lower magnetic response. The magnetic highs correspond to Mesozoic metamorphic and igneous rocks of mountainous areas flanking the valley to the north and south. The southern part of the region is unsurveyed.

Matanuska Valley is located in the forearc terrane of the Alaska-Aleutian volcanic arc (Bruhn and Pavlis, 1981). The geologic history of this region as a marine depositional trough ended by orogeny in Paleocene and early Eocene time. Neogene faulting in the Matanuska Valley was extensive and caused by subduction of the Pacific plate beneath the convergent margin of the North American plate. Neogene deformation occurred mainly as a result of movement on multiple sets of faults that transcut the terrane. The east-northeast trending Castle Mountain fault, named by Barnes and Payne (1956) and an unnamed fault separating the Matanuska and Chickaloon Formations along the south side of the Matanuska River show evidence for substantial vertical movement. The high-angle Castle Mountain fault, perhaps the dominant structural feature of Matanuska Valley, can be traced for tens of kilometers and had several kilometers of Neogene displacement. Grantz (1964) describes right lateral separation along the fault throughout Mesozoic and Early Tertiary time and a large vertical separation since Oligocene time. The southern border of Matanuska Valley is not obviously a single fault but a number of faults that have acted to produce in part the low-lying position of the block (Capps, 1927). North-trending transcurrent faults are present throughout Matanuska Valley, and some extend across the Castle Mountain fault and into the flanks of the Talkeetna Mountains (Bruhn and Pavlis, 1981). Several tear faults cut across the axis of Wishbone Hill syncline, having developed at least in part contemporaneously with the folding. The strike faults have locally caused elimination or repetition of strata (Tuck, 1937b). Strata are also affected by a large number of faults with a small throw; these sometimes cut the axes of folds. Slickensides with shallow and deep grooves and striations give evidence for complex fault movements.

The Chickaloon Formation has been considerably folded and faulted since its deposition (fig. 14). Deformation of coal-bearing rocks increases eastward with only slight folding and faulting in the western part of the field. Complex folding, faulting, and shearing characterize the eastern part of the field and coals become progressively higher in grade upward in the valley. Chickaloon Formation rocks are only moderately indurated even when severely deformed (Grantz, 1964). Coals of Matanuska Valley have a complex structural geology compared to mine areas of the contiguous 48 states, and are strongly folded and deformed compared to subbituminous and lignite beds of the Susitna basin to the west. Many minor faults and flexures in the Chickaloon Formation do not carry through into the overlying Wishbone and Tsadaka Formations, which are generally characterized by greater competence and resistance to deformation.

The relatively parallel zones of major faulting bordering Tertiary and Cretaceous rocks of the Matanuska Valley on the north and south separate these rocks from older and more highly deformed metamorphic and intrusive rocks of the mountains (fig. 15; Barnes and Payne, 1956). Formations of the valley are a part of the downfaulted block compressed between dioritic rocks of the Talkeetna Mountains on the north, and metamorphosed sediments, volcanics, and intrusive rocks of the Chugach Mountains on the south. Upper Cretaceous and Tertiary rocks unconformably overlie older Mesozoic rocks (Bruhn and Pavlis, 1981).

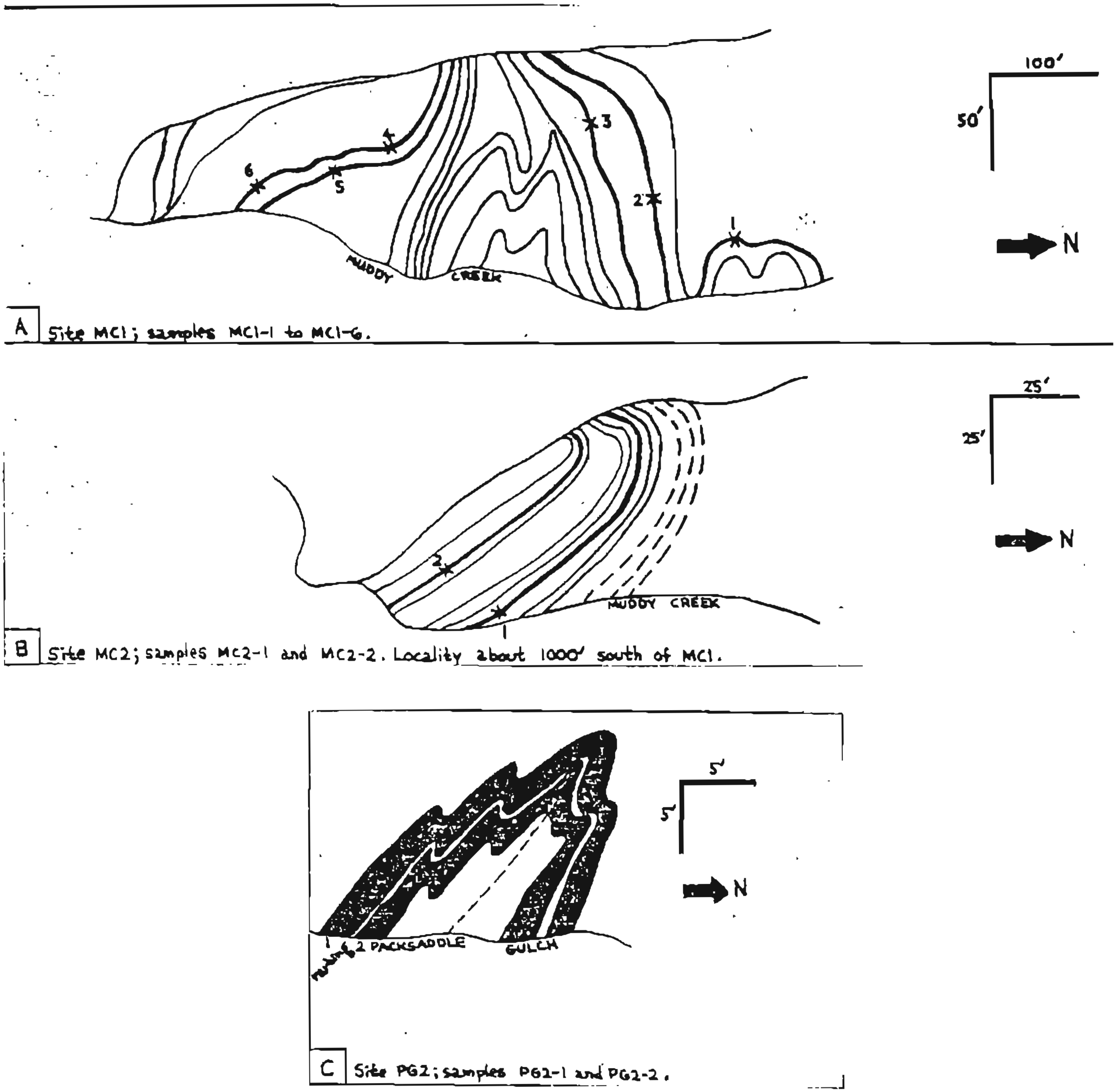


Figure 14. Schematic drawings of general structural style and relationship of folding, tilting, and igneous intrusive activity to coal seams in outcrops at six localities in Matanuska Valley.

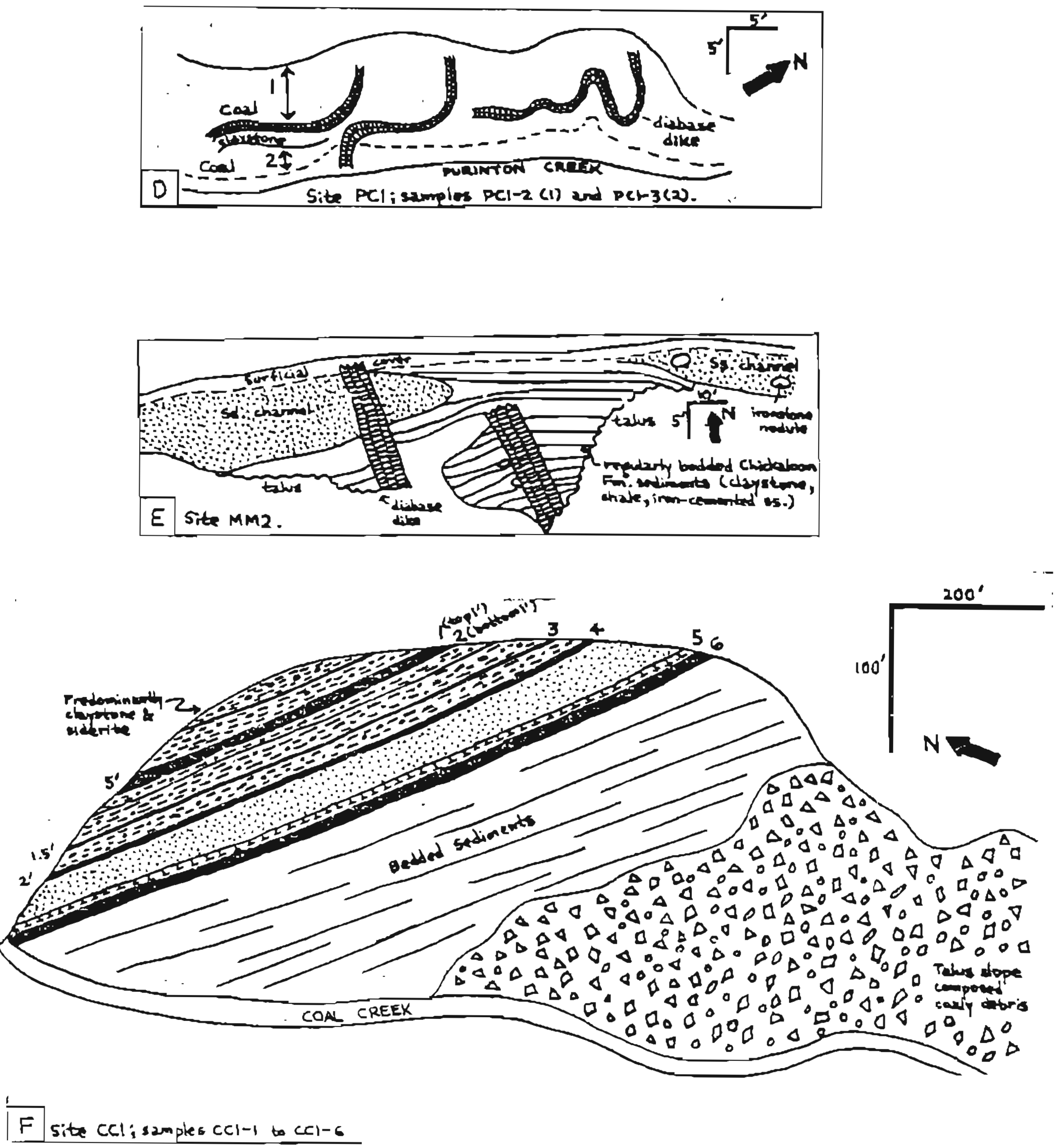


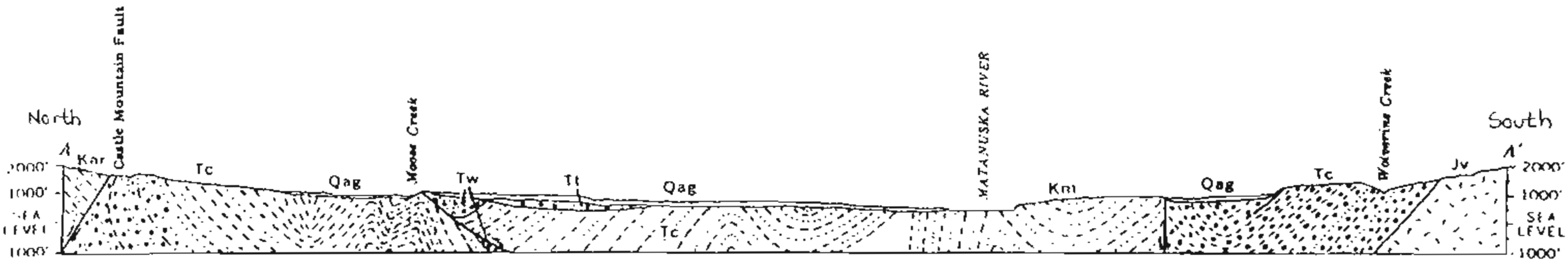
Figure 14 (con.)

Wishbone Formation
(Tw)

Predominantly well-indurated, gray to tan (fresh) and tawny-red (weathered) conglomerate, lenticular sandstone, and silty claystone. Conglomerate is composed of pebbles, cobbles and boulders of fine-grained igneous and metamorphic rock, chert, vein quartz, and jasper in a sandy matrix. Numerous lenticular cross-bedded sandstones that range from a few inches to 40 ft, thin lenses of silty claystone and siltstone and occasional fossilized wood fragments. Finer clastics predominate in lower part and grade imperceptibly into underlying Chickaloon Formation. More resistant conglomerate layers stand out as ridges and ledges.

Tsadaka Formation
(Tt)

Predominantly poorly indurated, fine to coarse conglomerate; pebbly, arkosic sandstone; silty sandstone; and siltstone. Conglomerate boulders and cobbles of granite and diorite occur in a soft, friable, granitic or volcanic and metamorphic matrix. Minor scattered coal lenses and beds of carbonaceous shale are also present.



SECTION ALONG LINE A-A'

Chickaloon Formation
(Tc)

Interbedded claystone, siltstone, sandstone, fine conglomerate, and coal. Predominantly light- to dark-purplish-gray to black claystone, generally thin bedded, weathers with concoidal fracture, and contains varying amounts of carbonaceous matter that becomes coaly in many instances. Often contains coal streaks and locally grades into bone and coal. Sandy or silty claystone to siltstone that is common throughout region is chiefly feldspathic with brown mica and scant quartz; occasionally laminated but mostly cross-bedded. Sandstone is gray to buff and feldspar-rich or greenish-gray and chlorite-rich, poorly indurated except for local iron and calcium carbonate cementation, cross-bedded, well sorted, and locally pebbly; often grades into fine conglomerate. Often contains carbonaceous plant fragments and impressions. Conglomerate lenses contain pebbles and cobbles of semirounded vein quartz, chert, and volcanic and metamorphic rocks with occasional clay clasts, all in a sandy matrix. Coal ranges from subbituminous to anthracite, black, dull to bright, platy to blocky, with low to moderate ash and low sulfur contents. Strata lack persistence and tend to thin or intergrade within relatively short distances; locally contain iron carbonate (siderite) in thin layers, nodules, or irregularly distributed masses that range from a few inches to several feet in diameter. The Chickaloon Formation is composed stratigraphically of a lower noncoal-bearing facies that consist of interbedded fine clastics and minor, thin, discontinuous coals. The upper coal-bearing facies consists of generally coarser clastics and more persistent and thicker coals. Paleocene in age.

Matanuska Formation
(Km)

Interbedded marine claystone, sandstone, and fine conglomerate. Predominantly dark-olive to greenish-gray to black claystone, highly indurated, massive, locally silty with limestone nodules, lenticular zones, platy fracture, and abundant fossils. Fossils consist primarily of Inoceramous shell fragments and ammonites. Sandstone is greenish-gray, highly indurated, and evenly bedded, with wood fragments and glauconite grains; it is coarser in lower part of section and contains locally sandy limestone lentils or concretions with fossil mollusk (pelecypods and ammonite) cores. Sandstone weathers gray and is stained brown by iron oxide. Highly indurated conglomerate lenses contain pebbles, cobbles, or boulders of semirounded plutonic and volcanic rocks, quartz, chert, and minor limestone or mudstone fragments. Iron sulfide nodules are locally present in finer grained clastics, while calcite veinlets and concretions are common in coarser clastics. Mid- to Late Cretaceous in age.

Figure 15. Generalized north to south cross-section of the lower Matanuska Valley with detailed lithologic descriptions of important Tertiary and Cretaceous geologic units. Modified from Barnes, 1962a.

Chickaloon Formation rocks strike generally parallel to the easterly-northeasterly trend of Matanuska Valley being N. 60° E. west of Chickaloon River and N. 75° to 90° E. east of Chickaloon River. Dips of strata are variable but show a tendency toward steep angles throughout most of the area. Coal beds are nearly vertical and overturned in places, as for example on the north bank of lower Chickaloon River (Chapin, 1920). Some areas show a relatively continuous uniform dip for considerable distances. Folding of Chickaloon Formation rocks is predominantly open but locally can be sharp, of an asymmetric character, fairly complex, or unpredictable in nature.

Dike intrusions have contributed to the progressive devolatilization of the coals of the Matanuska Valley. These intrusives are abundant in the eastern part of the field, less abundant in the central part, and of only very minor occurrence in the western part.

Structure has significantly affected the lateral continuity of coals of the Chickaloon Formation in the Matanuska Valley. They have been crumpled and have pinched out laterally incident to folding in the region. However, rapid change in coal bed thickness is also due in part to the original lenticular character of the sediments.

The Wishbone Hill district occupies the western part of the Matanuska coal field. The district takes its name from a prominent synclinal ridge that extends some 7 mi northeastward from Moose Creek to Eska Creek. The topographic feature of Wishbone Hill is the surficial expression of the Wishbone Hill syncline, a canoe-shaped open fold (fig. 16). This topographic high is bounded on the north and south by narrow erosional troughs. Resistant, curving ridges of Wishbone Formation conglomerate crops out on both limbs of the syncline, which converge just west of Eska Creek resulting in the 'wishbone' form. The axis of the syncline has been traced eastward beyond Eska Creek, where it is broken by transverse faulting, the ridge-forming conglomerate has been eroded away, and the structure has little topographic expression. Moose Creek heads in the Talkeetna Mountains, flows south to Wishbone Hill, and crosses the Moose Creek district at the western end of Wishbone Hill (Apell, 1944; Alaska Geological Society, 1964).

The general strike of rocks of the Wishbone Hill district is south 55° to 80° west, the same trend as Matanuska River, mountain fronts, and structural lines. The dip of beds along the axis of the syncline varies from a few degrees to nearly 90° in local areas of tight folding and in some faulted blocks. Common dips of beds on the south limb vary from 12° to 30°; the north limb is generally more steeply dipping (25° to 35°). The synclinal axis plunges to the southwest from 10° to a maximum of 25°; because of this plunge, strata higher in the coal series crop out progressively to the west.

A period of tectonism occurred prior to deposition of Wishbone Formation as indicated by the angular unconformity at the base of the unit. The Wishbone Hill syncline was formed in the period between the deposition of the Wishbone and Tsadaka Formations; this is indicated by truncation and erosion of folded strata in the Wishbone and Chickaloon Formations (Clardy, 1982). The Chickaloon Formation is less competent than the overlying conglomerates and has been affected by numerous smaller faults and subsidiary folds.

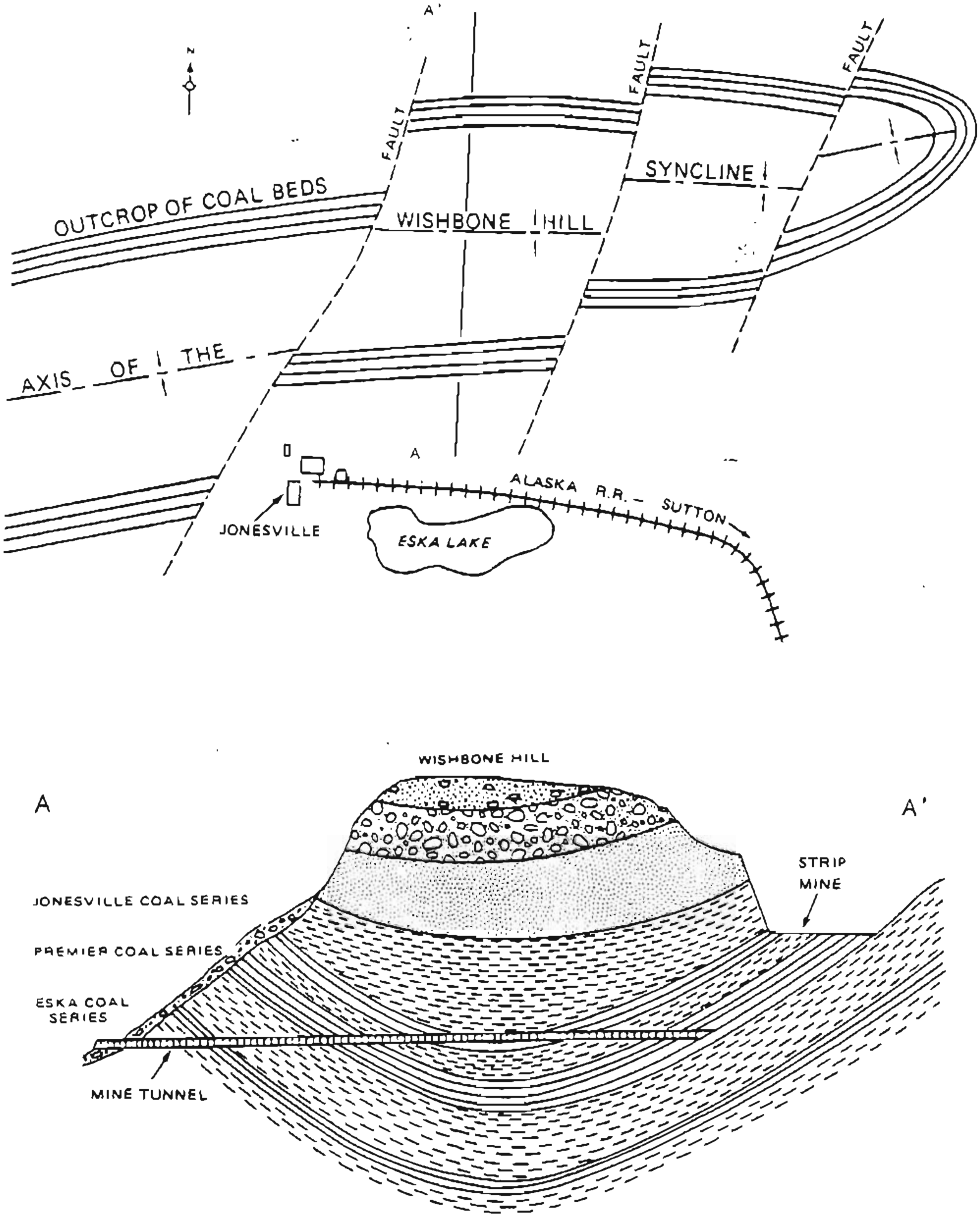


Figure 16. Plain view and schematic cross section of Wishbone Hill syncline. No scale implied. Modified from Patsch, 1981.

Faults of the Wishbone Hill district are generally steeply dipping or vertical. Strikes of the faults vary from N. 25° E. in the eastern part of the district to about N. 45° W. on Moose Creek. The Castle Mountain fault forms the northern boundary of the district separating it from the Talkeetna Mountains. The fault trace is marked by a zone of crushing in the Arkose Ridge and Chickaloon Formations about 1,000 ft wide along the south slope of Arkose Ridge and Eska Mountain. It has brought the Arkose Ridge Formation up into contact with the Chickaloon Formation along the northern edge of the district. Considering the thickness of the intervening Matanuska Formation, this would indicate a vertical displacement of at least 4,000 ft. Between the Castle Mountain fault and the north limb of Wishbone Hill syncline, exposed beds of Chickaloon Formation dip at relatively high angles mainly to the southeast.

The Wishbone Hill syncline has been cut by a number of transverse faults which divide the region into a series of blocks (Bain, 1946). The north-trending tear faults on Wishbone Hill offset the axis and limbs of the syncline at a number of places and probably represent late secondary shears related to deformation along the Castle Mountain fault system (Bruhn and Pavlis, 1981). Although displacements are usually no more than 350 ft, they can be as much as 2,000 ft, mainly horizontal (Alaska Geological Society, 1964). The surface expression of the main Jonesville fault (fig. 17) can be observed at the eastern end of Wishbone Hill, where two large masses of Wishbone Formation conglomerate are separated from the main body by a valley filled with landslide debris. Locally, fault zones are marked by coal breccias (fig. 18).

Chickaloon Formation beds of the Eska Creek area lie at the eastern end of the Wishbone Hill synclinal trough, the axis of which strikes across the creek. Chickaloon Formation strata are extensively deformed by both folding and faulting in the Knob Creek area. The Matanuska Formation is exposed along a fault at the eastern margin of this area.

The coal beds of the Wishbone Hill district crop out around the margins of Wishbone Hill and extend to considerable depths. They are found on both flanks and around the noses of the syncline. This synclinal structure has considerably affected the commercial development of coal deposits in various parts of the district. The most productive mines of the district---Eska and Evan Jones---were on the east end of the gentler dipping south limb. The structure in the Evan Jones mine was comparatively simple and allowed for relatively continuous coal development there for nearly 50 yr (Alaska Geological Society, 1964). West of this area, the Chickaloon Formation on the south limb of the syncline is deeply buried length slide rock and glacial deposits (Barnes and Payne, 1956).

Complex structure is general to the Chickaloon district which has been subjected to extensive rock monuments. Faulting is more common than in the Wishbone Hill district. The strata are also considerably folded (fig. 19). The Navy Alaska Coal Commission's exploration, development work, and mining at Chickaloon and Coal Creek showed that the cost of future mining would be high because of structural complexity and abrupt changes in the character of coal beds (Gates, 1946). It was learned that this structure has affected

Figure 17. Surficial expression of Jonesville fault on north limb of Wishbone Hill syncline. The fault has shown about 500 ft of transverse offset with the east (left) block moving relatively to the south in the direction of dip. The drag on the beds, although originally interpreted as having been produced by normal faulting, was probably caused by this horizontal movement.

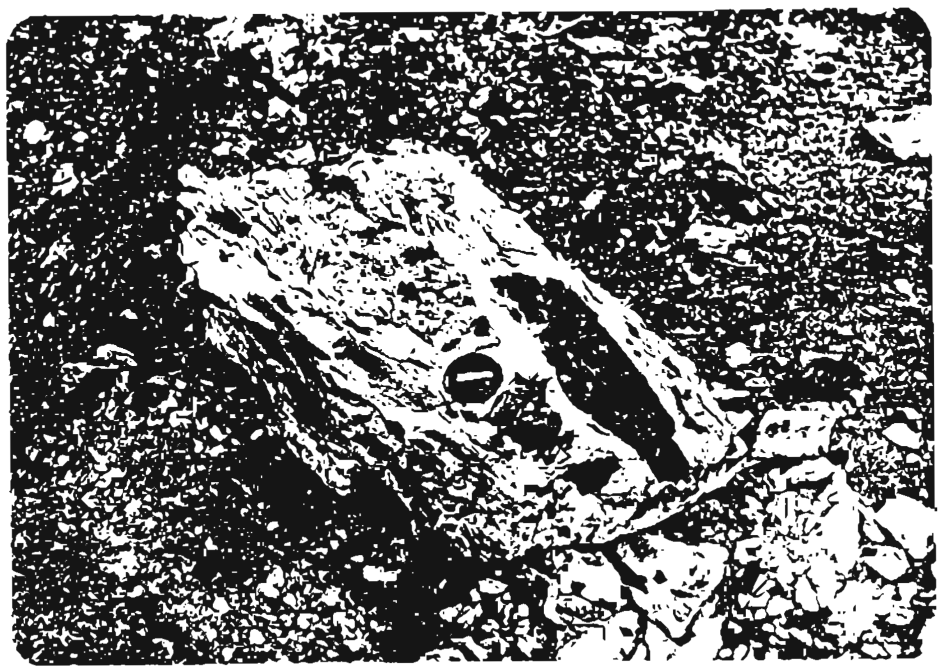


Figure 18. Coal breccia from Chickaloon Formation in vicinity of Evan Jones mine on north flank of Wishbone Hill. This rock probably formed in a fault zone.

Figure 19. Outcrop view of a fold in Chickaloon Formation beds on the north bank of Chickaloon River near its confluence with Matanuska River.

nearly every workable coal bed opened for mining. The Chickaloon area has been broken by one main fault and a series of smaller parallel faults that limit the known maximum strike length of principal coal beds to 600 ft. Structure is broadly synclinal considering the coal beds on both sides of the Matanuska River in the vicinity of Chickaloon. Igneous intrusives, which crop out in isolated masses, could be encountered in this area at any time in the process of mining.

Chickaloon Formation rocks on Coal Creek lie in a syncline whose axial trace strikes in a northeast and southwest direction. Coals are typically inclined 40° to 75°, but near the axis of the syncline the strata dip at right angles. Intrusions appear to be smaller in the Coal Creek area than they are elsewhere in the Chickaloon field.

The Anthracite Ridge district contains a coal basin with a broad synclinal trough structure. The axis of this major syncline appears to cross the Chickaloon River about a mile northeast of Chickaloon, extends northeast to Rush Lake, and then southeast toward lower Packsaddle Gulch (Capps, 1927). The southern limit of the Chickaloon Formation outcrop belt in the field is marked by an escarpment with steep cliffs and cascading streams. The valley itself has a thick cover of Quaternary gravels.

The general structural trend in the Anthracite Ridge field is parallel to the axis of the valley. Dips of 50° to 90° are common. Chickaloon Formation beds have undergone a great amount of compression in the vicinity of the great Anthracite Ridge fault (Capps, 1927), which is an extension of the Castle Mountain fault. Toward the summit of Anthracite Ridge, folds become more closely crowded together. Belts of closely crumpled beds have been superimposed on the major synclinal structure of the region. Many of the folds are overturned, and their upper parts have largely been removed by erosion. Coal beds are exposed along the uneroded remnants of the close folds. These coal beds have been crushed and shattered with inclusions of bone and shale. This complex folding of strata has greatly increased the potential difficulties of mining.

Upper Matanuska Valley is essentially a large graben, a block that has been down-dropped between two major faults. Besides the large Anthracite Ridge fault bordering the valley on the north, another large fault cuts along the lower slopes of the Chugach Mountains and forms the southern boundary of the field. Chickaloon Formation rocks are most severely deformed adjacent to these major faults of large displacement.

Chickaloon Formation rocks in the Anthracite Ridge field have been extensively intruded by both large and small dikes and sills. Most of the intrusive masses are of a sill-like character. The massive diabase injections particularly have caused increases in the rank of the coal throughout the region.

LITHOSTRATIGRAPHY

There are over 10,000 ft of Cretaceous through Oligocene-age sedimentary rocks exposed in the Matanuska Valley. This sedimentary package of rocks forms part of a thick succession of marine and continental rocks in the Cook Inlet basin (Clardy, 1982). Tertiary rocks of Matanuska Valley include the coal-bearing Chickaloon Formation and overlying Wishbone and Tsadaka Formations (table 1). Coal-bearing rocks occupy several irregularly shaped areas comprising about 380 mi^2 of the Matanuska basin west of Hicks Creeks and east of Moose Creek. Natural exposures are not numerous since they are easily eroded into smooth slopes and often covered by glacial, alluvial, and colluvial materials. Streams are locally entrenched in Chickaloon Formation rocks forming outcrops in adjacent bluffs. The best exposures are found along the banks of the Matanuska River and its tributary streams. The Chickaloon Formation is more extensively outcropped on the north side of the Matanuska River (Landes, 1927).

The Chickaloon Formation is at least 5,000 ft thick in the Matanuska Valley (Clardy, 1982). The formation differs from Kenai Group strata of the Susitna lowland in age, lithology, and structure, presence of associated intrusives, and in the character of interstratified coal seams. The Chickaloon Formation consists of a lower sequence of conglomerate and lithic sandstone and an upper sequence of siltstone and coal (Clardy, 1982). The unit exhibits rapid variations in lithologic character, alteration of beds, and irregularity of sequence along strike. Locally, alternating series of thin-bedded sandstone and shale occur, whereas elsewhere beds are gradational through fine, medium, to coarse sediments (Waring, 1936). Chickaloon Formation beds are moderately well consolidated, more coherent on fresh surfaces, but overall less resistant to weathering and erosion than Mesozoic rocks. Individual beds are lenticular and laterally discontinuous because of depositional thickening and thinning (Capps, 1927).

Shales are most abundant in the Chickaloon Formation although sandstone predominates in the lower half. They vary from gray and drab to dark bluish gray and black. They are feldspathic and contain brown mica, little quartz, minor pyrite, and abundant carbonaceous material. Their relatively high content of black organic material contrasts with younger Tertiary shales of other basins. The shales are often sandy and gritty and vary in grain size along bedding (Capps, 1927; Apell, 1944). Although bedding is generally poorly developed and joint planes are not well-defined, they are locally laminated and sometimes fissile. Pressure and movements have caused slickensiding and slabbing of shale units. Interbeds include sandstone strata and coal and bone streaks and veinlets. The shales are soft and inclined to break with conchoidal fracture, disintegrate fairly easily on exposure, and tend to cave when coal is removed. Concretionary iron carbonate or ironstone in thin layers, lenses, fairly persistent beds, nodules, nodule trains, and irregularly distributed masses from a few inches to several feet is common in Chickaloon Formation shales and some coal beds (fig. 20).

Chickaloon Formation sandstones are typically gray to yellowish and locally exhibit a greenish-gray tone. They sometimes show a 'salt-and-pepper' texture and contain shale fragments. They vary from relatively soft, slightly indurated to fairly well-consolidated, hard and dense rocks. Sandstones are thick-bedded in the basal part of the formation. Grain size and composition also varies considerably within and between beds. They often form an aggregate of partly decomposed and angular grains. Feldspathic sandstones contain

Table 1. Stratigraphic sequence of rocks in the Wishbone Hill district Modified from Barnes and Payne, 1956 and Alaska Geological Society, 1964.

Age	Formation	Character	Thickness (ft)
Quaternary		Alluvium, terrace gravels, and moraine deposits.	0-150+
	Unconformity Tsadaka formation	Coarse conglomerate, sandstone, siltstone.	700+
Tertiary	Unconformity Wishbone formation	Medium- to fine-grained conglomerate, sandstone, and minor claystone.	2,000
	Chickaloon formation	Interbedded claystone, siltstone, sandstone, and coal.	5,000+
Upper and Middle Cretaceous	Unconformity Matanuska formation	Shale and sandstone	4,000+
Middle(?) and Lower Cretaceous(?)	Arkose Ridge formation	Arkose, conglomerate, and shale.	2,000+

Figure 20. Opencut pit at Evan Jones mine on north flank of Wishbone Hill showing abundant siderite nodules and lenses in Chickaloon Formation coal-bearing strata.

abundant fairly fresh grains. Chloritic sandstones are greenish and form a greenstone with high rock fragments. Disseminated shreds of white mica are common in some sandstones. Predominantly, the sandstones appear to have been derived from a granitic body, possibly a diorite batholith (Landes, 1927).

A few thin beds of fine-grained conglomerate are scattered irregularly throughout the Chickaloon Formation, are of rather abrupt occurrence, and are not limited to a particular horizon. These coarse-grained sediments are harder and more resistant. The conglomerates contain well-rounded to subangular small (typically less 0.5 in.) pebbles of quartz and chert (Waring, 1936).

Several series of important coal beds occur in the upper portion of the Chickaloon Formation. These series will be discussed in detail in the resources section of this report. This coal-bearing strata resembles to a degree the Paleozoic coal measures of the Appalachian region (fig. 21). All coals of the Chickaloon Formation are part of the same general sequence and do not differ significantly in age. There is no evidence to indicate that coals at the east end of the field were more deeply buried than those on the west (Barnes, 1962a). However, coals in different parts of the field have not been closely correlated. The character of the coal beds vary within short distances as do the sandstone and shale units. Correlation of stratigraphic sections is based on lithology, sequence of beds, and thickness of stratigraphic intervals (Payne and Hopkins, 1944). Complicating factors to correlation are numerous faults, relative similarity of many beds, and lenticularity of individual beds (Tuck, 1937b). Coals will be discussed in detail in other sections of this report.

There is little evidence for natural burning of coal beds in Matanuska Valley mainly because of the relatively lower volatile matter contents and bituminous rank. Natural burning is more prevalent in Tertiary coal fields of Alaska with abundant subbituminous coal and lignite possessing high volatile matter contents. There are a few occurrences of whitened shales in the Matanuska Valley that are similar in appearance to porcelanite (which forms by natural baking), but these may be due to mineralized water circulating through porous zones in the rocks.

Volcanic ash partings can be observed in outcropping coal seams and often have been encountered in drill holes of the Matanuska coal field. Originally the partings consisted of feldspar and biotite phenocrysts in a glassy and pumiceous ash. The glassy portion of the ash has completely altered to a bentonite and the biotite has altered to a grayish brown type of flaky kaolinitic clay containing come iron-associated carbonaceous material. Although some kaolinitic partings naturally formed in ancient swamplike environments, many of these bentonitic and kaolinitic partings (the latter termed tonsteins) clearly originated as volcanic ash-fall tuffs.

The Chickaloon Formation was named by Martin and Katz (1912), forms the lowermost exposed Tertiary unit of Matanuska Valley (Alaska Geological Society, 1964), and is Paleocene to early Eocene in age (Barnes and Payne, 1956). It contains an abundant and well-preserved fossil flora in shales and sandy shales. Petrified wood occurs locally (fig. 22) and impressions of fossil leaves are abundant in the roof rock of coal seams. The fossil flora

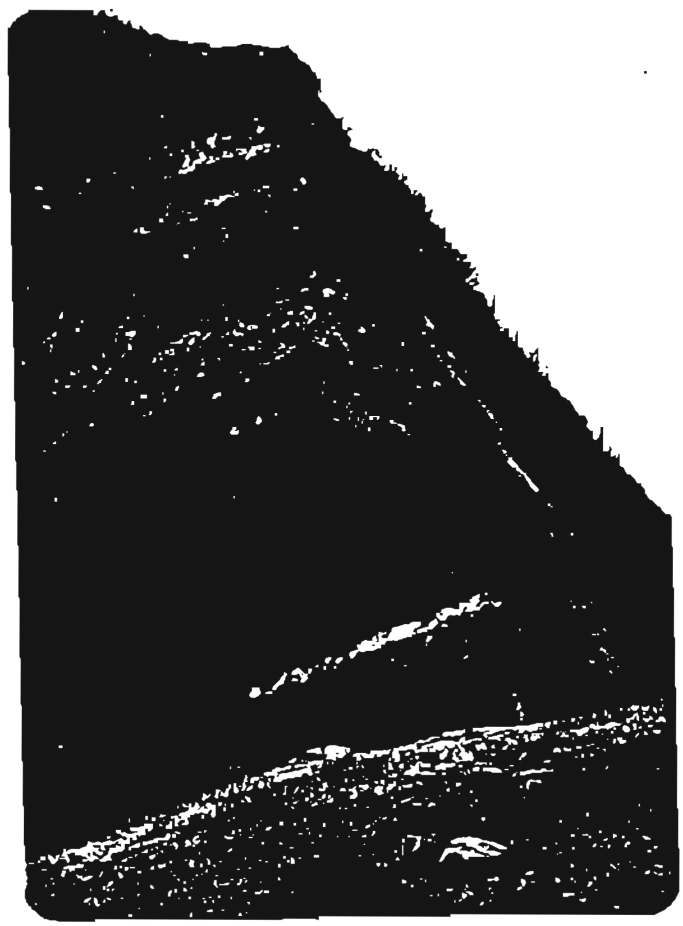


Figure 21. Evan Jones Coal Company mine highwall on north flank of Wishbone Hill. The light-gray colored bed near the base of the cut section is a siderite parting.

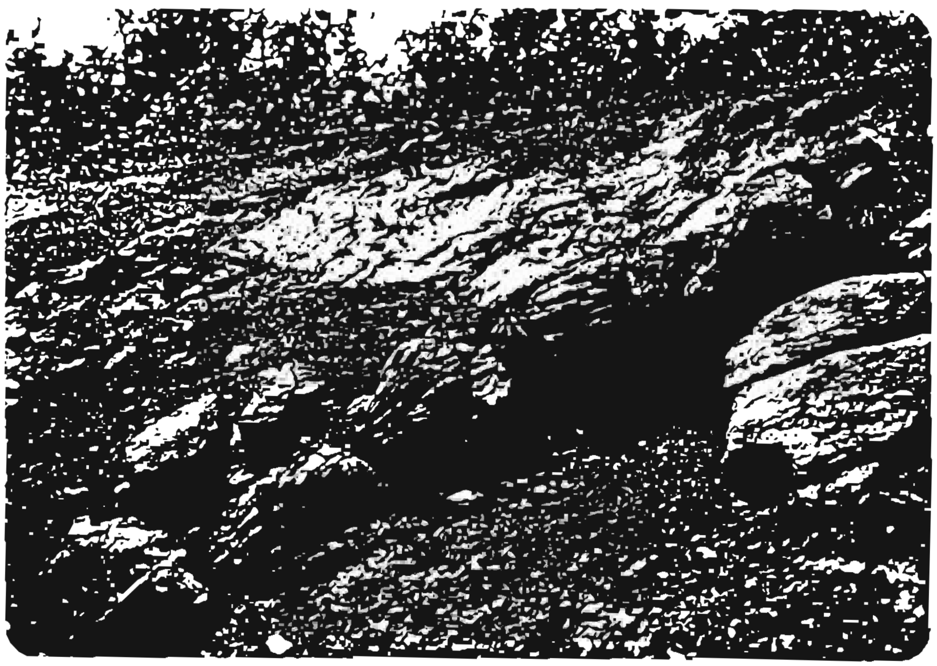


Figure 22. Replaced tree in Chickaloon Formation strata of southern opencut pit, Castle Mountain mine.

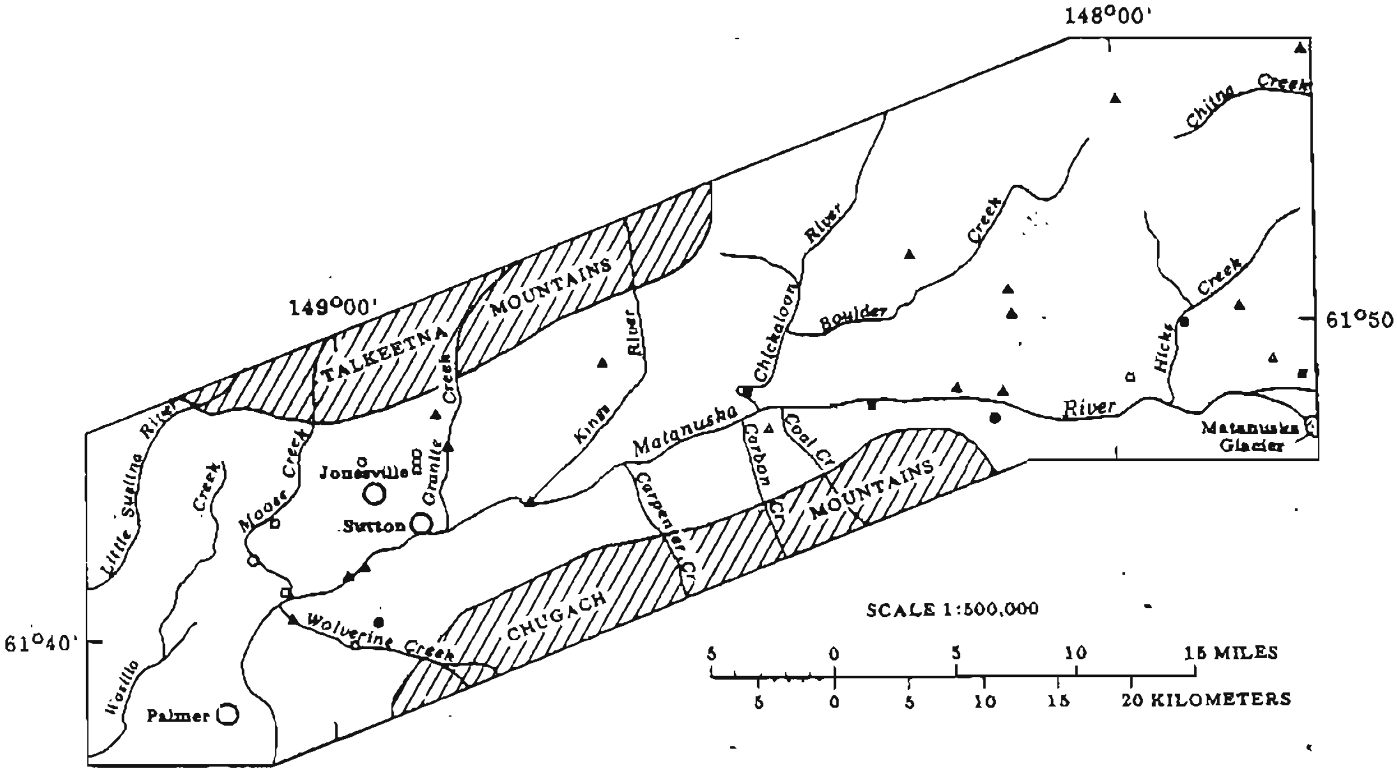
includes 38 modern genera among which are redwood (metasequoia), oak, alder, walnut, willow, cottonwood, cypress, and dogwood (fig. 23; Barnes and Payne, 1956). Martin and Katz originally assigned the formation to the Eocene Epoch based on its flora. Wolfe and others (1966) studied the fossil plants of the Chickaloon flora and believe that it indicates a warm and temperate Paleocene to early Eocene depositional period.

The stratigraphic relationships of the Chickaloon Formation with older rocks is complex. The unit unconformally overlies marine Upper Cretaceous beds of the Matanuska Formation. The only observable contacts of the Chickaloon and Matanuska Formations in the Matanuska Valley are along faults. Northeastward from Knik Arm to the Little Susitna field, the Chickaloon Formation underlies Kenai Group strata on their equivalents (Conwell and others, 1982).

Barnes and Payne (1956) made two significant stratigraphic changes for the Wishbone Hill district: 1) the series of arkosic shales and conglomerates of Arkose Ridge Formation were placed at the base of the Matanuska Formation and considered to be Late Cretaceous in age; the Arkose Ridge Formation was earlier considered Tertiary in age and in part equivalent to the Chickaloon Formation; and 2) the Eska conglomerate was divided on the basis of lithologic differences and the presence of an unconformity between them into the Wishbone Formation (lower unit) and Tsadaka Formation (upper unit). The Chickaloon Formation grades upward into conglomerates of Wishbone Formation in Wishbone Hill district (Barnes, 1962a; Alaska Geological Society, 1964).

The Chickaloon Formation crops out mainly in peripheral areas around the great mass of conglomerate that covers the central part of Wishbone Hill. Exposures of coal beds are generally limited to the more deeply incised streams and steeper hillsides, and to strip mine areas on the north flank of Wishbone Hill. In the western part of the Wishbone Hill district, the Chickaloon Formation is exposed along Moose Creek, where the minimum estimated thickness of strata below the coal-bearing section is 3,500 ft. The lower part of the Chickaloon Formation is exposed east and north of Wishbone Hill along Eska, Gloryhole, and Knob Creeks, where faulting and folding have likely resulted in some duplication of strata (Barnes and Payne, 1956; Alaska Geological Society, 1964). The entire Knob Creek area is covered by at least a thin veneer of unconsolidated material, but only the Matanuska and Chickaloon bedrock formations are exposed in the area.

Groups of coal beds can be correlated from one part of a district to another but individual beds can be traced only between different mines within a district. Four coal beds in folded and disrupted Chickaloon Formation strata lying on opposite sides of the strike-slip Premier fault have been locally correlated by palynology over a distance of 2,000 ft. Based on the existent sporomorph assemblage, a Paleocene age was assigned to this coal-bearing section (Ames and Riegel, 1962). The Premier series in the Wishbone Hill district have been radiometrically dated on minerals separated from volcanic ash partings in these coals. The average of the ages was about 55 m.y. which indicates a late Paleocene to early Eocene age for the Premier series (Conwell and others, 1982).



EXPLANATION

GENERAL CHARACTERISTICS OF CHICKALOON FORMATION FLORA

Description of megafossil floras;
Predominantly ferns, fan palms, cycads, conifers and various broad-leaf genera

Dominant genera;
Dennstaedtia americana, Onoclea hesperia, Trochodendroides serrulata, "Planera" microphylla, Carya antiquora, Quercophyllum groenlandicus, Dicotylophyllum flexuosa, Anemia elongata. and Hymenophyllum confusum

Inferred climate;
Subtropical to warm-temperate

FOSSIL — BEARING LOCALITIES

TERTIARY	○ Plant fossils - Miocene	Tsadaka Fm.
	■ Mollusk fossil - Paleocene	Chickaloon Fm.
	□ Plant fossils - Paleocene	
CRETACEOUS	● Mollusk fossils of Albian age	Matanuska Fm.
	■ Mollusk fossils of Campanian age	
	▲ Mollusk fossils of late Campanian and Maestrichtian age	
	△ Mollusk fossils questionably of late Campanian and Maestrichtian age	

Figure 23. Cretaceous and Tertiary fossil-bearing localities in the Matanuska Valley and general characteristics of the Chickaloon Formation flora. Adapted from Wolfe and others, 1966.

Several other thin and persistent layers of clay or claystone that are valuable in correlation are found in the Chickaloon Formation of Wishbone Hill district. The 'Eska Marker,' probably a tonstein, is located just below the roof of the Eska coal bed and consists of one or two thin (generally less 1 in.), light-colored, hard clay bands. On the north slope of Wishbone Hill, a light colored claystone which shows characteristics of a bentonite by swelling to a foot or more of plastic clay and may represent a decomposed volcanic ash (Barnes and Payne, 1956).

Coal beds in the Chickaloon district appear to lie in the middle of the Chickaloon Formation (Wolfe and others, 1966); there appears to be at least 2,000 ft of Chickaloon Formation beds below the coal and an equal amount between the coal and overlying Wishbone Formation. There are approximately 4,000 ft of Chickaloon Formation rocks covering both the northern and southern limbs of the Coal Creek syncline (Hill, 1923).

The Chickaloon Formation is over 2,000 ft thick in the Anthracite Ridge district and unconformably overlies Upper Cretaceous marine sedimentary rocks. There are many good exposures of the unit along gulches that drain the high-relief south slope of Anthracite Ridge. The outcrops consist chiefly of shale with minor sandstone and conglomerate, and includes three coal zones in the lower 1,500-1,600 ft (fig. 24). Although the strata are folded and faulted, their discontinuity was also effected by the nature of the original deposits. Shales in the area are dark gray to black, carbonaceous, and weather with conchoidal fracture. Sandstones are gray to yellowish, feldspathic, fairly well consolidated; a basal sandstone is greenish gray, chloritic, and thick bedded. Conglomerate beds are scattered throughout the formation and include well-rounded quartz and chert pebbles. A 30- to 50-ft white band crops out around the central part of the ridge and grades westward into a coarse sandstone underlain by a white hardened shale. The three coal zones contain typical coal beds from 1 to 10 ft thick and that grade laterally into claystone or shale and generally thin westward. The upper and middle coal zones crop out in the basin of Muddy Creek. All three coal zones are exposed on lower Purinton Creek, where many small intrusive bodies cut across coal beds altering their rank and minability.

Rocks of Adjacent Talkeetna and Chugach Mountains

The Matanuska Valley is formed by Tertiary and Upper Cretaceous rocks that have been downfaulted and juxtaposed against older rocks of the Talkeetna and Chugach Mountain masses to the north and south respectively. The Talkeetna Mountains were formed by the emplacement during Middle Jurassic time of a large complex batholith consisting of quartz diorite, granodiorite, granite, quartz monzonite, and alaskite. Remnants of the intruded rocks as well as sediments deposited after the intrusion occur around the edges of the batholith. The Talkeetna Mountains west of the Chickaloon River are dominantly granitic rocks with some gneissic, volcanic, and minor sedimentary rocks. These rocks exhibit no well-marked internal geographic or structural trend. They are bounded on the south by a major linear fault zone. The Talkeetna Mountains east of the Chickaloon River are comprised mainly by Mesozoic sedimentary and volcanic rocks. Tilted Jurassic, Cretaceous, and Tertiary

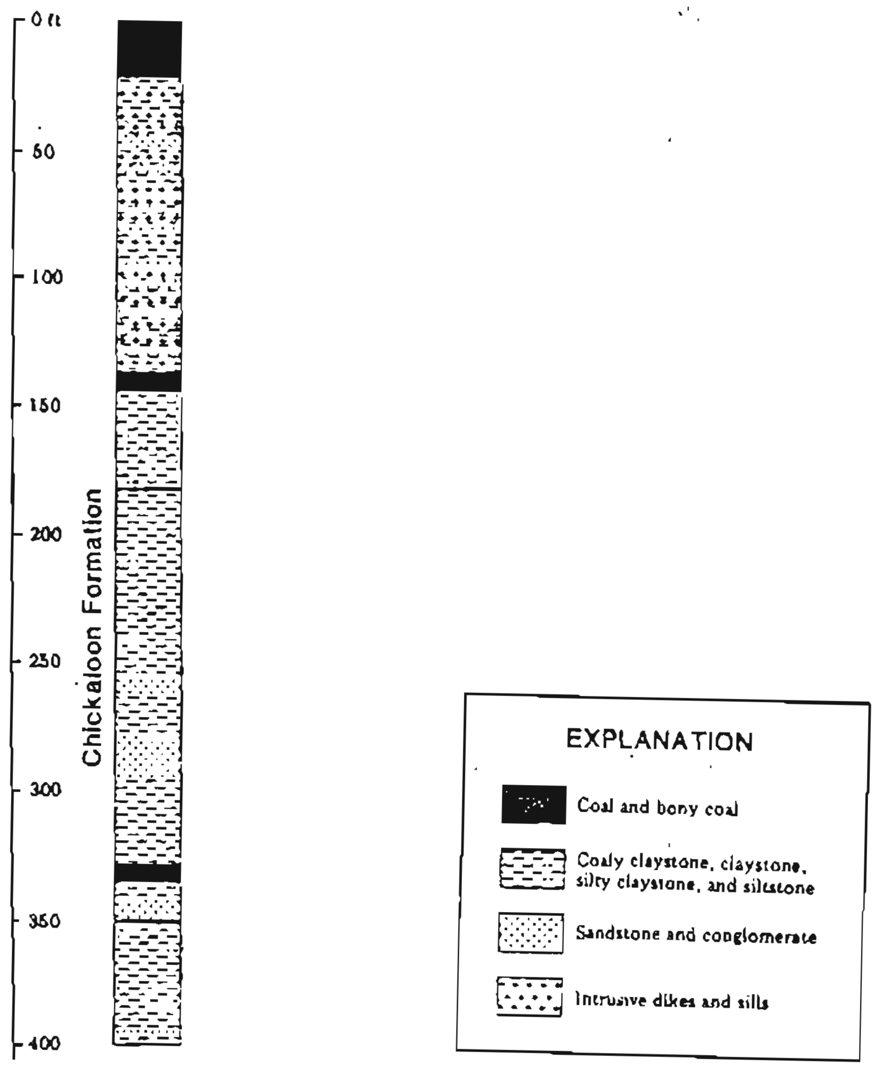


Figure 24. Generalized stratigraphic section from Anthracite Ridge area (adapted from Waring, 1936).

stratified rocks are overlain locally on summits by broad cappings of relatively horizontal late Tertiary conglomerates, lavas, and tuffs.

The Chugach Mountains are made up of upper Mesozoic metamorphosed volcanic rocks and interbedded slate, graywacke, schist, and greenstone, and younger granitic intrusive rocks. Metasedimentary and metavolcanic rocks of the Cretaceous and Jurassic McHugh Complex and Valdez Group cover considerable areas. These mountains are of the same general character both on the east and west sides. Sharp structural flexures and faults characterize the boundary between the Chugach Mountains and the Matanuska Valley (Capps, 1927; Alaska Geological Society, 1964; Clardy, 1982).

Arkose Ridge Formation

The Arkose Ridge Formation outcrops in a belt extending westward from the Chickaloon River along the northern edge of Matanuska Valley. The unit is most widely and typically exposed on Arkose Ridge, northwest of Wishbone Hill. Near Moose Creek, the formation is more than 1,500-ft thick; locally, within the region it is over 2,000-ft thick. It is more highly indurated than the Chickaloon Formation and differs significantly in gross lithologic characteristics. It consists of moderately deformed, nonmarine arkose, feldspathic sandstone, conglomerate, and shale. The formation is Cretaceous in age based on mapping, petrography, and potassium-argon age determinations (Csejtey and others, 1976), and is correlative with mollusk-dated marine beds in the lower part of the Matanuska Formation, which ranges from Albian to Maestrichtian in age.

The formation lies along the north side of the large-scale high angle Castle Mountain fault and rests nonconformably on quartz diorite and muscovite schist of the Talkeetna batholith. It contains abundant plant fragments mainly of nonmarine origin. The provenance of the clastic material is in the granitic rocks of the southwestern and central Talkeetna Mountains (Alaska Geological Society, 1964). The restricted outcrop distribution suggests local-source fanglomerate deposits (Clardy, 1982), and its composition indicates rapid sedimentation (Grantz and Wolfe, 1961).

Matanuska Formation

The Matanuska Formation, a unit named by Martin (1926), composes more than a third of the bedrock outcrops of the Matanuska Valley, and probably underlies Tertiary rocks and Quaternary deposits that occupy remaining areas in the valley. The rocks of the formation are exposed to the south, east, and north of the Wishbone Hill district; at the eastern edge, they are exposed in fault contact with the coal-bearing Chickaloon Formation. Near Billy Creek in the Nelchina area, where the unit overlies beds of Sinemurian to Neocomian age and is succeeded upward by coal-bearing rocks of Paleocene and early Eocene age, its structure is simpler and exposures more complete than in the Matanuska Valley. At its type section on Granite Creek in the lower Matanuska Valley, the Matanuska Formation has an aggregate thickness of at least 4,000 ft (Grantz, 1964; Clardy, 1982).

The Matanuska Formation is readily distinguishable from the Chickaloon Formation on the basis of lithology. In general, Matanuska Formation rocks are harder than those of the Chickaloon Formation, and consist of a thick succession of dark-gray siltstones and shales and light-colored sandstones and thin, rare beds of conglomerate. The shales are darker than Chickaloon Formation shales and have a platy fracture; sandstones are darker and more evenly bedded. The lower half of the unit is practically all shale, whereas the upper half consists of alternating beds of sandstone and shale with sandstone predominating. The formation rocks of the upper part of the Matanuska Valley are of the same general lithologic character as those in the lower part of the valley (Capps, 1927; Grantz, 1964).

The Matanuska Formation contains beds from Early Cretaceous (Albian) to Late Cretaceous (Maestrichtian), an angular unconformity separates the Matanuska Formation from the overlying Chickaloon Formation and is generally representative of tectonic activity and erosion. The Late Cretaceous Kaguyak and Chignik Formations on the Alaska Peninsula are generally correlative to rocks of the Matanuska Formation and are of similar character and tectonic aspect (Grantz, 1964). Because the Matanuska Formation in the Matanuska Valley is more indurated and more deformed, it was probably involved in tectonic events before the Chickaloon Formation was deposited. Rocks of the Matanuska Formation generally dip more steeply or are more severely faulted than rocks of the Chickaloon Formation in nearby outcrops (Grantz and Jones, 1960; Grantz, 1964).

The Matanuska Formation was deposited in an unstable seaway that extended to about the present northern limit of the Matanuska Formation in the Nelchina area. The formation contains abundant marine fossil mollusks, particularly *Inoceramus*, foraminifers, and radiolaria in many beds that are indicative of middle to outer sublittoral to outer bathyal or abyssal environments of deposition. However, plant fossils have been found that may indicate continental or near-shore deposition for part of the formation (Grantz and Jones, 1960; Grantz, 1964; Alaska Geological Society, 1964).

'Eska Conglomerate'

The Eska Conglomerate is an informal unit originally named by Martin and Katz (1912) for exposures of conglomerate overlying the Chickaloon Formation on Eska Creek. Barnes and Payne (1956) divided the Eska Conglomerate into the Wishbone and Tsadaka Formations based on the angular unconformity separating them and on lithologic differences. The contrasts between the Wishbone and Tasadaka Formations include: 1) Wishbone Formation is well-indurated, and Tsadaka Formation is poorly indurated; 2) presence of jasper in Wishbone Formation, absence in Tsadaka Formation; 3) relative scarcity of granitic rock in Wishbone Formation, but coarse conglomerate beds of granite and diorite in Tsadaka Formation; and 4) Wishbone Formation derived mainly from Chugach Mountains, whereas the Tsadaka Formation formed mainly by alluvial fans building southward into the Matanuska Valley with emergence of Talkeetna Mountains (Alaska Geological Society, 1964).

Wishbone Formation

The Wishbone Formation was named by Barnes and Payne (1956) for prominent-scarp exposures of the unit at its type locality, Wishbone Hill, where the outcrop belt extends between the Premier mine and Jonesville. Minor exposures of the formation are found along the Little Susitna River adjacent to the Castle Mountain fault, and steep cliffs in the unit are found at Castle Mountain and Puddingstone Hill, where the maximum thickness exceeds 3,000 ft. The Wishbone Formation ranges from 1,850 ft to 2,000 ft thick at Wishbone Hill (Barnes and Payne, 1956; Conwell and others, 1982).

The formation is a well-consolidated, pebble-cobble conglomerate with interbedded feldspathic sandstone and lenses of siltstone and claystone. The well-rounded and poorly sorted pebbles, cobbles, and few boulders of the conglomerate consist primarily of fine-grained volcanic and metamorphic clasts with some chert, vein quartz, and jasper. The unit coarsens upward from the finer clastics at the base to thick, crossbedded sandstone and massively-bedded conglomerate that are common in the upper part.

The Wishbone Formation is Paleocene to early Eocene in age (Alaska Geological Society, 1964) and forms the lower part of the former Eska Conglomerate. The contact of the Wishbone Formation and underlying Chickaloon Formation is gradational and conformable at most localities, but is overlain by an angular unconformity and is truncated by the Tsadaka Formation. Eocene volcanic rocks overlie the Wishbone Formation with slight angular discordance on Castle Mountain and Puddingstone Hill. Based on lithology and stratigraphic position, Clardy (1982) found that the West Foreland Formation of the Cook Inlet basin was a lateral equivalent of the Wishbone Formation of the Matanuska Valley. The Wishbone Formation has undergone about the same deformation as Chickaloon Formation and underlying Cretaceous rocks (Barnes and Payne, 1956).

Sandstones of Wishbone Formation were derived from a predominantly volcanic source terrane as indicated by the high lithic content and salient augite population of the heavy-mineral fraction. Paleocurrent observations from formation outcrops show that main current directions are to the south and southwest at Wishbone Hill and to the west and southwest at Castle Mountain. Sedimentary texture and structure suggests that the Wishbone Formation was deposited in an alluvial fan environment. Thick sections of massive to crudely-stratified cobble conglomerates suggest sheet-flood debris deposited along a mountain front near the proximal portion of a fan. Horizontally-bedded sandstones with silt lenses and abundant wood fragments suggest filling of cut-off channels of an associated braided-stream environment (Clardy, 1982).

Tsadaka Formation

The Tsadaka Formation is best exposed at its type section in Tsadaka Canyon, the drainage of the lower Matanuska Valley through which Moose Creek flows. At this locality, the formation is at least 700 ft thick (Alaska Geological Society, 1964). It is poorly exposed on Wishbone Hill, where it is estimated to be at least 200-ft thick. The formation is lithologically different than the Wishbone Formation. The basal Tsadaka Formation consists of poorly indurated boulder-cobble conglomerate beds 45- to 100-ft thick and of variable composition, generally with a high content of acid plutonic (granite and diorite) clasts and a paucity of volcanic and chert clasts in a friable matrix of arkosic sandstone or granitic debris. The upper part of the formation consists of interbedded, lenticular and discontinuous, silty claystone, siltstone, medium- to coarse-grained pebble sandstone, and fine- to coarse-grained conglomerate (Clardy, 1982; Conwell and others, 1982).

The formation is the youngest bedrock unit of the Wishbone Hill district (Barnes and Payne, 1956), and is of middle Oligocene and late(?) Oligocene age. It composes the upper part of the former Eska Conglomerate of Martin and Katz (1912). It was named by Barnes and Payne (1956), who separated the uppermost beds of conglomerate (Tsadaka Formation) on Wishbone Hill from the underlying conglomerate (Wishbone Formation). The Tsadaka Formation lies with angular unconformity on Wishbone Formation on Wishbone Hill, but directly overlies deformed beds of Chickaloon Formation in Tsadaka Canyon, where the entire Wishbone Formation has apparently been removed by erosion. Clardy (1982) suggests that the Tsadaka Formation of the Matanuska Valley is a lateral equivalent of Calderwood and Fackler's (1972) Hemlock Conglomerate of the Cook Inlet basin Kenai Group.

The Tsadaka Formation is only mildly folded since it was deposited post-deformationally to the Wishbone Hill syncline. Renewed uplift and erosion in the predominantly plutonic Talkeetna Mountains contributed detritus as indicated by a southerly direction of sediment dispersal in Tsadaka Canyon. Heavy-mineral suites also suggest a felsic igneous association with a secondary low-grade metamorphic source terrane. The formation was probably deposited in alluvial fan and braided-stream environments along a mountain front (Clardy, 1982).

Tertiary Intrusive Rocks

Numerous dikes and sills intrude Tertiary sedimentary rocks of the Matanuska Valley and are present throughout almost all coal-bearing areas (figs. 25-27). The areal distribution of larger intrusives have been mapped. Intrusive rocks are less abundant on the west in the lower Matanuska Valley; only a few small basic dikes are known in the Moose Creek-Eska Creek area. In central and eastern Matanuska Valley, Tertiary coal-bearing rocks have been extensively intruded. The intrusives form trap ridges in the Anthracite Ridge area (Barnes and Payne, 1956; Wolfe and others, 1966).

Intrusive rocks are not confined to any particular horizon of the Chickaloon Formation, nor are they limited to Tertiary rocks. Cretaceous rocks have been intruded as well. Intrusive rocks are believed to represent one general period of Neogene volcanic activity. The intrusions appear to antedate the disturbance which caused the maximum folding of the Chickaloon Formation. Igneous rocks are intruded partly parallel to the axes of folding as long and fairly persistent dikes. The thickness of intrusives ranges from inches up to several hundred feet; most sills and dikes are less than 15 ft thick.

Figure 25. Diabase sills with diagnostic jointing pattern in Chickaloon Formation coal-bearing strata of the Castle Mountain mine, central Matanuska Valley.

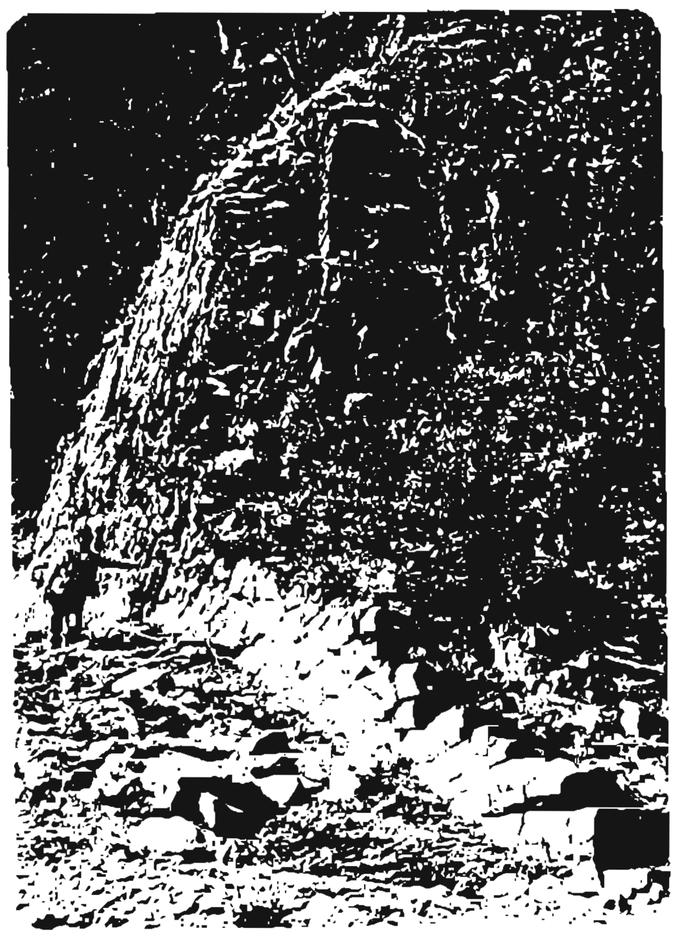


Figure 26. Steeply-dipping, prismatically-fractured diabase sill at Matanuska River site MR1. The large prisms appear similar to basalt columns.

Figure 27. Narrow diabase dike cutting through Chickaloon Formation coal-bearing strata in Packsaddle Gulch, Anthracite Ridge field.

The intrusives include both basic and felsitic rocks. Diabase is most abundant and a few minor sills and dikes are vesicular and basaltic. Dense, dark gray to black or greenish diorite porphyries, andesites, and gabbros are also present. Pliocene(?) basalt flows overlie the Wishbone Formation unconformably on Castle Mountain and are intercalated with pyroclastic rocks.

The appearance of intrusive rocks varies due to the degree of coarseness or granularity, arrangement of minerals, and in the order of crystallization. They vary considerably in granularity. Thicker sills tend to be coarser grained in the middle portion, which is chiefly a textural rather than mineralogical differentiation. The intrusives range from coarse-grained gabbros in which component minerals are clearly visible to fine-grained basalts. Coarse-grained diabases are composed of plagioclase feldspar (approximate composition of laboradorite) considerably altered to sericite and chlorite, augite over half of which is altered to chlorite, and magnetite. The fine-grained diabases are near the texture of basalt, plagioclase feldspar nearly unaltered, iron oxides altered to hydroxides, and the remainder of the matrix almost completely altered to carbonates. The surfaces of some larger sills are vesicular or amygdaloidal with patches of zeolites (Waring, 1936).

Felsitic intrusive rocks mostly form sills and follow bedding planes of sediments. Diabase and gabbro are more laccolithic in form and occur in roughly lenticular masses doming the strata and sending out sill and dike leaders into the adjacent rock. Larger intrusive masses have greater effects due to size and number of apophyses in the form of sills in or along bedding plane surfaces of coal beds. If they have spread for a considerable distance in contact with a coal, they can render large portions of it worthless by completely devolatilizing it. The effects of small dikes and sills generally do not extend far and don't affect coal seriously; if they are a few feet away, the coal is generally unimpaired or may be improved in quality (Martin and Katz, 1912; Chapin, 1920).

Contact phenomena of dikes or sills with coal usually include the production of a dense hard coke. Natural coking effects can be observed in outcrops or beds on the south limb of Coal Creek syncline, south slope of Castle Mountain, Chickaloon area, Gravel Creek vicinity, and Kings River. The coal adjacent to the magma assumes a prismatic structure, and at all points the prisms are perpendicular to the plane of the intrusion. Diabase changes from a dark-greenish trap to a felsitic variety resembling aplite or quartz porphyry. Strong contact metamorphism by dikes or sills adjacent to shales indurated and baked them into a hard, dense, fine-grained porcelanite zone to several inches or a few feet thick. On the west bank of Young Creek about 1 mi above Kings River, Tertiary sedimentary rocks directly overlie dense and fine-grained felsite porphyry (Hill, 1923; Merritt, 1985).

In general, coal may locally or areally be improved in chemical character by intrusive effects, but overall is more likely to deteriorate or be destroyed. The presence of thick sills in the Matanuska Valley coal-bearing rocks appears to be principally responsible for upgrading coal rank eastward. In the western part of Matanuska Valley, where igneous intrusives are generally absent, the coals are of high-volatile bituminous rank. In the eastern part of Matanuska Valley, where igneous intrusives are prevalent, the coals are high-rank bituminous, semianthracite, and anthracite (Chapin, 1920).

Intrusive rocks in the Matanuska Valley have and will continue to complicate engineering and economic mining. They have resulted in making an undetermined percentage of coal areas of doubtful value. There are probably many intrusive masses that do not outcrop but would be encountered with mining. When large and extensive masses of hard intrusive rock are encountered during mining along projected gangways and counters of underground mines, they may necessitate a change in mine plan or possibly shut down operations. This is essentially what forced the closure of the Chickaloon mine of central Matanuska Valley. In the Wishbone Hill district, there are no igneous rock bodies that have significantly hampered past mining operations or affected the quality of large blocks of coal. In central and eastern Matanuska Valley, intrusive rocks have seriously affected the quality and ultimate minability of the coal deposits (Alaska Geological Society, 1964).

Quaternary and Holocene Deposits

The Matanuska Valley has experienced a complex history of glaciations and fluvial aggradation and incision. Resultant deposition includes glacial, glaciofluvial, high-terrace gravel, colluvial, talus, landside, modern alluvial flood-plain, and thin lacustrine materials (fig. 28). Unconsolidated sediments are not thick east of Moose Creek but local glaciofluvial and terrace deposits exceed 100 ft in depth; glacial material east of Eska Creek is about 50 ft thick (Barnes and Payne, 1956; Kreig and Associates, 1983).

The Matanuska coal field lies in the formerly glaciated valley of the Matanuska River. The Matanuska Glacier probably filled the entire valley from side to side and joined other large glaciers to form the ice mass occupying Cook Inlet. Smaller glaciers occupied valleys in the high mountains. Glacial boulders on top of Wishbone Hill indicate that it was overriden by the Matanuska Valley glacier. West of the Chickaloon River, former glaciers and glacial streams deposited large volumes of detritus. The morainal deposits are more extensive toward the west end of the lower Matanuska Valley where they cover all but a few scattered areas of Tertiary rocks. In the Wishbone Hill district, outwash and morainal deposits are absent only on steeper slopes where they have been removed by recent stream erosion. Morainal deposits along south flank of Wishbone Hill have characteristic topography of numerous potholes and steep-sided depressions, some reaching a depth of 150 ft (Capps, 1927; Tuck, 1937b).

Terrace deposits are especially well developed throughout lower Matanuska Valley but are better developed at low altitudes. Benches or terraces found along Moose and Eska Creeks represent stages in the downcutting of the Matanuska River to its present level. River-cut and -modified stepped benches along the sides consist of interbedded gravels and coarse, yellow silt. The gravel bands, lenses, and pockets contain pebbles predominantly less 2 in. but also include abundant 6-in. cobbles and boulders to 2 ft. The clasts are generally stratified and fairly well sorted, and are

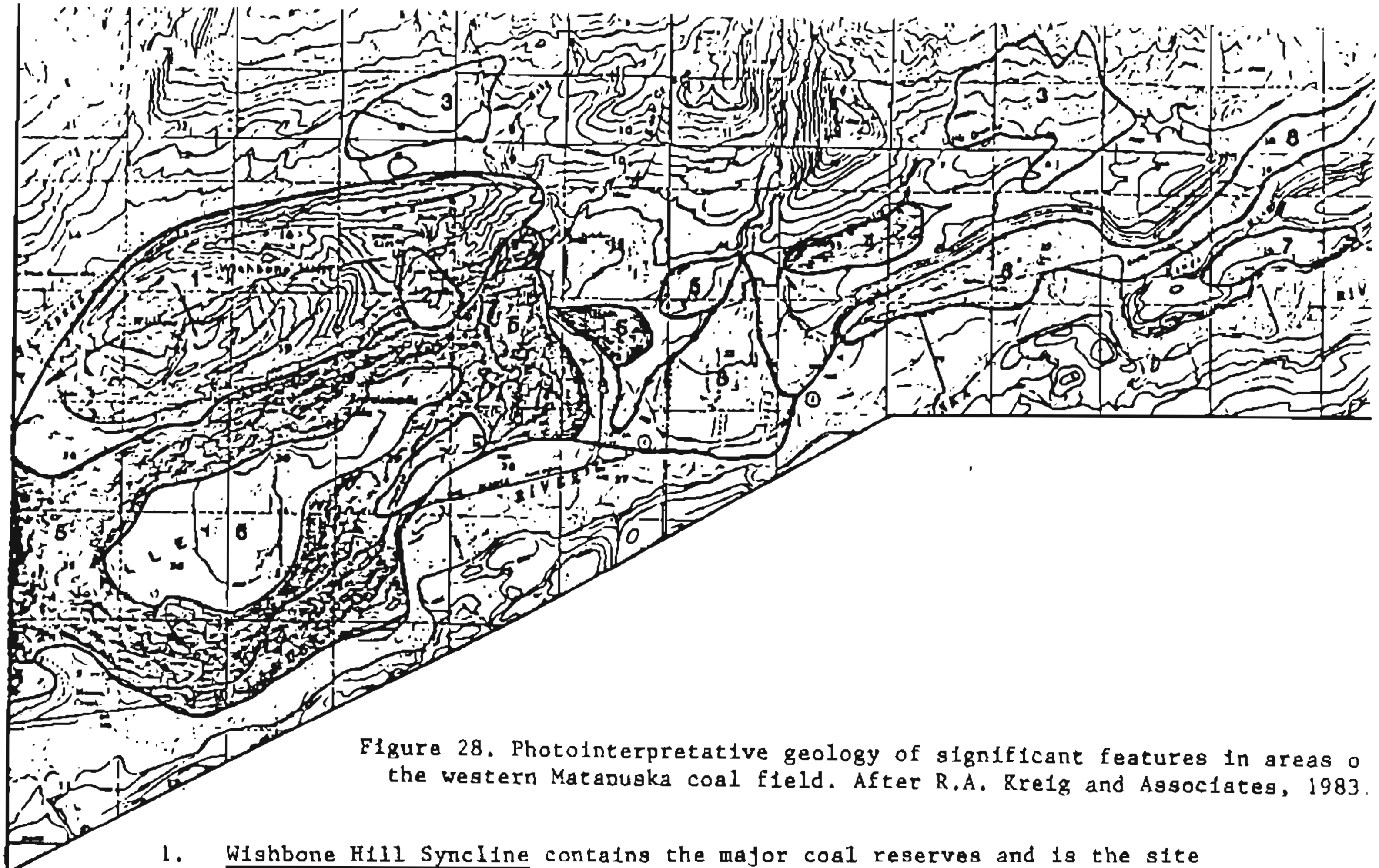


Figure 28. Photointerpretative geology of significant features in areas o the western Matanuska coal field. After R.A. Kreig and Associates, 1983.

1. Wishbone Hill Syncline contains the major coal reserves and is the site of previous mining. Beds on both limbs have average dips of 35 to 40°. Open pit mining on the north limb supplanted underground mining by the late 1950's.

2. Though active landsliding is not apparent in the area, this large landslide occurred where glacially oversteepened slopes transect steeply dipping Tertiary bedrock. Similar oversteepening would have to be avoided in excavations.

3. Colluvial fans, more active in past preglacial environment, may be the thickest unconsolidated deposits along the upper valley walls. Generally the upper slopes are underlain by the dense basal till (0 to 30 ft) overlying bedrock.

4. Fine grained lacustrine and quiet water deposits may exist in small basins impounded by glacial ice or outwash deposits. Though these deposits may not be common, their poor foundation characteristics require consideration.

5. Ice contact deposits are obvious in a field extending from Eska Creek to west of Moose Creek. These deposits are locally very thick over bedrock. They may provide excellent material sources.

6. Outwash deposits and ice contact deposits blanket the hill south of Seventeenmile Lake to an unknown depth.

7. High level alluvial terrace gravels are present throughout the valley. These terraces are remnants of Matanuska River deposits aggraded to a higher base level during late Pleistocene glacial ice damming of the Matanuska Valley.

8. Low level alluvial terraces and modern floodplains are the result of incision and regrading of valley streams to the existing base level.

composed predominantly of granite with abundant sandstone, shale, and fine-grained basic rocks. Higher terraces form less-developed gravel benches in mountain valleys tributary to the Matanuska River (Capps, 1927).

Relatively thick talus deposits are found along the lower mountain and hill slopes and have formed as a result of normal weathering processes. The lower slopes of Wishbone Hill are covered by a mantle of loose debris, mainly a choatic mass of irregular conglomerate blocks, which have accumulated as talus or resulted from extensive landslides. The numerous landslide deposits in the Wishbone Hill district have commonly been derived from Wishbone Formation conglomerates, and are most extensively developed immediately west of Jonesville, where they form a mappable geologic unit. The deposits probably formed by oversteepening caused by glacial erosion in combination with zones of weakness due to faulting. These deposits are more resistant than the underlying, easily erodible coal-bearing rocks. Some landslides have occurred relatively recently (Barnes and Payne, 1956; Alaska Geological Society, 1964).

Modern stream alluvial and gravel deposits are well developed along the larger streams of the Matanuska Valley and on many smaller ones of relative low gradient. The deposits compose the flats and gravel bars along the course of the Matanuska River, which is a heavily overloaded glacial stream with irregular flow (Capps, 1927).

GEOLOGIC HISTORY

During Late Jurassic time, the Matanuska Valley region was uplifted and intruded by granitic rocks. Areas to the northwest were still below the sea in Early Cretaceous time and thick deposits of limestone were formed. Terrestrial nonmarine proximal clastics of the Arkose Ridge Formation were derived from granitic source rocks in the Talkeetna Mountains to the north during Late Cretaceous and deposited in an extensional trough of the Cook Inlet basin. Subsequently, marine fossiliferous shales and sandstones of the Matanuska Formation were deposited. Regional uplift caused withdrawal of the sea, emergence, and erosion. An episode of folding closed off Cretaceous time.

An extensive fresh water basin developed in the Paleocene and the nonmarine Chickaloon Formation sediments were derived from source areas farther to the north. Coal-forming marshes developed in areas of a low fluvial plain slightly above sea level. Recurrence of swamp conditions formed peat beds of moderate extent through early Eocene time. The Chugach Mountains area began to rise subsequently causing a coarsening of sedimentation and the deposition of thick conglomerate beds of the Wishbone Formation. Secondary fine-grained detritus was derived from the Talkeetna Mountains. Strong folding and faulting closed the Eocene epoch creating most of the structures observed today in the Chickaloon and Wishbone Formations. The Chugach area particularly was intensely deformed. By middle and late(?) Oligocene, the structural trough was farther depressed between the rising Talkeetna and Chugach areas. Alluvial fans and braided deposits built southward off the front of the Talkeetnas forming coarse conglomerates of the Tsadaka Formation. During the Miocene and Pliocene, additional uplifts occurred in the Talkeetna and Chugach areas causing further deformation, erosional weathering and leveling of Tsadaka and older formations. Dikes and sills intruded older Cretaceous and Tertiary sedimentary rocks in the Pliocene, and layers of basaltic lava are unconformably laid down on Tsadaka Formation. The lavas have been preserved on the crests of Castle Mountain and Puddingstone Hill.

Since the Pliocene, erosion and weathering have continued to abrade and carve further details into the rocks of the Matanuska Valley. Modern streams formed and continued this erosion process. Extensive glaciation in the Quaternary covered lower Matanuska Valley with more than 3,000 ft of ice at its maximum. Melting of the ice caused uplift of the region and the formation of deep stream channels and the deposition of morainal deposits and terrace gravels. Postglacial drainages were reestablished and erosion continued. The Matanuska River began to cut its present valley (Waring, 1976; Barnes and Payne, 1956).

DEPOSITIONAL ENVIRONMENTS AND PROVENANCE

The coal-bearing Chickaloon Formation of the Matanuska Valley comprises continental fresh-water deposits that accumulated under temperate humid climatic conditions in Paleocene to early Eocene depocenters northeast of Cook Inlet basin. Sediments were deposited on an extensive interior plain of little or no gradient only slightly above sea level (Barnes and Payne, 1956). The lower part of the Chickaloon Formation formed in fluvial braided to meandering stream environments (table 2); deposition tended to be relatively rapid. The upper part of the Chickaloon Formation formed in fluvial meandering to paludal environments. Different parts of the succession are indicative of alternating periods of weak and strong orogenic movements. In general, uplift of source regions began a new cycle of clastic deposition (Payne, 1945).

Kirschner and Lyon (1973) interpreted a significant stratigraphic change and a regional unconformity based on heavy mineralogy and lithology at the end of Chickaloon deposition. They proposed a distant source north of the present Alaska Range for Chickaloon and Tsadaka Formation sediments. Clardy (1974) however proposed a nearby source for both the Wishbone and Tsadaka Formations and probably also for the Chickaloon Formation based on interpretation of grain size and heavy and light mineral assemblages. The major change in provenance from a predominantly volcanic source terrane for the Wishbone Formation and a plutonic source for the Tsadaka Formation is regional in scope and represents a major structural-stratigraphic event in the entire Cook Inlet basin (Clardy, 1982).

Second-order sedimentary cycles in the coal measures began with the dominance of river sedimentation forming coarse-grained, cross-bedded sandstone with lenticular conglomerate at the base grading upward into finer clastics containing a few widely spaced coal beds. Fine sandstone, siltstone, and silty claystone was deposited during flood events on this broad plain. Abundant fossilized leaves, twigs, and trunks of plants and trees that lived on and between the flood plains were preserved throughout the deposits. Thicker claystone beds were deposited in stagnant flood plain lakes and

Table 2. Summary of chief lithologic characteristics and depositional environments of Tertiary and Cretaceous sedimentary rock formations of Matanuska Valley. Compiled from Clardy, 1978.

Formation	Age	Thickness	Lithology	Stratigraphic relationship	Depositional environment
Tsadaka Formation	Oligocene; time equivalent of lowest beds of Kenai Group	Over 150 m in Tsadaka Canyon	Crudely stratified, massive conglomerate; marginal conglomeratic facies of Kenai Group	Overlies Wishbone and Chickaloon formations with a distinct angular unconformity in lower Matanuska Valley	Sheet-flood debris deposited on alluvial fans
Wishbone Formation	Eocene	550-600 m	Well lithified conglomerates, sandstones, and siltstone	Overlies Chickaloon Formation unconformably in Matanuska Valley	Fluvial environment; alluvial fans and associated braided streams, perhaps meandering stream deposits in part
Chickaloon Formation	Paleocene	At least 1,500 m thick in Matanuska Valley	Well indurated claystones, siltstones, sandstones, conglomerates, coal	Conformable with overlying Wishbone Formation south of Willow Creek in southwestern Talkeetna Mountains	Fluvial braided to meandering stream environment in lower part, and fluvial meandering to paludal environment in upper part
Arkose Ridge Formation	Paleocene	Unknown	Coarse-grained clastics---arkosic conglomerates, minor shales	Nonconformably overlies plutonic rocks along south flank of Talkeetna Mountains and overlies Talkeetna Formation to northeast	Local source, fanglomerate deposit
Matanuska Formation	Early to late Cretaceous (Albian to Maestrichtian)	Over 1,200 m thick at type section in Matanuska Valley	Siltstones, sandstones, and cobble conglomerates	Underlies Tertiary rocks with local disconformity	Marine; sublittoral to outer bathyal or abyssal deposition by density currents or submarine slumps

ponds, and thinner clay beds in coals represent a temporary cessation of bog conditions.

Quiescence in source regions led to relative long-sustained regional swamp conditions forming series of closely spaced coal beds. Individual lenticular coal beds which wedge out laterally and are found in relative stratigraphic isolation in sandstone, siltstone, and claystone sections were deposited in flood plain bogs when river sedimentation still held sway. Streams became sluggish and drainages ponded causing the water-table to rise during periods of swamp domination. Bony coal, bone, and coaly claystone formed when flood waters had temporary and limited access to the swamps. The degree of dominance of bog conditions varied locally as reflected in wide lateral variation in the proportion of coal to clastic beds. For example, the Premier series thickens with increased clastic content in the eastern part of Wishbone Hill district. In the Paleocene, this area was periodically subjected to the influx of flood plain silts, whereas areas to the west were more sheltered (Barnes and Payne, 1956; Payne and Hopkins, 1944). Lower ash coal beds formed in areas of swamps inaccessible to flood waters. Transitions occur from cleaner coal within basin centers to ashy coal and clay along basin rim areas (Waring, 1936).

COAL PETROLOGY

Methods of Analysis

Procedures of the International Committee on Coal Petrology and the hard coal terminology of Stach's Textbook of Coal Petrology (1982) were adopted and followed for the petrologic analysis of coal samples from the Matanuska Valley.

Coal samples (about 50 grams) were crushed to -20 mesh, kneaded with epoxy resin, and briquetted in a 1.5-in. (i.d.) diameter mold using a hydraulic press at 4,000 to 5,000 PSI. The pellets were ground using a Buehler automet and consecutively a 120 diamond lap and a 30 metal-banded diamond lap, and then polished in 1 and 0.05 aluminum oxide suspensions.

A Swift point counter was used for quantitative maceral determinations. All pellets were randomly counted to avoid bias; 1,000 counts were made of the different macerals encountered along grid traverses. Maceral contents were recorded on a volume percent, mineral-matter-free basis.

Vitrinite reflectance measurements were made on a Leitz Ortholux triocular body microscope equipped with an MPV-3 system and a motorized-drive stage. A square-leaf diaphragm with a 5 square measuring area on the specimen was used, and an interference filter was inserted to give a peak transmittance at 546 nm wavelength. Bausch and Lomb Company optical glasses were used as reflectance standards. The mean maximum reflectance of vitritite particles was measured in oil along equally spaced traverses; 100 measurements were made on each sample. The polished pellets were dried in a desiccator prior to taking reflectance measurements (Rao and Wolff, 1981).

Discussion of Results

Matanuska Valley coals show petrologic compositions high in vitrinite with minor inertinite and liptinite contents. The respective maceral terminology used for classification in low- and high-rank coals are summarized in table 3. Tables 4 and 5 list average maceral compositions for Matanuska Valley bituminous and anthracite coal samples. Quantitative data on individual samples are enumerated by rank in tables F12 to F14 of appendix F. Photomicrographs of mainly liptinitic coal macerals from samples of the region showing their general types, diagnostic morphology, and common associations are presented on plate 4.

The vitrinite group content in Matanuska Valley bituminous coals ranges from 89 percent to essentially 100 percent, and the mean content is about 96 percent in the 56 samples analyzed (table 4). Vitrinite and vitrodetrinite are the main macerals of the group. Corpocollinites, gelinite, and pseudovitrinite are of very minor occurrence. Semianthracite-anthracite (table 5) and subbituminous coals (table F12, appendix F) show similarly high vitrinite contents.

Inertinites show a mean content over 1 percent in both bituminous and semianthracite-anthracite coals of the Matanuska Valley, but range up to over 4 percent (volume, mineral-matter-free basis). Fusinite, semifusinite, sclerotinite, macrinite, and inertodetrinite are all present in these high rank coals but consistently average less 0.3 percent each. Matanuska Valley subbituminous coals show similar inertinite contents.

Liptinites (or exinites) occur as minor components in coals of the Matanuska Valley. The mean liptinite content in the bituminous coals is 3 percent, but in the semianthracite-anthracite coals it is only 0.1 percent. In the bituminous coals, liptinites range to about 9.5 percent but to only 1.0 percent in the anthracitic ranks. The few subbituminous coals analyzed show a range in liptinite content from 2.2 to 8.8 percent. Liptodetrinite, resinite, suberinite are the most abundant liptinite maceral types, and exsudatinite, cutinite, sporinite, and alginite are very rare.

Figure 29 shows a ternary diagram for maceral compositions of Matanuska Valley coal samples. Maceral group proportions are plotted by rank in an enlarged-scale triangular diagram beginning at the established 89 percent vitrinite base level. In general, the bituminous coals exhibit the broader distribution in this plot. The anthracitic coals plot near the vitrinite end member and the subbituminous coals fall relatively closer to the liptinite end member.

Mean-maximum vitrinite reflectance values (Rom) for Matanuska Valley coal samples are summarized in figure 30, and listed individually in table F15 of appendix F. Table F16 (appendix F) compares reflectance values with their respective ASTM rank. Reflectance increases with the rank of a coal as indicated in figure 31 by the plot of Rom vs. dry, ash-free carbon content. Reflectance values in Matanuska Valley samples show a broad range from 0.47 to 5.34 percent, and generally support the rank grades (subbituminous B to meta-anthracite) assigned by coal quality assessment. Considering that these

Table 3. Maceral terminology used in petrologic analysis of Matanuska Valley coals. Modified from Rao and Smith, 1983.

<table>
<tr><th colspan="3">Low Rank Coal Classification</th><th></th><th colspan="3">Bituminous Coal Classification</th></tr>
<tr><th>Maceral Group</th><th>Maceral Subgroup</th><th>Maceral</th><th>Maceral Class for this study</th><th>Maceral Type</th><th>Maceral</th><th>Maceral Group</th></tr>
<tr><td rowspan="7">huminite</td><td rowspan="2">humo-telinite</td><td rowspan="2">ulminite</td><td rowspan="3">vitrinite</td><td colspan="2">telinite</td><td rowspan="7">vitrinite</td></tr>
<tr><td colspan="2">vitro-detrinite</td></tr>
<tr><td colspan="2">humo-detrinite</td><td>telo-collinite</td><td rowspan="4">collinite</td></tr>
<tr><td rowspan="3">humo-collinite</td><td>gelinite</td><td>gelinite</td><td>gelo-collinite</td></tr>
<tr><td rowspan="2">corpo-huminite</td><td>phlobaphinite</td><td rowspan="2">corpo-collinite</td></tr>
<tr><td>pseudo-phlobaphinite</td></tr>
<tr><td colspan="2">—</td><td>pseudo-vitrinite</td><td></td><td>pseudo-vitrinite</td></tr>
</table>

Classification applicable to all Coals

Maceral Group	Maceral Class for this study
inertinite	fusinite
	semifusinite
	macrinite
	inertodetrinite
	sclerotinite
	micrinite

Maceral Group	Maceral Class for this study
liptinite	sporinite
	resinite
	exsudatinite
	cutinite
	thick cutinite
	alginite
	other liptinite
	suberinite

Table 4. Summary of coal petrologic data for 38 bituminous coal samples from the Matanuska Valley.

Maceral	Range	Mean
Vitrinite	57–97	80
Pseudovitrinite	0.0–0.2	0.0
Gelinite	0.0–1.0	0.1
Phlobaphinite	0.0–0.2	0.0
Pseudophlobnphinite	0.0–3.6	0.3
Vitrodetrinite	2–42	15
Total vitrinite	89–100	96
Fusinite	0.0–1.8	0.2
Semifusinite	0.0–2.0	0.2
Sclerotinite	0.0–1.2	0.3
Macrinite	0.0–0.4	0.3
Inertodetrinite	0.0–3.2	0.3
Total inertinite	0.0–4.8	1.1
Cutinite	0.0–2.2	0.1
Sporinite	0.0–0.2	0.0
Resinite	0.0–4.4	0.9
Suberinite	0.0–5.8	0.7
Alginite	0.0–0.2	0.0
Liptodetrinite	0.0–7.2	1.6
Exsudatinite	0.0–0.8	0.1
Total liptinite	0.0–9.4	3.0

Table 5. Summary of coal petrologic data for 17 semianthracite and anthracite coal samples from the Matanuska Valley.

Maceral	Range	Mean
Vitrinite	52-98	82
Pseudovitrinite	0.0-7.8	0.7
Gelinite	0.0-0.0	0.0
Phlobaphinite	0.0-0.0	0.0
Pseudophlobaphinite	0.0-0.0	0.0
Vitrodetrinite	2-34	10
Total vitrinite	66-100	94
Fusinite	0.0-2.6	0.3
Semifusinite	0.0-1.6	0.1
Sclerotinite	0.0-1.4	0.3
Macrinite	0.0-1.0	0.1
Inertodetrinite	0.0-1.6	0.3
Total inertinite	0.0-4.2	1.2
Cutinite	0.0-0.0	0.0
Sporinite	0.0-0.0	0.0
Resinite	0.0-0.8	0.1
Suberinite	0.0-0.0	0.0
Alginite	0.0-0.0	0.0
Liptodetrinite	0.0-0.4	0.0
Total liptinite	0.0-1.2	0.1

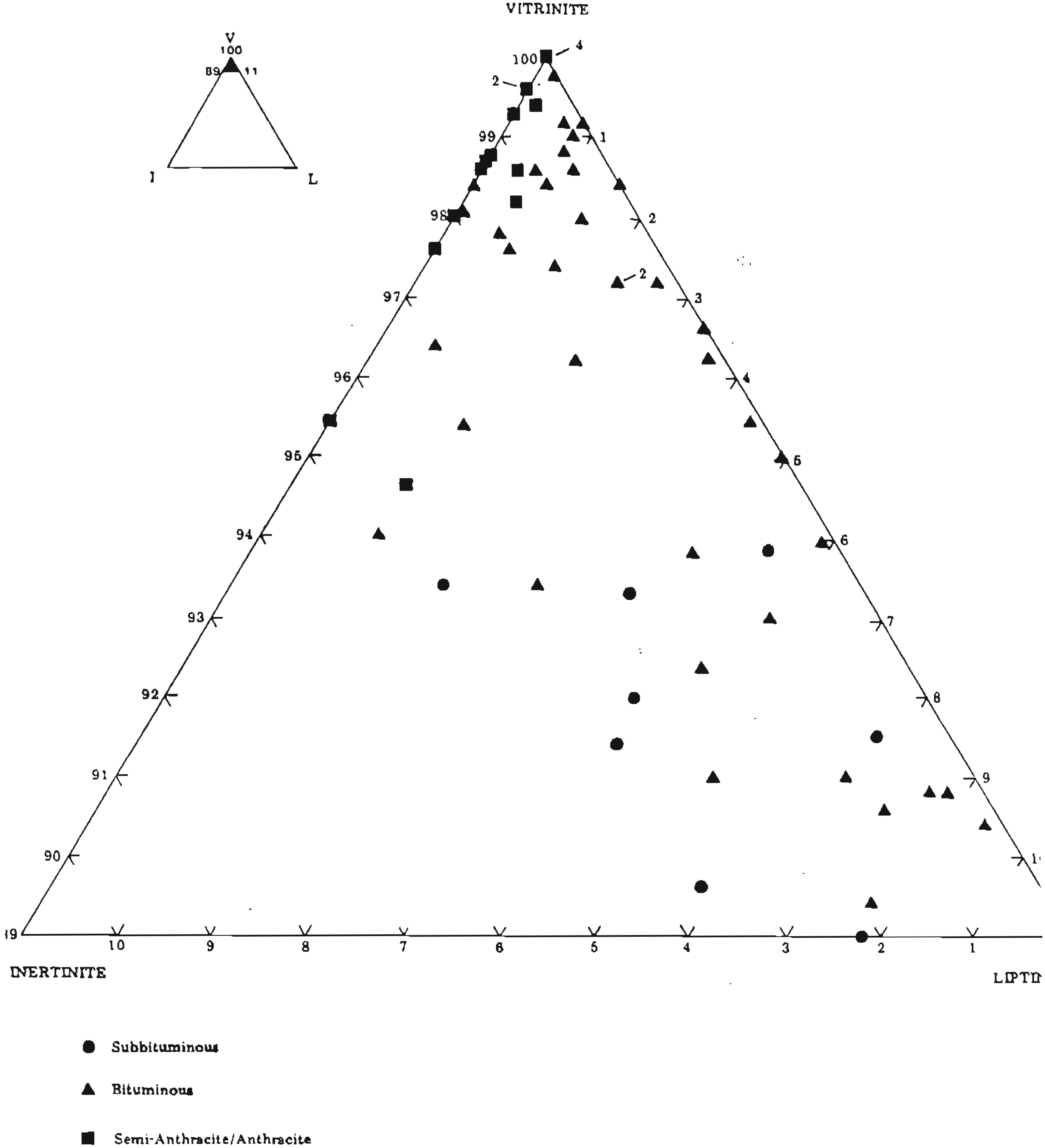


Figure 29. General ternary plot of petrologic data for Matanuska Valley coal samples by rank. End members shown are the three major maceral groups.

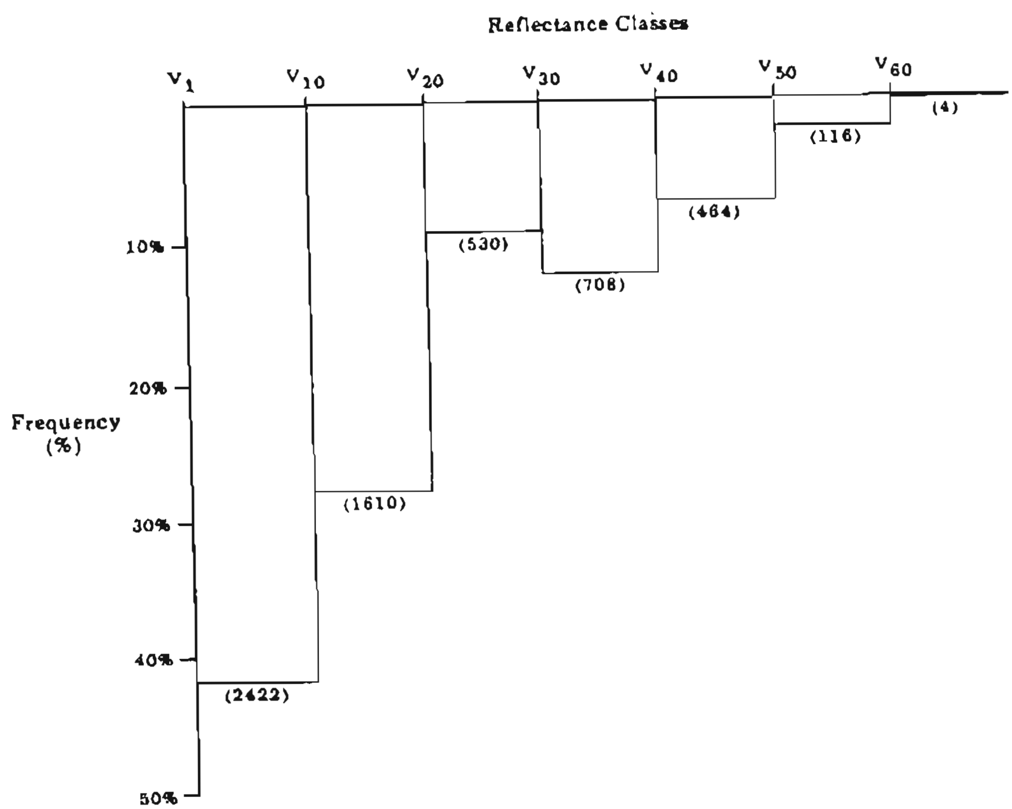


Figure 30. Distribution of vitrinite reflectance data for Matanuska Valley coal samples. Number in parentheses indicates the total number of grains counted at the given reflectance class interval.

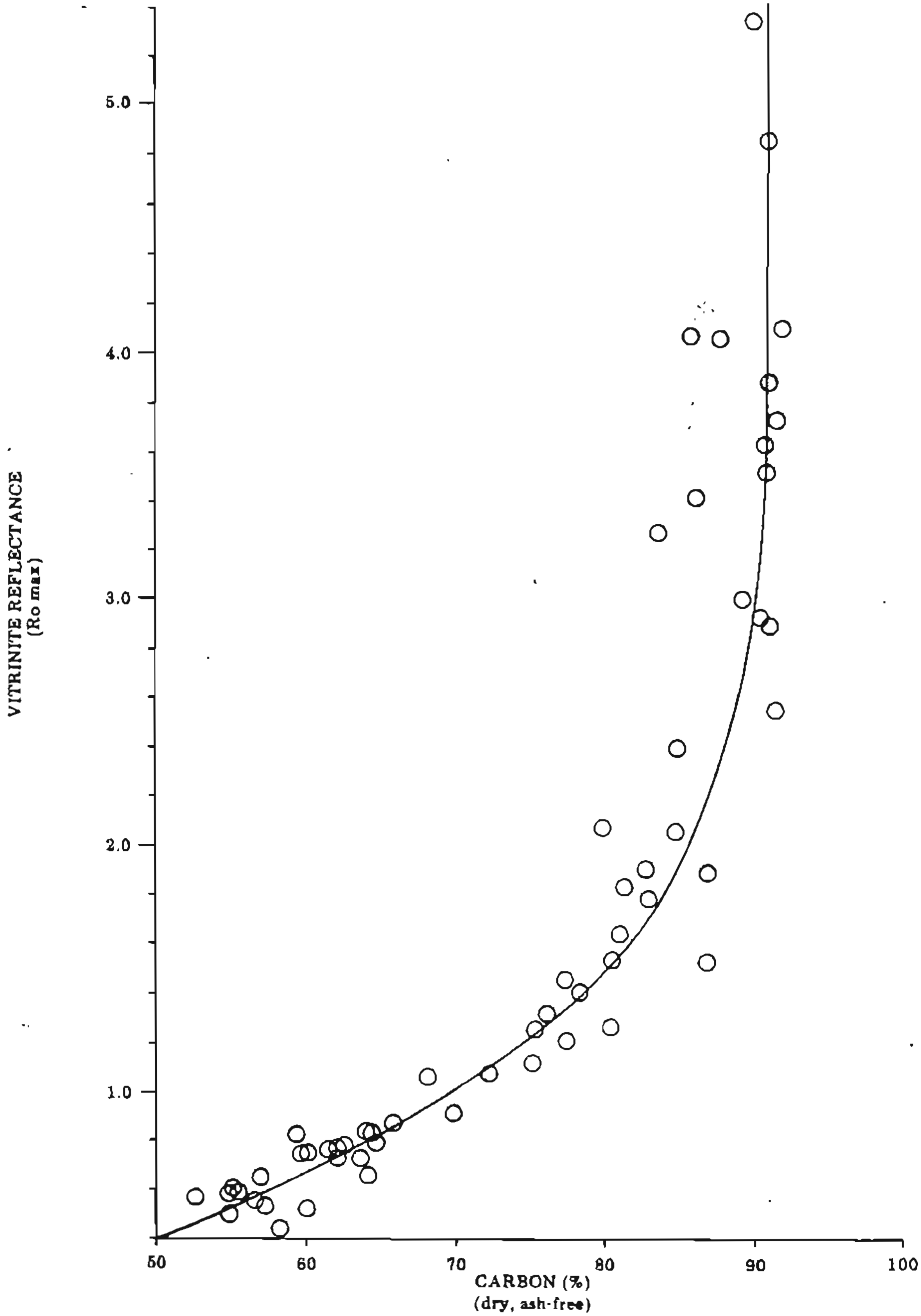


Figure 31. Scatter plot showing the general direct relationship of mean-maximum vitrinite reflectance values (Rom) with percent carbon (dry, ash-free basis) in coal samples analyzed from the Matanuska Valley.

samples are from outcrops containing weathered and oxidized coal, vitrinite reflectance should be considered a more reliable measure of rank than proximate analysis data.

Vitrinite reflectance values increase from the lower to upper Matanuska Valley (fig. 32). This generally corresponds to rank increases eastward in the valley. The generalized isopach map also shows a lowering in vitrinite reflectance around the margins of the Matanuska basin. However, this has not been demonstrated conclusively because of the amount of data used in constructing this illustration.

The petrology of Matanuska Valley coals is consistent with their interpreted origin in early Tertiary paludal (swamp) environments associated with a continental-fluvial depositional system. It also reflects the strong influence of post-depositional thermal effects that have progressively more severely altered coal maceral assemblages eastward in the region.

Locally, the thermal effects of contact metamorphism have produced natural coke. Merritt (1985) discussed an occurrence of natural coke at the Castle Mountain mine and estimated temperatures of formation at 450 to 500°C. Fracturing due to rapid cooling produced locally well-developed prisms at the site (fig. 33). The contact surface with the underlying sill is diffuse and irregular (fig. 34). The apparent rank of the highly altered coal was established as anthracite.

The possibility of using Matanuska coals for coking and byproducts has been investigated off and on in the past. These byproducts include gas, briquetted fuel, ammonium sulfate, light oil, tar, and toluol (Chapin, 1920). Selvig and others (1944) studied 14 Alaska coals seeking an alternate source of liquid fuel to supplement imports of petroleum products. This investigation was part of a general survey of the physical and chemical properties of Matanuska, Nenana (Suntrana), Broad Pass, and Fortymile prospect coals. The yields of low-temperature carbonization products of the Matanuska coals are summarized in table 6. The Matanuska samples formed weak, friable cokes. Because of their higher fixed carbon content, the Matanuska coals yielded considerably more residue---72.7 percent and 68.8 percent, respectively, for coals of Eska and Jonesville mines---than the other Alaskan samples tested. The low-temperature carbonization products of the bituminous coals from the Matanuska field were 1) a coke weighing about 70 percent of the original coal; 2) 29 to 41 gallons of tar and light oil per ton of coal; 3) about 10 percent of water, and 4) 840 to 970 Btu in gas per pound of coal. The Eska sample (Upper Shaw bed) had the highest yields of tar and light oil of all samples examined---40.9 gallons per ton of coal. Of the other coals tested, the No. 6 bed in the old Suntrana mine proved to be the second most important as a potential source of fuel oil. The gas from the Eska coal also had the highest Btu value per ft^3, but the volume was smaller than for the other coals tested (table 7). Because of its high calorific value, the Btu in gas per pound of coal was the highest for any of the coals carbonized. The Jonesville coal ranked next to the Eska coal as a source of gas (Selvig and others, 1944).

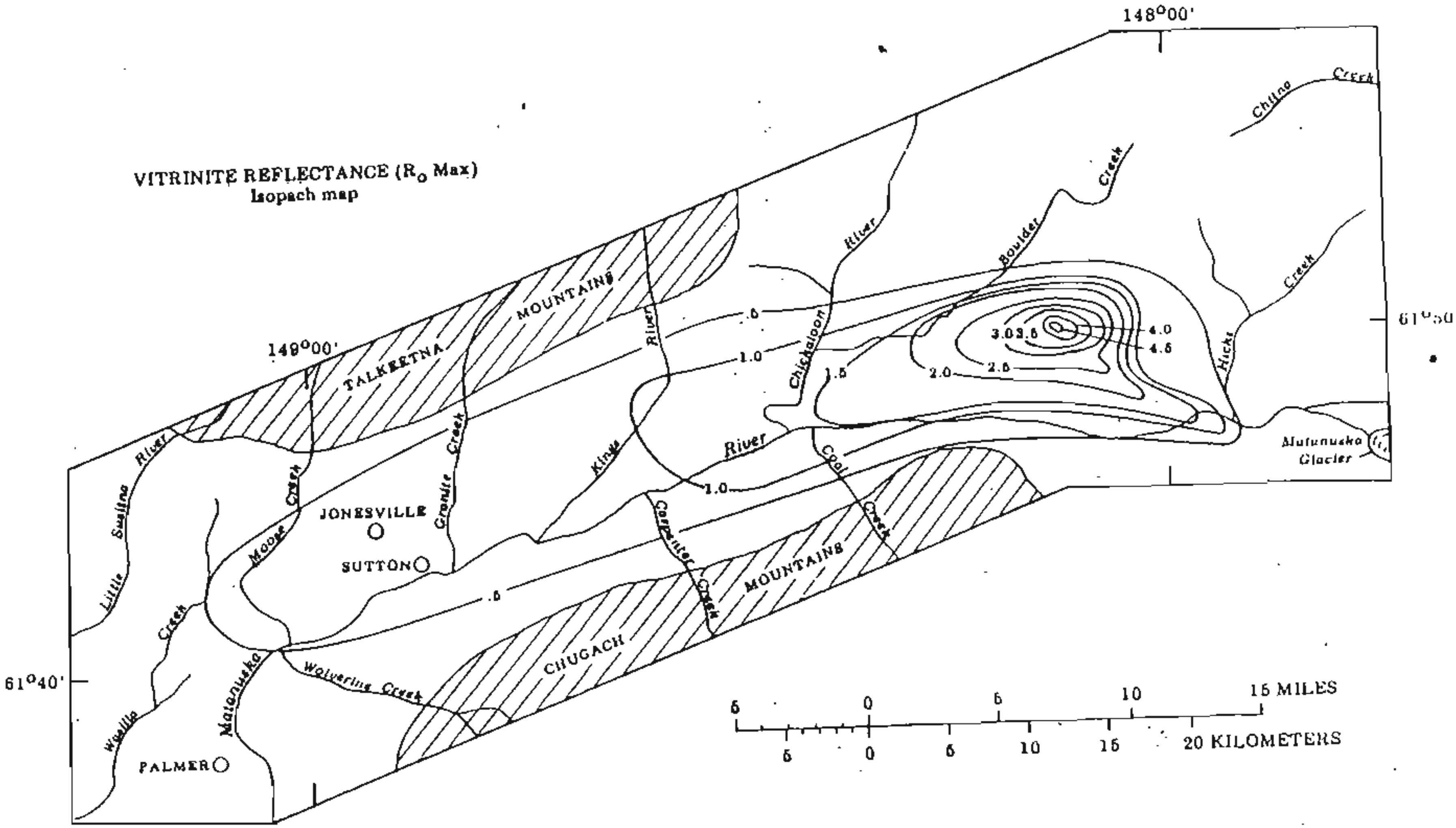


Figure 32. Highly generalized isopach map of mean-maximum vitrinite reflectance variation in coal samples of the Matanuska Valley.

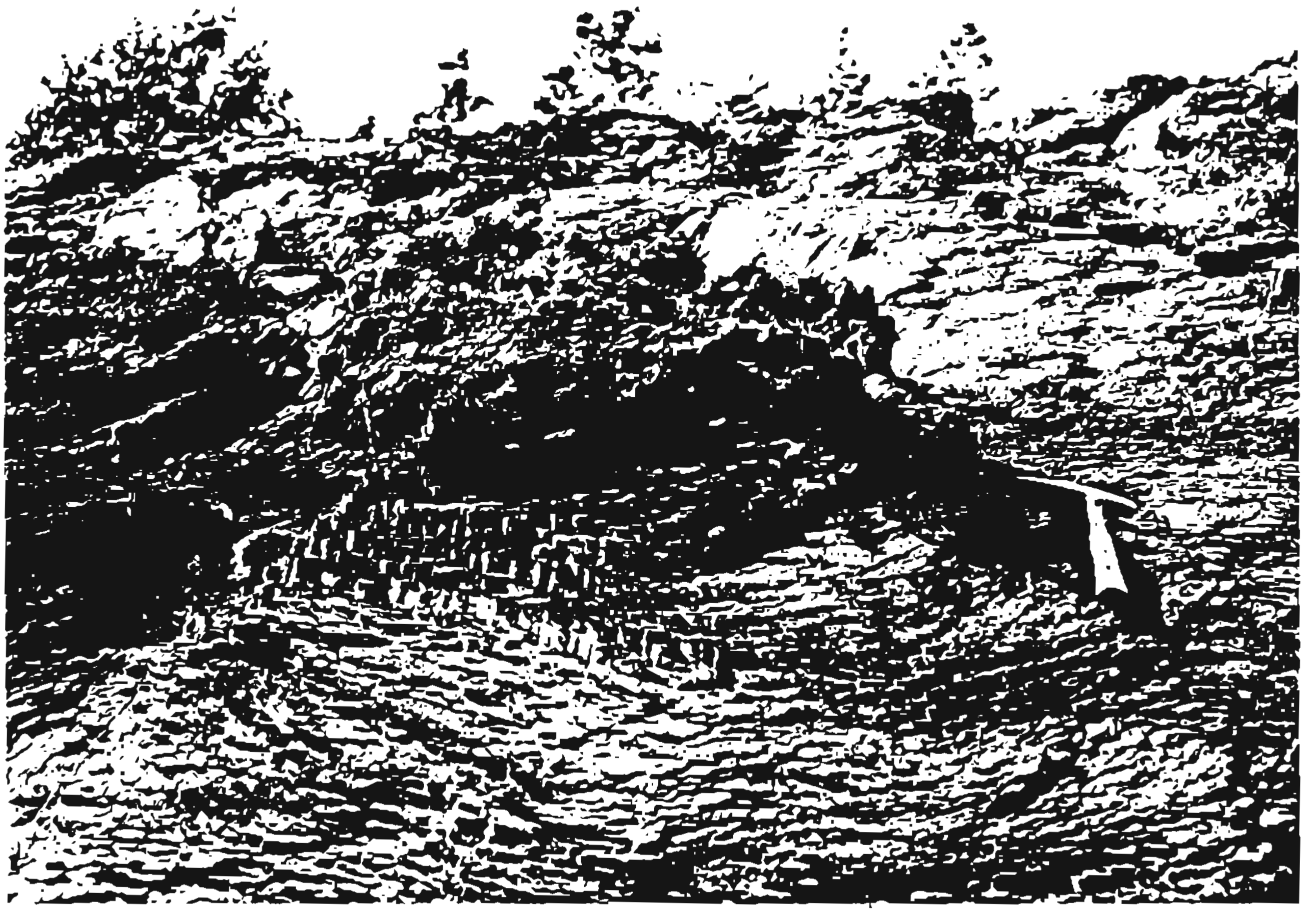


Figure 33. Prismatically fractured natural coke in the basal portion of the northern pit coal seam, Castle Mountain mine.

Figure 34. Diffuse and irregular coke-intrusive contact surface in the northern opencut pit, Castle Mountain mine.

Table 6. Fisher low-temperature carbonization assay yields of Matanuska Valley coals calculated to the as-received basis. From Selvig and others, 1944.

			Yields, percent by weight of coal						Yields, per ton of coal			
District	Mine	Bed	Carbonized residue	Tar	Light oil	Water	Hydrogen sulfide	Gas	Gas ft^3	Tar gal.	Light oil, gal.	Tar and light oil, gal.
Matanuska	Eska	Upper Shaw	68.8	15.9	0.90	9.0	0.11	5.3	2140	38.1	2.8	40.9
Matanuska	Jonesville	No. 8	72.7	11.2	0.62	10.0	0.05	5.4	2100	26.8	2.0	28.8

Table 7. Physical and chemical properties of gas from Fisher low-temperature carbonization assay. From Selvig and others, 1944.

			Air- and H_2S-free									
			Gross heating value*		Composition, dry, percent by volume							
District	Mine	Bed	Btu/ft³	Btu/lb of coal	CO_2	Illuminants	H_2	CO	CH_4	C_2H_6	N_2	Air-free H_2S
Matanuska	Eska	Upper Shaw	911	970	13.8	4.9	9.1	7.5	46.0	16.0	2.7	1.3
Matanuska	Jonesville	No. 8	801	840	20.9	4.4	10.0	8.2	40.1	13.5	2.9	0.6

*Gas stripped of light oil and saturated with water vapor at 60°F and under a pressure of 30 in. of mercury.

CENTER SECTION

PLATE 4
(24 figures)

Plate 4---Photomicrographs of fluorescing liptinites and associated macerals in Matanuska Valley coal samples. Polished section, oil immersion, width of field of view about 140 microns. Sample codes: EC = Eska Creek; MC = Muddy Creek; RM = Red Mountain; CC = Coal Creek; PG =Packsaddle Gulch; and WH = Wishbone Hill. Sample number listed in parentheses.

Figure 1. Thin cutinite, sclerotinite, minor resinite (EC1-1).

Figure 2. Sclerotinite---twin-celled teleutospore and teleutospore with four cells, resinite, liptodetrinite (EC1-1). (Teleutospores are winter cells of fungi.)

Figure 3. Sclerotinite---triple-celled teleutospore, partly deformed, resinite, liptodetrinite (EC1-1).

Figure 4. <u>Sclerotites</u> sp. with resinite filling cells, sporinite, liptodetrinite (EC1-1).

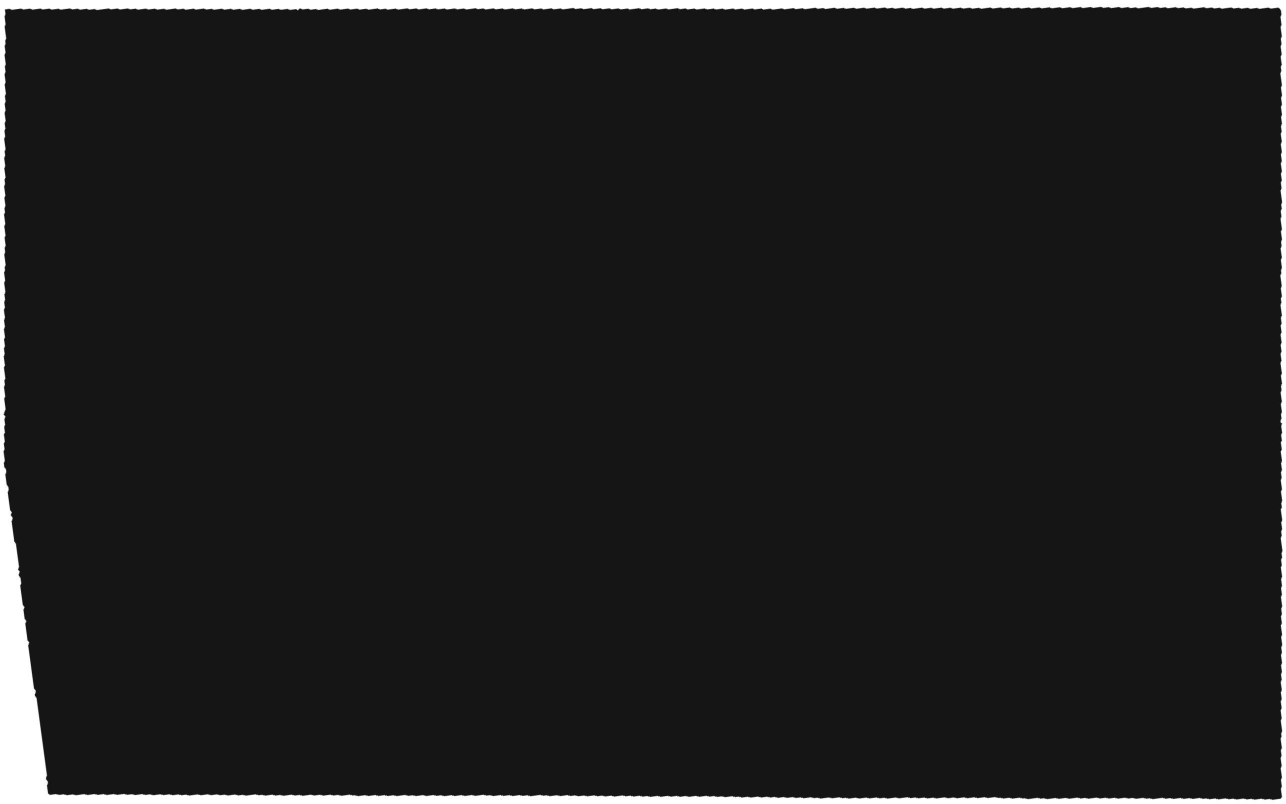


Figure 5. Alginite, sporinite, minor thin cutinite (MC1-6).

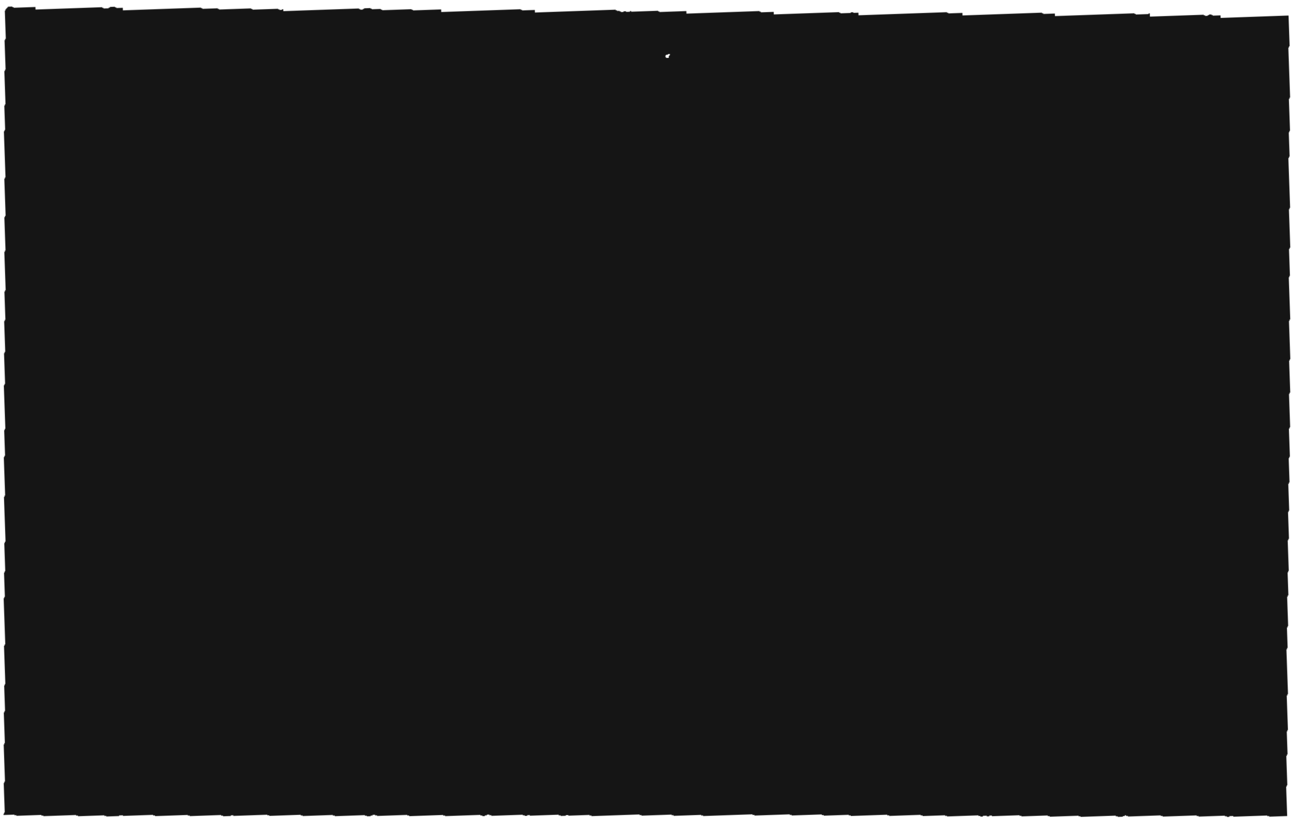


Figure 6. Sporinite and alginite (MCl-6).

Figure 7. Sporinite (MCI-6).

Figure 8. Thin cutinite, sporinite, resinite, and liptodetrinite (RM1-2).

Figure 9. Sclerotinite (*Sclerotites* sp.) with resinite (RM1-2).

Figure 10. Altered vitrinite in natural coke (CC1-5).

Figure 11. Altered vitrinite with liptinite (CC1-5).

Figure 12. Altered vitrinite and disseminated mineral matter (CC1-5).

Figure 13. Graphitoid sphaeroliths or small spheres formed by deposition from the gas phase during heat alteration (CCl-5).

Figure 14. Altered vitrinite with liptinite (CCI-5).

Figure 15. Altered vitrinite (PG4-1).

Figure 16. Thick cutinite, minor resinite and liptodetrinite (WH3-5).

Figure 17. Suberinite and vitrinite (WH3-5).

Figure 18. Phlobaphinite, resinite, other minor liptinites (WH3-5).

Figure 19. Sclerotinite, vitrinite, resinite, liptodetrinite (WH3-5).

Figure 20. Suberinite, vitrinite, minor thin cutinite (WH3-5).

Figure 21. Sclerotites sp., resinite, sporinite (WH3-5).

Figure 22. Suberinite, resinite, liptodetrinite, and sclerotinite (WH3-5).

Figure 23. <u>Sclerotites</u> sp., resinite, and liptodetrinite (WH3-5).

Figure 24. Thick cutinite (WH3-2).

COAL CHARACTER AND QUALITY

Summary of Previous Research

The high quality of Matanuska Valley coal makes it a prime target for near-term coal development. Along with coals of the Bering River field, Matanuska Valley coals are among the highest quality coals on the Pacific side of North America. Because of their strategic location close to the Pacific coast and nearby an existing railroad network, Matanuska Valley coals hold certain transportation advantages with respect to proximity to potential markets. They are the only known deposits of bituminous coal in the Alaska railbelt region.

The overall character of Matanuska Valley coals has been primarily affected by their progressive metamorphism (diastrophic carbonization) eastward. The coals increase in rank from subbituminous and high-volatile bituminous in the lower Matanuska Valley through medium- and low-volatile bituminous in the central part to low-volatile bituminous, semianthracite, and anthracite in the upper Matanuska Valley. This general trend can be seen in table 8. The dominant factor in increasing the rank of the coals was heat resulting from contact metamorphism accompanying igneous intrusions and regional deformation. Thus the gradation in rank is due predominantly to localized phenomena and not regional metamorphism. Intrusive dikes and sills are more abundant in the coal measures of the upper Matanuska Valley and have played the key role in increasing the rank of the coal. Barnes (1962b) noted that the coals of the region do not differ significantly in age, are part of the same general sequence, and were buried to similar depths.

Deformation of the Chickaloon Formation has reduced the amount of recoverable coal and also the percentage of lump coal available. Continuity and ash vary markedly within relatively short distances. Minor faults and shear zones have decreased the quality of the coal by introducing abundant extraneous mineral-matter to the coal. Veins of calcite are common to fractures of seams, and pyrite is sometimes noticeable in very small crystals (Barnes and Payne, 1956).

Both Matanuska Valley and Houston area coals were washed during production years. Geer and Yancey (1946) described the mechanical cleaning of Matanuska Valley coals. A Forester jig was used to wash 65,000 tons of Houston coal mined between 1949 and 1952. Geer and Fennessey (1962) completed additional washability studies of several beds in the Wishbone Hill area and found that washability characteristics varied widely. Some coals were found to be amenable to mechanical cleaning, some could provide only inferior fuel despite mechanical cleaning and others were capable of providing premium quality coal when properly prepared. Some of the coals analyzed contained a large amount of intermediate-density material, and therefore lend themselves to the production of a middling or secondary fuel that might be suitable for low-cost mine site power generation. Conwell (1975) concluded from float-sink analyses that the separation of ash from Matanuska Valley coals varied in difficulty. Conwell and others (1982) suggested that maximum use of the resource might be a multiphase cleaning plant that produced three separates: 1) a ± 10-percent ash product, 2) a 10- to 26-percent ash product, and 3) a reject.

Table 8. Comparison of general coal quality of Wishbone Hill and Anthracite Ridge coal to that of the Little Susitna field (modified from Conwell and others, 1982).

Parameter	Little Susitna field	Wishbone Hill	Anthracite Ridge
Moisture	14-20	3-7	2-7
Volatile matter	31-33	33-41	8-32
Fixed carbon	34-39	37-47	46-81
Ash	9-20	5-24	4-22
Heating value	8,460-9,210	10,400-12,500	11,510-14,210

Rao (1968) reported the concentrations of trace elements for certain Matanuska Valley coals among analyses of other Alaskan coals. He found that the coals fell within the ranges found in coals from the lower-48 states. The organic affinity series established from the percent of elements associated with floats and also from the ratio of concentration in float-and-sink ash was Ge (V, Be, Co), Ni (Cr, Ba, Zr), Ti (Ga, Cu), and Pb. The concentration of minor elements was found to be higher in the ash of float fractions compared to sink ash in the high-rank coals.

Coals of the Eska-Moose field vary in quality from bed to bed. Ash is the key factor varying in the character and quality between beds and in different areas. This can be seen in table 9, which compares to the contents of ash and sulfur and the heating values of coals of previous mines in the Wishbone Hill and Chickaloon districts. Based on their ash content, Barnes and Payne (1956) divided coal beds into five rock types---coal, bony coal, bone, coaly claystone, and claystone. They found that bony coal occurred in two varieties locally: 1) a dark brownish gray type with a dull luster and with impurities rather evenly disseminated; and 2) a lustrous black coal with intercalated laminae of carbonaceous claystone or dull bands of impure coaly material. They described bone (coal with over 50 percent ash) as a dark brownish gray carbonaceous rock with shaly partings and relatively heavy and tough compared to coal.

Although coals of the Eska-Moose field have a bright luster on fresh exposure, they lack the lustrous sheen of coals common in the Chickaloon and Castle Mountain fields of the central Matanuska Valley. Coals of the Eska-Moose field are harder than the higher-rank bituminous coals of central Matanuska Valley, and resultantly it is possible to obtain a higher proportion of lump coal. Coals in the Eska-Moose field commonly exhibit two well-developed cleats. Calcite has formed along prismatic cleavage surfaces particularly common in the vicinity of faults. Petrified logs are present in some coal beds. The coal beds vary in thickness laterally, interfingering and splitting, with local thickenings and pinch-outs of subordinate beds.

Coals of the Eska-Moose field of the lower Matanuska Valley are typically low-rank bituminous; they are usually high-volatile B bituminous but occasionally are high-volatile A bituminous rank. Ash content is highly variable as stated earlier, ranging from 4.5 to 25 percent and averaging about 11 percent. The fuel ratios (volatile matter/fixed carbon) of coals are around 1.2 and do not show a consistent increase in beds at lower horizons, as is common in some fields. Low moisture (less 10 percent) and sulfur (0.3 to 0.5 percent) minimizes problems associated with spontaneous combustion. The coals store well and are not particularly prone to disintegration (slacking). Heating values range from about 10,500 to 13,000 Btu/lb on an as-received basis. Cooper and others (1946) and Warfield (1967) reported poor to fair coking and caking properties for coals of this area. Davis and others (1952) studied the carbonization properties of the No. 3 bed, Evan Jones mine, a high-volatile B bituminous coal, and reported that it yielded a poorly fused coke or char. Sanders (1981) states that the coals are noncoking.

Table 9. Average ash, sulfur content, and calorific value for coal samples from various mines in the Matanuska Valley. Compiled from various sources.

Mine	No. of samples	Ash % (as received)	Sulfur % (as received)	Btu/lb (as received)
Matanuska Center	3	15	0.5	11,200
Rawson	3	8	0.4	11,900
Buffalo	10	13	0.3	11,800
Baxter	4	7	0.3	12,600
Premier	10	8	0.4	12,600
Doherty	2	20	0.5	10,600
Evan Jones	15	18	0.4	11,000
Knob Creek	2	9	0.4	10,200
Eska	36	14	0.4	11,700
Chickaloon	2	8	0.6	13,900
Coal Creek	1	10	0.4	13,600

Generally speaking, mining of coal in the Eska-Moose field should be considerably less expensive than mining the higher rank coals farther east. Because of the high ash, both crushing and washing will be necessary to produce a satisfactory commercial coal. Hence a coal washery will need to be constructed at any new mine. Coal of the Eska-Moose field can be classified as a good steam coal (table 10). It has been used extensively in the Anchorage area in the past for power generation and heating.

Coals of the Young Creek field to the east appear to be intermediate in quality between coals of the Eska-Moose field and the Chickaloon field. They are typically of high-volatile A bituminous rank, although locally they range to higher and lower ranks. Their fuel ratio commonly ranges from 2.1 to 2.9, which is comparable to the fuel ratio of Kings River coals of the Castle Mountain field.

The coals of the Castle Mountain field are typically medium- to low-volatile bituminous. In 1964 a large coking sample was cut from an unmined segment of the southern open pit, Castle Mountain mine. After it was washed to reduce the ash content from 16.5 to 10.4 percent, carbonization tests indicated that the coal would produce a strong coke (Warfield, 1967). Rao (1975) also analyzed this coal, the Castle Mountain No. 1 seam, and found it to be the only coal of coking quality in the area. He also reported that it contained no known deleterious trace elements.

The Chickaloon field includes coals on the north side of the Matanuska River in Chickaloon valley and coals east of and in the vicinity of Coal Creek on the south side of Matanuska River. These coals are typically of medium- to low-volatile bituminous rank and have a fuel ratio about 3.3. Some Chickaloon and Coal Creek coals are of coking quality and can be used in coke manufacture; other coals of the region possess some distinct coking properties. Davis and others (1952), after testing the carbonization properties of the M bed from the Chickaloon mine, reported it to be strongly coking. A large amount of impure natural coke is found throughout the field. Anthracite has formed locally by the effect of intrusion of diabase sills next to a coal bed. The effect of sills in coking coals in the Coal Creek area has not been as extensive as in the northern Chickaloon and Castle Mountain fields.

Coals of the Chickaloon field have been broken into benches by thick shale partings and also contain thin shale bands and bone. The beds show effects of severe crushing and are generally soft, fragile, friable, and display no well-defined planes of fracture. They contain abundant impurities and will require washing to reduce their ash content. Although pyrite is not abundant, it can be observed rarely as scales or minute balls. Rao (1968) reported the presence of silver in coals from the Chickaloon district in concentrations up to several parts per million in coal ash.

Coals of the Anthracite Ridge field are of high quality, predominantly low-volatile bituminous but with some semianthracite and anthracite. Coals of this field have been more highly altered than farther west. The bituminous coal beds possess some coking properties (Warfield, 1967). Anthracite is actually very limited and occupies only a small area on the south flank of

Table 10. Coal quality specifications for coal sold by the Evan Jones mine (from Patsch, 1981).

Parameter	Specification
Moisture (as received)	8.5% maximum
Ash (dry)	15% maximum
Btu/lb (dry)	12,090
Sulfur	0.4-0.5%
Ash fusion	2,800°F

Anthracite Ridge. The anthracite is similar to that of the Bering River field but slightly lower in quality compared to Pennsylvania anthracite (table 11). It is heavy, hard and firm, little fractured for surface coal and has a high luster. Metamorphism devolatilized the coal and produced the anthracite from which the ridge takes its name. Heat from intruding thick masses of diabase and other igneous rocks drove off some of the volatile matter from coals of original lower rank and produced the semianthracite and anthracite.

The character of the coal beds of the Anthracite Ridge field varies greatly within short distances. They are crushed, truncated, and locally shattered with inclusions and rare partings of bone and shale. The beds are discontinuous and thicken and thin irregularly. Outcrops are of local extent. Faults along bedding produced squeezing and irregular thickening of the coal and local zones of crushing. However, the faulting and close folding had little appreciable effect in improving the rank of coal. The factors that devolatilized and improved the character of the coals of the Anthracite Ridge field also greatly increased the difficulties of mining it.

Results of Current Coal-Quality Research

Matanuska Valley coals analyzed during this study show that rank varies from subbituminous B to metaanthracite (fig. 35; appendix F). The range in various rank indicators are: 1) vitrinite reflectance from 0.47 to 5.34 percent; 2) dry, mineral matter free volatile matter content from 7 to 47 percent; 3) dry, ash-free fixed carbon from 52 to 93 percent; 4) bed moisture from 2.5 to 15 percent; and 5) moist, mineral-matter free heating value from 11,400 to 15,100 Btu/lb.

Ash content is the most variable quality parameter exhibiting a broad range from 2 to 47 on an as-received basis (table 12). The content of ash generally appears to increase toward the margins of the Matanuska basin fig. 36). Some coals in the Moose Creek area, coals of the southern Young Creek field and adjacent to Kings River of the central Matanuska Valley, and anthracitic coals of the Anthracite Ridge field show the lowest ash contents.

The total sulfur content of Matanuska Valley coals is low (less 1 percent) in all samples analyzed (fig. 37). Organic sulfur is typically the most abundant form in Matanuska Valley coals as it is in most Alaskan coals. Figure 37 shows that even weathered outcrop samples of Matanuska Valley coals have very low sulfate sulfur contents. Locally sulfates can be observed on coal seam surfaces (fig. 38). The mean and maximum contents of total sulfur in Matanuska Valley areas on a moisture- and ash-free basis are respectively 0.7 to 1.3 percent (fig. 39). The isopach map of figure 40 indicates that total sulfur content in coals decreases toward the margins of the Matanuska basin. It tends to be relatively lower in the Eska-Moose field of the western Matanuska Valley and to be relatively higher in the Chickaloon and Anthracite Ridge fields; this would be expected due to the introduction of sulfide minerals during natural coking.

Coals become progressively devolatilized upward in the Matanuska Valley (fig. 41). It is currently unclear whether the volatile matter content actually increases toward the margins of the Matanuska basin as shown. More

Table 11. Comparison of Matanuska, Bering River, and Pennsylvania anthracites.

	Matanuska coal field, Alaska[1]	Bering River coal field, Alaska[2]	Pennsylvania[3]
Moisture	6.3	7.3	3.7
Volatile matter	7.6	6.4	5.4
Fixed carbon	74.7	77.0	80.7
Ash	11.4	9.2	10.2
Sulfur	0.5	1.2	0.7
Btu	12,070	12,350	12,980
Fuel ratio	10.1	12.2	15.0

[1] Mean of 11 samples analyzed during this study.
[2] U.S. Bureau of Mines, 1946, p. 62-67; mean of 10 samples.
[3] Average of three samples from Slatjck, 1980; Cady, 1978; and Babcock and Wilcox, 1972.

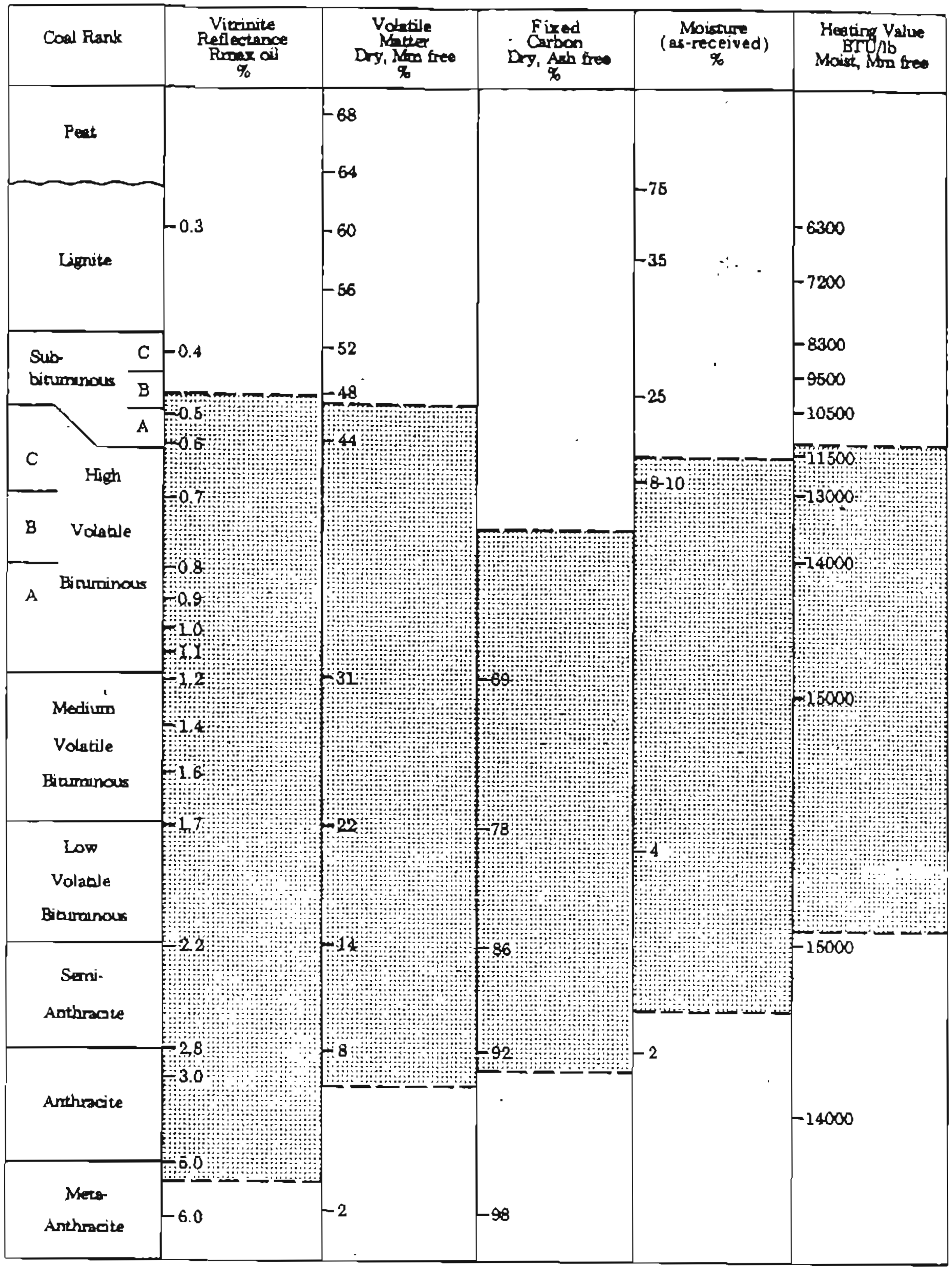


Figure 35. Comparison of different rank parameters to ASTM classification. Adapted from Stach and others, 1984, table 4, p. 45. Shaded areas show the general range of values for different rank parameters in Matanuska Valley coal samples. The range of values shown here serves only as an apparent indication of rank since it is based on outcrop samples.

Table 12. Summary of proximate and ultimate analysis data for Matanuska Valley coal samples.

Statistic	Basis*	Moisture	Volatile matter	Fixed carbon	Ash	Heating value	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
	1	3-15	6-34	27-87	2-47	6,300-14,300	2.4-5.6	40-76	0.9-1.7	7-21	0.3-0.7
Range	2	- -	6-37	29-90	2-49	6,600-14,800	1.9-5.3	42-79	1.0-1.9	3-13	0.3-0.7
	3	- -	8-47	53-92	- -	13,000-15,700	3.0-6.3	76-91	1.6-2.3	3-15	0.5-0.9
	1	6	18	56	20	10,700	4.1	59	1.3	11	0.5
Mean	2	- -	20	60	21	11,700	3.7	63	1.4	7	0.5
	3	- -	25	75	- -	14,300	4.9	83	1.9	9	0.7

*1 - As received; 2 - Moisture-free; 3 - Moisture and ash free.

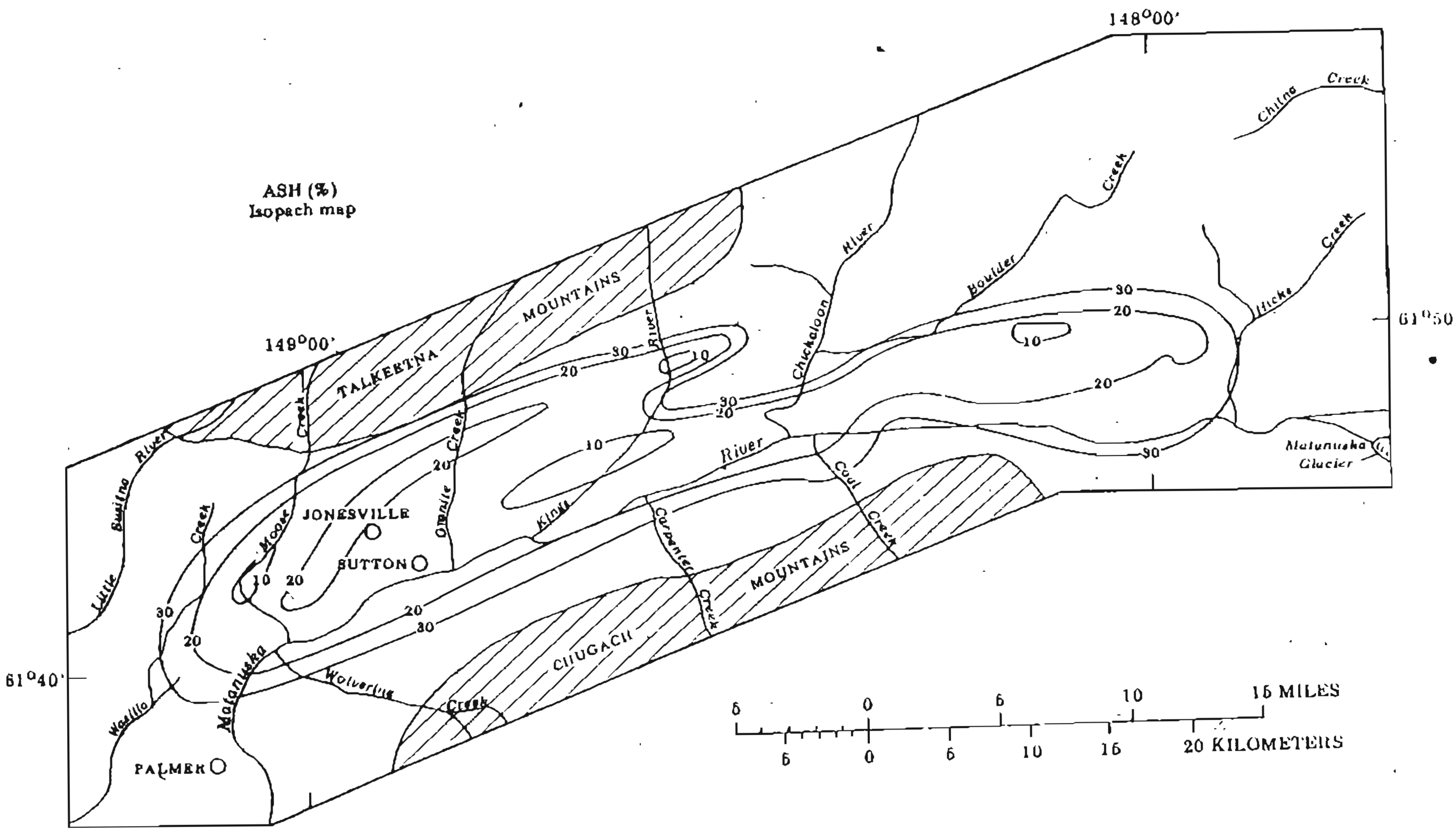


Figure 36. Highly generalized isopach map of ash content and distribution in coal samples (as-received basis) of the Matanuska Valley.

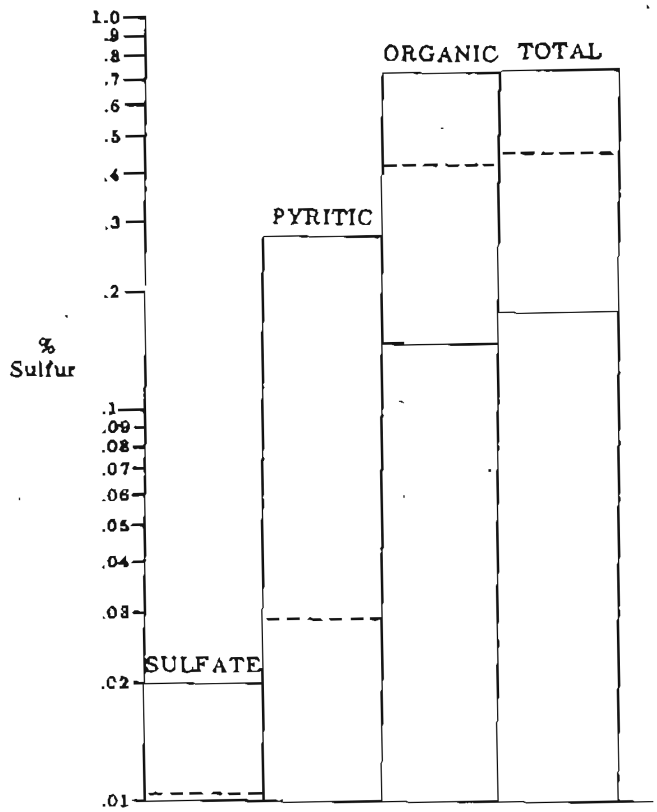


Figure 37. Bar graph showing the maximum and arithmetic mean values for the percent total sulfur and sulfur forms of 58 analyzed Matanuska Valley coal samples (as-received basis).

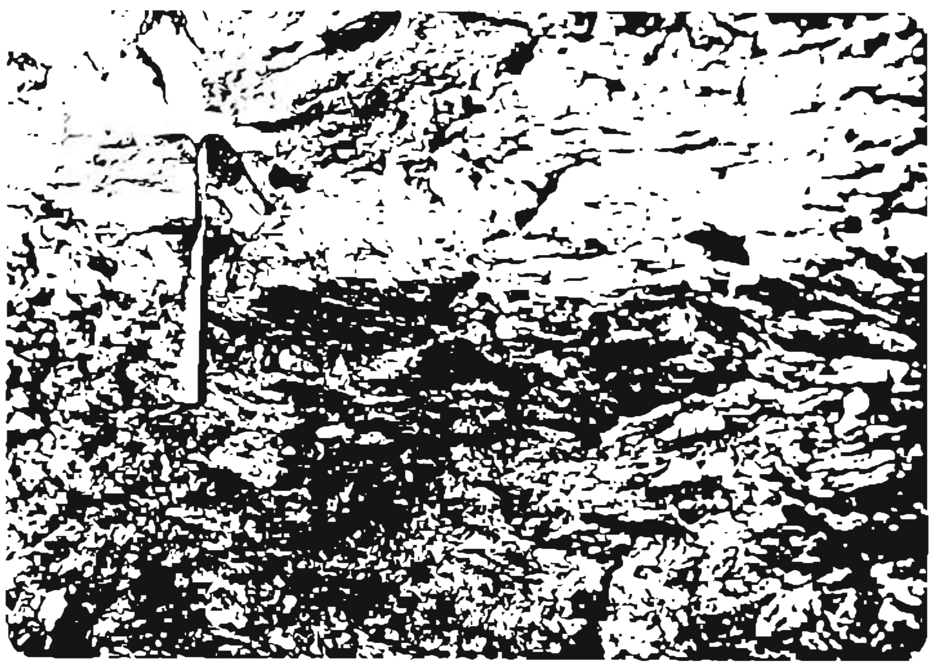


Figure 38. Weathered sulfate compounds coating surfaces and filling voids near top of coal seam in Evan Jones mine area. The coarse-grained sandstone roof rock is also observable in upper-left portion of photo.

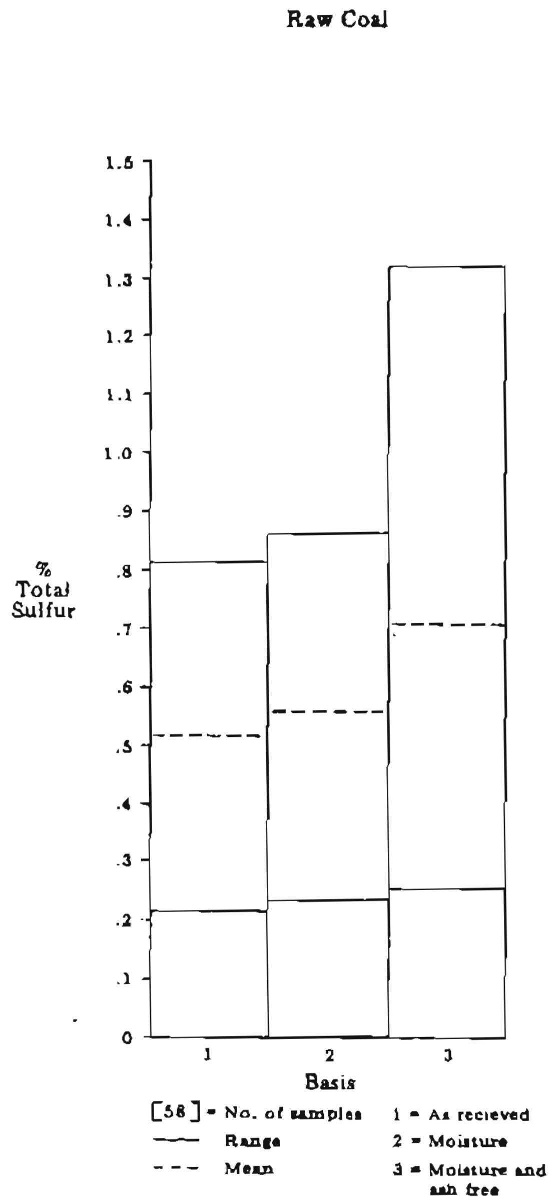


Figure 39. Bar graph showing the range and arithmetic mean values for the percent total sulfur of analyzed Matanuska Valley coal samples (different bases).

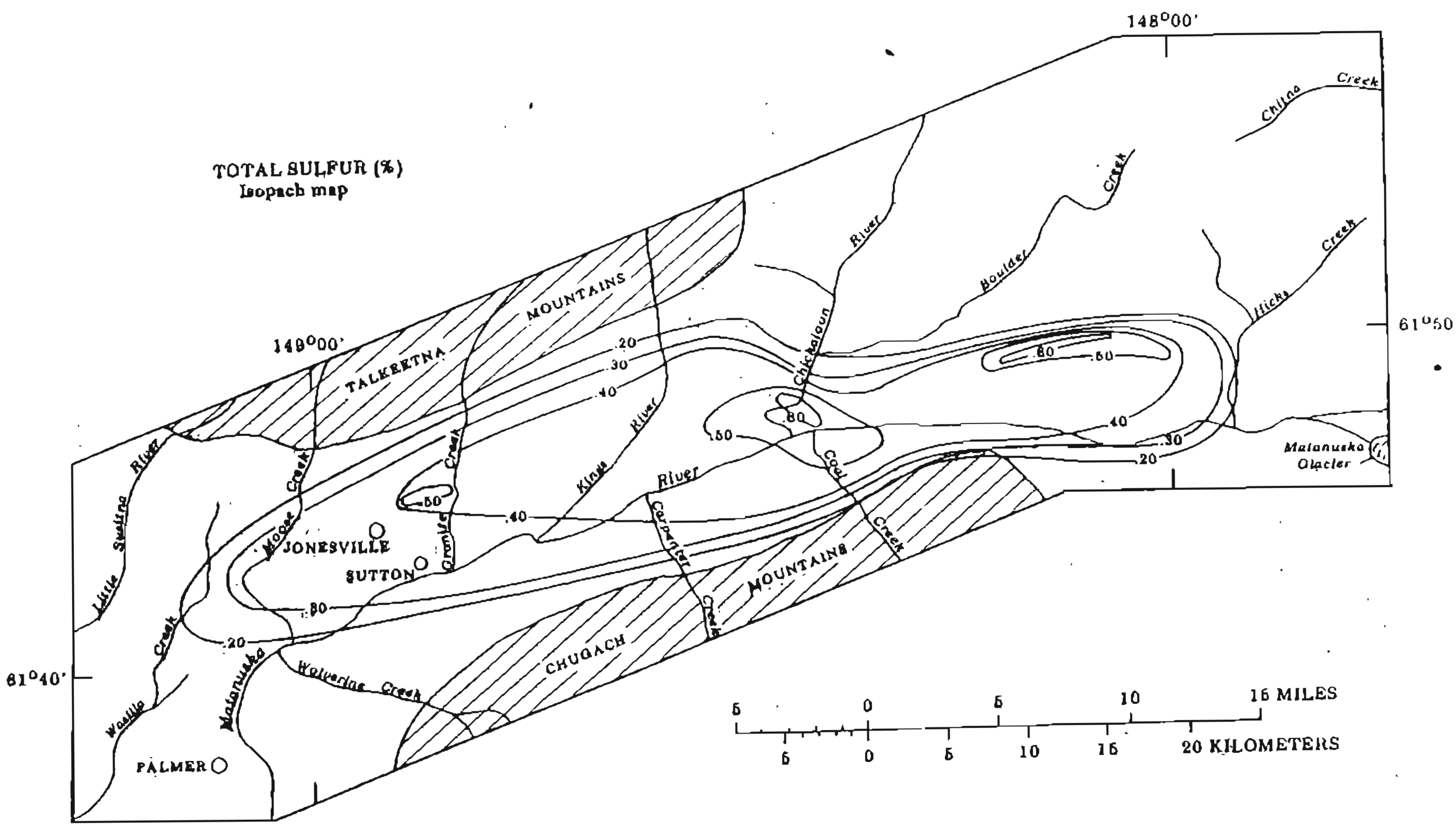


Figure 40. Highly generalized isopach map of total sulfur distribution in coal samples (as-received basis) of the Matanuska Valley.

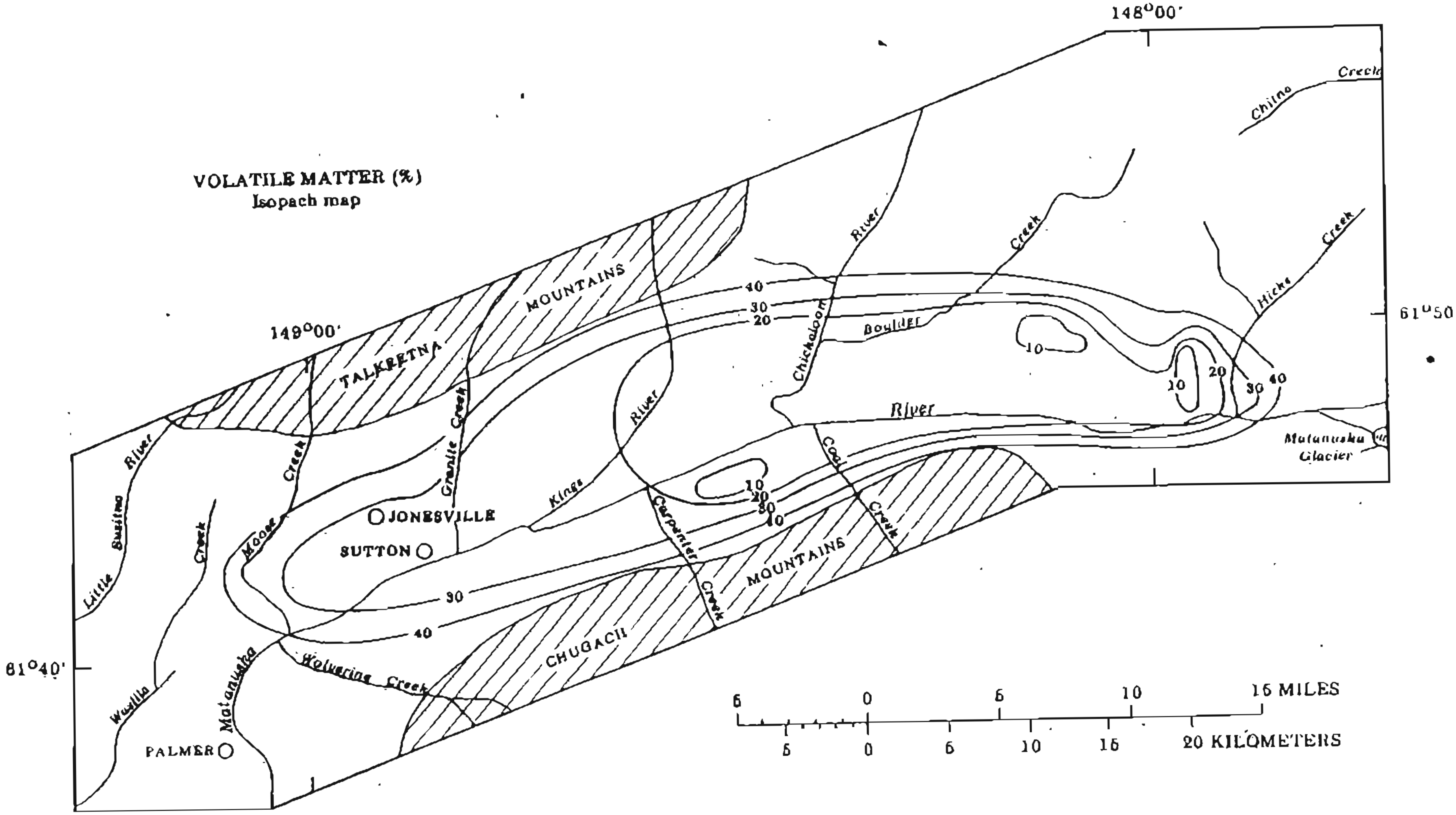


Figure 41. Highly generalized isopach map of volatile matter content and distribution in coal samples (as-received basis) of the Matanuska Valley.

data is needed to confirm this inference. Fixed carbon content and calorific value are generally known to increase eastward in the Matanuska Valley with gradation in rank (figs. 42 and 43).

Scatter plots of paired proximate and rank-indicative variables for Matanuska Valley coal samples show the direct relationship of heating value and fixed carbon content (fig. 44) and the inverse relationship of ash and fixed carbon contents (fig. 45). Matanuska Valley coals analyzed show that they predominantly contain moderate to high ash contents, but also include some low ash coals, very high ash coals, and impure coals (fig. 45).

The major-oxide composition of Matanuska Valley bituminous coals generally falls within the ranges established for bituminous coals elsewhere in the world (table 13). Most of the inorganic matter in the coals is accounted for by silica, aluminum, iron, calcium, and phosphorous oxides. The mean contents for the major oxides are listed in table 14, and show relatively high abundances of CaO and P_2O_5. P_2O_5 is particularly significant because of its importance in steelmaking processes.

The ternary diagrams of figures 46 through 54 show the distribution and relationship of various major oxide end members in Matanuska Valley coals by rank, and generally confirm the trends in composition demonstrated in table 14. SiO_2 and Al_2O_3 often vary with the total ash content of coal. The silica content here decreases significantly with increasing rank, but alumina reveals no clear relationship. Fe_2O_3, CaO, P_2O_5, MgO, SO_3, BaO, SrO, and Mn_3O_4 appear to increase in content in Matanuska Valley coals with increasing rank, whereas K_2O decreases as does silica with increasing rank.

The free-swelling indices (FSI) of Matanuska Valley coals indicate that most are noncaking and nonswelling (fig. 55). However, several samples exhibited some degree of swelling; these included coals from Coal Creek, Chickaloon River, and Muddy Creek. Only one sample from the Castle Mountain mine (the No. 1 seam) was strongly caking; it had a FSI of 7.5. Rao (1976) reported a FSI of 8 for this seam. The FSI of a coal also may be used as a preliminary indication of its potential coking quality. Warfield and others (1966) found that an unblended reduced-ash sample of the No. 1 seam produced a strong coke of foundry quality, and that a 30 percent blend of the coal with a Utah-base coal also produced a reasonably good coke.

Ash-fusibility tests yield the melting temperatures and deformational changes in an ash cone of a particular coal sample. Ash-fusion temperatures vary with the ash content of coals and is generally less for low-rank coals. However, because of the variability in coals and their inherent ash content and character, tests are required on individual coals. Table 15 compares ash-fusion temperatures for various United States coal-ash samples in a 4-point (reducing atmosphere only) test. Matanuska Valley coals show the highest temperatures. High-melting and -fusing ash of these coals may indicate their preferred utilization in dry-bottom type furnaces where they would not have a tendency to stick in the ash hopper and be difficult to remove (Corriveau and Schapiro, 1979). Conversely, low-fusing coals tend to form clinkers in static fuel beds and cause slag deposition on furnace walls and boiler tubes, but are preferred in slag-tap pulverized-fuel and cyclone

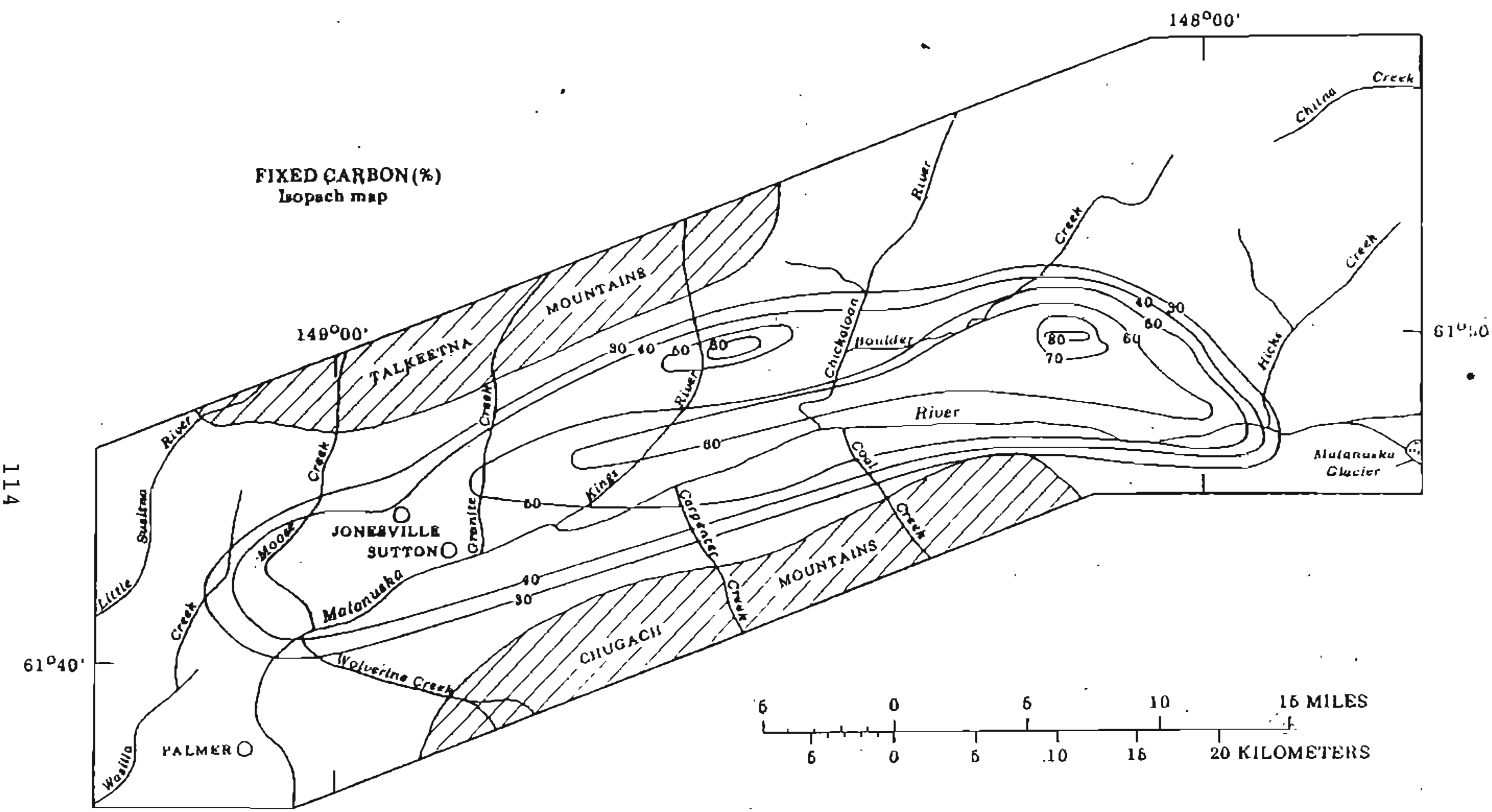


Figure 42. Highly generalized isopach map of fixed carbon content and distribution in coal samples (as-received basis) of the Matanuska Valley.

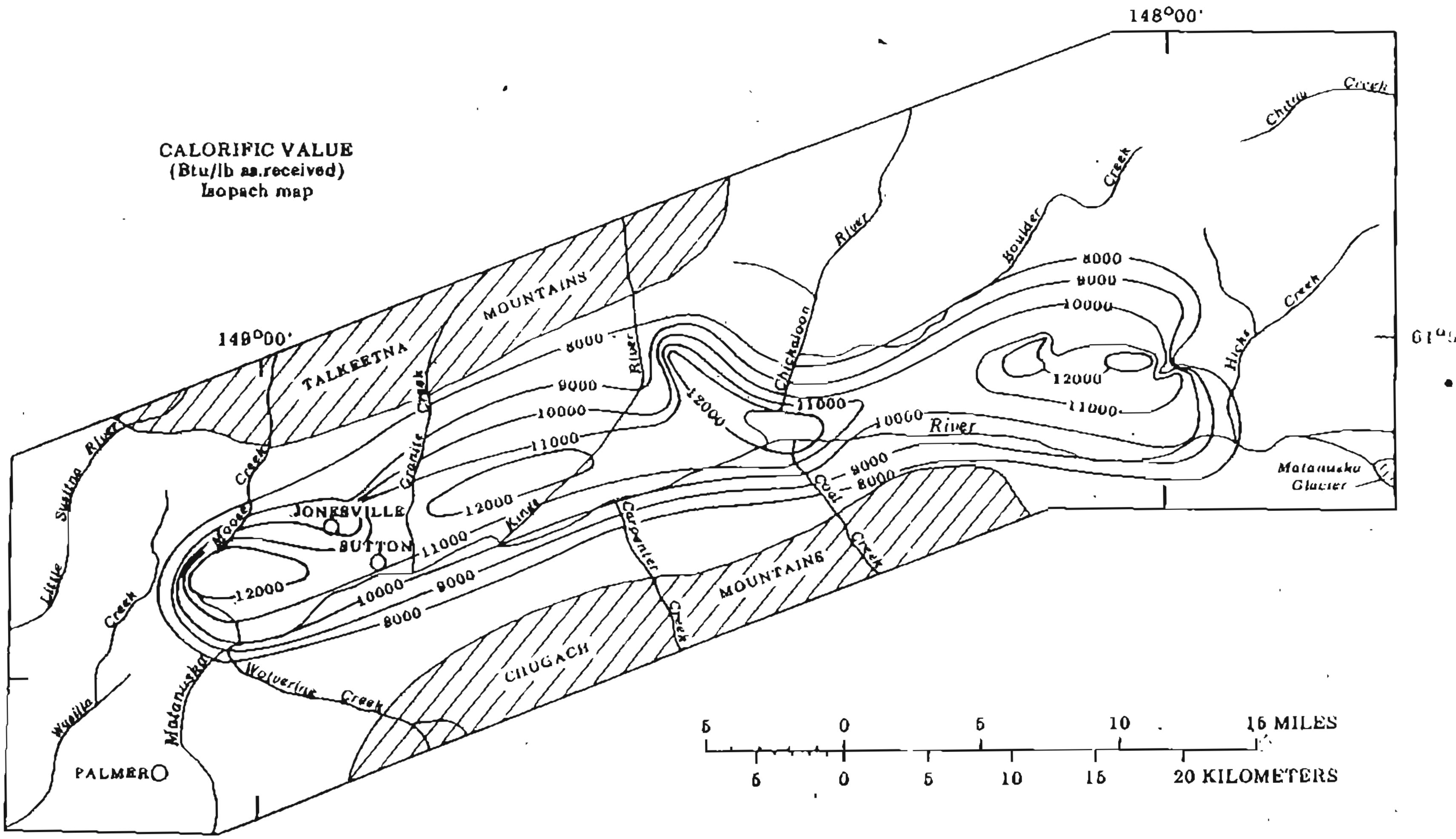


Figure 43. Highly generalized isopach map of calorific value and distribution in coal samples (as-received basis) of the Matanuska Valley.

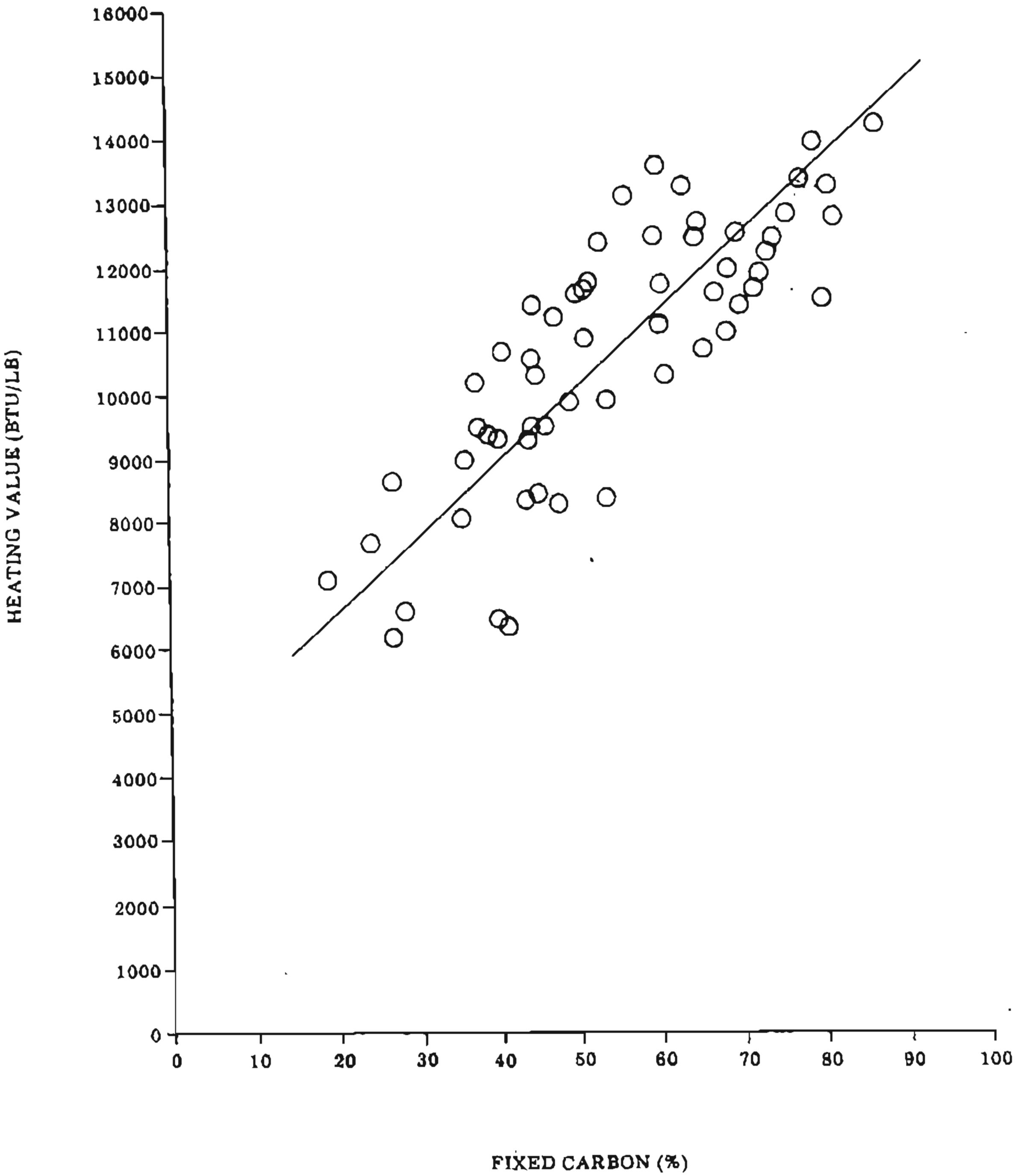


Figure 44. Scatter plot showing the direct relationship of the heating value (in Btu/lb) with the fixed carbon content for coal samples analyzed from the Matanuska Valley (proximate data, as-received basis).

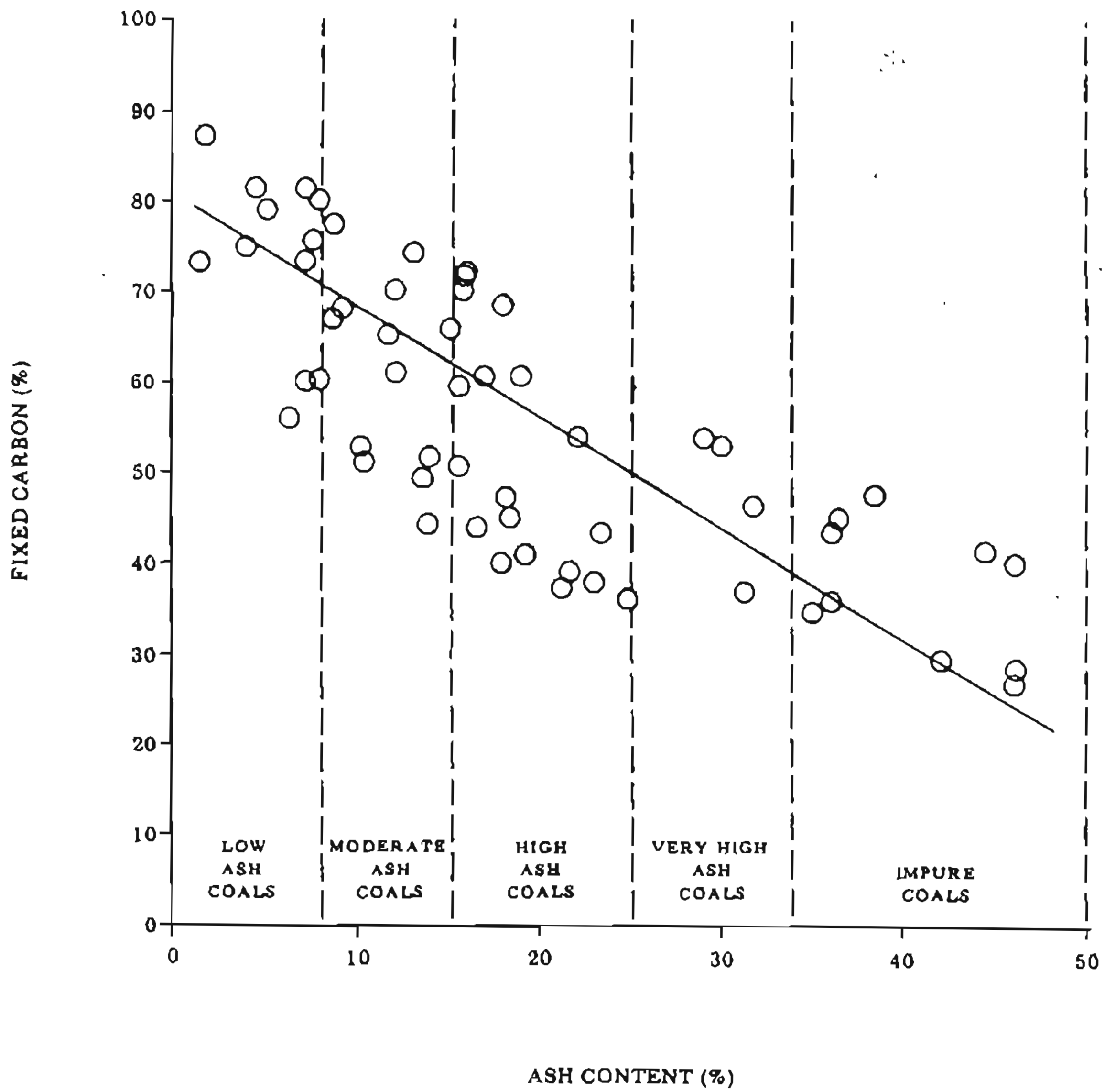


Figure 45. Scatter plot showing the inverse relationship of the fixed carbon content and ash content for coal samples analyzed from the Matanuska Valley (proximate data, as-received basis).

Table 13. Typical limits of major-oxide ash composition of Matanuska Valley coals compared to other coals. Ranges in other coals from McClung and Geer, 1979.

Constituent	Matanuska Valley	United States	England	West Germany
Acidic oxides:				
Silica (SiO_2)	23-63	20-60	25-50	25-45
Alumina (Al_2O_3)	25-38	10-35	20-40	15-21
Titania (TiO_2)	0.9-2.3	0.5-2.5	0-3	- -
Basic oxides:				
Ferric oxide (Fe_2O_3)	1-17	5-35	0-30	20-45
Calcium oxide (CaO)	0.3-19	1-20	1-10	2-4
Magnesia (MgO)	0.4-2.6	0.3-4	0.5-5	0.5-1
Alkalies (Na_2O+K_2O)	0.5-3.5	1-4	1-6	- -
Other oxides:				
Sulfur trioxide (SO_3)	0.1-4.4	0.1-12	1-12	4-10
Phosphorous pentaoxide (P_2O_5)	0.02-8.0	0.7-5.5	0-3	- -

Table 14. Mean composition of major oxides in all Matanuska Valley raw-coal-ash samples, composition by rank and relationship with rank (weight percent, ignited basis).

Oxide	Mean weight % all ranks	Mean weight % subbituminous	Mean weight % bituminous	Mean weight % anthracite	Relationship with rank
SiO_2	50.46	57	51	43	Decreases
Al_2O_3	29.90	29	30	29.5	Constant
Fe_2O_3	4.50	3.04	4.41	5.88	Increases
CaO	4.10	2.12	3.80	6.51	Increases
P_2O_5	3.75	0.76	2.80	3.20	Increases
K_2O	1.53	1.85	1.53	1.26	Decreases
MgO	1.50	1.17	1.28	2.40	Increases
TiO_2	1.48	1.57	1.43	1.58	Constant
SO_3	1.21	0.97	1.01	1.97	Increases
Na_2O	0.74	0.66	0.58	1.29	Unclear
BaO	0.35	0.17	0.32	0.58	Increases
SrO	0.30	0.16	0.29	0.42	Increases
Mn_3O_4	0.03	0.021	0.032	0.038	Increases
Undetermined	1.34	1.47	1.06	2.08	Unclear

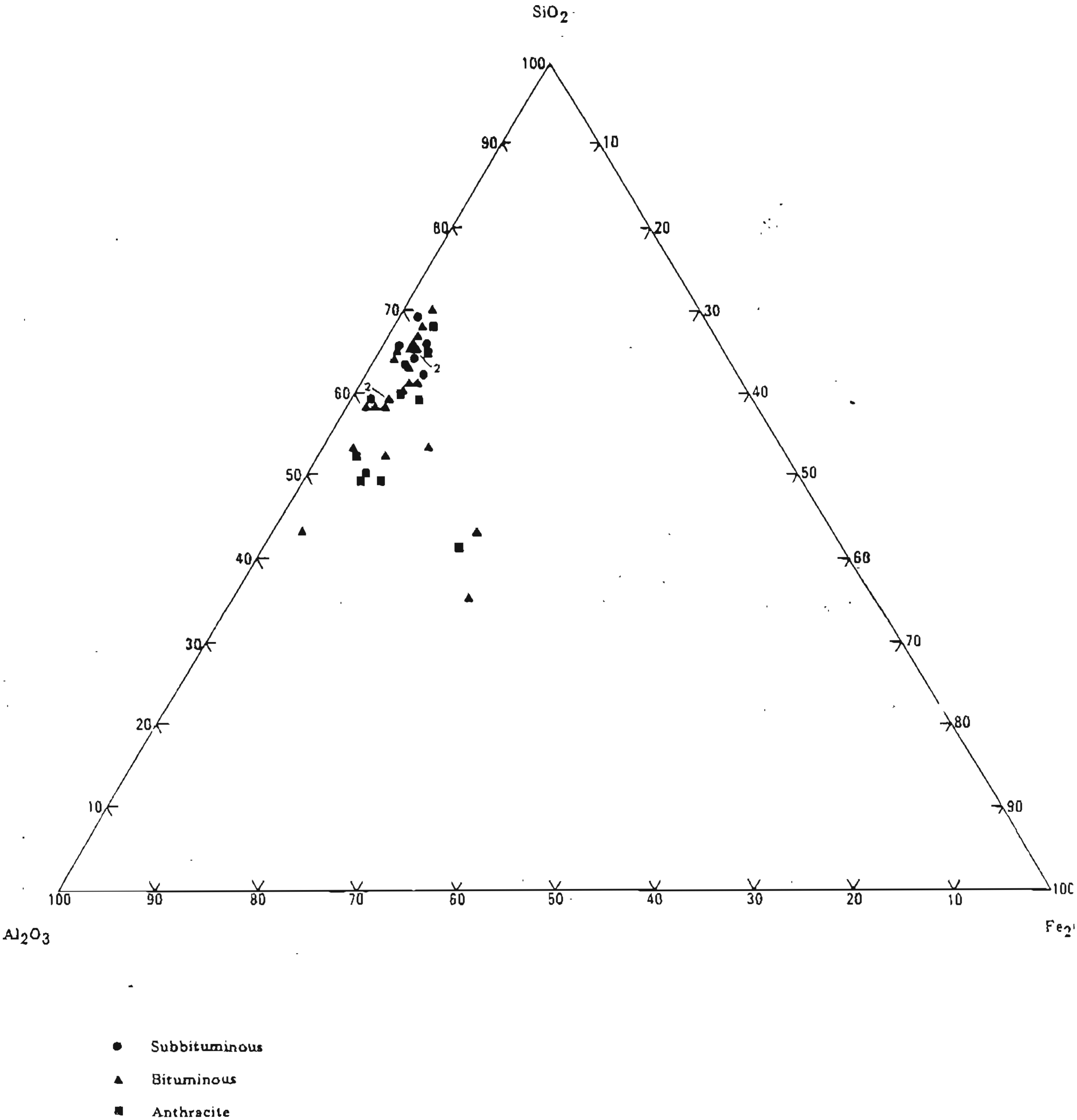


Figure 46. Ternary plot of major oxides SiO_2-Al_2O_3-Fe_2O_3 in ashes of Matanuska Valley raw coals of various ranks.

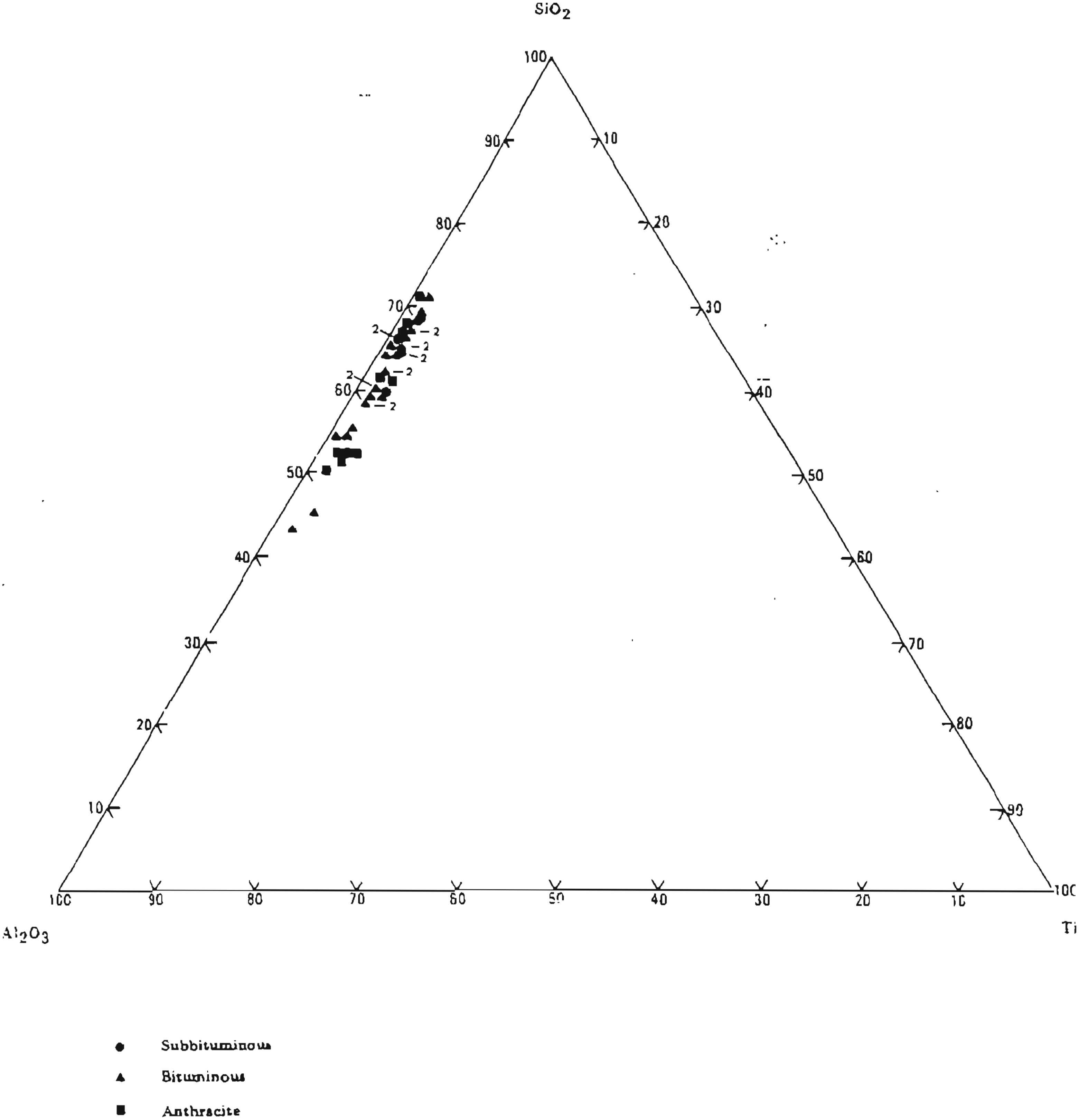
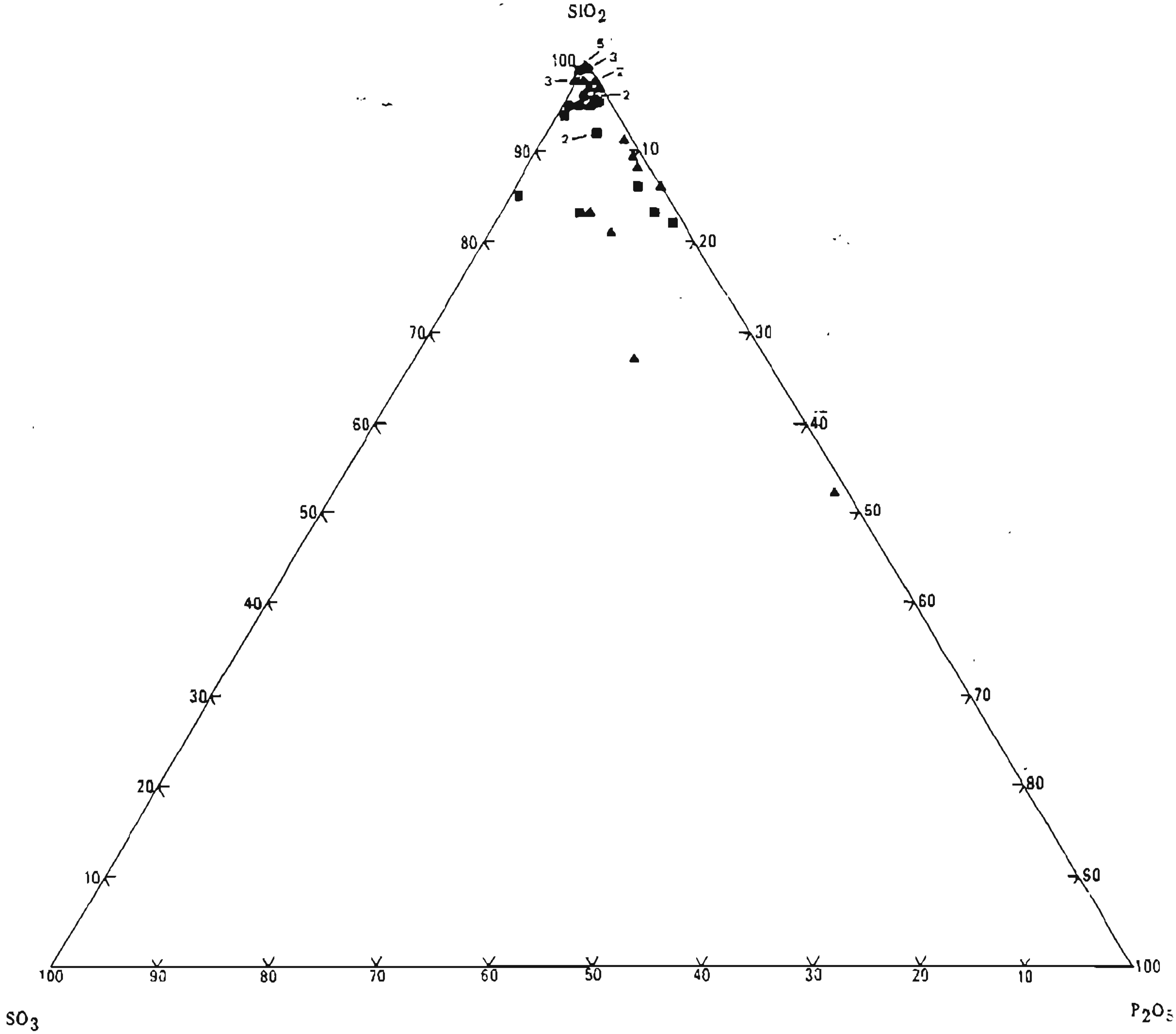


Figure 47. Ternary plot of major oxides SiO_2-Al_2O_3-TiO_2 in ashes of Matanuska Valley raw coals of various ranks.



● Subbituminous

▲ Bituminous

■ Anthracite

Figure 48. Ternary plot of major oxides SiO_2-SO_3-P_2O_5 in ashes of Matanuska Valley raw coals of various ranks.

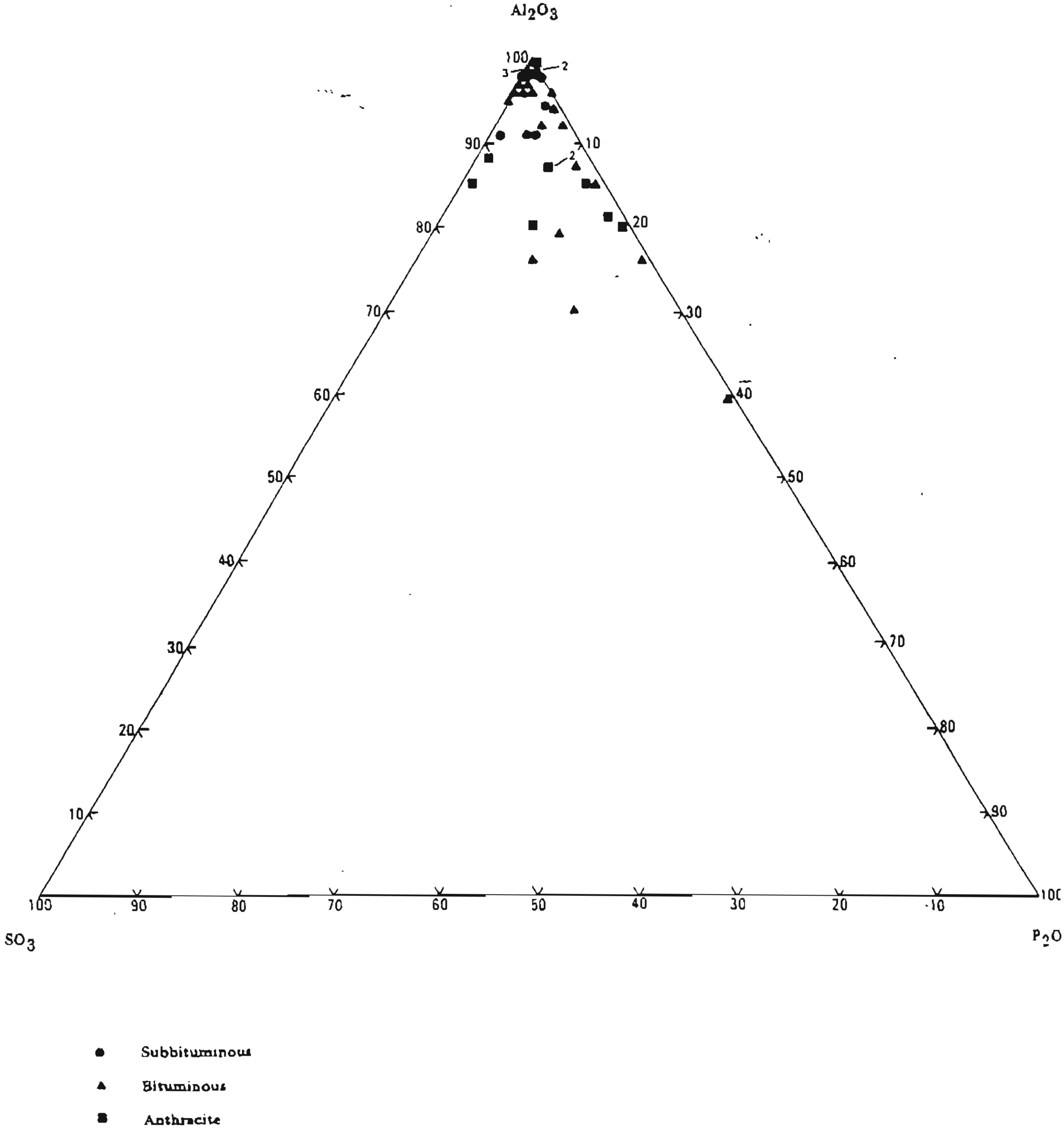


Figure 49. Ternary plot of major oxides Al_2O_3-SO_3-P_2O_5 in ashes of Matanuska Valley raw coals of various ranks.

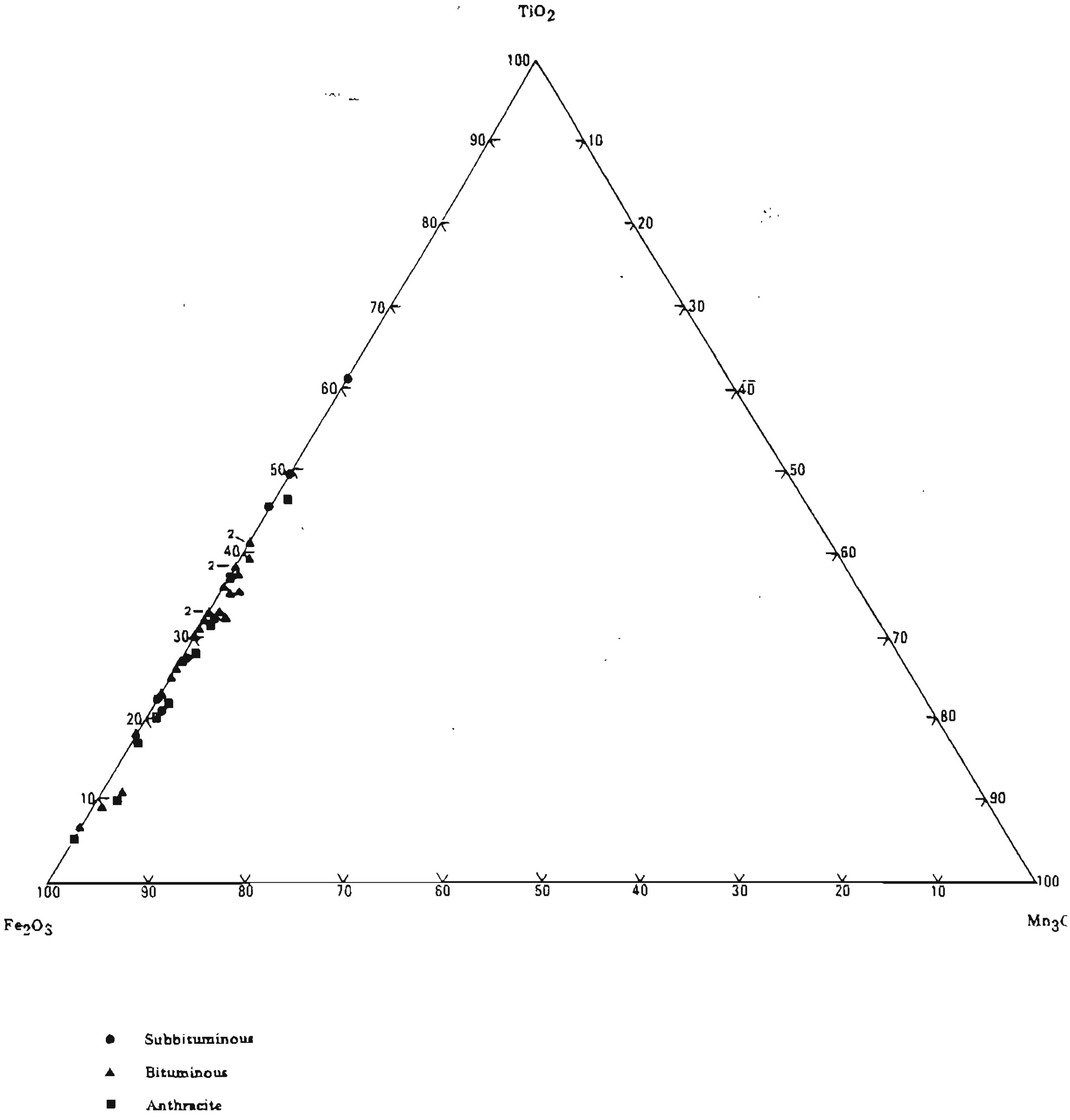


Figure 50. Ternary plot of major oxides TiO_2-Fe_2O_3-Mn_3O_4 in ashes of Matanuska Valley raw coals of various ranks.

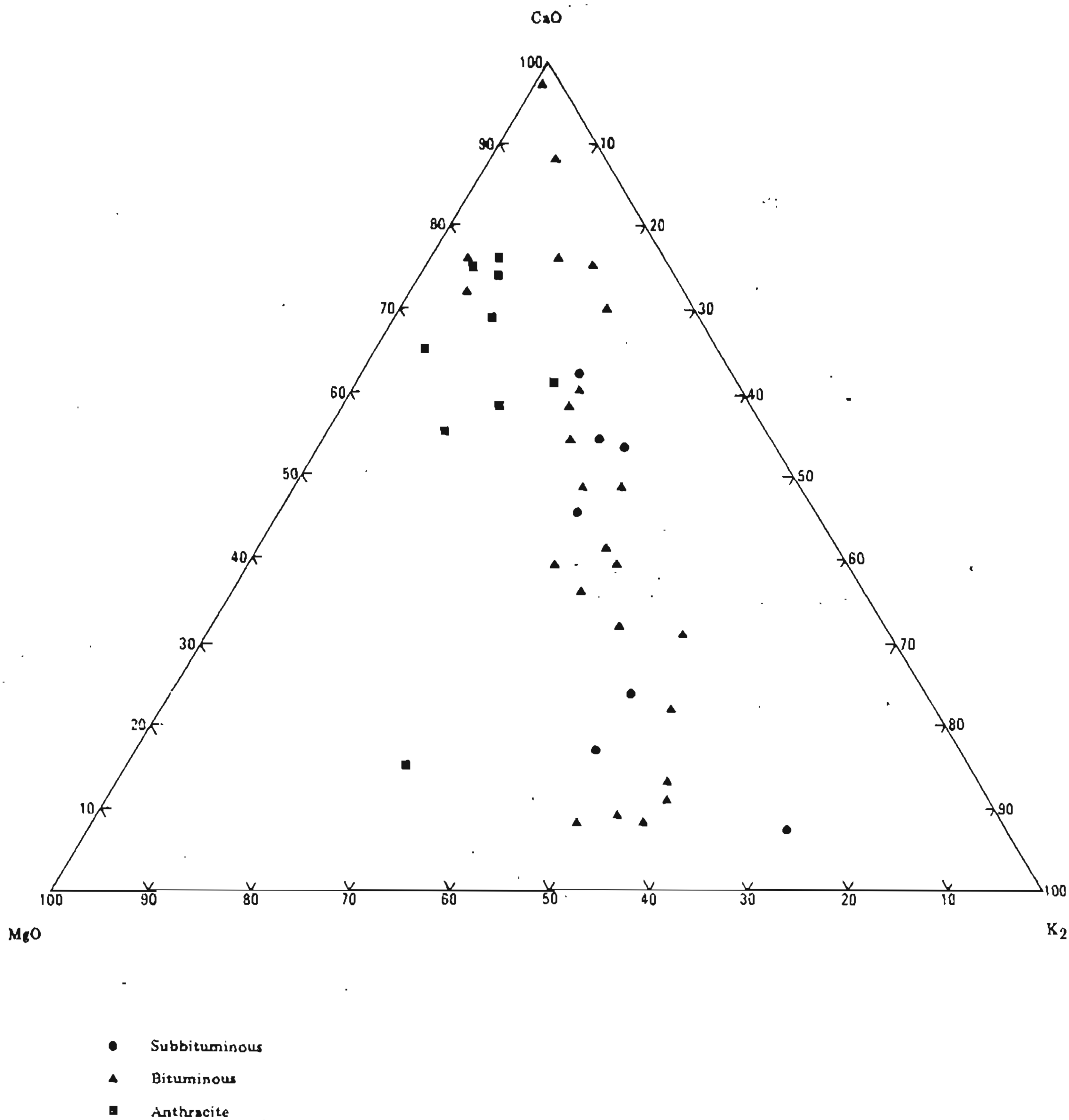


Figure 51. Ternary plot of major oxides $CaO-MgO-K_2O$ in ashes of Matanuska Valley raw coals of various ranks.

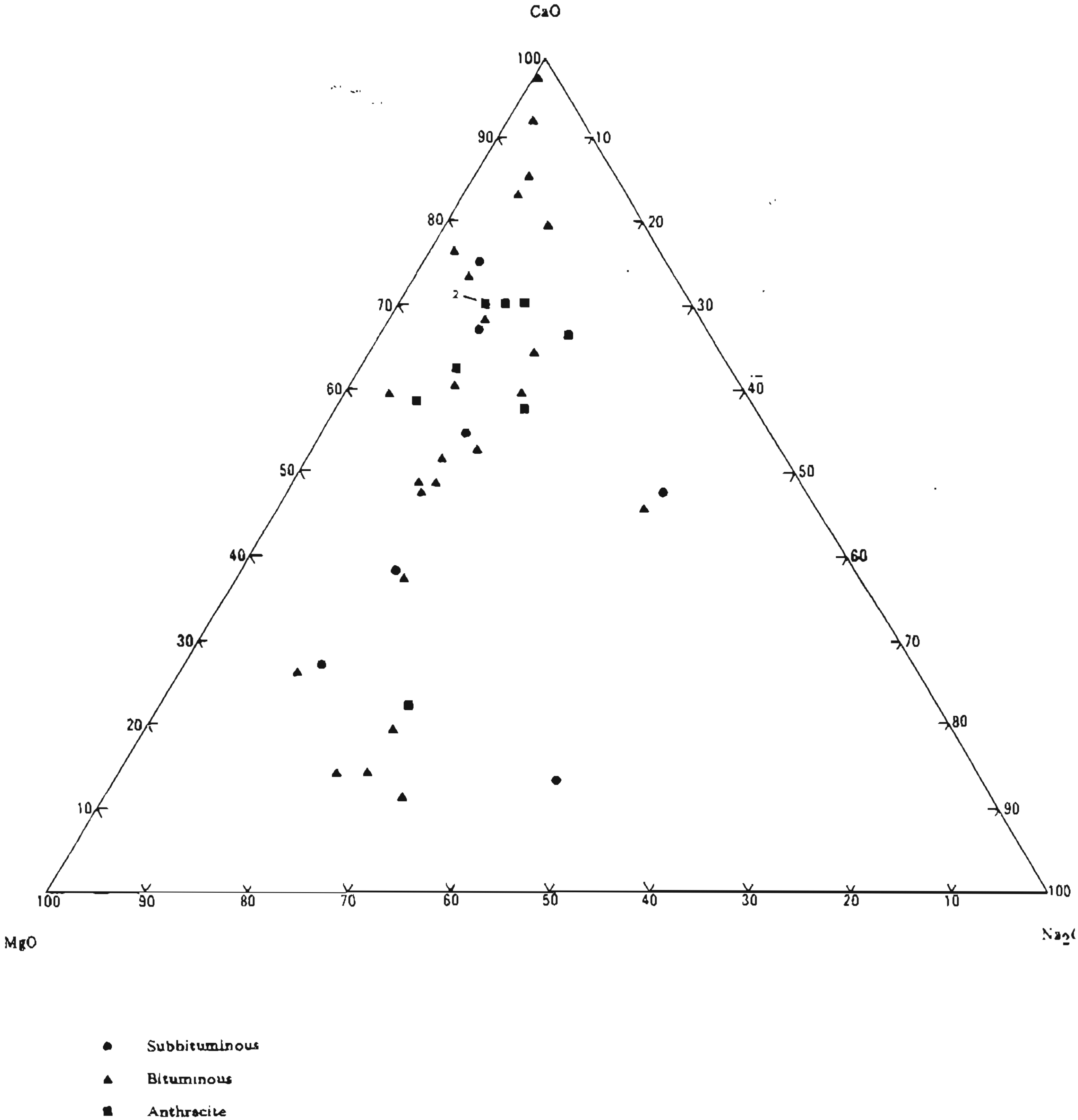


Figure 52. Ternary plot of major oxides CaO-MgO-Na_2O in ashes of Matanuska Valley raw coals of various ranks.

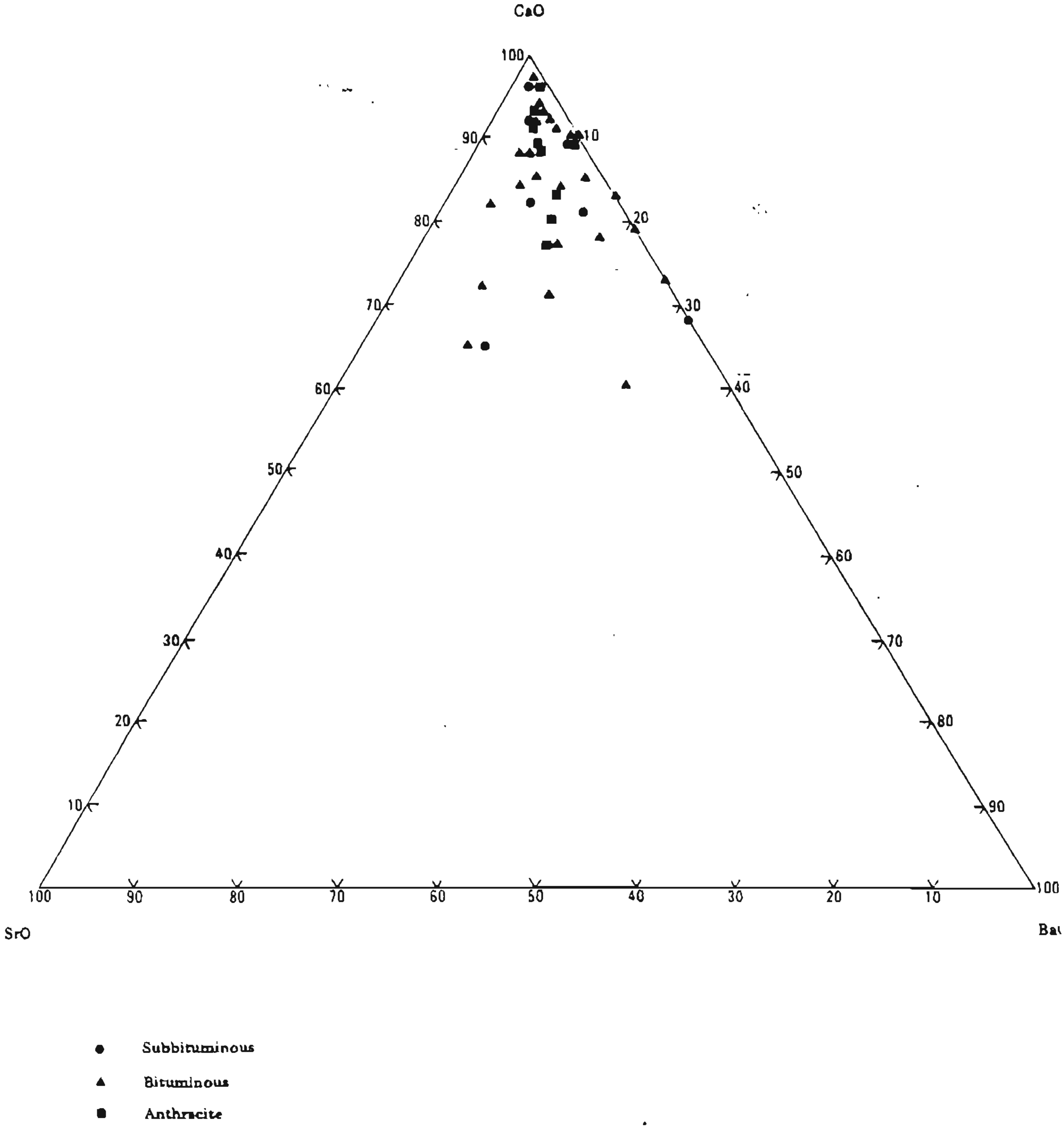


Figure 53. Ternary plot of major oxides CaO-SrO-BaO in ashes of Matanuska Valley raw coals of various ranks.

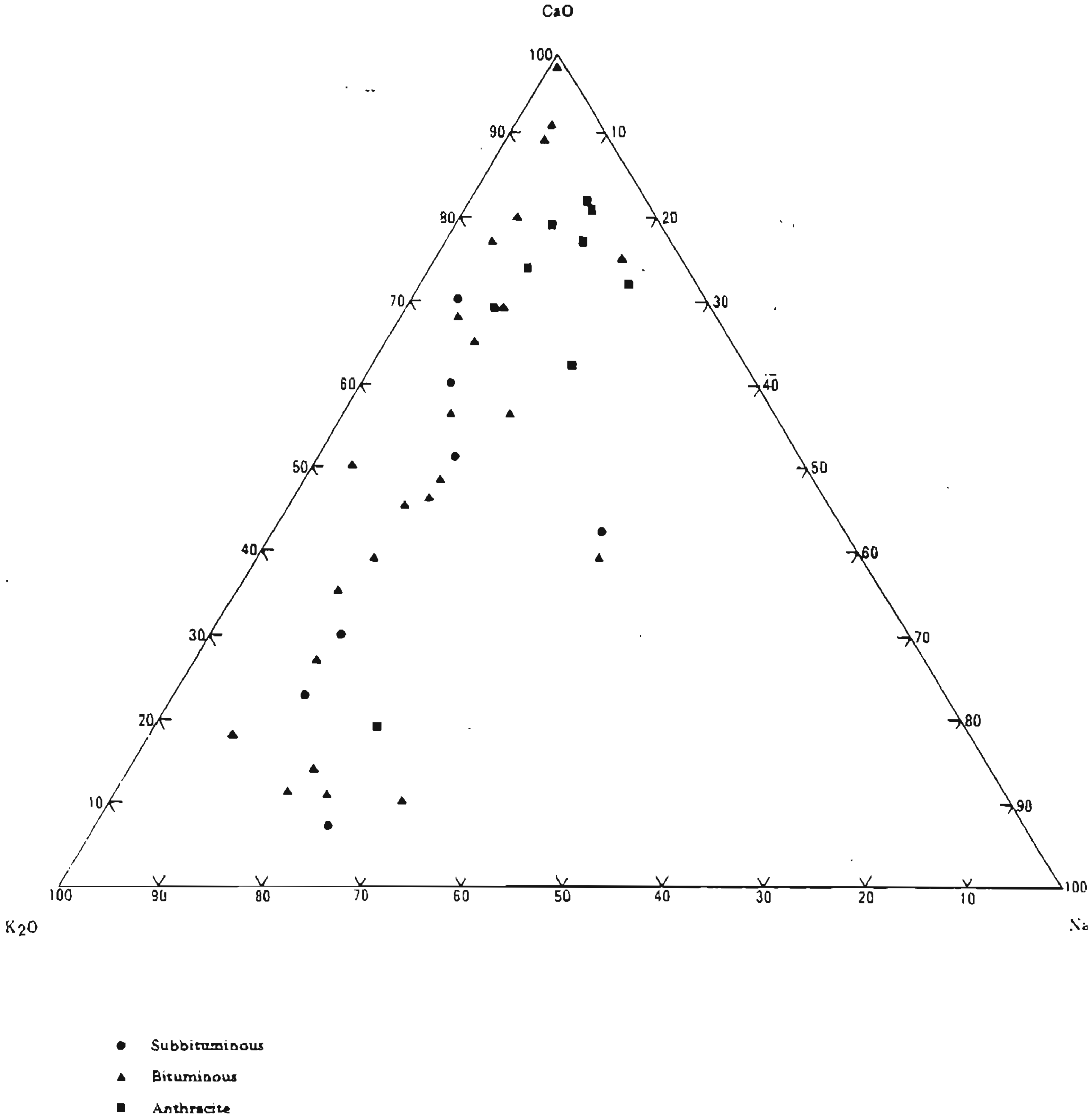


Figure 54. Ternary plot of major oxides $CaO-K_2O-Na_2O$ in ashes of Matanuska Valley raw coals of various ranks.

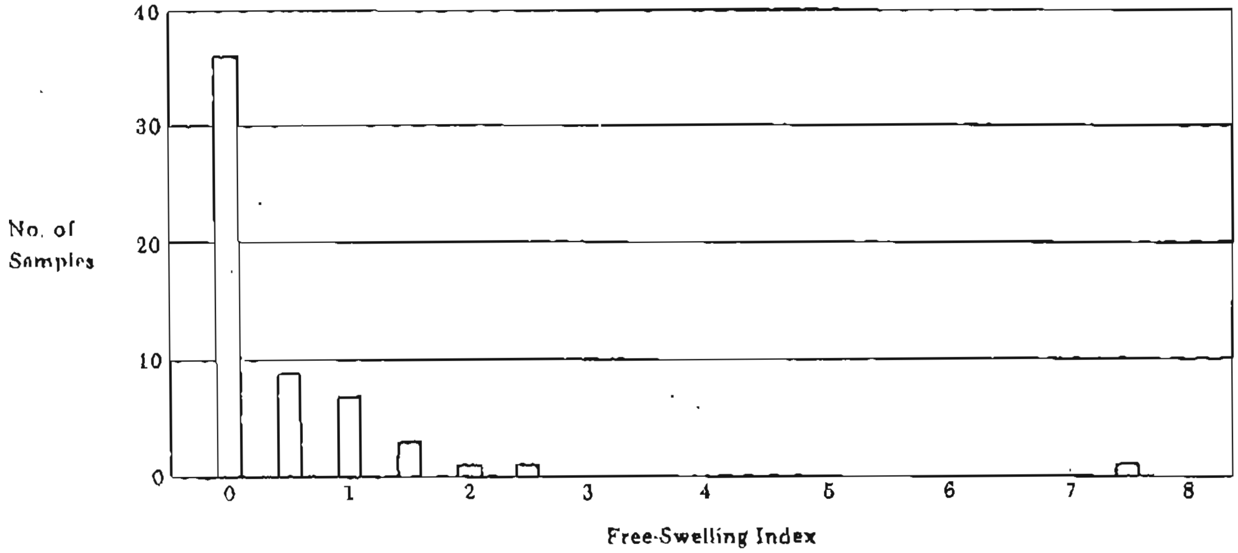


Figure 55. Free-swelling indices for Matanuska Valley coals.

Table 15. Ash fusion temperatures (°F) for representative coals compared to Matanuska Valley coals.

	Pittsburgh W.V.[1]	Illinois No. 6[1]	Wyoming subbituminous[1]	Texas lignite[1]	Matanuska Valley subbituminous(1)	Matanuska Valley bituminous(2)	Matanuska Valley anthracite(3)
Initial deformation:	2030	2000	1990	1975	2490	2280	2340
Softening:	2175	2160	2180	2130	2510	2315	2380
Hemispherical:	2225	2180	2250	2150	2530	2390	2440
Fluid:	2370	2320	2290	2240	2555	2500	2490

[1] Source: Babcock & Wilcox Company, 1972.
( ) = no. of samples. Total Matanuska Valley samples = 6.

furnaces where the ash is removed from the bottom of the furnace in a liquid state. The few Matanuska Valley samples included in this comparison and the results shown do not allow broad generalizations to be made in this case. It is generally known that the iron content of ash has an inverse relationship with initial deformation and softening temperatures (fig. 56); that is, as the total iron content increases, initial deformation and softening temperatures are concurrently lowered.

The American Society of Metallurgical Engineers (ASME) has derived a series of parameters that have been used to determine the fouling and slagging properties of coals for boiler use (table F9, appendix F). Major oxide ash-analysis results are used in the derivative equations. In general, coals can be divided into two broad groups base on ash analysis: 1) coals with bituminous-type ash, wherein the Fe_2O_3 content is greater than the CaO + MgO content; and 2) coals with lignite-type ash, wherein the Fe_2O_3 content is less than the CaO + MgO content (Schmidt, 1979). Eastern U.S. coals generally have bituminous type ash, whereas western U.S. coals generally have lignite type ash. Of the forty Matanuska Valley coals examined, they split fairly evenly between bituminous-type ash and lignite-type ash. This designation does not rigidly correlate with rank. Matanuska Valley subbituminous coals showed predominantly lignite-type ash (5:2), bituminous coals more often showed bituminous-type ash (13:11), and anthracite coals had predominantly lignite-type ash (7:2).

Schmidt (1979) states that since the ASME parameters were mainly developed for eastern U.S. coals, they may not be applicable to western U.S. coals. Indeed, he affirms that slagging and fouling factors related to coal-fired boilers are not applicable to western coals. Table F10 of appendix F summarize the criteria used in evaluating fouling and slagging based on the ASME parameters. Data related to these determinations for Matanuska Valley coals are found in tables F8 and F9 of appendix F. Based on the fouling factor and Na_2O content Matanuska Valley coals indicate the possibility of low to high fouling characteristics. Based on the T_{250} temperatures (temperatures at which the viscosity of slag reaches 250 poise) and slagging factors, Matanuska Valley coals indicate low to moderate slagging characteristics. Detailed analyses are required to adequately determine the likely performance of individual coals in combustion facilities. Figure 57 is a graph showing the relationship of T_{250} temperature to total base ash composition (1) and T_{250} temperature to dolomite percentage (2).

The energy traces of X-ray fluorescence spectra of 50 Matanuska Valley raw coal samples are shown in figure 58. Attendant instrument settings and conditions holding for the preparation of the spectra are listed. The spectra show relative semiquantitative abundances of various elements---Al, Si, P, S, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, and Sr. Sample identification, rank, and the percentages of ash, S, Si, Fe, and Sr are annotated.

Figure 59 summarizes the range of minor element contents commonly found in Matanuska Valley coals with other coals of the world. Most elements show considerably lower abundances in Matanuska Valley coals; these include Mn, Zn, B, As, Ni, Pb, Zr, Cu, Sn, Co, Cr, La, Y, Ga, and Be. Other elements---Ti, Sr, Ba, and Mo---reveal similar abundances to other coals.

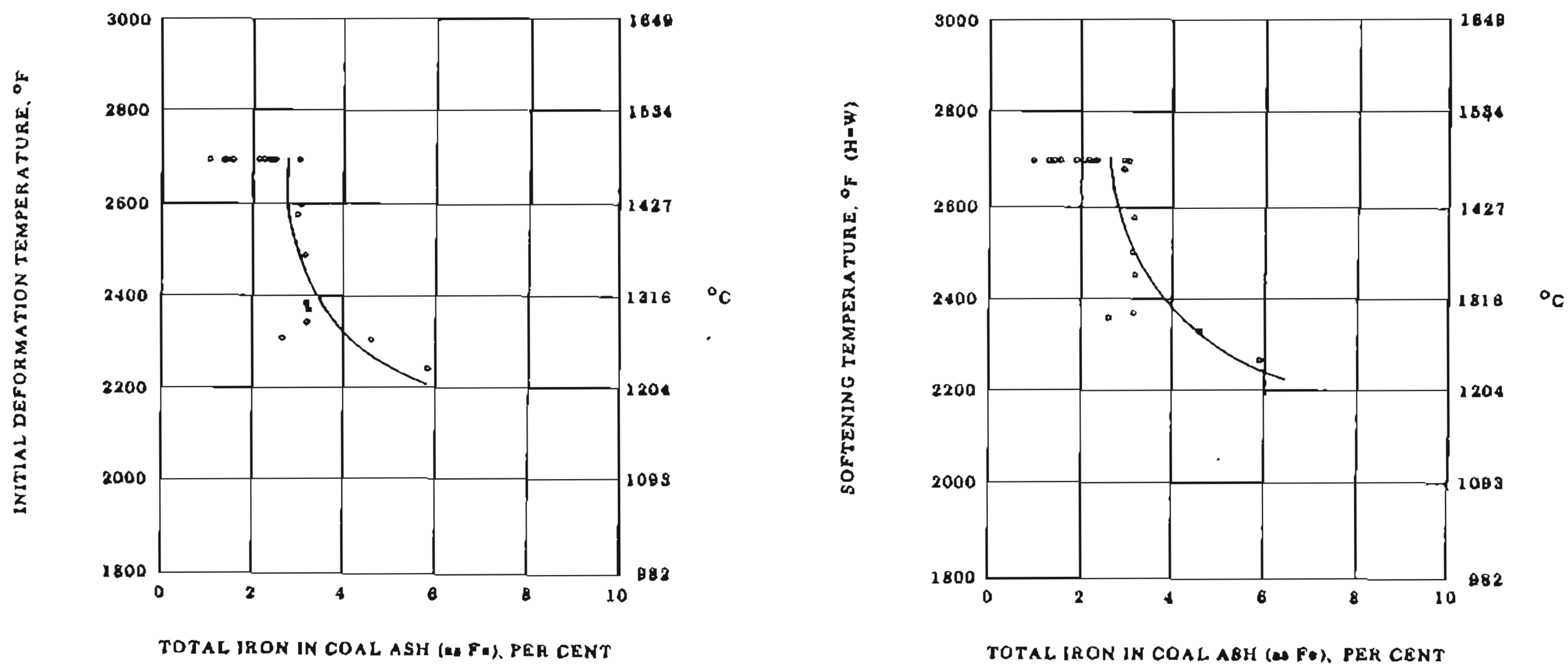


Figure 56. Plots showing the influence of iron content on coal-ash fusion temperatures (reducing condition only) in Matanuska Valley coal samples. After Ely and Barnhart, 1963; Corriveau and Schapiro, 1979.

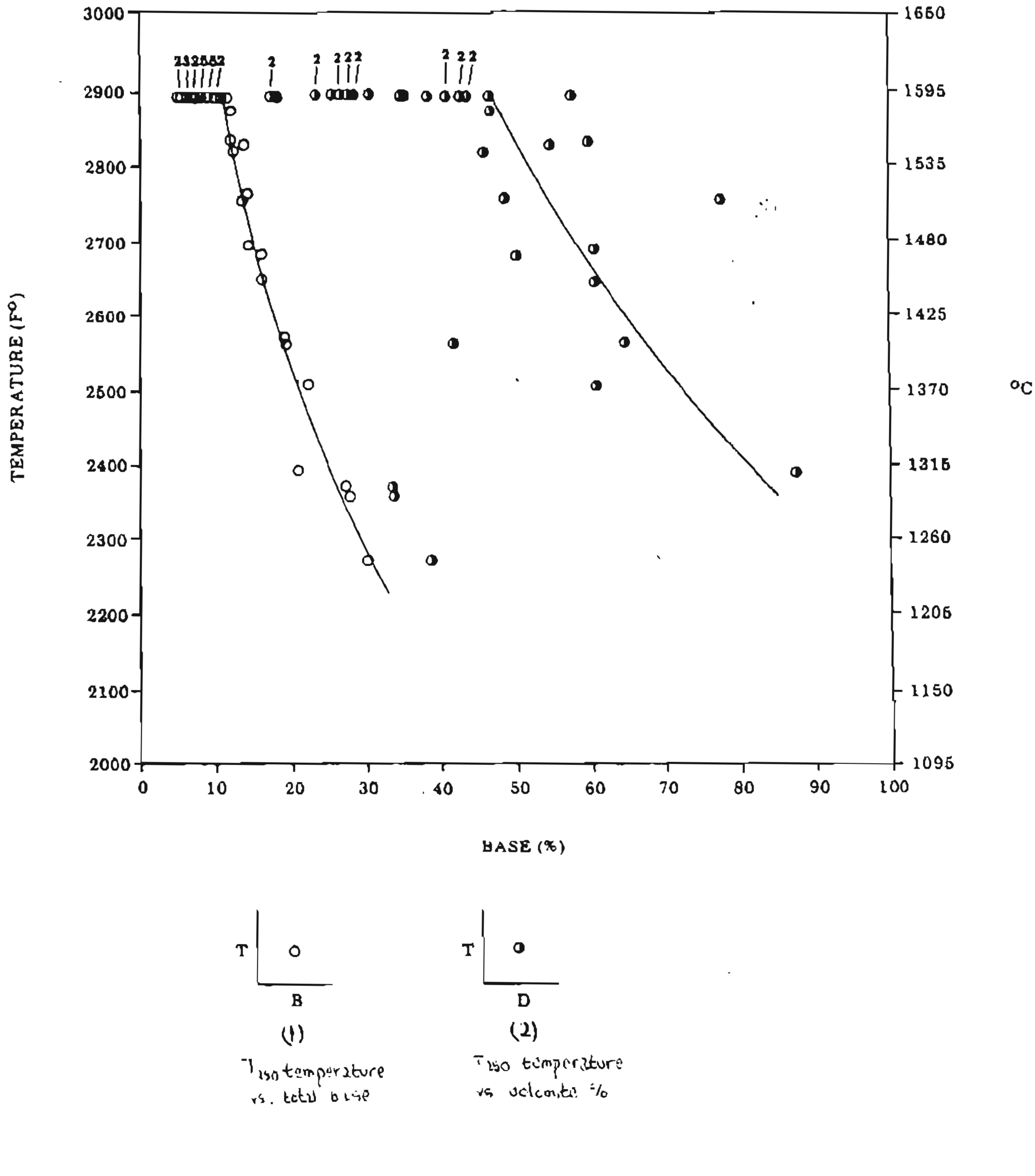


Figure 57. Comparison of T_{250} temperatures (temperatures at which the ash-viscosity curves reach about 250 poise) with total base content (1) and dolomite percentage (2).

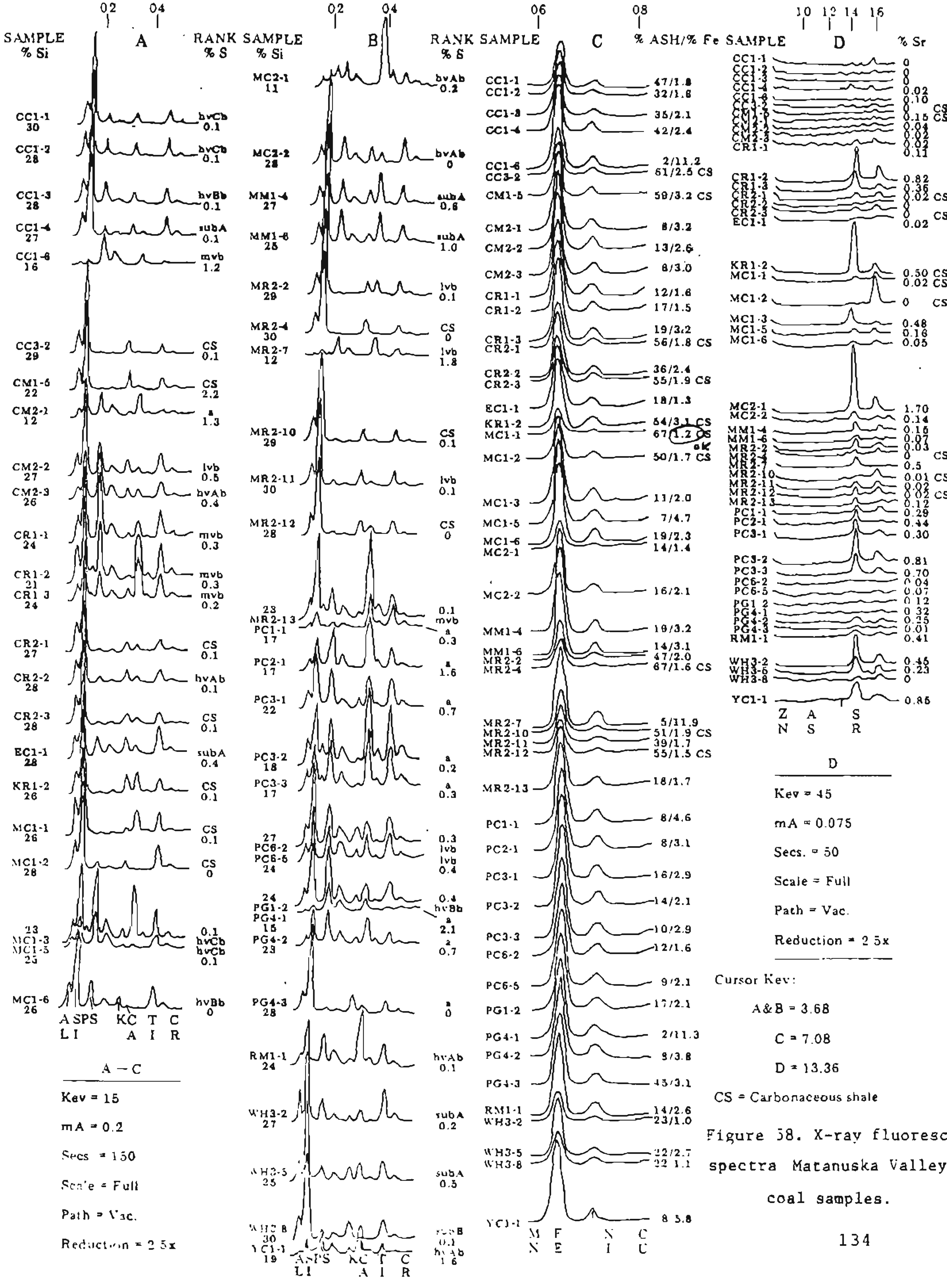


Figure 58. X-ray fluorescence spectra Matanuska Valley coal samples.

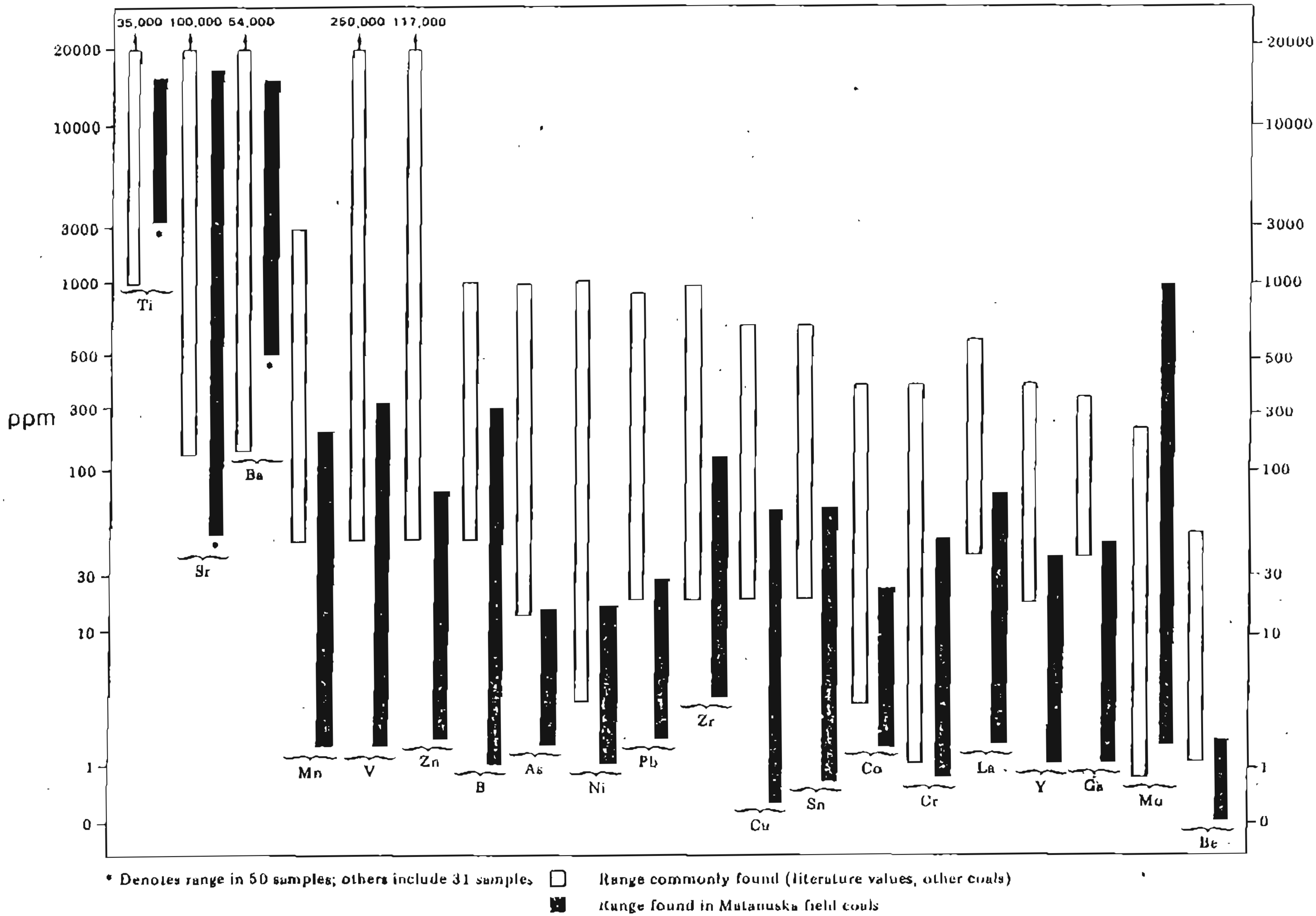


Figure 59. Range of trace element contents commonly found in coal ash compared with the range found in Matanuska Valley coals. Literature range from Mason, 1966, fig. 9.5, p. 242.

Figures 60 through 62 are histograms showing the distribution of 18 additional trace and minor elements in Matanuska Valley coals. Matanuska Valley coals show higher contents of F, Sc, V, Br, I, Cs, Ce, Sm, Eu, and Th than coals of the Illinois basin, Appalachian coal fields, and western United States (table 16). Matanuska Valleys coals are lower in Ge than Illinois basin and Appalachian coals, but higher in Ge than other western U.S. coals. Matanuska Valley coals contain similar contents of Rb as Illinois basin and Appalachian coals but higher contents of Rb than other western U.S. coals. Matanuska Valley coals contain similar contents of Cd as Illinois basin coals but higher contents of Cd than Appalachian and other western U.S. coals.

Certain elements are known to be generally enriched in many coal-ash samples over their average content in the Earth's crust (that is, higher than their Clarke values). Table 17 summarizes the average contents and factors of enrichment for these elements in coal ash in general and coal ash of Matanuska Valley samples compared to the respective Clarke value. In Matanuska Valley coals, those elements (As, U, B, Mo, Cd, Ga, and Sc) having average contents higher than the Clarke value exhibit a comparatively low factor of enrichment than other coals. Indeed, several elements (Ge, Be, Co, Ni, and Pb) normally enriched in coal ash show contents in Matanuska Valley coals actually lower than the Clarke value.

In summary, the coals of the Chickaloon Formation of the Matanuska Valley are among the highest quality coals in Alaska. They compare favorably with coals of the Bering River, northern Alaska, Nulato, and Chignik-Herendeen Bay fields. The relative high quality of Matanuska Valley coals is reflected in the measured values for most rank parameters including calorific value, fixed carbon, and vitrinite reflectance. Although the coals are generally low in sulfur, their typical moderate to high ash contents will make crushing and washing necessary to produce a satisfactory commercial coal.

COAL RESOURCES AND RESERVES

All coal known in the Matanuska Valley occurs in the Chickaloon Formation. Coal beds of this unit are generally 3 to 10 ft thick but locally are found to near 40 ft. Regional geologic structure complicates the calculation and estimation of coal resources in a given block and in the valley as a whole. Most resource analysts acknowledge that there could be substantial undiscovered underground coal deposits in areas of the Matanuska field. The coal resources of the region have been estimated by various authors (table 18). Barnes (1967) estimated the total coal resources of Matanuska Valley at 274 million tons. McGee and O'Connor (1975) estimated total coal resources at 248 million tons. Sanders (1981) states that although the probable total coal resources are close to 500 million tons, only some over 100 million tons of this has been identified. Merritt and Belowich (1984) recalculated potentially minable coal resources for the five major coal fields of the Matanuska Valley (table 19) at three levels of assurance (high, moderate, and low) and projected to a depth (overburden limit) of 500 ft. They arrived at figures of about 80, 120, and 180 million short tons respectively at the three levels of assurance.

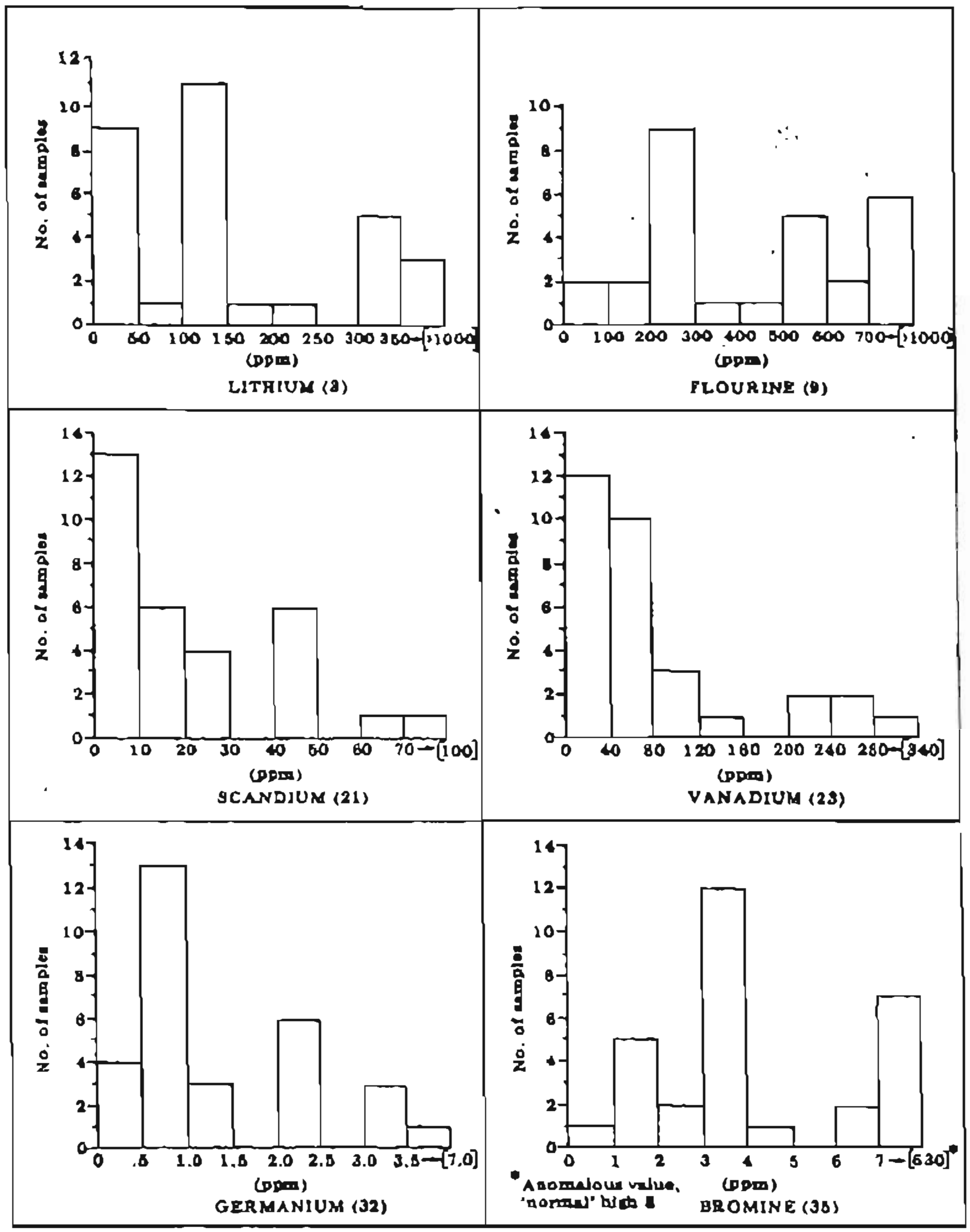


Figure 60. Histograms showing the general distribution of lithium, fluorine, scandium, vanadium, germanium, and bromine in analyzed Matanuska Valley raw coal ash samples.

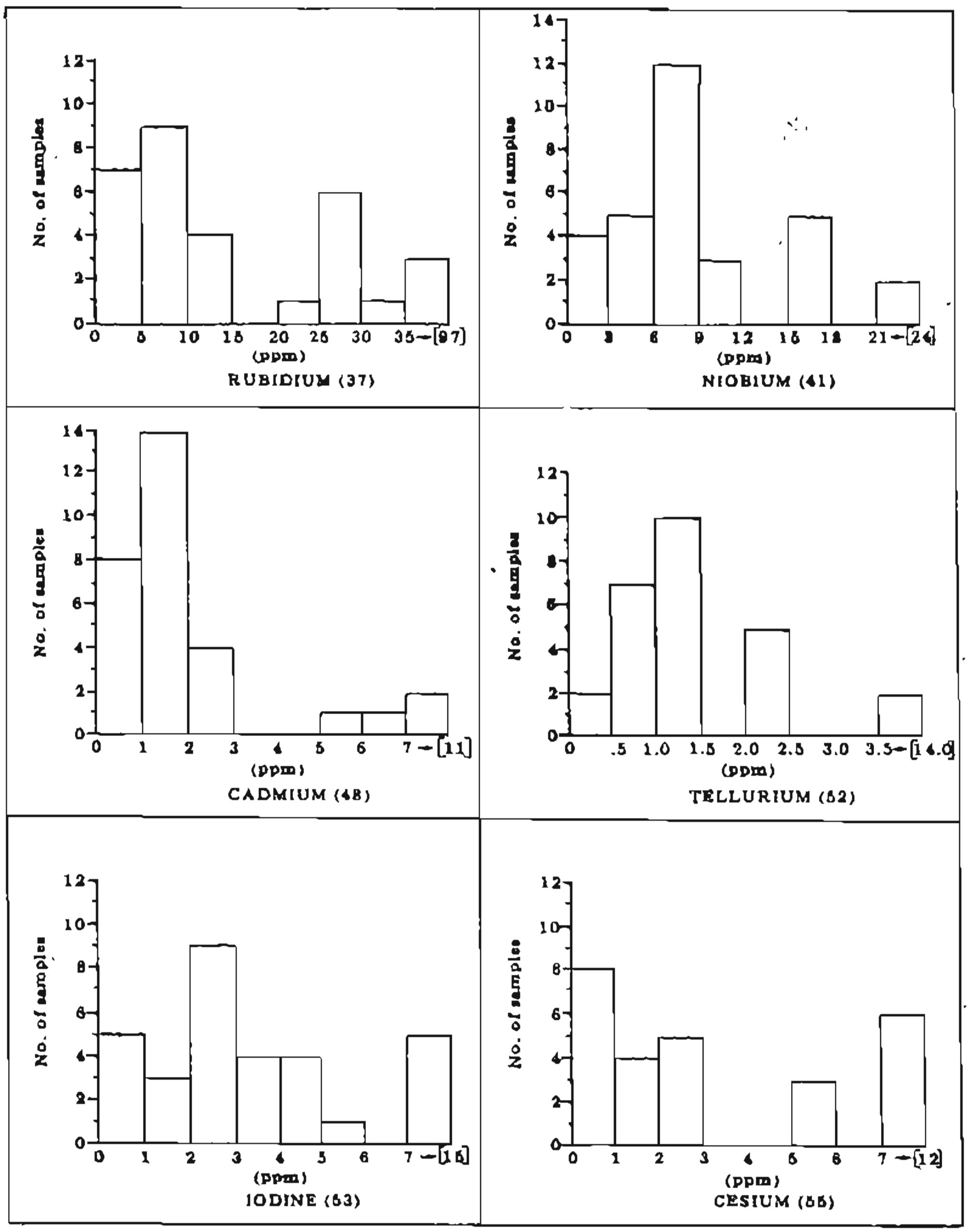


Figure 61. Histograms showing the general distribution of rubidum, niobium, cadmium, tellurium, iodine, and cesium in analyzed Matanuska Valley raw coal ash samples.

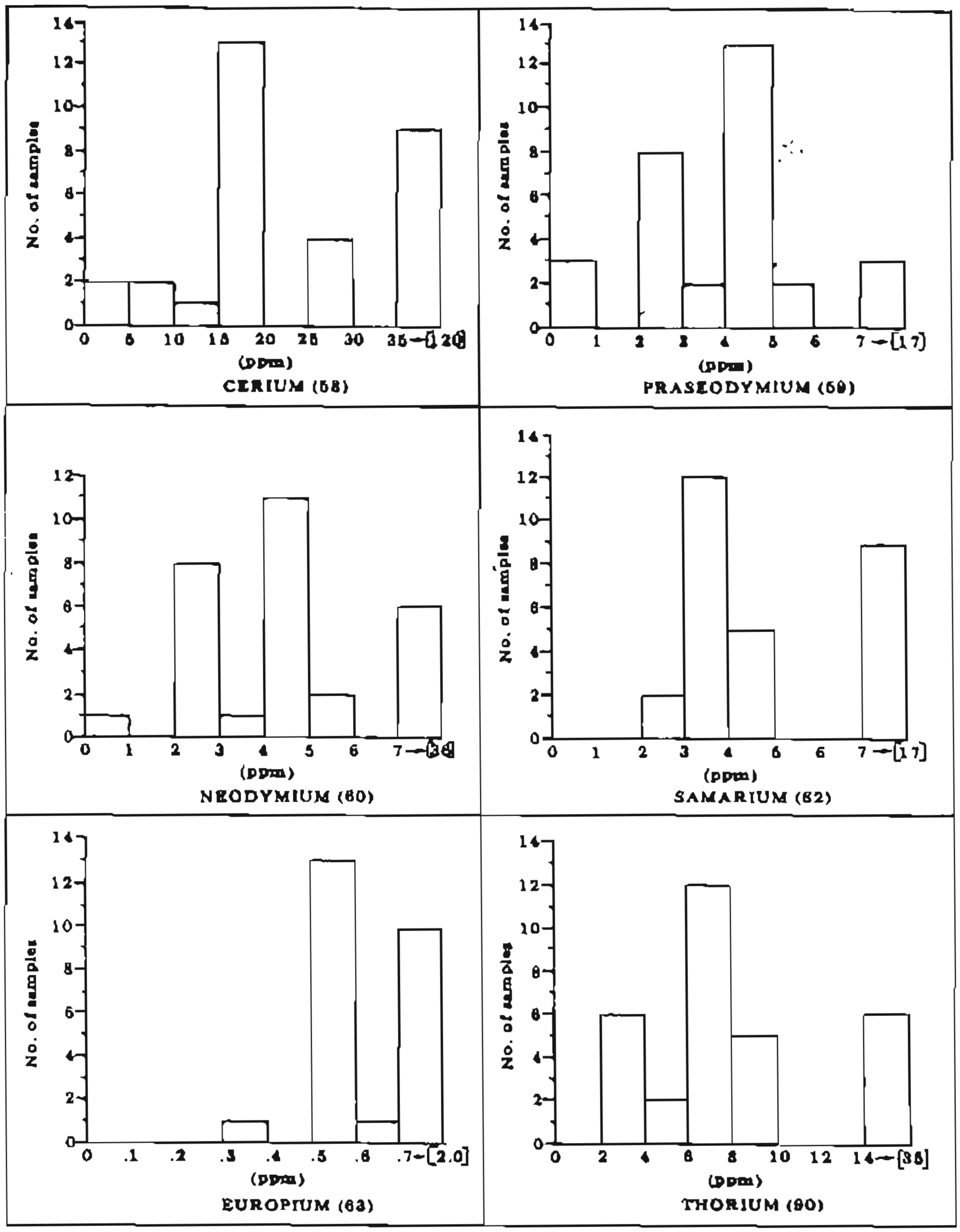


Figure 62. Histograms showing the general distribution of cerium, praseodymium, neodymium, samarium, europium, and thorium in analyzed Matanuska Valley raw coal ash samples.

Table 16. Comparison of arithmetic mean, minimum, and maximum values for certain trace-element contents in Matanuska Valleys coals with Illinois basin, eastern United States, and western United States coals [in ppm; 1 = arithmetic mean; 2 = minimum value; 3 = maximum value; and 4 = number of samples].

Element	Illinois Basin*				Appalachian coal fields*				Western United States*				Matanuska Valley			
	1	2	3	(4)	1	2	3	(4)	1	2	3	(4)	1	2	3	(4)
Fluorine (F)	67	29	140	(113)	89	50	150	(23)	62	19	140	(29)	374	51	710	(24)
Scandium (Sc)	2.7	1.2	7.7	(56)	5.1	1.6	9.3	(14)	1.8	0.50	4.5	(22)	23	0.5	100	(31)
Vandium (V)	32	11	90	(113)	38	14	73	(23)	14	4.8	43	(29)	80	2	340	(31)
Germanium (Ge)	6.9	1.0	43	(113)	1.6	0.10	6.0	(23)	0.91	0.10	3.0	(29)	1.4	0.3	7	(29)
Bromine (Br)	13	0.6	52	(113)	12	0.71	26	(23)	4.7	0.50	25	(29)	27	0.7	630	(30)
Rubidium (Rb)	19	2.0	46	(56)	22	9.0	63	(14)	4.6	0.30	29	(22)	19	1	97	(31)
Cadmium (Cd)	2.2	0.1	65	(93)	0.24	0.10	0.60	(23)	0.18	0.10	0.60	(29)	1.9	0.4	11	(29)
Iodine (I)	1.7	0.24	14	(56)	1.7	0.33	4.9	(14)	0.52	0.20	1.0	(22)	3.7	0.4	15	(30)
Cesium (Cs)	1.4	0.5	3.6	(56)	2.0	0.40	6.2	(14)	0.42	0.02	3.8	(22)	4.0	0.2	12	(25)
Cerium (Ce)	14	4.4	46	(56)	25	11	42	(14)	11	2.8	30	(22)	29	2	120	(31)
Samarium (Sm)	1.2	0.4	3.8	(56)	2.6	0.87	4.3	(14)	0.61	0.22	1.4	(21)	4.8	2	17	(28)
Europium (Eu)	0.26	0.1	0.87	(56)	0.52	0.16	0.92	(14)	0.20	0.07	0.80	(22)	0.70	0.3	2	(24)
Thorium (Th)	2.1	0.71	5.1	(56)	4.5	1.8	9.0	(14)	2.3	0.62	5.7	(22)	8.8	3	35	(26)

*From Gluskoter and others, 1977.

Table 17. Factors of enrichment for certain rare elements in coal ash of Matanuska Valley samples compared to the average contents for the same elements in the Earth's crust.

Element	Average content in earth's crust* (gms/ton)	Average content in coal ash* (gms/ton)	Average content in coal ash Matanuska field** (gms/ton)	General factor of enrichment*	Factor of enrichment based on Matanuska field samples**
Ge	1.5	500	1.4	330	0.9
As	2	500	5.4	250	2.7
U	2.7	400	4.7	150	1.7
B	10	600	75	60	7.5
Mo	1.5	50	6.2	30	4.1
Cd	0.2	5	1.9	25	9.5
Be	2.8	45	1.0	16	0.4
Co	25	300	8.7	12	0.3
Ni	75	700	7.2	9	0.1
Pb	13	100	10	8	0.8
Ga	15	100	18	7	1.2
Sc	22	60	23	3	1.0

*From Mason, 1966, table 9.5, p.241.

**Number of Matanuska samples used in compilation for each element As, B, Co, Ni, Pb, Ga, Sc = 31; Ge, Mo, Cd, Be = 29; U = 23.

Table 18. Coal-resource estimates by various authors for areas of the Matanuska coal field (mst = million short tons, bst = billion short tons). Older estimates do not take into account subsequent mining and improved definition of deposits.

Area	Measured	Identified (indicated and inferred)	Hypothetical
Matanuska Valley			
1. McGee and Emmel, 1979	6.6 mst	112 mst	149 mst
2. McGee and O'Connor, 1975	- -	99 mst	248 mst
3. Barnes, 1967	- -	125 mst	274 mst
4. Sanders, 1982	- -	100 mst	500 mst
5. McFarland, 1978	30.0 mst	- -	- -
Matanuska province			
Renshaw, 1983	6.6 mst	96 mst	2.4 bst
Eastern Matanuska field			
Barnes and Byers, 1945	- -	70 mst	- -
Western Matanuska field			
Payne and Hopkins, 1944	9.0 mst	- -	- -
Wishbone Hill district			
1. Barnes and Payne, 1956	- -	100 mst	- -
2. Patsch, 1981	- -	106 mst	- -
Northern limb, Wishbone Hill syncline			
1. Rao and Wolff, 1981	- -	100 mst	- -
2. Race, 1962	- -	185 mst	- -
3. McFarland, 1961	10.0 mst (2.0 mst strippable)	- -	- -
Moose Creek district			
1. Apell, 1944	0.5 mst	2.8 mst	- -
2. U.S. Bureau of Mines, 1944	0.5 mst	3.2 mst	- -
Moose-Granite Creek field			
Griffith, 1905; 1906a,b	- -	18 mst	- -

Table 18. Coal-resource estimates by various authors for areas of the Matanuska coal field (mst = million short tons, bst = billion short tons). Older estimates do not take into account subsequent mining and improved definition of deposits.

Area	Measured	Identified (indicated and inferred)	Hypothetical
Matanuska Valley			
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3. Barnes, 1967	- -	125 mst	274 mst
4. Sanders, 1982	- -	100 mst	500 mst
5. McFarland, 1978	30.0 mst	- -	- -
Matanuska province			
Renshaw, 1983	6.6 mst	96 mst	2.4 bst
Eastern Matanuska field			
Barnes and Byers, 1945	- -	70 mst	- -
Western Matanuska field			
Payne and Hopkins, 1944	9.0 mst	- -	- -
Wishbone Hill district			
1. Barnes and Payne, 1956	- -	100 mst	- -
2. Patsch, 1981	- -	106 mst	- -
Northern limb, Wishbone Hill syncline			
1. Rao and Wolff, 1981	- -	100 mst	- -
2. Race, 1962	-.-	185 mst	- -
3. McFarland, 1961	10.0 mst (2.0 mst strippable)	- -	- -
Moose Creek district			
1. Apell, 1944	0.5 mst	2.8 mst	- -
2. U.S. Bureau of Mines, 1944	0.5 mst	3.2 mst	- -
Moose-Granite Creek field			
Griffith, 1905; 1906a,b	- -	18 mst	- -

Table 18. Coal-resource estimates by various authors for areas of the Matanuska coal field (mst = million short tons, bst = billion short tons). Older estimates do not take into account subsequent mining and improved definition of deposits.

Area	Measured	Identified (indicated and inferred)	Hypothetical
Matanuska Valley			
1. McGee and Emmel, 1979	6.6 mst	112 mst	149 mst
2. McGee and O'Connor, 1975	- -	99 mst	248 mst
3. Barnes, 1967	- -	125 mst	274 mst
4. Sanders, 1982	- -	100 mst	500 mst
5. McFarland, 1978	30.0 mst	- -	- -
Matanuska province			
Renshaw, 1983	6.6 mst	96 mst	2.4 bst
Eastern Matanuska field			
Barnes and Byers, 1945	- -	70 mst	- -
Western Matanuska field			
Payne and Hopkins, 1944	9.0 mst	- -	- -
Wishbone Hill district			
1. Barnes and Payne, 1956	- -	100 mst	- -
2. Patsch, 1981	- -	106 mst	- -
Northern limb, Wishbone Hill syncline			
1. Rao and Wolff, 1981	- -	100 mst	- -
2. Race, 1962	- -	185 mst	- -
3. McFarland, 1961	10.0 mst (2.0 mst strippable)	- -	- -
Moose Creek district			
1. Apell, 1944	0.5 mst	2.8 mst	- -
2. U.S. Bureau of Mines, 1944	0.5 mst	3.2 mst	- -
Moose-Granite Creek field			
Griffith, 1905; 1906a,b	- -	18 mst	- -

Table 18 (con.)

Area	Measured	Identified (indicated and inferred)	Hypothetical
Eska and Evan Jones			
Payne and Hopkins, 1944	5.9 mst (above 860 ft level)	- -	- -
Eska Creek			
1. Jolley and others, 1952	1.6 mst	3.5 mst	- -
2. Rao and Wolff, 1981	0.6 mst	- -	- -
3. Barnes, 1951	0.7 mst	- -	- -
4. Evans, 1925	- -	5 mst	25 mst
Evan Jones			
1. McFarland, 1961	- -	40 mst	- -
2. Rao and Wolff, 1981	- -	100 mst	- -
Coal Creek			
1. Evans, 1913	- -	6.4 mst	- -
2. Mining Congress Jounral, 1922	- -	2 mst	- -
Chickaloon district			
1. Barnes, 1967	- -	- -	23 mst
2. Evans, 1925	- -	5 mst	20 mst
3. Mining Congress Journal, 1922	0.3 mst	- -	- -
Chickaloon-Kings River			
Evans, 1913	- -	- -	19.2 mst
Kings River-Chickaloon-Coal Creek			
Griffith, 1905; 1906a,b	- -	15 mst	62 mst
Chickaloon and Anthracite Ridge districts			
Barnes, 1967	- -	- -	25 mst
Anthracite Ridge			
Waring, 1936	- -	- -	0.75 mst

Table 19. Estimates of potentially minable coal resources of the Matanuska coal field (in millions of short tons to projected depth of 500 ft; from Merritt and Belowich, 1984).

Field	High assurance	Moderate assurance	Low assurance
Eska-Moose	32.5	45	60
Young Creek	2.5	5	8
Castle Mountain	6.5	10	25
Chickaloon	20.5	30	40
Anthracite Ridge	4.5	10	20
Other (scattered)	14.5	20	30
Total	81	120	183

All previous coal-resource estimates in the Matanuska Valley need to be critically examined. The older estimates are inaccurate now because of subsequent mining and the early poor definition of deposits. Further exploration will be necessary to more accurately determine the true recoverable reserves of coal.

Little Susitna Field

Some earlier workers have considered the Little Susitna field to be a district of the Matanuska field. However, the coals of the Little Susitna field below to the middle and upper Kenai Group and hence are younger than the coals of the Chickaloon Formation of the Matanuska field. The Tertiary section here is relatively thin, nearly horizontal or dip gently southward, and are locally folded and faulted. A thick conglomerate unit equivalent to the Wishbone Formation separates the subbituminous coal-bearing series that is essentially correlative with the Tsadaka Formation from noncoal-bearing facies of the Chickaloon Formation (Barnes and Payne, 1956). The 2 to 3 mi wide by 20 mi long strip of land is located north of the Castle Mountain fault along the southwestern toe of the Talkeetna Mountains between the Matanuska and Susitna basins. The coal-bearing unit contains several coal beds less 3 ft thick and one 10 ft bony coal bed in strata less 1,000 ft below surface. Mining in the past was conducted on a small-scale at four localized sites and depleted much of the minable resource (Patsch, 1981). The quantity and quality of the remaining coal does not approach commercial levels; the beds are generally too thin and dirty to be economic (Barnes and Sokol, 1959).

The field is near Houston, a station on the main line of the Alaska Railroad at Mile 175. Houston is 60 mi north of Anchorage at an elevation of 240 ft. The original discovery of coal in the area was made in a right-of-way cut incidental to the railroad construction in 1917. The U.S. Bureau of Mines conducted an exploration program in 1951 and 1952 that included 2,000 ft of diamond drilling. Ten coal beds were intersected but only two of these were estimated to be persistent enough for mining. The reserves of these two beds were calculated to be at least 5 million tons of coal in a 0.5 mi^2 area. The estimated total potential resource was 14.6 million tons (May and Warfield, 1957).

South of the Little Susitna field in the northeastern part of the Cook Inlet province is an area bounded by the Castle Mountain and Border Ranges faults that contains thick flat-lying to gently folded middle Tertiary and younger coal-bearing sediments (Conwell and others, 1982). The total coal resources of this area are little known.

Eska-Moose (Wishbone Hill) Field

The Eska-Moose coal field extends from Moose Creek on west to Knob Creek on east, and includes an area about 8 mi long and 1.5 mi wide. Its western end is about 6 mi north of Palmer. West of Moose Creek, the Chickaloon Formation becomes thinner; strata are more flat-lying and less broken by faults but there are no coals of workable thickness.

The general stratigraphic coal sequence in the district was established by mapping of Barnes and Payne (1956) and U.S. Bureau of Mines drilling and trenching (Alaska Geological Society, 1964). Coal beds are largely confined to the upper 1,400 ft of the formation with only a few thin coal beds in the lower part of formation. The beds extend upward to within a few hundred feet of the base of the Wishbone Formation. The thickness of the coal-bearing part of the formation thins westward from the Eska area. Moose Creek coal beds are found in the upper part of the Chickaloon Formation, whereas the Eska area coals occur several hundred feet lower in the formation.

Over 20 coal seams with a thickness over 3 ft are known to occur in Wishbone Hill district. Although seams to 23 ft thick are known, 8 ft is the average maximum thickness of beds. Thicker beds are composites of clean coal benches separated by claystone, coaly claystone and bony coal (Alaska Geological Society, 1964). In no instance has more than about 12 ft of coal been mined from a single bed.

The Chickaloon Formation underlies most of Wishbone Hill district, which accounts for the principal coal resources of the Matanuska field. Barnes (1967) estimated the coal resources of the district at 112 million tons with the most readily mined 6 million tons of coal already removed; this left 106 million tons in place---52 million tons indicated resources and 54 million tons inferred resources. Barnes' estimate excluded relatively unknown areas on the south limb of Wishbone Hill. Patsch (1981) estimated that about half of the remaining resources of the district are held under lease by the Evan Jones Coal Company which operated the Evan Jones mine from 1959 until its closure in 1968 (fig. 63). Merritt and Belowich (1984) estimated high-, moderate-, and low-assurance potentially minable coal resources of the Eska-Moose field at 32.5, 45, and 60 million short tons respectively to a projected depth of 500 ft.

The Eska coal area lies near the east end of the district about 8 mi west of the Young Creek field and 3 mi about junction of Eska Creek with the Matanuska River. Coal beds of the Eska area have been identified on both limbs of the Wishbone hill syncline and on both the east and west sides of the creek. Barnes (1951) estimated the amount of coal of minable thickness west of Eska fault zone and above the Eska mine level at 700,000 tons. Sanders (1981) estimated remaining identified resources of the Eska area at 600,000 tons.

The adjoining Knob Creek area lies immediately east of Eska Creek. This area forms a further eastward extension of the Wishbone Hill district, and includes at least 14 coal beds ranging from 2 to 9.5 ft in thickness. The Mrak Coal Company mine operated a surface mining operation in the area in the late 1950's and early 1960's. Barnes (1962) estimated remaining resources in the Knob Creek area at 27 million tons but most of this only recoverable by underground mining.

The coals of the Eska-Moose field occur in four groups (zones or series) of three or more beds separated by comparatively thick sections of barren strata or strata containing only thin unminable beds (table 20). These series have been named (in descending order) the Jonesville, Premier, Eska, and

Figure 63. Evan Jones Coal Company surface mine cut on north flank of Wishbone Hill. In 1953, 1,000 tons of coal per day were being produced here.

Table 20. Coal groups of the Chickaloon Formation, Wishbone Hill district. Adapted from Alaska Geological Society, 1964; Conwell and others, 1982.

Group name	Thickness	Equivalent named or numbered beds
Jonesville Coal Group	120 ft, Evan Jones Mine	Beds 1 through 4, Evan Jones Mine (exposed but unnamed on Moose Creek at the Premier Mine, found in drill holes on the south limb and near the axis of the Wishbone Hill syncline) 2-5 ft thick. To west at Moose Creek, group contains much bony coal of lower quality.
Interval	170-220 ft, north side of Wishbone Hill.	
Premier Coal Group	90-100 ft, Moose Creek. 100 to 260 ft, eastern part of district. (The thickness of the group increases rather abruptly from west to east along the north side of Wishbone Hill. This is thought to be the result of differential compaction of the strata which separate the coal beds of the group), one-third of total thickness is coal.	Beds 7, 7A, 7B, and 8, Evan Jones Mine. Chapin, Maitland, David, and Emery beds in the Eska Mine.
Interval	75 ft (average).	
Midway Coal bed	7.5 to 12 ft on Moose Creek including various thicknesses of bone and claystone. Consists of two or three 1½ to 2½ ft benches of coal separated by 2 to 2½ ft of coaly claystone in eastern part of district.	Bed 9, Evan Jones Mine.

Group name	Thickness	Equivalent named or numbered beds
Interval	100 ft, Moose Creek, 70-200 ft eastern part of district.	
Eska Coal Group	60-75 ft, Eska Mine.	Bed 10 and adjacent beds, Evan Jones Mine. Eska, Shaw and Martin beds, Eska Mine. These coal beds vary considerably in thickness across Wishbone Hill. The Martin bed consists of one to three benches, each with 1 to 3.5 ft of clean coal. The Shaw bed occurs in two benches 2 to 3.5 ft thick separated by coaly claystone and claystone. In central Wishbone Hill area, the Shaw bed pinches out and grades into coaly claystone. The Eska bed has layers of 0.8 to 5.8 ft thick clean coal with bony coal and claystone partings and interbeds.
Interval	200 ft, Moose Creek.	
Burning Bed Coal Group	125 ft on Moose Creek, 35 ft in eastern part of district (group appears to pinch cut in center of Wishbone Hill, thickest on northeast and southeast ends. Two to eight individual coal beds (none greater than 3 ft thick) are separated by partings and thin beds of bony coal and claystone.	

Burning Bed coal groups (Barnes and Payne, 1956). The Midway coal bed occurs in the middle of the four groups; it is a rather stratigraphically isolated but persistent bed that has not been included in either of the groups. These groups are more persistent than individual beds, and have been used for correlation purposes throughout the district. Different names have been used in past for equivalent beds or groups of beds at various mines throughout the Eska-Moose field.

Burning Bed Coal Group

The Burning Bed coal group forms the lowest series of beds of the Wishbone Hill district. In the western part of the Wishbone Hill district, the group is only exposed on the limbs of the Burning Bed anticline southwest of the Baxter mine. This Moose Creek cliff exposure contains a 125-ft thick coaly section with several thin beds of coal. The group took its name from a burning bed of coal in this cliff. On the northwest limb of the Burning Bed anticline, the entire group is exposed including eight beds of coal aggregating 25-ft thick with about 13.5 ft of clean coal. On the southeast limb, the lower five beds are exposed. The thickest bed is 3 ft.

In the eastern part of the Wishbone Hill district, the Burning Bed coal group thins to about 20 ft near the old Eska mine portal and to 35 ft on the north slope of Wishbone Hill. This series of thin and unminable but persistent coal and coaly claystone beds lie 200 to 300 ft stratigraphically below the Eska coal group (Barnes and Payne, 1956).

Eska Coal Group

The Eska coal group outcrops only to a very minor extent in the western part of the Wishbone Hill district. A slumped outcrop on the top of a bluff on the southeast side of Moose Creek exposes a 5-ft thick bed believed to be part of the group. In the Buffalo mine area, the group is 45- to 60-ft thick as found in drill holes. It includes four beds here that are thought to represent the entire group; each of the beds is about 2.5 ft thick. On the north slope of Wishbone Hill, the group consists of a carbonaceous zone containing thin noneconomic coal layers. No coal has been produced from the Eska coal group in the western part of the Wishbone Hill district (Barnes and Payne, 1956).

In the eastern part of the Wishbone Hill district, the Eska coal group thickens to 60 or 75 ft and contains four prominent beds. The top of the group is 250 to 450 ft below the base of the Premier group. The series was identified in mine workings and drill holes east of Eska Creek and traced westward through the Eska and Evan Jones mines. The Eska group was best exposed at the Eska mine and was found in drill holes west of Jonesville on the south limb. It has been mined extensively in the past on both sides of Eska Creek and on both limbs of the Wishbone Hill syncline. The Eska mine crosscut tunnel connected the two limbs of the Wishbone Hill syncline. The Eska group includes the Eska bed, the upper Shaw bed, the lower Shaw bed, and the Martin bed (Gates, 1946).

The Martin bed is the lowest member of the Eska coal group. As mined at Eska, the member consists of two benches 1.5- to 2.0-ft thick each and separated by a 0.5 to 2.0-ft parting of coaly claystone. West of Eska Creek, the Martin bed has been mined on both limbs of the syncline.

The Shaw or No. 10 bed generally consists of two benches known locally as the Upper (4-ft thick) and Lower Shaw (5-ft thick). They have been mined on both sides of Eska Creek on the north limb of the Wishbone Hill syncline but only west of the creek on the south limb.

The Eska bed was one of the principal seams mined at Eska. Its distribution and extent is similar to that of the Shaw bed. It locally reached 6-ft thick in the south limb workings but thinned to about 2 ft at the west end of the north limb workings. The seam typically contains a few thin bony streaks and partings (Barnes and Payne, 1956).

Midway Coal Group

The Midway coal group lies about 'midway' between the Eska and Premier coal groups. In the western part of the Wishbone Hill district, the group is locally of minable quality and thickness although it has not been developed. The group has been identified in drill holes, mines, and outcrops in the Moose Creek area, where it lies stratigraphically isolated about 75 ft below the base of the Premier group. The bed is 7.5-ft thick and includes 6.0 ft of clean coal on the average. At the Matanuska Center mine it increases to almost 12.0-ft thick (Barnes and Payne, 1956).

The Midway or No. 9 bed of the Evan Jones mine in the eastern part of the Wishbone Hill district consists of a 12-ft coal zone including three coal layers 1- to 2-ft thick each. In the Evan Jones crosscut tunnel, the bed is located about 90-ft below bed 8. In the west bank of Eska Creek, the bed corresponds to the same stratigraphic position as it does in the western part of the district, that is about midway between Eska and Emery beds. Here, it includes two benches of clean coal 1- to 1.5-ft thick separated by a 3.5-ft thick claystone. The relatively persistent bed has also been found in drill holes west of Jonesville on the south limb of Wishbone Hill. On the north slope of Wishbone Hill, the Midway bed is represented by a coal zone of variable thickness including one or two thin coal layers (Barnes and Payne, 1956).

Premier Coal Group

The Premier coal group contains the largest reserve of minable coal in the Wishbone Hill district. In the western part of the district, this middle series is 90 to 100 ft thick and consists of a series of relatively closely spaced beds. Clean coal makes up about one-third of the total thickness of the group, but at the Matanuska Center mine makes up two-thirds of the exposed part of the group. The group extends about 5 mi with little change in thickness from the Premier mine to the north slope of Wishbone Hill. Beds of the group have been mined in the past at the Premier, Baxter, Buffalo, Rawson, Wishbone Hill, and Matanuska Center mines.

Premier coal bed No. 3 constitutes most of the coal produced from the western part of the Wishbone Hill district. This bed correlates with the 'Big bed' of Barter mine, bed No. 2 of Buffalo mine, and bed No. 4 of Matanuska Center mine. In mine, outcrop, and drill-hole sections, the seam averages 9-ft thick with 8-ft of coal.

Premier coal beds No. 4 and 4A are the lowermost two beds of the coal group and average about 3 ft thick each. They are separated by 2 to 3 ft of claystone and coaly claystone. The two seams merge into one 11 to 12 ft thick seam at the Matanuska Center mine.

Coal beds above Premier bed No. 3 form the upper part of the Premier group. This zone contains a large tonnage of coal in beds 4 to 8 ft thick in a structurally complex area northeast of Wishbone Hill mine. In the mines along Moose Creek, these beds were found to be generally more bony and to contain more partings and lateral seam variations. Premier coal bed No. 2 is the second best in the Premier mine area of the western Wishbone Hill district. It is 8-ft thick and includes several partings of bone, claystone, and ironstone concretions. Premier coal bed No. 1 is 4-ft thick at the Premier mine (Barnes and Payne, 1956).

The Premier group increases in thickness eastward to over 250-ft thick in the vicinity of the Evan Jones mine. This eastward thickening is believed to be due to differential compaction of deposits of differing composition and not to eastward thickening into a depositional basin. In the eastern part of the Wishbone Hill district, the Premier group forms an aggregation of rather widely spaced beds. The series has been identified at several points between the Premier mine and the east side of Eska Creek above Eska. The base of the Emery (No. 8) bed is the base of the Premier group.

The beds of the Premier group have been named differently at Eska and Evan Jones. The Emery bed at the Eska mine is called the No. 8 seam at the Evan Jones mine. The Emery bed was first mined on the west side of Eska Creek, where it had a total thickness of 7.5 ft with 5.5 ft of clean coal. The bed is faulted out east of Eska Creek. At the Evan Jones mine, the bed is 7-ft thick, but only the lower 5-ft was mined in the past.

The David bed (No. 7B at Evan Jones mine) has been mined to a small extent in the past on both sides of Eska Creek. On the east side, it averages 2- to 2.5-ft thick, and on the west side 3-ft thick.

The Maitland bed (No. 7A at Evan Jones mine) was first mined west of Eska Creek, where it was referred to as the Kelly bed. On the east side of the creek, it consists of 2 benches separated by 4 to 7 ft of interburden. The upper bench ranges from 1.5 to 2-ft thick and the lower bench ranges from 2.5 to 3.5 ft thick. In the Evan Jones crosscut tunnel, the No. 7A bed consists of a 8.5-ft thick coaly zone with 2 ft of clean coal at the base.

The Chapin bed (No. 7 at Evan Jones mine) is exposed on both sides of Eska Creek but has been mined in the past only on the east side where it consists of 4.5 ft of coal in 2 benches separated by 2 ft of shale. In the

Evan Jones crosscut tunnel bed No. 7 includes a 1-ft thick upper bench and a 3-ft thick lower bench separated by a 3-ft parting.

Bed No. 6 in the Eska area consists of two benches of coal separated by 1 ft of coaly claystone. The upper bench is 2.5-ft thick and the lower bench is 4.0-ft thick. No coal beds above the Chapin bed have been developed in the Eska area. In the Evan Jones crosscut tunnel, the two benches are respectively thicker. The upper bench is 3-ft thick but includes only 2 ft of clean coal. The lower bench is 5.5 ft thick but includes 3 partings of claystone and iron carbonate 3 to 5 in. thick. In an outcrop on the north slope of Wishbone Hill, the No. 6 bed is 7-ft thick and includes 6 ft of clean coal.

Bed No. 5 in the Eska area consists of a 17-ft thick coal zone including three benches of coal 1-, 4-, and 6-ft thick. In the Evan Jones crosscut tunnel, a 9-ft coal zone includes less 4 ft of clean coal in several thin benches. On the north slope of Wishbone Hill, the coal zone includes 4 ft of clean coal and 8 ft of bone and bony coal (Barnes and Payne, 1956).

Jonesville Coal Group

The Jonesville coal group is the uppermost coal series of the Chickaloon Formation in the Wishbone Hill district. The top of this group is the top of the formation. The group trends intermittently from the Premier mine area on Moose Creek to the south limb workings of the Evan Jones mine near Eska Creek.

In the western part of the Wishbone Hill district, the Jonesville coal group ranges from over 20 to 60 ft thick and lies stratigraphically about 120 ft below the base of the Wishbone Formation. A 23-ft-thick coal zone at one locality along Moose Creek includes a 4.5-ft thick upper bed, 9 ft of claystone, and a series of thin beds at the base. Only a small amount of coal has been mined from the upper bed at one site. In general, the beds of the Jonesville group are of poor quality in the western part of the district (Barnes and Payne, 1956).

The Jonesville coal group was named after the Jonesville mine camp of the eastern part of the Wishbone Hill district. The beds of this group were first mined on the south limb of the Wishbone Hill syncline at Jonesville. The group has been identified in drill holes west of Jonesville. They are also locally exposed on the north side of Wishbone Hill. In the Evan Jones mine area, the group is 120 ft total thickness, and includes beds 4, 3, 2, 1, 0, and 00. Bed No. 1 was found in the upper tunnel of the Evan Jones mine to consist of a 7-ft zone of coaly shale. On the north limb opposite Jonesville, it was 5-ft thick and contained a few thin layers of coal. In the south limb workings of the Evan Jones mine, bed No. 2 averaged 2- to 3-ft thick. Bed No. 3 was the most extensively mined coal bed in the old south-limb workings of the Evan Jones mine; it ranged from 7.5- to 12-ft thick and contained a few thin shale partings. Bed No. 4 is the uppermost coal bed of the Jonesville group and was mined only in the old south-limb workings of the Evan Jones mine, where it averaged 3 to 4 ft thick. This seam was not observed in outcrop on the north slope of Wishbone Hill (Barnes and Payne, 1956).

Young Creek Field

The Young Creek coal field contains a relatively small coal-resource base. Merritt and Belowich (1984) estimated high-, moderate-, and low-assurance, potentially-minable coal resources at 2.5, 5, and 8 million short tons, respectively to a projected depth of 500 ft. Outcrops of the field are found about 3 mi west of Kings River near the mouth of Young Creek and also in the upper part of its valley. Two seams of unworkable thickness (0.5 and 1 ft) crop out in a section located 3.5 mi above the junction of Young Creek with Kings River. These seams locally contain tiny nodules of clay and pyrite. The beds occur in a synclinal trough with dips of 20° on the limbs.

The Young Creek field also includes the deposits of the Red Mountain area. Martin (1911) measured a section (table 21) at about the 3,600-ft elevation on the northface of Red Mountain. This poorly exposed section was located about 4 mi north of the mouth of Young Creek and included over 12 aggregate ft of coal. Martin reported the strike as N. 67° E. and the dip as 54° SE. The author trenched a coal seam at about the 3850 ft level on the north side of the mountain. This bed was certainly thicker than the maximum 8-ft thick bed reported on the mountain. Although possibly in a recumbent fold, the bed could be over 25-ft thick. Analysis revealed this bed to be of high-volatile C bituminous rank (sample RM1-1, appendix F).

Castle Mountain Field

The Castle Mountain coal field lies in the central Matanuska Valley northwest of the Chickaloon field. The character and occurrence of coals closely resembles those of the Chickaloon field, and perhaps they should be combined together as one field.

A small-scale surface mine on the south shoulder of Castle Mountain operated in the field from 1958 to 1960 and produced about 18,800 metric tons of coal from two separate opencut pits. In the southern pit, coal was mined from two seams that strike N. 22° W. and dip 37.5° to the northeast (fig. 64). The strike length of this pit is 75 m with a downdip distance of 23 to 30 m. The top seam (Castle Mountain No. 2) averaged 1.8 m in thickness and the bottom seam (Castle Mountain No. 1) averaged 2.6 m in thickness. The seams were separated by 2.0 m of interburden (clay and bone). The overburden and seatrock consisted predominantly of a hard sandstone (Maloney, 1958). A small quantity of Castle Mountain No. 1 seam was unmined in the north end of the pit.

The southern and northern opencut pits are offset about 30 m by a right-lateral transverse fault striking S. 70° W. A single coal bed of about 1.8 m thickness was mined in the northern opencut pit over a nearby parallel strike length of 120 m and a downdip distance of 30 m. Warfield and others (1966) concluded that the coal beds of the two pits were noncorrelative or that one seam in the northern pit had thinned to nonexistence over a very short strike length. In fact, it does appear as if mining ceased when the coal beds thinned to noneconomic thicknesses at the nontruncated ends of the opencuts.

Table 21. Red Mountain coal-bearing section of Martin (1911).

Lithology	Thickness (ft)
Shale with ironstone nodules	- -
Coal	7.4
Shale	0.1
Coal	1.2
Shale	0.1
Coal	0.5
Shale	0.1
Coal	0.6
Shale	0.05
Coal	0.3
Shale	0.04
Coal	0.2
Shale	0.05
Coal	2.0

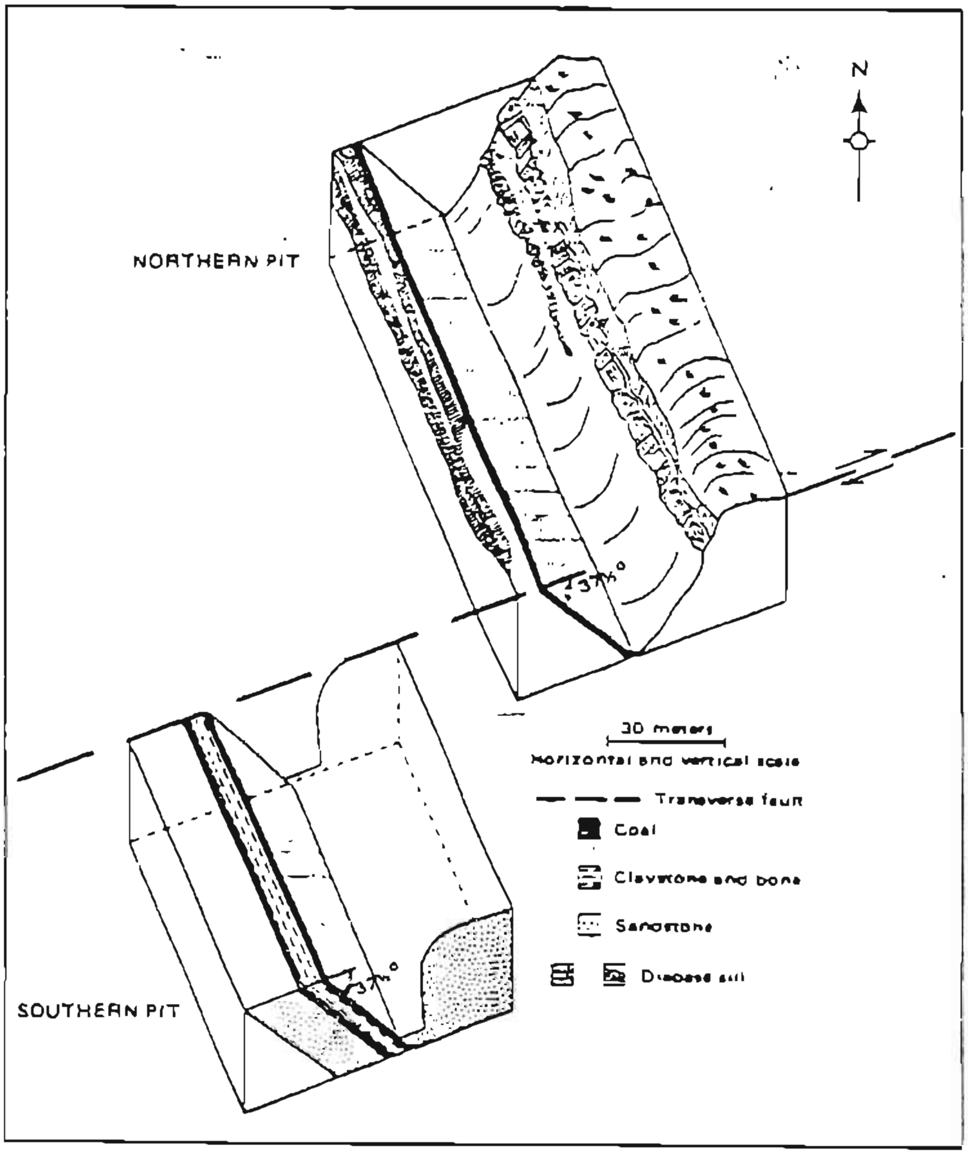


Figure 64. Schematic configuration of the northern and southern opencut pits of the Castle Mountain mine. Mining in the southern pit ended when the right-lateral transverse fault was encountered but resumed after offset and discovery of the seam in the northern pit. From Merritt, 1985.

A small quantity of coal was unrecovered from the lower portion of the northern pit seam between the present toe of the dip slope and the highwall.

Remaining in-place reserves are low in the immediate vicinity of the Castle Mountain mine. High-, moderate-, and low-assurance minable-coal-resource estimate projections to a depth of 150 m for the Castle Mountain field are respectively 6.5, 10, and 25 million short tons (table 19; Merritt and Belowich, 1984). One 100-acre state coal lease located at the east end of the field is still active.

The Castle Mountain field also includes deposits on the Kings River district which lies about 5 miles west of the Chickaloon River. The main area of coal outcrops lies about 9 to 9.5 mi above the junction of Kings and Matanuska Rivers. Four separate beds observed in outcrops aggregate 28 ft total thickness; they are respectively 6-ft, 10-ft, 2-ft, and 10-ft thick. Particularly on the east side of the river, the beds are capped by igneous rock flows, which have coked large portions of them. Hill (1923), noting the highly faulted and broken condition of the beds here, and the prevalent intrusives that have coked a large percentage of the coal beds, stated that he could not foresee future mining and development of coal beds in the Kings River area. More recent evaluations of the coal resources tends to confirm that early assessment.

Significant coal-bearing outcrops are also located in Edwardson Gulch in a mountainous ravine on the west side of Castle Mountain. Clardy (1974) measured stratigraphic sections in this area.

Chickaloon Field

Coal deposits of the Chickaloon field cover at least 12 mi^2, including most of the Chickaloon River valley south of Castle Mountain and to 5 mi above it mouth. It is estimated to contain the second largest coal resource of the Matanuska Valley, and is only surpassed by the deposits of the Eska-Moose field discussed earlier. Barnes (1967) inferred 24 million tons of resources in the Chickaloon district of central Matanuska Valley. Merritt and Belowich (1984) estimated high-, moderate-, and low-assurance, potentially minable coal resources at 20.5, 30, and 40 million short tons respectively to a projected depth of 500 ft (table 19).

The coal deposits of the field were extensively mapped and explored in the first quarter of this century. A good deal of development work was also completed in the past. Early trenching and pits during exploration uncovered 19 bituminous coal beds from 2.5 to over 10 ft thick. Mining in the past has taken place at Chickaloon near the mouth of the Chickaloon River and on Coal Creek south of the Matanuska River.

The Chickaloon field is characterized by complex structure, discontinuous coal beds of indefinite correlation, and widespread igneous intrusions. The rocks dip steeply northward and strike northeastward to nearly due east from Chickaloon. These factors combine to make most of the coal of the field unminable. However, it is possible that local conditions are more favorable and that substantial reserves of minable coal are present.

The principal surface outcrops of coal beds are on the north bank of the lower Chickaloon River near the old town site of Chickaloon (fig. 65). This site lies near the old Watson Camp about 1.5 mi above the junction of the Chickaloon and Matanuska Rivers. The bluff here rises about 100 ft from the alluvial flat of the river to a terrace covered with glacial gravels. East of Chickaloon the coal-bearing Chickaloon Formation strata pass beneath the gravel-covered benches and are generally concealed.

Eight seams of the Chickaloon field aggregate nearly 50 ft of coal (Crane, 1913). These include the No. 1 through No. 8 seams which average repectively 5.3 ft, 4.8 ft, 8.8 ft, 5.5 ft, 9.3 ft, 2.5 ft, 10.8 ft, and 2.7 ft.

The Chickaloon field also includes deposits on Coal Creek about 2 miles southeast of the town of Chickaloon and directly opposite the junction of Chickaloon River with the Matanuska River (fig. 66). Six seams on Coal Creek aggregate 35 ft (Crane, 1913). These include the No. 1 through No. 6 seams which average respectively 5.0 ft, 8.5 ft, 7.5 ft, 7.0 ft, 0.5 ft, and 6.5 ft. The coal resources of Coal Creek probably amount to at least 2 million tons.

Anthracite Ridge Field

The Anthracite Ridge field occupies a rolling upland area north of the Matanuska River and south of Anthracite Ridge between Boulder and Hicks Creeks. It is situated between sharp linear fronts of the Talkeetna and Chugach Mountains. Its east end lies just west of the terminus of Matanuska Glacier. The field is traversed by the Chickaloon Trail. The field is further delimited on the west and east respectively by the drainage basins of Sawmill Creek and Packsaddle Gulch. The field is 4 miles wide by 7 miles long and contains an area of about 25 mi^2.

Coals are exposed at many places in the Anthracite Ridge field (fig. 67). These generally occur well upon the flanks of mountains at about 3000 to 4000 ft elevation. Capps (1927) measured sections of all accessible coal exposures of the upper Matanuska Valley. The three major outcrop areas of the field are: 1) in the southwest along lower Purinton Creek; this area contains some 160 acres and forms the central deposits of field; 2) along the north-central part of the ridge; and 3) in the east, in the basin of Muddy Creek, an area less than 320 acres.

Dikes intrude across the southern boundary of the Anthracite Ridge field and limits extension to the south; older non-coal-bearing rocks cut off extensions in other directions. The intrusives form a prominent scarp on the south side of Anthracite Ridge with pronounced waterfalls and cascades. The area of the field between this scarp and the Matanuska River contains no outcrops of coal beds.

The Anthracite Ridge field contains a dozen or more coal beds in a zone of several hundred feet belonging to the lower or middle portion of the Chickaloon Formation (Richards and Waring, 1933). These beds pinch and swell and lack continuity beyond several hundred feet. Although beds 2-ft thick or

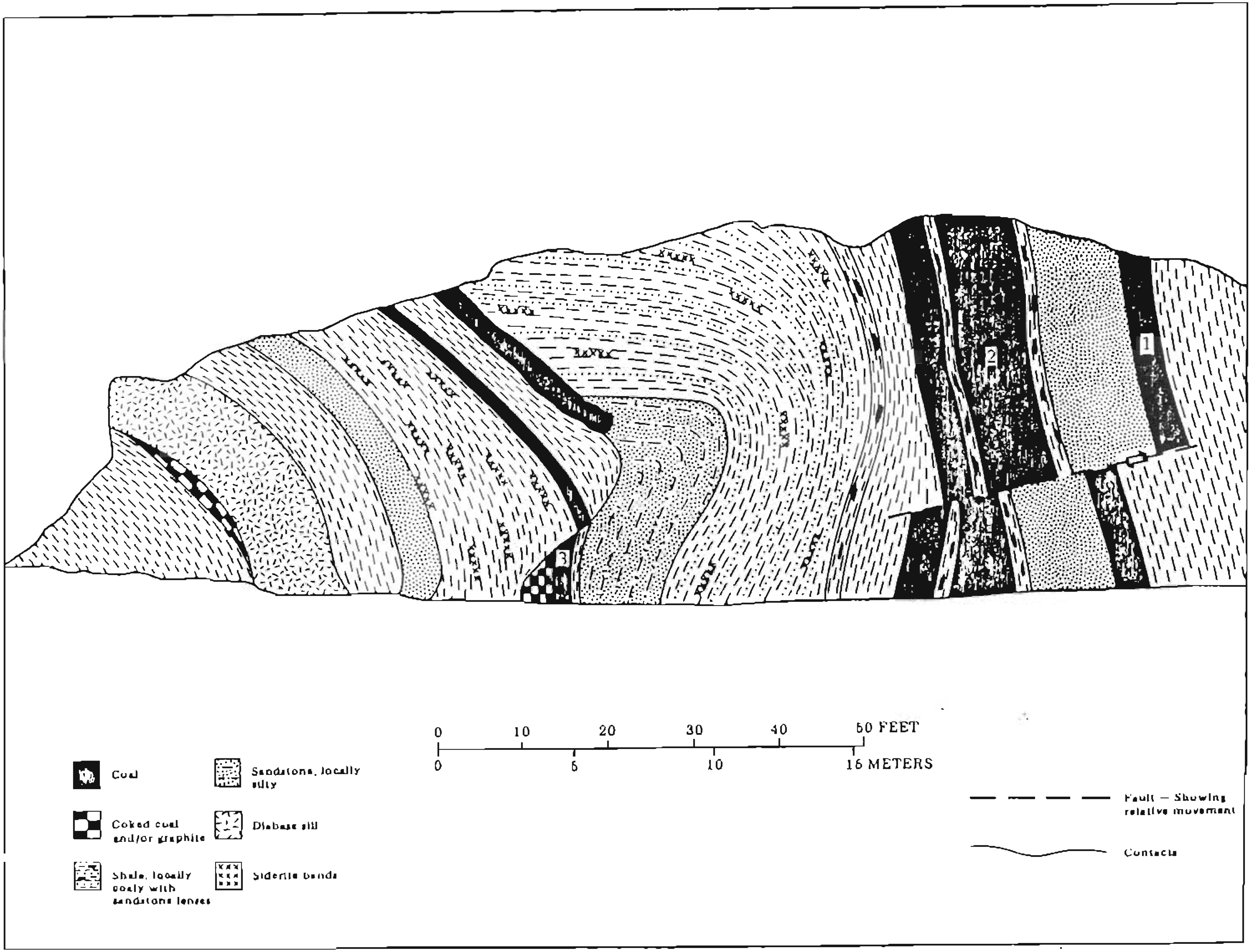


Figure 65. Schematic drawing of Chickaloon Formation outcrop section at site CR1 on the lower Chickaloon River. Sampled coal beds are indicated: 1 = CR1-1, 2 = CR1-2, and 3 = CR1-3. Analyses (see

Figure 66. Outcrop view of Coal Creek seam, Chickaloon field.

Figure 67. Bituminous coal seams on Glenn Highway outcrop, upper Matanuska Valley.

less are predominant, the average maximum thickness is 8 ft, beds 10 to 16 ft are found locally, and two beds of 24- and 34-ft maximum thicknesses have been measured at outcrops near the northwest border of the basin. Thicker coal occurrences are associated with diabase dikes.

The field includes three main coal bearing zones---lowest, middle, and upper zones. The highest and middle zones are found in the northern part of the area along the central part of the ridge. The middle and lowest zones are found in the eastern part of the area in the basin of Muddy Creek. All three zones are found in the southwestern part of the area along lower Purinton Creek. The upper zone contains about six bituminous to semianthracite coal beds in a 400-ft interval of sediments. The middle zone contains four or five beds aggregating 10 ft of coal in a 50-ft stratigraphic interval. Although beds of the middle zone are closely folded in places, they have not been appreciably altered and are of bituminous rank. The lower coal zone contains a 6-ft bed of bituminous coal near the middle of Muddy Creek (Waring, 1936).

The coals on the Anthracite Ridge field do not extend to any significant depth. In 1932, eight diamond-core holes were drilled in the synclinal area south of the Anthracite Ridge principal outcrops. Drilling extended to 1,820 ft maximum depth on one hole. Although anthracite veinlets were found at considerable depths (1,500 to 1,600 ft), the drilling proved that there were no significant coal beds in that area. The reason for this is simply that no coal-forming materials of substantial quantity were deposited in this area.

A small area of anthracite coal is found on the south slope of Anthracite Ridge near the head of Purinton Creek. The known area of anthracite coal is confined to an area 0.5 mi long by 0.25 mi wide. This area is folded and faulted and could supply only a very small amount of anthracite or other specialty coal. Most coal beds exposed in the southern and eastern parts of the Anthracite Ridge field are relatively thin seams of bituminous rank.

Capps (1933) estimated that one 20-acre tract in the Purinton Creek area held 750,000 tons of anthracite and semianthracite. Waring (1936) estimated that the field contained several million tons of predominantly semianthracite coal. Merritt and Belowich (1984) estimated potentially minable coal resources of the field to a projected depth of 500 ft at high-, moderate-, and low-assurance levels to be 4.5, 10, and 20 million short tons respectively (table 19).

In general, the coals of the Anthracite Ridge field are not believed to hold but marginally significant economic importance. Mining could take place only on a very small scale. The most promising areas are in the vicinity of the three branches of Purinton Creek, where the coals vary from bituminous to anthracite in rank.

Other Areas

Merritt and Belowich (1984) estimated the total potentially minable coal resources of other scattered areas in the Matanuska Valley at high-, moderate-, and low-assurance levels to be 14.5, 20, and 30 million short tons respectively to a projected depth of 500 ft (table 19). These areas include deposits in the vicinity of Little Granite Creek, Carpenter Creek, Carbon Creek, and O'Brien Creek.

Little Granite Creek

This area may contain coal beds of minable thickness and quality but will require extensive subsurface exploration (Barnes, 1962).

Carpenter Creek

A small exposure of Chickaloon Formation strata containing coal beds lies near Carpenter Creek southwest of the western shoulder of Kings Mountain. This strata occurs in an isolated block that was detached from the Coal Creek area with the unheaval of Kings Mountain. Subsequently, the connecting strata between the two areas was eroded away (Hill, 1922). This remnant is not believed to have significant commercial value.

A second minor exposure on the west side of Carpenter Creek contains a 3-ft coal bed that strikes N. 75° W. and dips 75° N. and is interbedded with carbonaceous shale. A 4-ft thick basic sill intrudes the Chickaloon Formation strata about 20 ft below the bed and several other sills are located in the vicinity. A rhyolite-porphyry dike 20-ft thick truncates the coal between an old tunnel portal and the top of the hill. The coal is traversed by various stringers of calcite, generally broken and dirty, but locally clean and shiny. (Landes, 1927).

Carbon Creek

The southern limb of the Coal Creek syncline has been uplifted in the Carbon Creek area, flattened out and eroded away. The Chickaloon Formation strata exposed along Carbon Creek is older that the coal-bearing part of the unit exposed on Coal Creek (Hill, 1922). The coaly strata here are found in a severely deformed and faulted zone that has been intimately intruded by dikes and sills.

O'Brien Creek

Exposures on O'Brien Creek are found in a small area near the eastern end of the Matanuska coal field and were first explored by the Navy Alaskan Coal Commission during regional geologic reconnaissance. The coals of O'Brien Creek on the south side of Matanuska River belong to the middle coal zone of the Anthracite Ridge field. The devolatilization of coals here is generally less advanced than in the Anthracite Ridge field. The beds in the O'Brien Creek area occur in a detached block, a remnant isolated by erosion, and highly tilted and intensely folded (Hill, 1923). Coal beds are cut by pronounced faults. The coal-bearing strata are covered by surficial gravel and are exposed above an altitude of 1,700 ft. Smaller outcrops of coals in the vicinity of O'Brien Creek are found in the gulches 0.25 mi east and west of it. The resources of the area have not been calculated because of the complex structure affecting the coal beds.

In summary, there are five small fields with substantial coal deposits within the Matanuska Valley and other minor resources at scattered locations. The Eska-Moose and Chickaloon fields contain about two-thirds of the estimated potentially-minable coal resources. There exists the possibility of significant undiscovered underground coal deposits in areas of the Matanuska field.

OVERBURDEN CHARACTER AND RECLAMATION POTENTIAL

Little research has been performed to date relating to the characterization of Matanuska Valley coal overburden. Mitchell and others (1981) of the University of Alaska, Palmer Agricultural Experimental Station have analyzed spoil bank materials from the abandoned Jonesville mine site near Sutton and have recently conducted revegetation research---soil fertility and plant material studies. The materials examined contain appreciable amounts of both coal and shale and remain nearly void of vegetation. Mining at the site ended over 15 years ago. The mine spoil materials are low in organic matter and characterized by coarse textures that have led to rapid drying of the surface zone. Inadequate moisture levels during seed germination and early plant growth have resulted in seeding failures and poor stands. Test-plot trials in 1980 revealed that irrigation and particularly mulching aided plant growth (Kreig and Associates, 1983).

The limiting chemical constraints to plant reestablishment at the site are the major plant nutrients nitrogen, phosphorous, and less significantly potassium deficiencies. A high pH (8.3) that may be controlled by a HCO_3 system yielding free carbonates may hinder the availability of phosphorous and certain micronutrients (as zinc, copper, manganese, and iron). The secondary cations calcium and magnesium appear to be satisfactory. The site is deficient in both ammonium ion (NH_4) and nitrate (NO_3). It shows no potential for the development of high levels of salt or sodium accumulation. Sodium absorption ratios are below the range associated with poor soil structure and resultant effects on plant growth (Mitchell and others, 1981).

Results of coal overburden analyses performed in this study are summarized in table 22. Individual sample results are listed in table G1 of appendix G. The samples analyzed reveal variant textures; the typical sample is composed of 59 percent sand, 19 percent silt, and 22 percent clay. Several of the samples fall within poor texture zones based on their utility as a subsoil rooting medium during reclamation (fig. 68). These samples are characterized by excessive clay (>40 percent) or excessive sand (>70 percent).

The 27 samples had a mean pH of 7.3. Sulfur contents were very low (fig. 69); the mean total sulfur content was 0.12 percent with most of this (0.11 percent) present as organic sulfur. Lime contents were also low averaging less than 1 percent. The samples showed no significant potential for the development of acidic mine spoils. Acid potential was measured based on the pyritic sulfur content and on the total sulfur in the samples. Both methods arrived at mean excess values of inherent neutralizing capacity ranging from 1.9 tons $CaCO_3$ equivalent per 1,000 tons of material (total sulfur) to 5.4 tons $CaCO_3$ equivalent per 1,000 tons of material (pyritic sulfur). Acid-base

Table 22. Summary geochemical and physical characteristics of analyzed coal overburden samples from the Matanuska Valley.

Overburden parameter	Range	Mean	Units
Paste pH	4.7-9.0	7.3	pH
Electrical conductivity	0.1-2.2	0.6	umho/cm
Saturation percentage	20-56	36.3	%
Water soluble cations			
Calcium	0.3-9.9	1.1	meq/liter
Magnesium	0.1-7.0	1.7	
Sodium	0.4-24.0	3.5	
Potassium (saturated paste)	1.4-17.2	7.4	mg/l
Sodium adsorption ratio	0.2-36.9	5.8	ratio
Exchangeable sodium percentage	1.0-55.7	12.2	%
Particle size			
Sand	9-85	59.2	%
Silt	9-53	18.8	
Clay	5-49	22.0	
Texture	C, CL, L, LS, SL, SCL, SiCl	- -	- -
Organic matter	0.9-32.0	5.1	%
Extractable nutrients			
Nitrate nitrogen (NO_3-N)	0.5-5.0	2.3	ppm
Phosphorous	<1.0-10.4	<1.6	
Potassium	39-252	128	
Pyritic sulfur	<0.01-0.4	<0.02	%
SO_4 sulfur	<0.01-0.1	<0.01	%
Organic sulfur	<0.01-0.76	0.11	%
Total sulfur	<0.01-0.78	0.12	%
Lime	<0.01-1.5	0.6	%
Acid potential (total sulfur)	-19.4-12.4	1.9	Tons $CaCO_3$ equivalent/ 1,000 tons
Acid potential (pyritic sulfur)	-0.9-14.4	5.4	do.
Trace elements			
Boron	1.50-5.30	3.05	ppm
Copper	0.24-18.88	3.53	
Molybdenum	<0.10-1.45	<.16	
Lead	0.14-7.04	1.12	
Selenium	<0.01	<0.01	

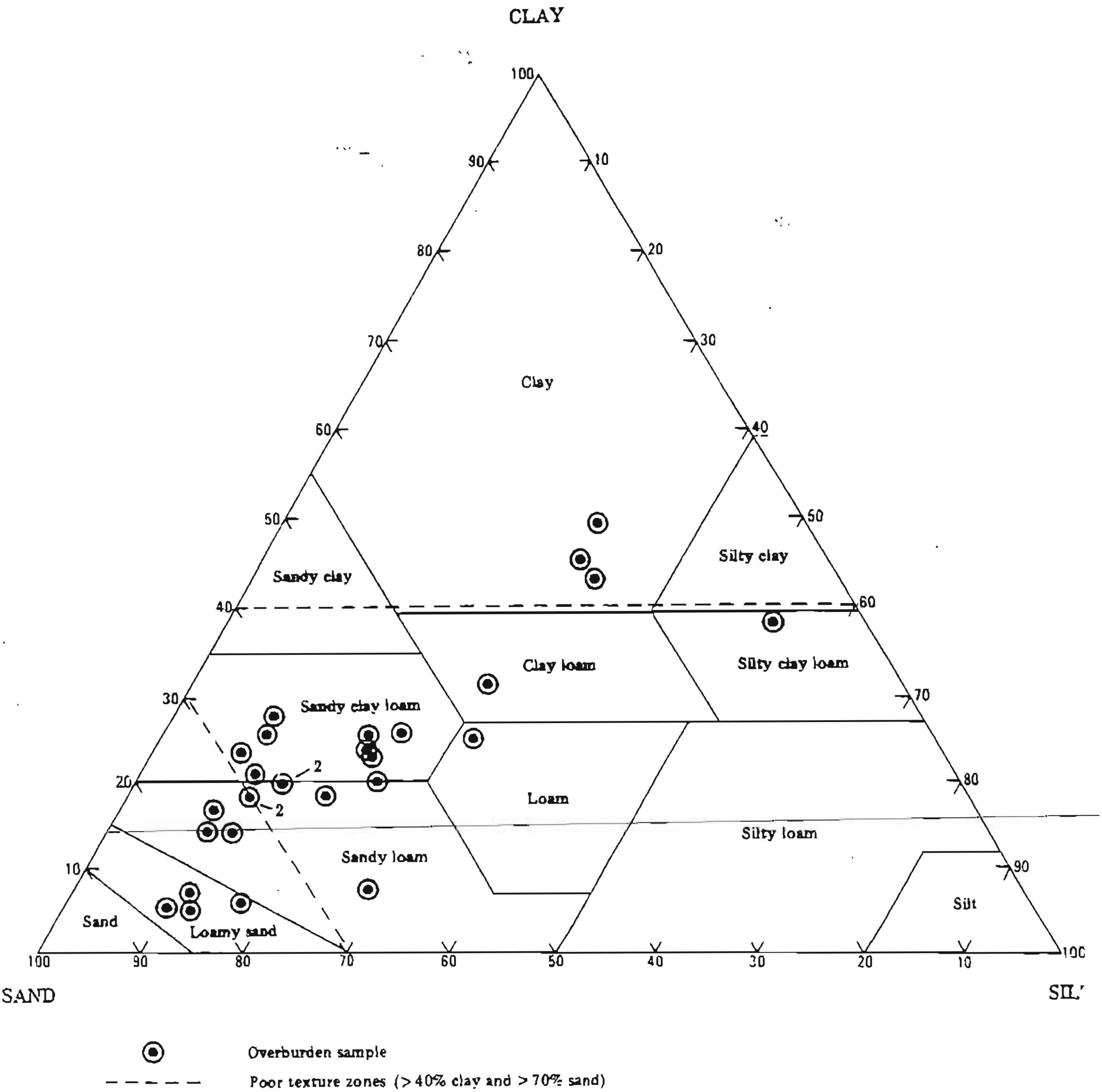


Figure 68. Ternary plot of particle sizes and textures for analyzed Matanuska Valley coal-overburden samples.

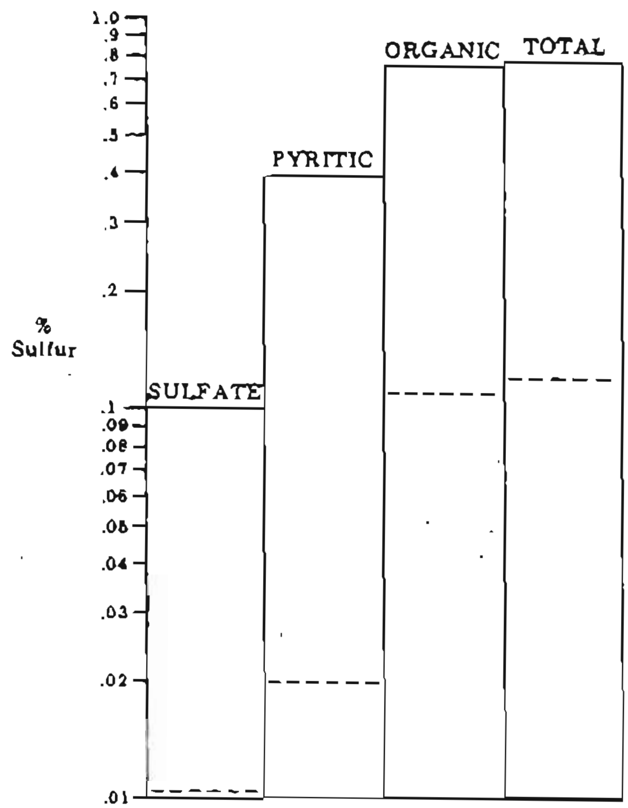


Figure 69. Bar graph showing the range and arithmetic mean values for the percent total sulfur and sulfur forms of 27 analyzed Matanuska Valley coal-overburden samples.

profiles are presented in figures 70 through 76 for several Chickaloon Formation coal-bearing sections from the Matanuska Valley. Sample codes and paste pH, pyritic sulfur, total sulfur, lime, and organic matter values are annotated to the profile sections for convenience in interpretation. The Wishbone Hill section (figs. 75 and 76) does reveal three samples exhibiting significant deficiencies of 10 to 20 tons $CaCO_3$ equivalent per 1,000 tons of material. Most of the other sections---including Mrak mine area, Coal Creek, Matanuska River, Castle Mountain, and Purinton Creek---show prevalent excesses in inherent neutralizers.

Electrical conductivity, saturation percentage, sodium adsorption ratios, exchangeable sodium percentages, organic matter, and trace elements all fall within limits set for good soil suitability characteristics (compare table 22 with the guideline criteria of tables G2 and G3 of appendix G). Levels of extractable major nutrients may indicate the necessity of soil amendments, particularly of nitrates and phosphorous and locally potassium.

Generally speaking, the overburden character of Matanuska Valley samples examined during this evaluation support conclusions of earlier research. Overall, this shows that few problems can be expected with regard to the physical and geochemical properties of these ultimate minesoil materials and that future reclamation and revegetation programs should be successful.

HYDROLOGY

The sparse hydrologic data that have been collected in the Matanuska Valley are for the stream basins of the Wishbone Hill district. Most hydrologic data that have been collected are for Moose and Eska Creeks (table 23). Gloryhole and Knob Creeks are important feeder streams of Eska Creek, which has a drainage area of 13.4 mi^2 at Sutton. The drainage basins of the region are narrow and precipitous with sparse vegetation. Flooding in the past has been severe on occasion. Moose Creek particularly has had a long history of flooding which has damaged railroad beds and tracks into the area; the track was last rehabilitated in 1941 but was destroyed again in 1942 (Barnes and Payne, 1956; Kreig and Associates, 1983).

In general, drainages of basins supplied by glacially-fed streams remain higher in the summer months. Lower stream flows typify late winter, and higher flows follow spring breakup and after heavy summer and fall rains. No significant data are available on suspended sediment yields for the streams. However, predominant bicarbonate dissolved solids are lowest during periods of high flow, and highest in winter and early spring minimum-flow periods. Hydrogeochemical analyses reveal low total iron levels (Kreig and Associates, 1983).

CONCLUSIONS

There are a large number of variable factors that bear on the economic viability of the Matanuska field coal deposits. They are situated near rail, highway, and deep-water ocean transportation. The main reason for the construction of the railroad through the valley was interest in coal

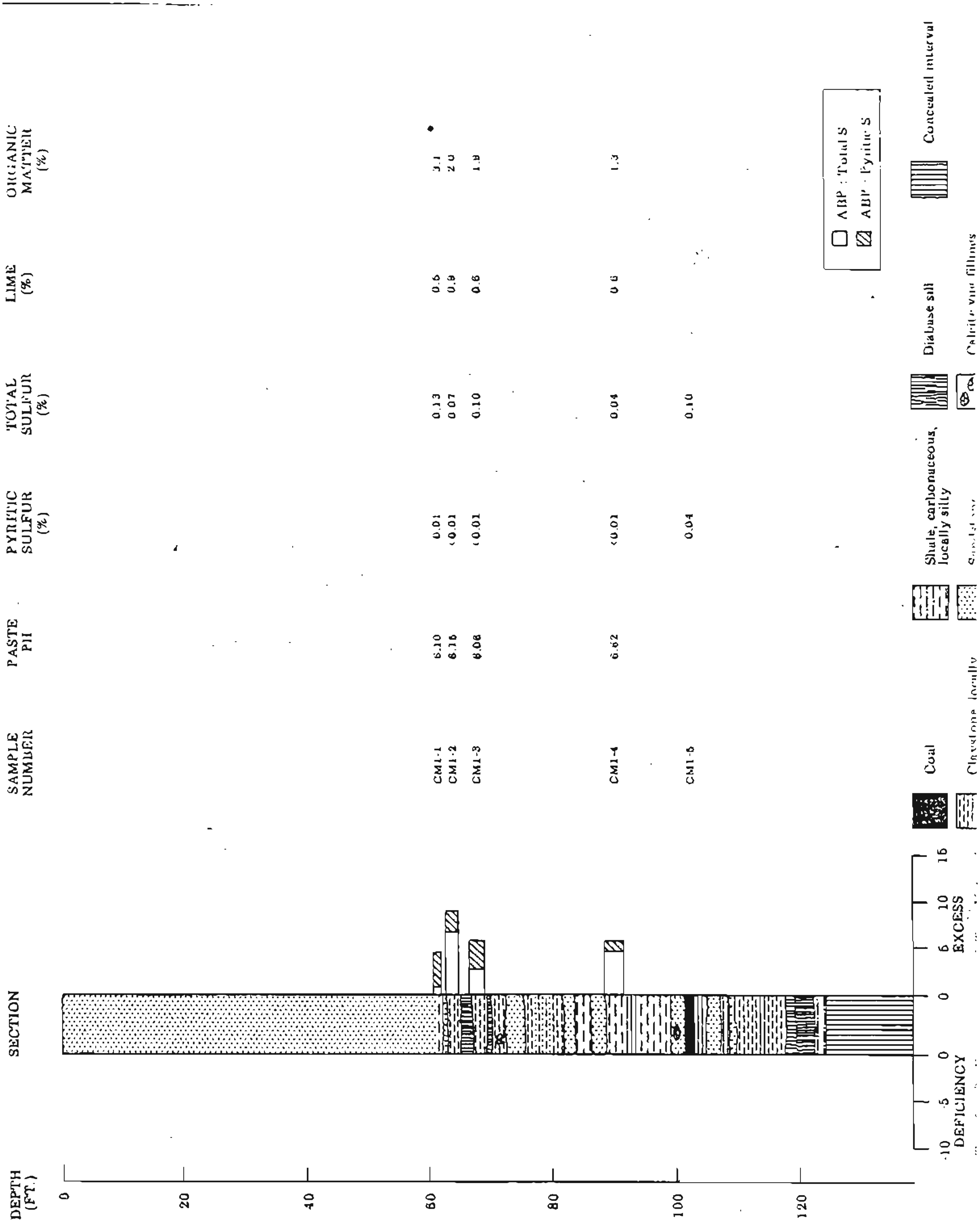


Figure 70. Acid-base account and other geochemical characteristics for overburden samples of a Castle Mountain coal-bearing section (site CM1).

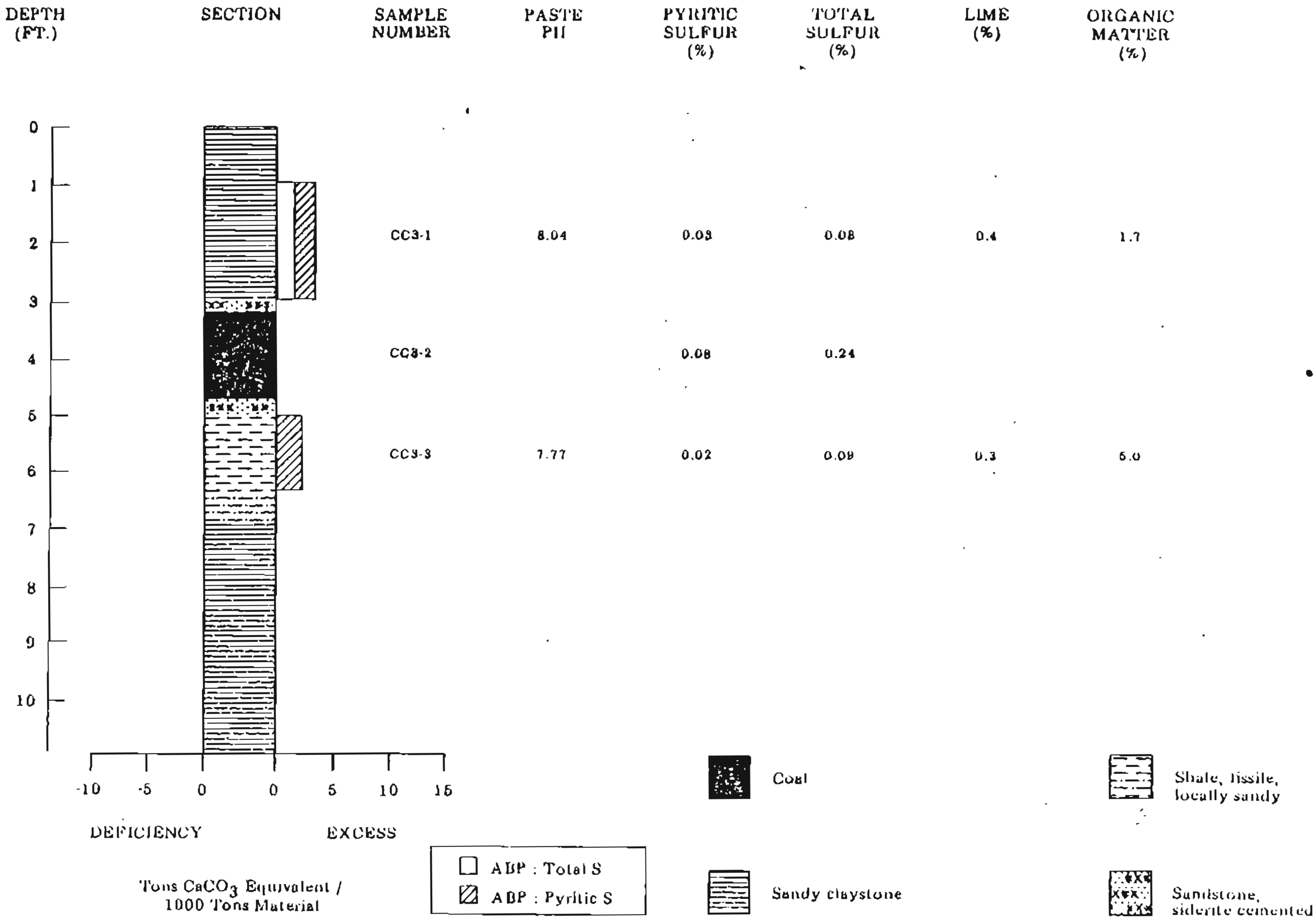
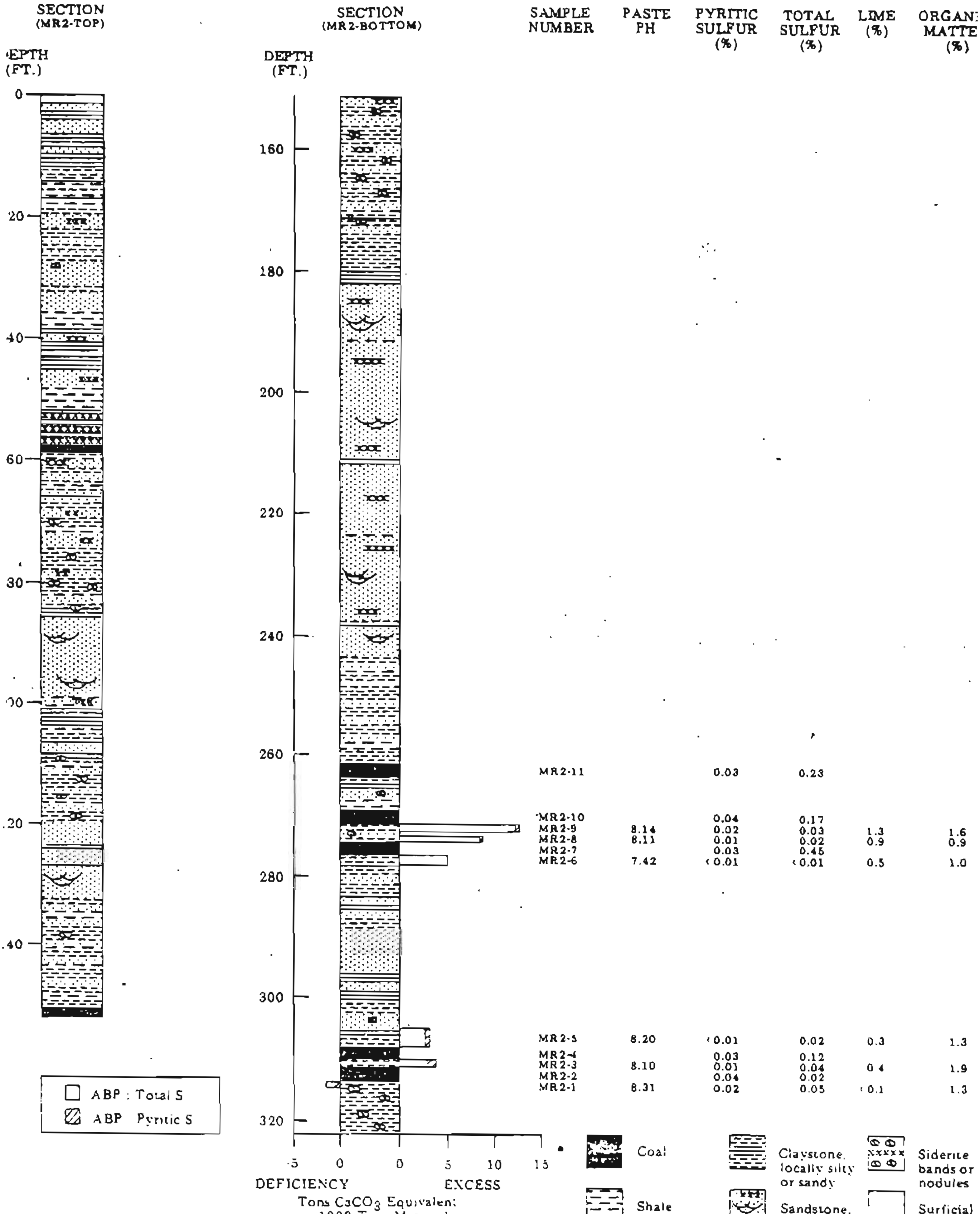


Figure 71. Acid-base account and other geochemical characteristics for overburden samples of a Coal Creek coal-bearing section (site CC3).



SAMPLE NUMBER	PASTE PH	PYRITIC SULFUR (%)	TOTAL SULFUR (%)	LIME (%)	ORGANIC MATTER (%)
MR2-11		0.03	0.23		
MR2-10		0.04	0.17		
MR2-9	8.14	0.02	0.03	1.3	1.6
MR2-8	8.11	0.01	0.02	0.9	0.9
MR2-7		0.03	0.45		
MR2-6	7.42	<0.01	<0.01	0.5	1.0
MR2-5	8.20	<0.01	0.02	0.3	1.3
MR2-4		0.03	0.12		
MR2-3	8.10	0.01	0.04	0.4	1.9
MR2-2		0.04	0.02		
MR2-1	8.31	0.02	0.05	<0.1	1.3

Figure 72. Acid-base account and other geochemical characteristics for overburden samples of a Matanuska River coal-bearing section (site MR2).

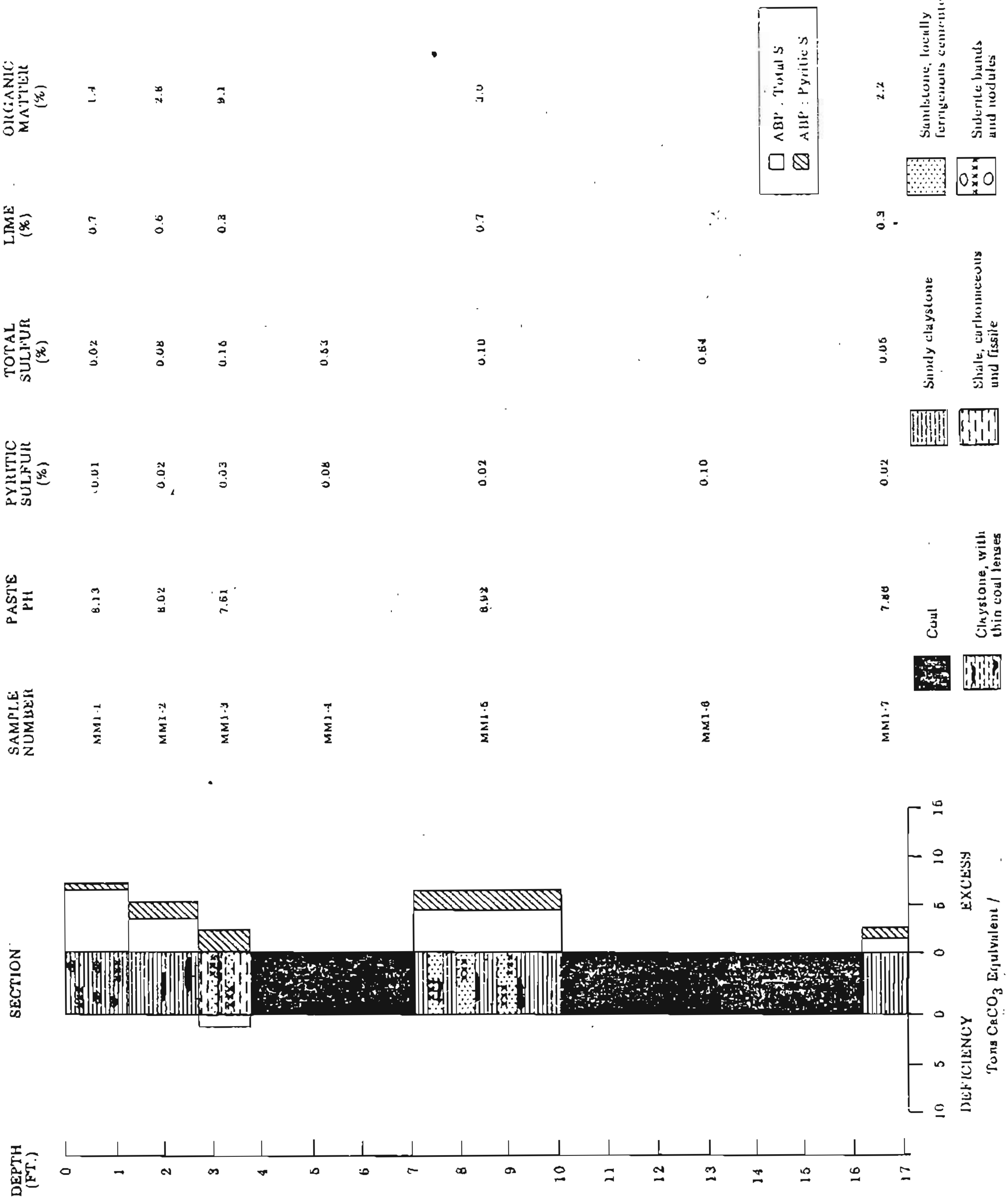
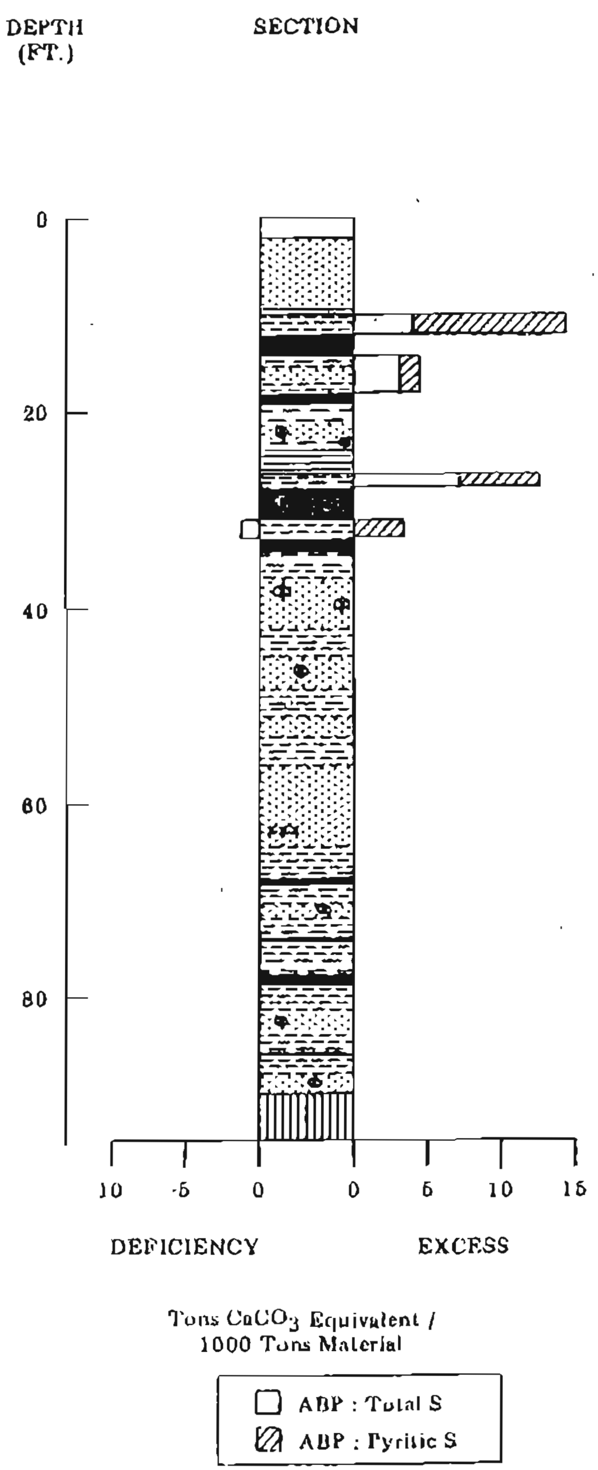


Figure 73. Acid-base account and other geochemical characteristics for overburden samples from a Mrak mine area coal-bearing section (site MM1).



SAMPLE NUMBER	PASTE PH	PYRITIC SULFUR (%)	TOTAL SULFUR (%)	LIME (%)	ORGANIC MATTER (%)
PC6-1	5.81	0.02	0.36	1.5	31.0
PC6-2		0.02	0.49		
PC6-3	5.12	0.02	0.06	0.6	3.7
PC6-4	4.68	0.02	0.19	1.3	32.0
PC6-5		0.02	0.34		
PC6-6	5.20	0.02	0.17	0.4	7.7

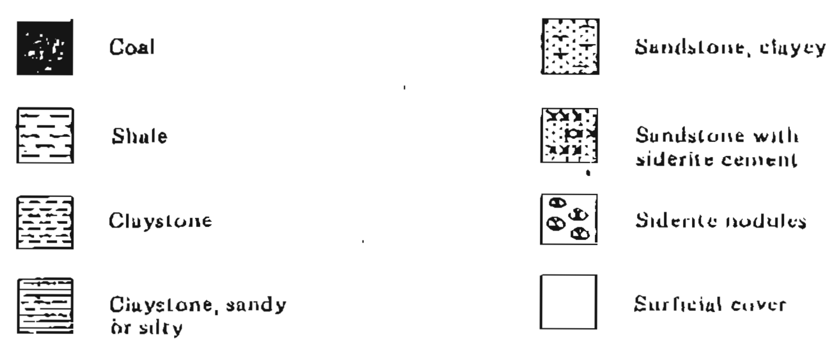


Figure 74. Acid-base account and other geochemical characteristics for

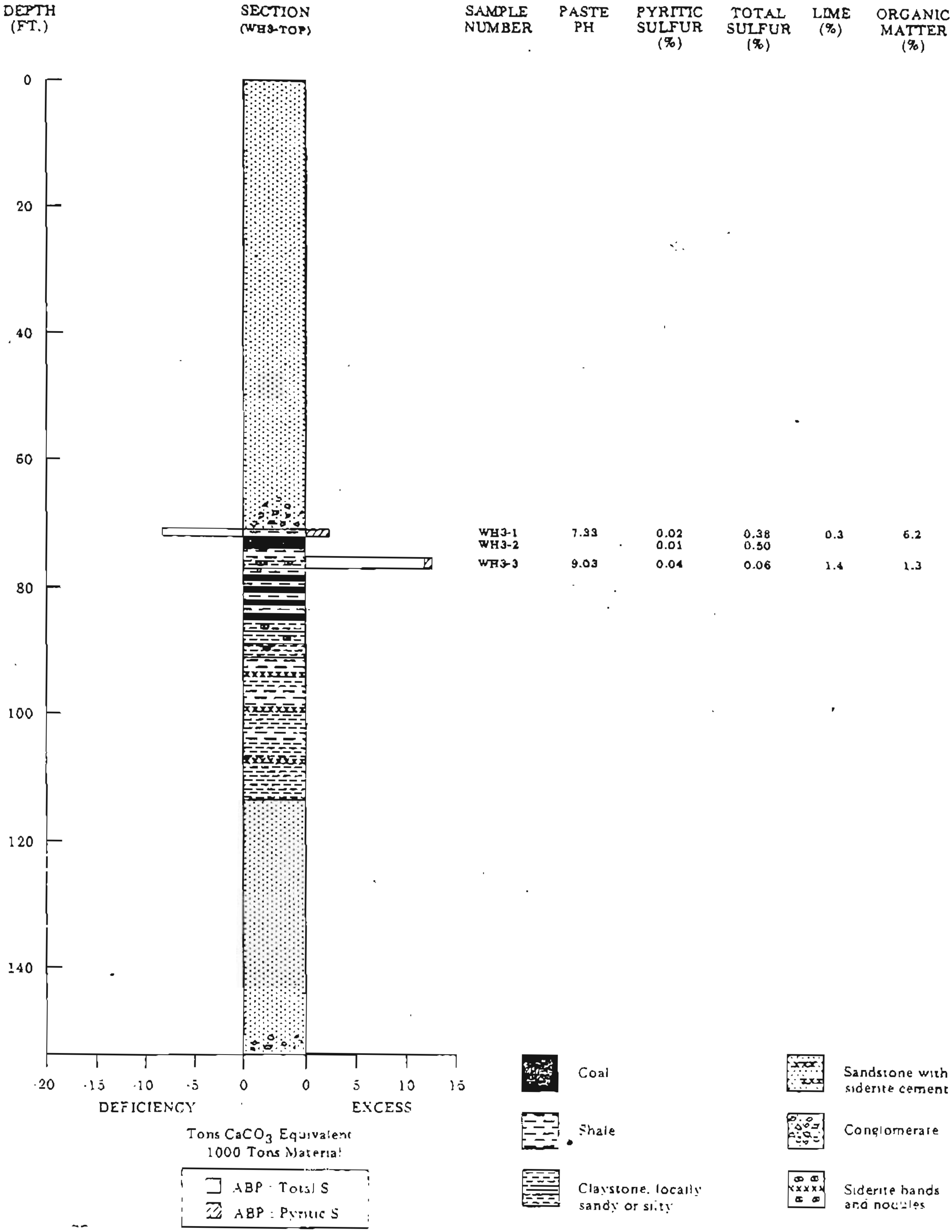
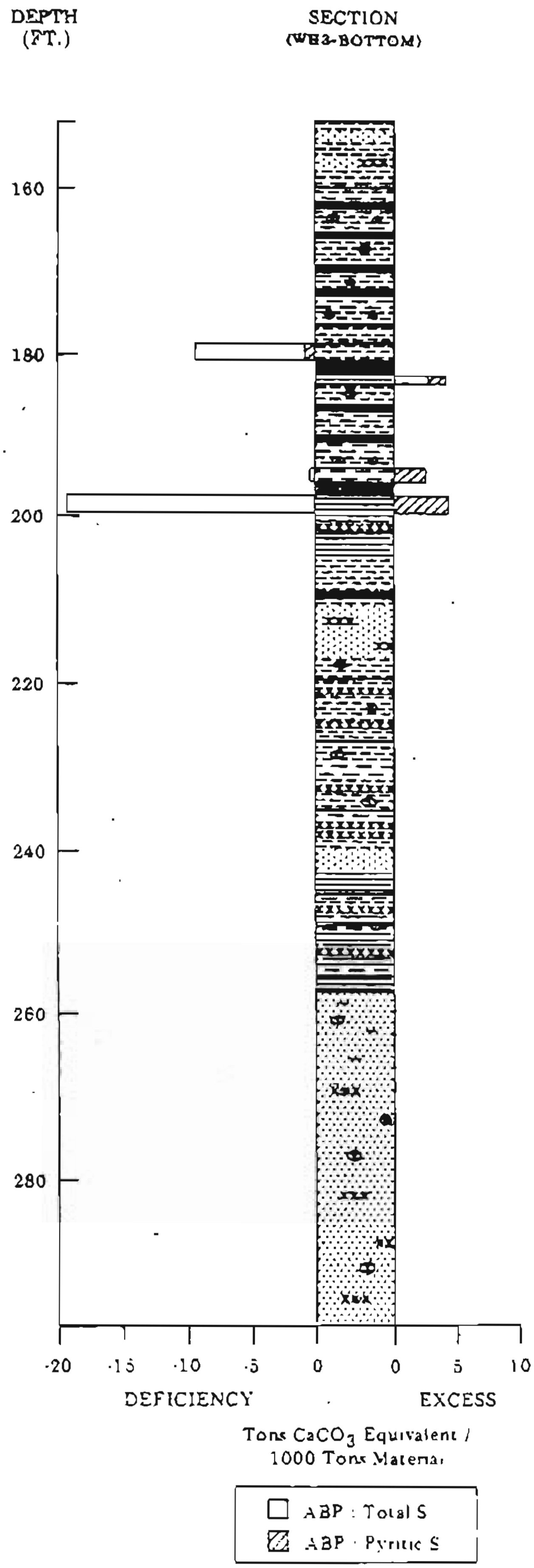


Figure 75. Acid-base account and other geochemical characteristics for overburden samples of a Wishbone Hill coal-bearing section (site WH3, top).



SAMPLE NUMBER	PASTE PH	PYRITIC SULFUR (%)	TOTAL SULFUR (%)	LIME (%)	ORGANIC MATTER (%)
WH3-4	8.11	0.03	0.13	<0.1	2.6
WH3-5		0.01	0.34		
WH3-6	8.38	<0.01	0.04	0.4	1.2
WH3-7	8.08	0.01	0.10	0.3	7.6
WH3-8		0.01	0.25		
WH3-9	8.66	0.02	0.78	0.5	3.7

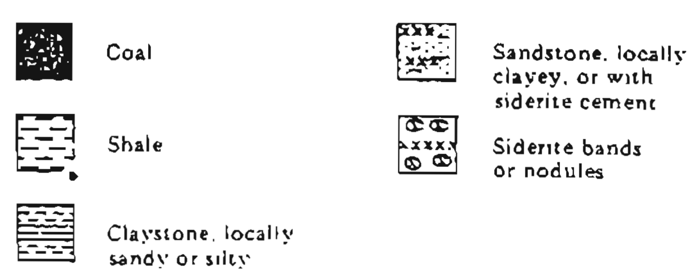


Figure 76. Acid-base account and other geochemical characteristics for overburden samples of a Wishbone Hill coal-bearing section (site WH3, bottom).

Table 23. Dissolved solids, total iron, and hydrologic flow data for Moose and Eska Creeks, Wishbone Hill district. Adapted from Kreig and Associates, 1983.

Drainage	Flow (cfs)*	Total iron (mg/l)*	Dissolved solids (mg/l)*
Moose Creek	108 (8/1955)	0.01-0.03	70.76 (winters 1951/52)
(Buffalo and Premier mines area)	373 (7/1956)	(1951/1952)	41-57 (summer and fall levels, 1951/1952)
Eska Creek	1,680 (peak flow, 8/1971)	0.01-0.03 (6/1951)	70 (3/1956)
(Evan Jones Mine area)		No iron (3/1956)	32-44 (6/1951)

*cfs = cubic ft per second; mg/l = milligrams per liter.

development. The lower Matanuska Valley has been the site of most historic production and will be the probable site of most near-term future production.

It is evident that structural complexity in the region will add to exploration, development, and mining costs. The structure in the region has had a significant influence on mining operations in the past and will continue to do so in the future. Faulting and folding complicates mining potential and directly affects the direction and extent of mining. Careful investigations of structural conditions and underground exploration will be required to determine the minability of particular tracts. In general, dips are too steep for use of continuous miners. The numerous faults may prevent mining of certain blocks, but relatively large and undisturbed minable blocks are present in the lower Matanuska Valley. Faults with displacements of inches to several feet may not seriously interfere with mining operations. However, larger-scale faults with displacements of hundreds of feet will have a great practical import to mining. Some overlying lower quality coal beds may be lost by the extraction of underlying higher quality seams first. The overall quality of Matanuska Valley coals is suitable for power-generating purposes.

Mining at Chickaloon and exploration at Coal Creek have shown that several problems may be encountered in coal deposits of central Matanuska Valley. These include: 1) Lack of persistence of coal beds along strike; 2) pinch and swell of beds within short distances; 3) numerous faults, some of large displacement; 4) presence of dikes and sills intruding the coal measures deteriorating their quality or cutting them out; 5) presence of impurities necessitating crushing and washing; 6) local abundance of coal-bed gas that may be problematic in underground mining and will necessitate adequate ventilation; and 7) steep angle-of-dips of coal beds (Capps, 1927). The latter problem resulted in the adoption of 'pitch-mining' methods at early mines in this region. By this method, coal broken from working faces moves by gravity sliding down sheet-metal-bottomed chutes to haulageways. Mine facilities of this type are still observable at the old Hecky mine on Coal Creek.

Although there has been considerable exploration completed on the high-rank coals in the upper Matanuska Valley, no development work has taken place, and they have not been mined because of the highly complex structure, numerous large and small intrusives cutting the coal-bearing series, and projected high mining costs. Extensive surface and underground exploration will be required to prove workable bodies of anthracite. The known area of anthracite is small and lies on high slopes of the mountain ridge---2,700 to 3,000 ft above the Matanuska River. Whether a successful anthracite mine will ever be developed here is questionable. Assuredly, any mine would be small-scale and supply only token amounts of high quality metallurgical or other specialty-type coal.

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APPENDIX A

Table A1. Chronology of events in Matanuska Valley coal mine development (from Martin, 1906b; Martin and Katz, 1912; Chapin, 1920, 1921; Waring, 1936; Tuck, 1937b; Apell, 1944; Barnes and Payne, 1956; McFarland, 1961; Alaska Geological Society, 1964; Patsch, 1981; and Clardy, 1982).

1868	Reconnaissance expeditions first begin into the Matanuska Valley.
1894	Occurrence of coal in Matanuska Valley learned about from Indians by prospectors and traders.
1895	Preliminary investigation of the coals along the Pacific seaboard of Alaska is conducted.
1896	W.H. Dall's report on the coal and lignite of Alaska is published.
1898	Exploration of the Susitna Valley is made by G.H. Eldridge.
1898-99	Matanuska Valley region is crossed by U.S. Army exploration parties. W.C. Mendenhall of Federal Geological Survey accompanied them, and his report included a topographic map of the region and descriptions of geographic and geologic features.
1903	Alaska Northern Railroad construction began. Very minor production of coal begins in Matanuska Valley.
1905	G.C. Martin completed a reconnaissance survey of the coal deposits of the Matanuska Valley including the Anthracite Ridge district. Coal prospecting takes place on bluff outcrops on north side of Chickaloon River.
1906	Martin's report on the coal in the Matanuska field is published. Matanuska Valley region was visited by a Federal Geological Survey party including two topographers (R.H. Sargent and T.G. Gerdine) and two geologists (Sidney Paige and Adolph Knopf). Use of coal for locomotive fuel is discontinued when entry to Alaskan coal lands is denied by the federal government.
1907	Publication of report by Paige and Knopf including a reconnaissance map of topography and geology in Matanuska Valley at scale of 1:250,000 and complete section of Tertiary and Mesozoic rocks is measured and described.
1909	Topographic survey of the lower Matanuska Valley is made by R.H. Sargent.
1910	G.C. Martin and F.J. Katz made a detailed geologic survey of the lower Matanuska Valley.

1912 Report of Martin and Katz on the lower Matanuska Valley published. It distinguishes and names the Chickaloon Formation and the Eska Conglomerate.

1913 1,100 tons of coal are extracted by U.S. Bureau of Mines from the Chickaloon Naval resource on the north side of the Chickaloon River. Over half was used for a steaming test on the U.S.S. Maryland and found to be suitable. G.C. Martin and J.B. Mertie, Jr. conducted geologic study of the middle and upper Matanuska Valley giving emphasis to the coal deposits.

1913-29 A total of 25,000 tons are produced at Chickaloon incident to development and by small-scale mining.

1914 Martin and Mertie publish their preliminary geologic report on the middle and upper Matanuska Valley. U.S. Congress passes the Coal Leasing Act.

1915 The Matanuska coal field is subdivided into 19 leasing units and government reservations by U.S. Bureau of Mines and permits were granted for coal prospecting. Alaska Northern Railroad is purchased by government and construction of the Alaska Railroad to Fairbanks begins.

1916 Coal land units in Matanuska Valley are first offered for leasing. Mining in the Wishbone Hill district of the Matanuska Valley begins with completion of the Moose Creek branch of the Alaska Railroad and the opening of the Doherty mine about 0.75 mi above the mouth of Moose Creek.

1917 The Eska mine is opened by William Martin and Associates and later is purchased by the Alaska Railroad. A branch of the Alaska Railroad is extended to Chickaloon. Chickaloon Coal Company drove three tunnels west of Chickaloon and drilled two core holes proving that the coals thinned toward the west and were not of great commercial value. G.C. Martin revisits the Matanuska Valley.

1917-18 The Baxter mine opens and produces coal during winter.

1918 A railroad spur is constructed to the Eska mine.

1918-19 Theodore Chapin studied structures of coal beds of Matanuska Valley and published two reports.

1918-20 Eska mine is only one in operation in Wishbone Hill district.

1919 G.C. Martin published progress report on mining developments in Matanuska Valley. Government-operated Chickaloon mine opened with 35 men producing over 4,000 tons of coal incidental to development.

1920 The Evan Jones mine is opened.

1920-21 Chapin published progress report on mining developments in Matanuska Valley. Exploratory work is completed by U.S. Navy Alaskan Coal Commission at Chickaloon. Two tunnels are driven, one into a 9-ft thick bed for 70 ft and ended in intrusive rock. A second entry 100 ft down-dip loses coal at fault-contact with upper Cretaceous rocks.

1921 Evan Jones mine began production on significant scale. The Eska mine is closed by government when coal from private operators supplants demand. Baxter mine is reopened for a short time. The Rawson mine is opened.

1921-22 U.S. Navy prospected coal beds on east side of Coal Creek including driving two tunnels near the creek, sinking numerous pits, and drilling of eight diamond drill holes on benchland east of the creek. U.S. Navy development work ended in Chickaloon district.

1922 Final report by Captain W.P.T. Hill of the Navy included studies on and recommendations relating to the Anthracite Ridge district. Development work at Premier mine began. Eska mine reopened when fire temporarily shut down the Evan Jones mine. Four different mines are in operation at various times in the district.

1923 Evan Jones mine reopened and Eska mine closed down again. The Baxter mine continued to produce some coal and new development work began at Rawson Mine.

1924 S.R. Capps and K.K. Landes completed reconnaissance geology of the Anthracite Ridge district and Chugach Mountains along the south side of Matanuska River.

1924-30 Test well for oil was drilled about 2 mi west of Chickaloon to a depth of 1,465 ft.

1925 Evan Jones and Premier mines are the principal coal producers of the district. Development work on the Evan Jones mine tunnel on the north limb of Wishbone Hill syncline began. The Alaska Railroad is extended to the Matanuska Center mine which began production. Alaska Matanuska Coal Company opened the Premier mine. The Baxter mine is finally abandoned after depletion of resources. Coal Creek mine is opened by Ross S. Hecky on west side of creek in beds prospected earlier by the U.S. Navy on the opposite side.

1925-30 1,650 tons of coal are produced and sold from the Hecky mine to the railroad which converted it to coke in an oven at Anchorage and used the product in the foundry of the railroad shops.

1926 The Rawson mine is closed. After the rail to the Premier mine is upgraded, it becomes the chief coal producer in Moose Creek district.

1928 The Doherty mine is reopened as the Pioneer mine. The Matanuska Center mine is closed.

1929 The Alaska Matanuska mine is closed.

1930 The federal government (through the Alaska Railroad and the U.S. Geological Survey) authorized the expenditure of $250,000 to investigate the mineral resources adjacent to the railroad.

1931 A detailed topographic and geologic survey and study of the coal deposits of the Anthracite Ridge district is completed by geologists R.W. Richards and G.A. Waring.

1932 Wishbone Hill Coal Company produced a small quantity of coal from the Rawson mine. Eight diamond drill holes were sank south of Anthracite Ridge with over 8,000 ft core-drilled. A government-sponsored diamond-drilling project was carried out in an attempt to locate minable coal beds west of Moose Creek near the southwest end of the Wishbone Hill district. Five holes were drilled about 1.5 mi southwest of the Premier mine, but no minable coal beds were discovered.

1933 Report of Richards and Waring conclude that outcropping beds in the Anthracite Ridge district were not of economic importance. Underground workings of the Premier mine were flooded.

1934 The New Black Diamond Coal Company takes over the workings at the Rawson mine.

1935 Total production at the Eska mine reached 215,000 tons, with only 6,000 tons mined prior to its purchase by the railroad.

1937 Ralph Tuck's topographic and geologic survey results of the eastern part of the Wishbone Hill district are published. An explosion at the Evan Jones mine takes lives of 14 men and shuts down operations. The Eska mine opens to meet coal demand.

1939-44 Mapping of the underground workings and geology of the Eska mine is completed by F.F. Barnes of the Alaska Railroad including surface prospecting on the eastern part of the district.

1940 Government-owned Eska mine is reopened.

1941 Both the Evan Jones and Eska mines are in full-time production.

1942 World War II stimulated increased production throughout the Wishbone Hill district. A drilling and trenching program began by U.S. Bureau of Mines on Moose Creek to extend the known area of minable coal deposits and prove additional tonnage as a stimulus to mine development.

1943 The Premier mine closed after producing some 165,000 tons of coal. G.O. Gates of the Federal Geological Survey completed a geological map of the Wishbone Hill area began by Ralph Tuck in 1934. A military coal commission was sent to Alaska and headquartered at Ft. Richardson in 1943 to investigate the coal resources of the territory and stimulate additional production in favorable areas.

1944 Eleven drill holes and several trenches on Moose Creek are completed. Total coal production at all Moose Creek mines reaches 250,000 tons.

1945 Three holes are drilled by the U.S. Bureau of Mines in the Eska area of eastern part of Wishbone Hill district.

1946 Eska mine is closed again.

1947-48 Nine holes are drilled by U.S. Bureau of Mines in extreme northeastern part of the Wishbone Hill district in an attempt to prove reserves east of the Eska East mine workings.

1949 Drilling was conducted in the southern part of the Wishbone Hill district west of Jonesville but was unsuccessful because the coal-bearing formation is covered by glacial deposits, talus, and landslide debris.

1949-58 U.S. Bureau of Mines core-drilling program on the north slope of Wishbone Hill is conducted.

1950 Surface mining of coal begins in Alaska when stripping began on outcrop of Evan Jones lease on the north side of Wishbone Hill.

1950-52 Drilling is extended north and west into area where the coal-bearing formation is overlain by a thick cap of conglomerate that forms the central part of Wishbone Hill.

1952 Nine different mines have been in operation in the Wishbone Hill district but only four were ever in operation at the same time.

1953 Maximum Alaska annual coal production over 285,000 tons attained. Underground prospecting and development begins at Mrak mine in the eastern part of the Wishbone Hill district.

1955 All production at Mrak mine is now from stripping.

1956 Barnes and Payne's report is published, describing in detail the structure and stratigraphy of the Wishbone Hill district. Placer Amex, Inc. (now Placer U.S., Inc.) purchased an interest in the Evan Jones Coal Company.

1959 All underground operations at the Evan Jones mine are phased out.

1968 When Evan Jones mine closed, its total life-time production over 48 years was 6 million tons. Conversion of two large military bases near Anchorage from coal to Cook Inlet natural gas forced closure of Matanuska Valley coal mines. The plants and equipment at the mine are sold, and the Palmer to Jonesville rails are pulled by the Alaska Railroad. Total estimated coal production in the Matanuska Valley is over 7.5 million tons.

APPENDIX B

Table B1. State of Alaska coal leases, Matanuska Valley.

Name	ADL	Description	Acres	Issued
Hawley Resource Properties, Inc.	32136	T. 19 N., R. 2 E., SM Sec. 13: NE¼ SW¼, NW¼ SE¼, SW¼ NE¼, N½ NW¼ SW¼, SE¼ NW¼ SW¼, S½ NW¼	230±	3/1/59
Hawley Resource Properties, Inc.	23803	T. 19 N., R. 2 E., SM Sec. 13: SW¼ SW¼, SW¼ NW¼ SW¼ 14: S½ NE¼ SE¼ S½ SW¼ SE¼ 23: N½ NE¼ NE¼	150±	7/8/64
Hawley Resource Properties, Inc.	32144	T. 19 N., R. 2 E., SM Sec. 22: S½ SW¼, W½ SE¼ 27: N½, N½ S½ 28: N½ SE¼, SE¼ NE¼, S½ SW¼ NE¼, NW¼ SW¼ NE¼	760±	2/1/66
R.W. Gore	33978	T. 20 N., R. 5 E., SM Sec. 21: N½ NE¼ 22: W½ NW¼ NW¼	100±	8/1/58
R.W. Gore	53509	T. 20 N., R. 5 E., SM Sec. 21: S½ NE¼	80±	3/25/68
American Exploration & Mining Co.	324600	T. 19 N., R. 3 E., SM Sec. 16: SW¼ NW¼, NE¼ SE¼ NW¼, W½ NE¼ SW¼, NW¼ SW¼, S½ SW¼ 17: S½, S½ N½ 18: SE¼, E½ SW¼, SE¼ NE¼ 19: NE¼, E½ NW¼	1,210±	8/10/70
Hawley Resource Properties, Inc.	309947	T. 19 N., R. 2 E., SM Sec. 22: E½ SE¼ 23: NW¼, W½ NE¼, N½ SW¼	400±	11/15/66

APPENDIX C

Table C1. Summary of drill-hole data, Matanuska coal field.

Map drill hole no. (pl. 2)	Reference drill hole	Reference report*	Total coal thickness (ft)	Elevation		Total depth (ft)	Thickest bed (ft)	Total coal thickness in		
				Top	Bottom			Beds >1 ft	Beds >2 ft	Beds >3 ft
1	DDH-6	1	30	788	-10	798	3.0	25	10	3
2	DDH-7	1	4	825	460	492[a]	2.0	4	4	0
3	DDH-8	1	22	883	350	731[a]	8.0	22	15	12
4	P-1	6	81	899	307	837[a]	8.0	70	61	43
5	MC17	6	0	892	801	91	0	0	0	0
6	MC15	6	48	849	-197	1046	20.1	50	38	34
7	MC14	6	2	847	199	648	2.0	1	0	0
8	MC13	6	0	863	703	160	0	0	0	0
9	MC12	6	0	855	675	180	0	0	0	0
10	MC16	6	7	794	195	599	2.1	6	4	0
11	MC11	6	0	766	532	234	0	0	0	0
12	MC10	6	13	738	-64	802	1.7	11	5	0
13	MC9	6	29	800	-111	911	4.8	24	19	12
14	MC8	6	32	874	-107	981	5.3	27	17	8

*1-Barnes and Payne, 1956.
2-Evan Jones Coal Company, 1949.
3-Hill, W.P.T., 1923; hole elevations taken from 1:63,360 topographic maps.
4-Jolley, T.R., and Toenges, A.L., 1952.
5-Tuck, Ralph, 1937; information taken from generalized graphical drill hole log reports.
6-Warfield, R.S., 1962.
7-Waring, G.A., 1936.

[a]Hole inclined at 45°.
[b]Hole inclined at 60°.
[c]Hole inclined at 56°.
[d]Hole inclined at 42°.
[e]Hole inclined at 17°.
[f]Horizontally drilled.

Map drill hole no. (pl. 2)	Reference drill hole	Reference report*	Total coal thickness (ft)	Elevation		Total depth (ft)	Thickest bed (ft)	Total coal thickness in		
				Top	Bottom			Beds >1 ft	Beds >2 ft	Beds >3 ft
15	MC18	6	40	785	219	566	4.8	30	16	5
16	MC7	6	1	1150	-867	2017	0.3	0	0	0
17	MC6	6	0	1150	-52	1202	0	0	0	0
18	MC5	6	0	1107	185	922	0	0	0	0
19	MC4	6	17	1100	88	1012	5.9	16	15	13
20	MC3	6	19	1096	138	958	7.0	18	17	17
21	MC2	6	94	1084	-321	1405	9.8	88	71	54
22	MC1	6	84	1063	131	932	7.1	78	63	44
23	DDH1	1	37	1003	552	612[a]	5.0	32	19	17
24	DDH2	1	35	1007	588	558[a]	6.3	34	22	16
25	DDH5	1	29	969	505	630[a]	5.0	29	25	12
26	DDH3	1	47	1021	610	553[a]	7.8	43	25	7
27	DDH9	1	88	1027	382	645	14.0	88	84	75
28	DDH4	1	45	1099	728	408[b]	7.0	43	28	14
29	DDH10	1	77	1024	435	640[a]	11.0	77	77	69
30	DDH11	1	27	1014	660	490[a]	7.5	27	25	21
31	WH7	6	27	834	-129	963	2.7	21	7	0
32	WH8	6	20	833	-54	887	2.3	11	4	0
33	WH3	6	31	785	-573	1358	3.0	28	10	3
34	WH4	6	38	842	-156	998	4.8	34	21	9
35	WH1	6	38	835	-169	1004	4.2	29	19	11
36	WH5	6	25	871	135	736	4.6	19	15	8
37	WH6	6	16	857	446	411	3.1	11	7	3
38	WH2	6	11	740	-17	757	2.5	9	9	5
39	EJ-1	2	8	812	631	181	7.0	8	7	7
40	WH14	6	0	731	731	0[f]	0	0	0	0
41	WH11	6	41	1197	-903	2100	4.6	32	20	8
42	WH10	6	33	1032	-1068	2100	2.9	20	14	4
43	WH12	6	35	1171	-943	2114	4.4	26	11	8
44	WH9	6	35	1240	-864	2104	3.5	31	26	19
45	WH13	6	0	1646	-61	1707	0	0	0	0
46	15-16	4	34	1220	523	805[b]	4.8	31	26	18
47	14-16	4	4	1230	803	493[b]	3.2	3	3	3

Map drill hole no. (pl. 2)	Reference drill hole	Reference report*	Total coal thickness (ft)	Elevation		Total depth (ft)	Thickest bed (ft)	Total coal thickness in		
				Top	Bottom			Beds >1 ft	Beds >2 ft	Beds >3 ft
15	MC18	6	40	785	219	566	4.8	30	16	5
16	MC7	6	1	1150	-867	2017	0.3	0	0	0
17	MC6	6	0	1150	-52	1202	0	0	0	0
18	MC5	6	0	1107	185	922	0	0	0	0
19	MC4	6	17	1100	88	1012	5.9	16	15	13
20	MC3	6	19	1096	138	958	7.0	18	17	17
21	MC2	6	94	1084	-321	1405	9.8	88	71	54
22	MC1	6	84	1063	131	932	7.1	78	63	44
23	DDH1	1	37	1003	552	612[a]	5.0	32	19	17
24	DDH2	1	35	1007	588	558[a]	6.3	34	22	16
25	DDH5	1	29	969	505	630[a]	5.0	29	25	12
26	DDH3	1	47	1021	610	553[a]	7.8	43	25	7
27	DDH9	1	88	1027	382	645	14.0	88	84	75
28	DDH4	1	45	1099	728	408[b]	7.0	43	28	14
29	DDH10	1	77	1024	435	640[a]	11.0	77	77	69
30	DDH11	1	27	1014	660	490[a]	7.5	27	25	21
31	WH7	6	27	834	-129	963	2.7	21	7	0
32	WH8	6	20	833	-54	887	2.3	11	4	0
33	WH3	6	31	785	-573	1358	3.0	28	10	3
34	WH4	6	38	842	-156	998	4.8	34	21	9
35	WH1	6	38	835	-169	1004	4.2	29	19	11
36	WH5	6	25	871	135	736	4.6	19	15	8
37	WH6	6	16	857	446	411	3.1	11	7	3
38	WH2	6	11	740	-17	757	2.5	9	9	5
39	EJ-1	2	8	812	631	181	7.0	8	7	7
40	WH14	6	0	731	731	0[f]	0	0	0	0
41	WH11	6	41	1197	-903	2100	4.6	32	20	8
42	WH10	6	33	1032	-1068	2100	2.9	20	14	4
43	WH12	6	35	1171	-943	2114	4.4	26	11	8
44	WH9	6	35	1240	-864	2104	3.5	31	26	19
45	WH13	6	0	1646	-61	1707	0	0	0	0
46	15-16	4	34	1220	523	805[b]	4.8	31	26	18
47	14-16	4	4	1230	803	493[b]	3.2	3	3	3

Map drill hole no. (pl. 2)	Reference drill hole	Reference report*	Total coal thickness (ft)	Elevation		Total depth (ft)	Thickest bed (ft)	Total coal thickness in		
				Top	Bottom			Beds >1 ft	Beds >2 ft	Beds >3 ft
48	13-16	4	63	1370	721	783[c]	3.8	57	28	14
49	E-1	5	22	1040	932	108	10.0	22	22	22
50	E-2	5	10	1045	978	67	5.0	10	10	10
51	E-3	5	11	1050	990	60	6.0	11	11	11
52	E-4	5	3	1062	996	66	3.0	3	3	3
53	E-5	5	13	1086	1024	62	10.0	13	13	10
54	E-6	5	13	1109	1005	104	9.0	13	13	13
55	E-7	5	9	1128	1083	45	9.0	9	9	9
56	E-8	5	5	1136	1042	94	5.0	5	5	5
57	E-9	5	8	1102	1069	33	8.0	8	8	8
58	E-10	5	7	1072	1028	44	5.0	7	7	5
59	E-11	5	10	1044	966	78	5.0	10	7	5
60	E-12	5	8	1035	980	55	8.0	8	8	8
61	E-13	5	12	1035	970	65	12.0	12	12	12
62	E-14	5	14	1035	938	97	9.0	14	9	9
63	E-15	5	10	1040	963	77	8.0	10	8	8
64	E-16	5	7	1042	937	105	2.0	7	2	0
65	E-17	5	7	1062	988	74	7.0	7	7	7
66	E-18	5	0	1086	1040	46	0	0	0	0
67	E-19	5	0	1123	1078	45	0	0	0	0
68	E-20	5	0	1120	1073	47	0	0	0	0
69	E-21	5	0	1083	1046	37	0	0	0	0
70	E-22	5	10	1054	993	61	10.0	10	10	10
71	E-23	5	10	1047	983	64	10.0	10	10	10
72	E-24	5	2	1042	975	67	1.5	2	0	0
73	E-25	5	6	1031	980	51	6.0	6	6	6
74	E-26	5	0	1020	970	50	0	0	0	0
75	E-27	5	0	1030	978	52	0	0	0	0
76	E-28	5	5	1036	917	119	1.0	5	0	0
77	E-29	5	1	1021	903	118	0.5	0	0	0
78	E-30	5	3	1030	893	137	2.0	3	2	0
79	E-31	5	11	973	888	85	11.0	11	11	11
80	E-32	5	0	972	912	60	0	0	0	0

Map drill hole no. (pl. 2)	Reference drill hole	Reference report*	Total coal thickness (ft)	Elevation Top	Elevation Bottom	Total depth (ft)	Thickest bed (ft)	Total coal thickness in Beds >1 ft	Total coal thickness in Beds >2 ft	Total coal thickness in Beds >3 ft
81	E-33	5	12	972	927	45	12.0	12	12	12
82	E-34	5	0	972	938	34	0	0	0	0
83	E-35	5	0	969	820	149	0	0	0	0
84	E-36	5	8	1055	904	151	1.0	8	0	0
85	E-37	5	5	1066	906	160	1.0	5	0	0
86	E-38	5	2	1047	892	155	1.0	2	0	0
87	E-39	5	7	1040	862	178	1.0	7	0	0
88	E-40	5	2	1033	853	180	1.0	2	0	0
89	E-41	5	3	1026	900	126	3.0	3	3	3
90	E-42	5	19	1017	911	106	12.0	19	15	15
91	E-43	5	5	1021	846	175	1.5	5	0	0
92	E-44	5	0	1011	935	76	0	0	0	0
93	E-45	5	0	1008	900	108	0	0	0	0
94	E-46	5	5	1012	833	179	5.0	5	5	5
95	E-47	5	9	1013	928	85	8.0	9	8	8
96	1-15	4	37	1031	438	593	3.5	28	14	4
97	2-15	4	18	1039	632	407	2.3	12	2	0
98	3-15	4	29	1075	471	604	2.4	24	12	0
99	4-15	4	25	1064	638	426	2.9	21	10	0
100	5-15	4	27	1068	412	656	2.9	19	7	0
101	6-10	4	24	1121	496	625	3.5	19	7	7
102	7-10	4	42	1223	561	662	3.0	38	21	9
103	8-10	4	28	1223	543	680	3.1	19	9	3
104	9-10	4	24	1263	758	505	2.5	18	9	0
105	CC-1	3	0	1375	541	1180[a]	0	0	0	0
106	CC-2	3	16	1380	860	735[a]	8.1	15	13	11
107	CC-3	3	15	1385	918	660[a]	3.1	10	6	6
108	CC-6	3	0.6	1395	1112	400[a]	0.3	0	0	0
109	CC-5	3	22	1395	1104	435[d]	6.1	20	19	17
110	CC-4	3	41	1400	979	596[a]	6.3	39	29	25
111	CC-7	3	0.6	1415	920	700[a]	0.3	0	0	0
112	CC-8	3	35	1440	872	804[a]	7.0	33	26	21
113	C-9	3	12	1200	-145	1345	1.7	9	0	0

Map drill hole no. (pl. 2)	Reference drill hole	Reference report*	Total coal thickness (ft)	Elevation		Total depth (ft)	Thickest bed (ft)	Total coal thickness in		
				Top	Bottom			Beds >1 ft	Beds >2 ft	Beds >3 ft
114	SW A	7	0	2320	2030	994[e]	0	0	0	0
115	SW	7	0	2320	1451	869	0	0	0	0
116	SSW	7	0	2400	1422	978	0	0	0	0
117	S	7	0	2460	1350	1110	0	0	0	0
118	SE	7	0	2490	671	1819	0	0	0	0
119	C	7	0	2680	2004	676	0	0	0	0
120	NE	7	0	2950	2188	762	0	0	0	0
121	NW	7	0	2810	2017	793	0	0	0	0

APPENDIX D

Table D1. Matanuska Valley coal locales (studied by Merritt and Belowich, 1983) with general description of coal outcrops shown on plate 2. Sample analyses are given in appendixes F and G.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples: Coal	Samples: Over-burden	Comments
1	Boulder Creek	BC1	20 N.	6 E.	16	Few hundred ft	Several	Thin (1.0-1.5 ft or less)	Moderate	2 (BC1-1, BC1-2)	- -	Chickaloon Formation outcrop section on north side of lower Boulder Creek, east of Chickaloon River. Shaley coal beds with medium-gray claystones and siderite bands and nodules. Sandstone lenses near middle of section, increase toward base. Carbonaceous shale with ironstone nodules and platy, weathered thin coal lenses interlaminated. Rare replaced logs. Shrinkage cracks have resulted in prismatic fracturing in sandstones near midsection.
2	Billy Creek	BiC1	22 N.	9 E.	26	Less 100 ft exposed	None	- -	25°	- -	- -	Sedimentary-rock (Chickaloon Formation?) exposure on lower Billy Creek, tributary to Caribou Creek in Talkeetna Mountains. Gray to brownish-gray silty claystones with calcite lenses and a few ironstone nodules. Claystones are slightly carbonaceous and fracture into small chips and prisms.
3	Billy Creek	BiC2	22 N.	9 E.	26	Few hundred ft	None	- -	20°	- -	- -	Exposure of Cretaceous Matanuska Formation(?). Mainly bluish to purplish-gray silty claystones with abundant brachiopods and belemnites, calcite veins, and ironstone nodules.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples Coal	Samples Over-burden	Comments
4	Coal Creek	CC1	19 N.	6 E.	5	275 ft	Six	5 ft	About 45°	6 (CC1-1, -2, -3, -4, -5, -6)	- -	Chickaloon Formation section on lower Coal Creek, south of Matanuska River and east of Kings Mountain. Common sequence of beds: intrusive sill, coke, coal, coke, intrusive sill. Prismatic fracturing locally evident in coke. Fissile shales. Siderite and ironstone bands and nodules.
5	Coal Creek	CC2	20 N.	6 E.	31	- -	- -	- -	- -	- -	- -	Site of old abandoned coal mine on lower Coal Creek (Hecky Mine). Tipple, adits, old buildings and structures, rail track, and other signs of former development present.
6	Coal Creek	CC3	20 N.	6 E.	31	About 75 ft	One	1.5 ft	30°	1 (CC3-2)	2 (CC3-1, -3)	Site on west side of Coal Creek about 1,500 ft south of old abandoned mine. Coal-bearing exposures along top of ridge above Coal Creek. Chickaloon Formation strata with coaly shales and claystones and iron-cemented sandstone beds typically <1 ft; abundant siderite nodules and bands. Minor faults indicated by drag of beds. Material loose and broken up and very prone to slumps and slides. Plant fossils (leaf impressions) in both claystones and siltstones. Roof and floor materials sampled. Coked coal seam and diabase 100 ft to northwest and 50 ft stratigraphically below site CC3.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples: Coal	Samples: Over-burden	Comments
7	Coal Creek	CC4	20 N.	6 E.	31	Less 100 ft	Two	2.0 ft	65°	2 (CC4-1, -2)	- -	About 0.25 mi northwest of outcrop at CC3 and stratigraphically below that section. A 30-ft-thick, massive, hard and dense sandstone overlies 6 ft of carbonaceous, sandy, firm claystone and a 2-ft-thick coal bed. A second 1-ft-thick coal bed sampled about 10 ft below upper seam. Iron-cemented sandstone nodules common. Dark-gray to black fissile, carbonaceous shales interbedded with claystones and sandstones. Plant impressions abundant. Local slumps and slides. Sites CC3 and CC4 may occur within synclinal structure that stretches from west side of Coal Creek to east side.
8	Carbon Creek	CbC1	19 N.	5 E.	1	Inde-terminate	None	- -	Moderate to steep	- -	- -	Section similar in appearance to section of Chickaloon Formation exposed at Boulder Creek, except no thin coal seams. More coarse-grained clastics than Chickaloon Formation outcrops elsewhere. Conglomerate beds 2 to 6 ft thick abundant, bounded by carbonaceous silty claystones.
9	Carbon Creek	CbC2	19 N.	5 E.	1	Few hundred ft	None	- -	Moderate to steep	- -	- -	Lower outcrop along Carbon Creek. Abundant dark-gray to black silty and sandy claystones but no coal seams. Diabase sills also present.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples Coal	Samples Over-burden	Comments
10	Cascade Creek	CsC1	20 N.	8 E.	30	Hundreds of ft	None	- -	Steep	- -	- -	Lower Cascade Creek. Chickaloon Formation strata with dark 'coal-like' benches of hard, sandy, carbonaceous claystone but no coal seams. Coals appear to be present in outcrops north of highway but absent from highway south to the Matanuska River.
11	Cascade Creek	CsC2	20 N.	7 E.	25	Hundreds of ft	None	Thin (2 in.) lenses	Steep	- -	- -	Chickaloon Formation strata composed predominantly of dark claystones and shales (1-4 ft) interbedded with competent, hard and dense, medium-grained sandstones containing coaly inclusions and carbonized plant material. These sandstones stand out dramatically in relief--they are differentially resistant to weathering. Dark claystones and shales contain thin coal lenses and form benches that are coal-like. More folded toward base. Siderite nodules and bands abundant in section.
12	Castle Mountain	CM1	20 N.	5 E.	15	About 160 ft exposed	One	1.2 ft	60-65°	1 (CM1-5)	4 (CM1-1, -2, -3, -4)	Little Gravel Creek on south slope, mid-plateau of Castle Mountain. See appendix C.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples		Comments
										Coal	Over-burden	
13	Castle Moun-tain	CM2	20 N.	5 E.	21	Less 100 ft exposed	Two	2-3 ft of lower seam remaining; upper seam and top 4-6 ft; lower seam mined out	30-40°	3 (CM2-1, -2, -3)	- -	Old Castle Mountain mine. Coal-coke-intrusive relationships observ-able. Diagnostic prismatic fractur-ing in coke. Two pits at mine site; sampled coals from both upper (east) and lower (west) pits. Portions of seams mined out. Also sampled coal stockpile.
14	Chicka-loon River	CR1	20 N.	6 E.	30	Inde-terminate	Three exposed	16 ft	Steep	3 (CR1-1, -2, -3)	- -	Site on south-facing slope on north side of Chickaloon River. At least one shaft was driven into face in 1920s. Talus slope covers about 50 ft vertically of lower part of out-crop; strata are exposed below rim of hillside for 30 ft. Carbonaceous claystones and fissile shales with thin lenses and pockets of coal on east side of outcrop. Diabase sill-coal-coke relationships observable at site. Local transformation from anthracite to meta-anthracite to graphite.
15	Chicka-loon River	CR2	20 N.	6 E.	19	About 200 ft with 50 ft inter-val con-cealed	At least six	2.5 ft	Moderate 28°	3 (CR2-1, -2, -3)	- -	Several relatively thin coal seams, shaly with claystone partings to a few inches thick. Carbonaceous claystones with plant fossil impressions and ironstone nodules. See appendix C.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples Coal	Samples Over-burden	Comments
16	Eska Creek	EC1	19 N.	3 E.	16	Less 200 ft exposed	Several	1.5 ft	30°	1 (EC1-1)	- -	Outcrop on Eska Creek with several relatively thin coal beds interbedded with black shale, bone, and claystone containing ironstone (siderite?) nodules. Local slump with 10 to 15 ft of displacement is present in middle of section.
17	Gravel Creek	GC1	19 N.	8 E.	3	Less 200 ft	None	- -	Moderate to steep	- -	- -	Section of Chickaloon Formation with 100 ft of claystones below 50 ft of gravel. Claystones dark gray and carbonaceous. Gravel deposits sculptured into alternating ridges and recesses by differential weathering.
18	Hick's Creek	HC1	20 N.	8 E.	24	150 ft exposed	Several lenses	Thin coal lenses to 2 in.	Moderate	- -	- -	Chickaloon Formation sedi-ments---predominantly dark gray to black graphitic and coaly claystones and black carbonaceous shales inter-calated with thin coal lenses. Iron-cemented (sideritic-?) sandstone nodules, lenses, and beds to 2 ft, very hard and dense.
19	Kings Moun-tain	KM1	19 N.	5 E.	15	Inde-terminate	Few	2 ft	Steep to near vertical	1 (KM1-1)	- -	Ravine exposure east of Carpenter Creek on northwest side of Kings Mountain near mid-elevation, west- to southwest-facing slope. Coal beds bony and shaly. Rhyolitic country rock.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples: Coal	Samples: Over-burden	Comments
20	Kings Moun-tain	KM2	19 N.	5 E.	15	Inde-terminate	Few	2 ft	Steep to over-turned	1 (KM2-1)	- -	About 0.25 mi downslope to northwest from KM1. Minor coal beds of Chicka-loon Formation generally occurring in lenses, pods, and pockets. Local graded bedding may indicate over-turning of strata. Gray siderite or limestone beds in series of carbona-ceous rocks. Abundant plant-leaf fossils in medium-grained, medium-gray, hard and dense sandstone.
21	Kings River	KR1	20 N.	5 E.	20	Few hundred ft	Four	4 ft	20-25°	3 (KR1-1, -2, -3)	- -	Exposure of Chickaloon Formation on east bank (west-facing slope) of Kings River near old Kings River camp. Predominantly sandstone cliffs of Chickaloon Formation with inter-mittent 10-ft-thick sections of claystone, shale, and coal.
22	Muddy Creek	MC1	20 N.	8 E.	16	Inde-terminate	Numer-ous	4 ft	Vari-able; general-ly steep to local-ly near vertical	6 (MC1-1, -2, -3, -4, -5, -6)	- -	West fork of Muddy Creek. Contorted section of Chickaloon Formation in mountainside that overhangs basin. Coal beds that rim top of mountain and basin appear less deformed than those below 4,000 ft level. Coals bituminous. Carbonaceous plant frag-ments in sandstones and shales. Re-placed trees, silicified wood, iron-stone, and siderite bands, nodules, and concretions.

Locale no.	Locale name	Locale code	Township	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples: Coal	Samples: Overburden	Comments
23	Muddy Creek	MC2	20 N.	8 E.	16	Indeterminate	Over 10	2 ft	Moderate to steep	2 (MC2-1, -2)	- -	Mountain slope on west side of west branch of Muddy Creek about 1,000 ft south of MC1. Coal-bearing section and general lithologic features similar to MC1.
24	Middle Creek	MiC1	20 N.	12 E.	20	Less 300 ft	None	- -	45°	- -	- -	Exposure of Chickaloon Formation(?) sediments on tributary east of Middle Creek that flows northward into East Fork. Section consists predominantly of bluish-gray shales, brownish claystones, and iron-cemented sandstones, all relatively thin-bedded; rocks are overlain with angular unconformity by resistant pebble-cobble conglomerate.
25	Mrak Mine	MM1	19 N.	3 E.	10	Less 100 ft exposed	Two in local outcrop	6 ft	7-10°	2 (MM1-4, -6)	5 (MM1-1, -2, -3, -5, -7)	Site near old Mrak Mine, which operated in early 1960s. Chickaloon Formation strata very lenticular; coal beds and other rocks seem to have pod-like or lensing character. Outcrop (partially mine cut) located along eastern nose of canoe-shaped, synclinal coal bowl that underlies Wishbone Hill. Small-scale faults and slumps complicate stratigraphy and hinder understanding bed continuity and correlation to south. Ironstone nodules and bands and replaced trees with coaly rims occur randomly in sequence. See appendix C.

Locale no.	Locale name	Locale code	Township	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples: Coal	Samples: Overburden	Comments
26	Mrak Mine	MM2	19 N.	3 E.	10	Less 100 ft exposed	None	- -	Fairly gentle	- -	- -	Outcrop with regularly bedded Chickaloon Formation sediments (dark claystones, shales, and iron-cemented sandstones) cut by prominent sandstone channels and crossed by at least two near-vertical dikes.
27	Matanuska River	MR1	20 N.	6 E.	26	Several hundred ft	Numerous	Thin (less 1 ft)	Moderate to deformed	1 (MR1-1)	- -	Jumbled, highly folded and deformed Chickaloon Formation sedimentary and metasedimentary rocks on north side of Matanuska River. Lenticular beds of bituminous coal near midsection. Minor faults and shear planes. Intrusive sills near base. Dense, hard sandstone and conglomerate lenses cap sequence. Carbonaceous claystones and shales, locally graphitic and with slickensides. Siderite lenses and nodules and calcite veins. Stretched coaly stringers and thin lenses often form pods or fill pockets. Carbonaceous plant fragments in sandstones and one replaced log.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples: Coal	Samples: Over-burden	Comments
28	Mata-nuska River	MR2	20 N.	8 E.	27	About 315 ft outcrop section described	Seven	2.5 ft	20-30°	6 (MR2-2, -4, -7, -10, -11, -12, -13)	6 (MR2-1, -3, -5, -6, -8, -9)	East of Gravel Creek on south-facing north bank of Matanuska River south-west of Index Lake. Contact with Matanuska Formation occurs just east of site. Coal beds of Chickaloon Formation moderately folded to S-folds locally, especially near west end of outcrop. All seams are bituminous. Section includes ironstone nodules and bands and dense, hard sandstone ledges 2 to 6 ft thick. See appendix C.
29	Mata-nuska River	MR3	19 N.	5 E.	4	Several hundred ft	None	Thin coaly lenses to 2 in.	Moderate to steep	- -	- -	Site on Matanuska River north of Kings Mountain. Coaly shale and clay-stone strata of the Chickaloon Forma-tion with thin intercalated coal lenses. These sediments are bounded by igneous rocks, mainly gabbro.
30	Purin-ton Creek	PC1	20 N.	7 E.	12	Inde-terminate	Two(?)	8-10 ft	40-45°	3 (PC1-1, -2, -3)	- -	Chickaloon Formation strata with diabase dikes and sills, which have greatly altered the coal seams---poorer quality nearer the dikes. Leaders of dike appear to have been injected into fractures and cleats of the coal seams, and to have cooked away the volatiles and added ash. Section may be contained within local slump block. Structural complexity impedes determination of strati-graphic relationship of sampled beds.

Locale no.	Locale name	Locale code	Township	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples: Coal	Samples: Overburden	Comments
31	Purinton Creek	PC2	20 N.	7 E.	12	Indeterminate	One	35-40 ft	Moderate	1 (PC2-1)	- -	Thick anthracite coal bed of Chickaloon Formation. Probably within local synclinal fold because dipping opposite to seams at PC1. Structurally appears to be local thickening. About 35 ft of coal in 40 ft of strata.
32	Purinton Creek	PC3	20 N.	7 E.	12	About 50 ft in local bank exposure	Three beds and minor lenses	6 ft	40°	3 (PC3-1, -2, -3)	- -	About 0.2 mi south along Purinton Creek drainage from PC2, several thin anthracite beds of the Chickaloon Formation crop out. See appendix C.
33	Purinton Creek	PC4	20 N.	7 E.	12	Indeterminate	Several	6 ft	56°	1 (PC4-1)	- -	Exposure on west side (east-facing slope) of draw to east of main gulch of Purinton Creek. Seams may correlate with those at PC3; several other thin (about 1-ft-thick) seams are exposed below sampled (6-ft-thick) bed. Section overlain by diabase. Coal displays characteristic prismatic fracturing diagnostic of coked seam.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples Coal	Samples Over-burden	Comments
34	Purin-ton Creek	PC5	20 N.	7 E.	12	Inde-terminate	Several	5 ft	Variable general-ly moderate to steep	2 (PC5-1, -2)	- -	Exposure located in third gulch east of main branch of Purinton Creek. Chickaloon Formation beds within a rather tightly folded anticline best exposed on west-facing slope of gulch. Sampled two anthracite beds.
35	Purin-ton Creek	PC6	20 N.	7 E.	23	Over 90 ft	At least four	3 ft	16°	2 (PC6-2, -5)	4 (PC6-1, -3, -4, -6)	Outcrop on Glenn Highway near Purin-ton Creek crossing point. Several re-latively thin (1- to 3-ft-thick) bituminous coal beds. Sampled two coal beds and their roof and floor materials. See appendix C.
36	Pack-saddle Gulch	PG1	20 N.	8 E.	9	Inde-terminate	Several	4 ft	Variable but general-ly moderate	3 (PG1-1, -2, -3)	- -	Relatively thick section of Chick-aloon Formation exposed in east and west canyon walls of Packsaddle Gulch on south flank of Anthracite Ridge. May be near correlative of strata of Muddy Creek. Coals appear more flat-lying at higher altitudes. Stronger dips and more folded lower in section. Located at about 4,350-4,400 ft elevation. Alternat-ing section of sandstones; silty, carbonaceous claystones; and black, fissile shales. Coal beds slightly folded and lenticular.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples		Comments
										Coal	Over-burden	
37	Pack-saddle Gulch	PG2	20 N.	8 E.	9	Inde-terminate	Two ob-served locally	2 ft	Steep to over-turned	2 (PG2-1, -2)	- -	Exposure on east-facing slope on west side of Packsaddle Gulch. Re-cumbent folded coal seams in core of small anticline. Probably strati-graphically lower than coal seams at PG1. Similar to larger fold struc-tures on Muddy Creek; beds near equi-valent within Tertiary section. Lower bed shows signs of shear. Carbonaceous claystone interburden to 3 ft thick but lenticular. Diabase dikes cut through Chickaloon Formation strata 200 ft south of site.
38	Pack-saddle Gulch	PG3	20 N.	8 E.	16	Inde-terminate	One	5 ft	Steep to near vertical	1 (PG3-1)	- -	Chickaloon Formation coal seam sampled 10 ft from diabase dike. Coal predominantly bright and vitreous; seam has two thin partings of brown claystone (<0.5 ft).
39	Pack-saddle Gulch	PG4	20 N.	8 E.	15	105 ft section described	Three	1.5 ft	Moderate	3 (PG4-1, -2, -3)	- -	Lenticular beds of Chickaloon Forma-tion with diabase flows. Lowest coal bed brighter and of higher rank than two seams above. See appendix C.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples Coal	Samples Over-burden	Comments
40	Red Moun-tain	RM1	20 N.	4 E.	22	Inde-terminate	Two	25 ft or more	50°	2 (RM1-1, -2)	- -	Site at about 3,850-ft elevation on north side of Red Mountain. Trenched coal seam much thicker than previously reported maximum 8-ft-thick bed. However, the coal seam could be within tight recumbent fold. Coaly shale and claystone partings within seam. A 7-ft-thick bed of similar strike and dip was sampled at about 3,775-ft elevation. Coaly shale and claystone lenses within seam. Relatively thick, medium-grained, whitish to tan, hard and dense sand-stone below second seam. Sandstone seatrock typical of Chickaloon strata; locally weathered and friable.
41	Wish-bone Hill	WH3	19 N.	3 E.	17	About 300 ft	Several	2 ft	35°	3 (WH3-2, -5, -8)	6 (WH3-1, -3, -4, -6, -7, -9)	West of mine-cut trenches at WH1 and WH2 on the northeast side of Wishbone Hill. General lithologic char-acteristics of Chickaloon Formation sediments. Sampled three coal seams and their roof and floor materials. See appendix C.

Locale no.	Locale name	Locale code	Town-ship	Range	Sec.	Outcrop section thickness (ft)	Coal beds	Maximum coal-bed thickness	Dip	Samples Coal	Samples Over-burden	Comments
42	Young Creek	YC1	20 N.	4 E.	35	About 60 ft exposed	One	3 ft	5°	1 (YC1-1)	- -	Site southwest along Young Creek from Red Mountain. Coal seam bounded by thin (1-2 ft) sandy claystones and then by sandstone adjacent to these.
43	Young Creek	YC2	19 N.	4 E.	3	About 50 ft exposed	One	1 ft	5°	1 (YC2-1)	- -	Site about 0.5 mile southwest of YC1. Chickaloon Formation sequence interbedded with hard and dense, medium-grained sandstones (1-2 ft thick) and coaly claystones and shales, locally silty to sandy.
44	Young Creek	YC3	19 N.	4 E.	9	Less 50 ft exposed	One	1 ft	25°	1 (YC3-1)	- -	Chickaloon Formation exposure southwest of YC2 along Young Creek with black, carbonaceous, fissile shales; silty, carbonaceous, firm claystones; and thin coal lenses. Local siderite nodules.

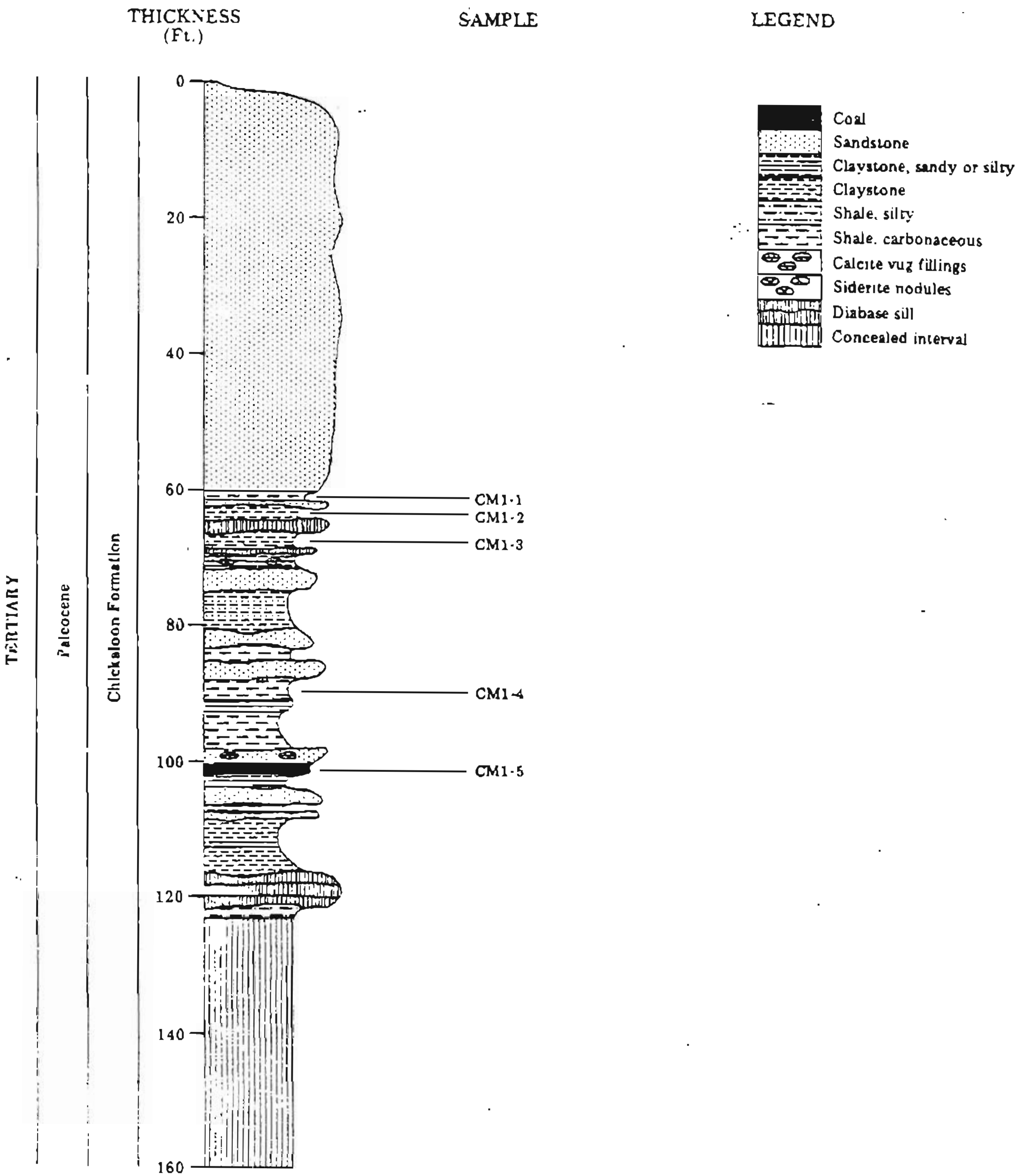

Figure E1. Castle Mountain section, Little Gravel Creek (CM1).

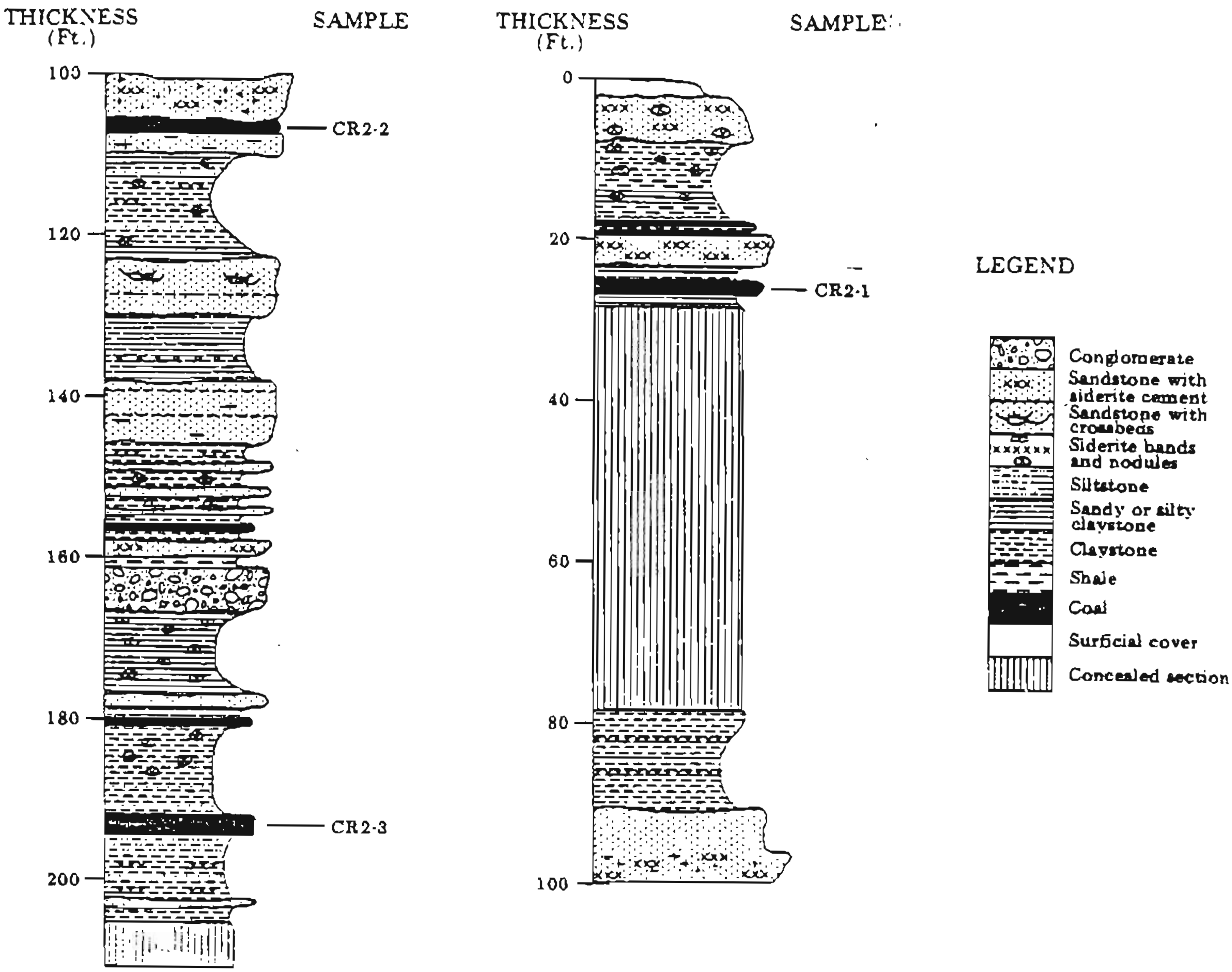

Figure E2. Chickaloon River section (CR2).

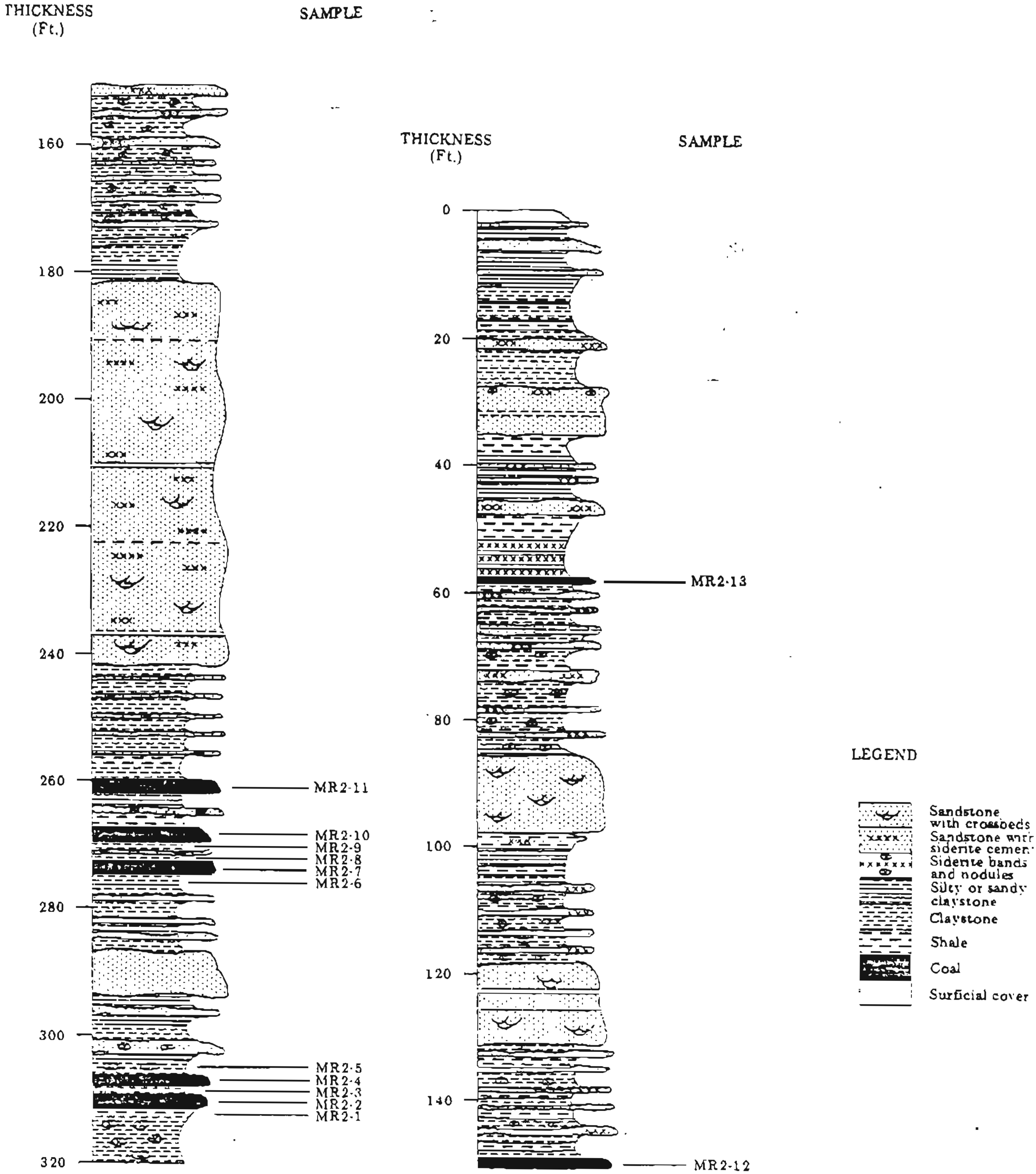

Figure E3. Matanuska River section (MR2).

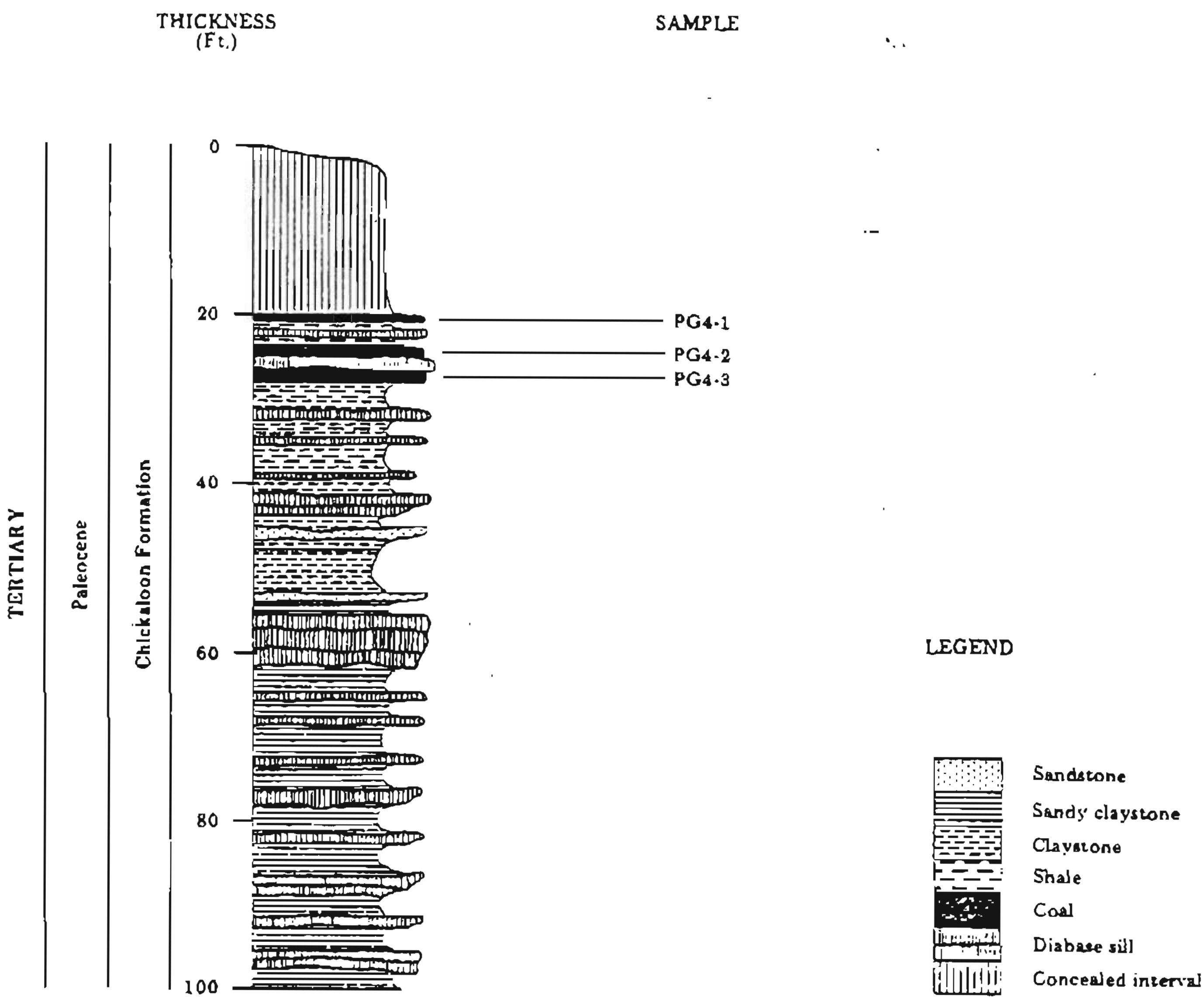

Figure E4. Packsaddle Gulch section (PG4).

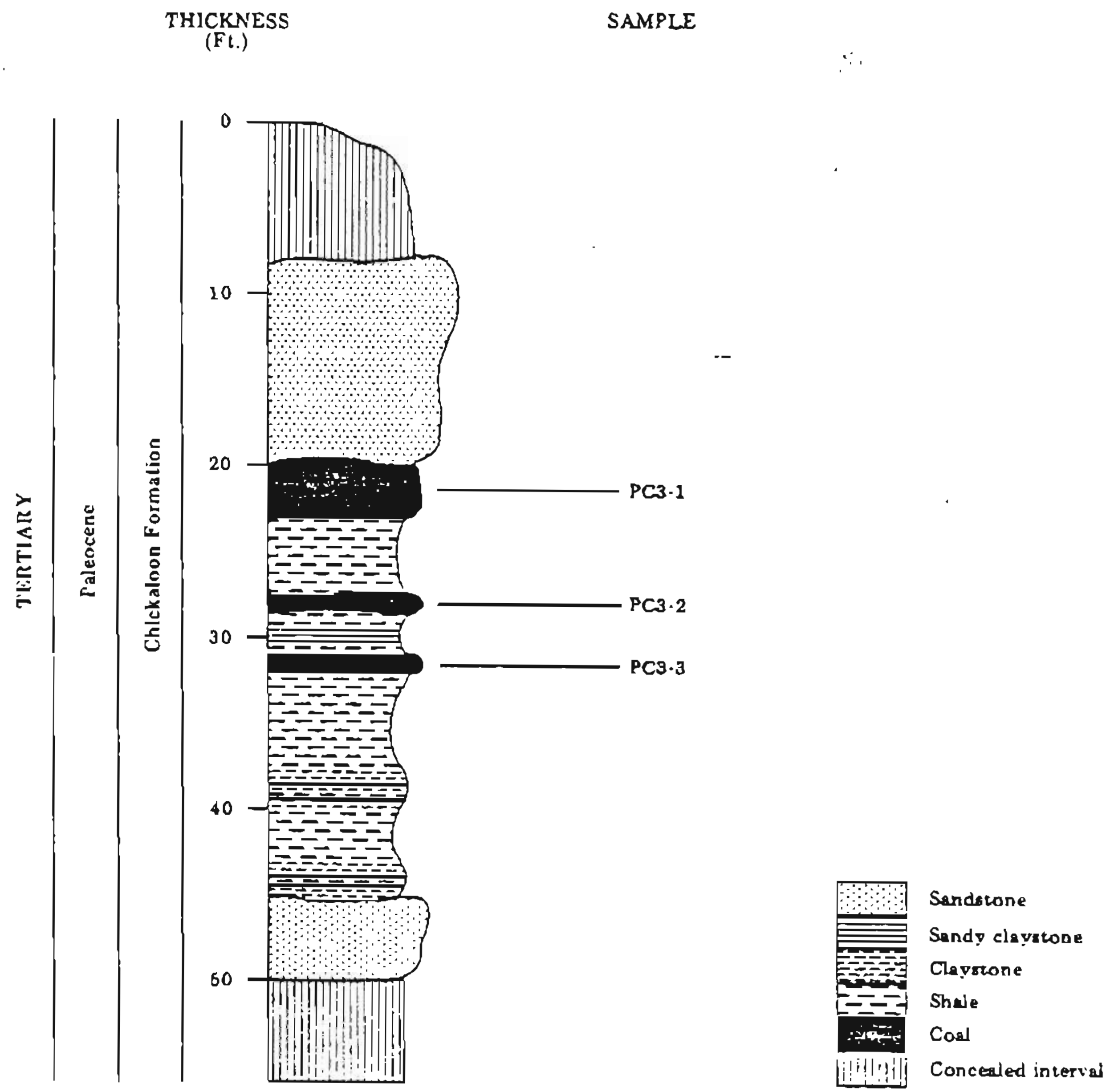

Figure E5. Purinton Creek section (PC3).

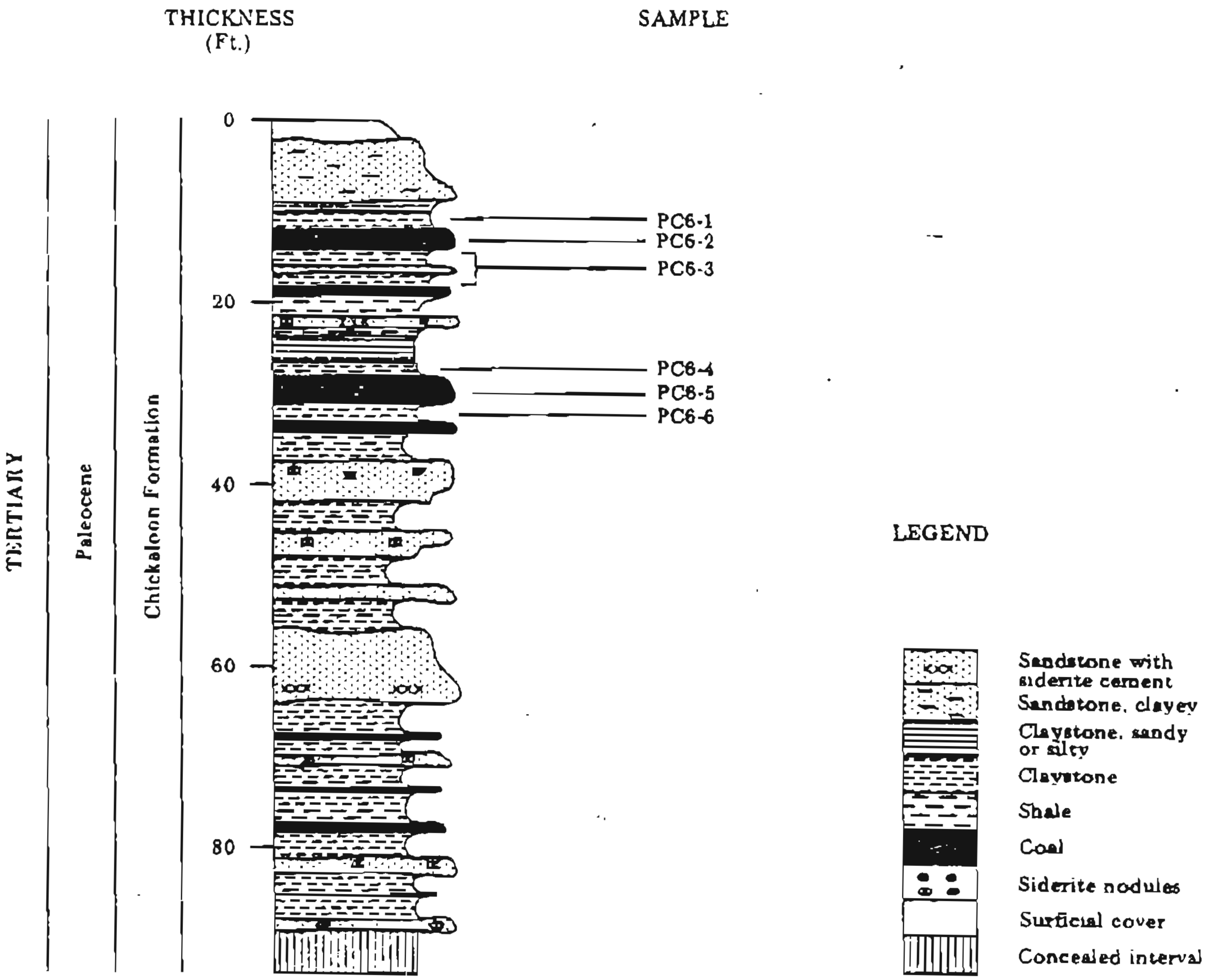

Figure E6. Purinton Creek section (PC6).

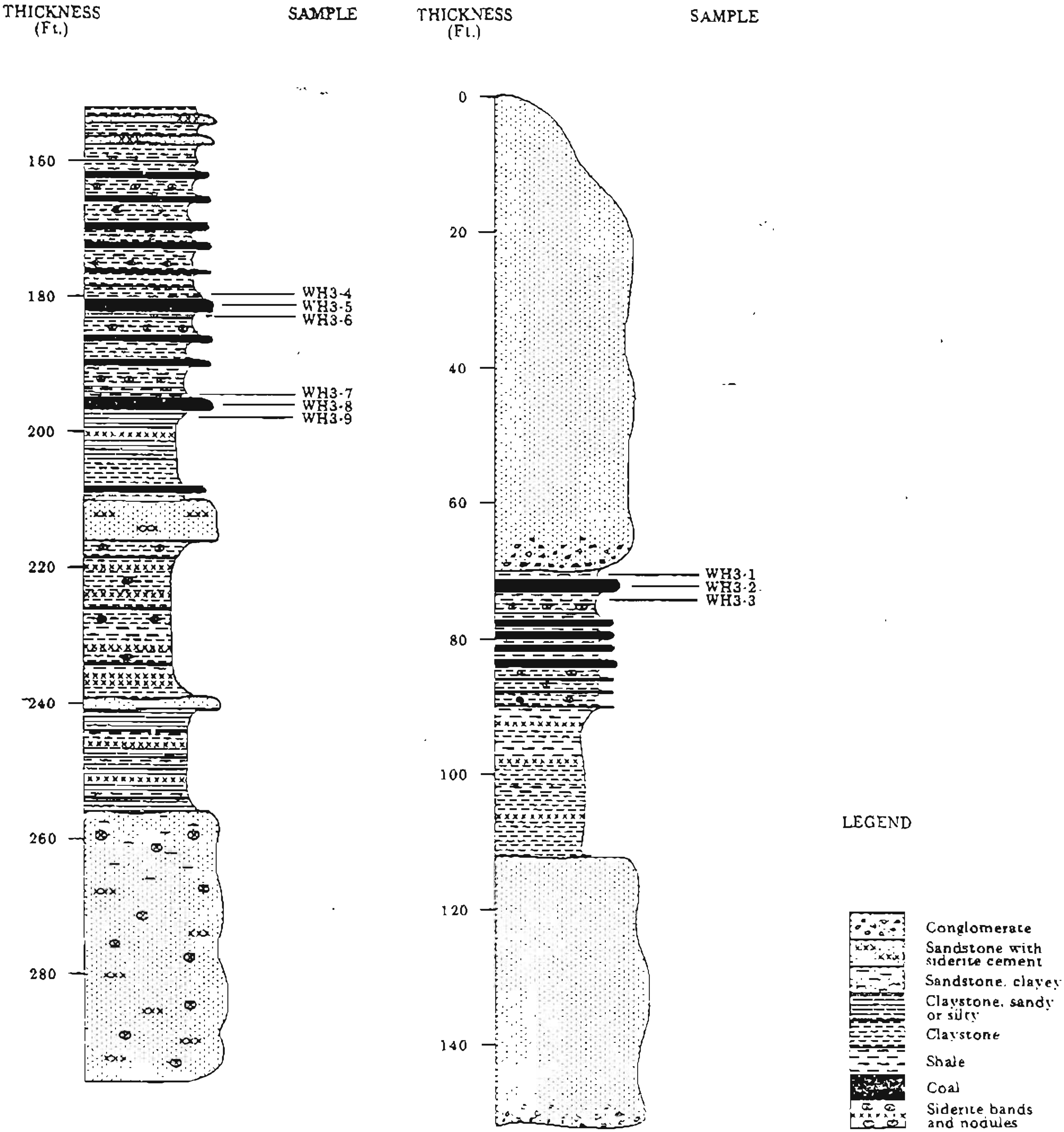

Figure E7. Wishbone Hill section (WH3).

Table E1. Kings River section (KR1).

Unit	Thickness (ft)	Sample
Top of section:		
Coal	2.0	KR1-3
Shale, coaly and claystone, carbonaceous	1.5	
Coal	1.0	
Shale, dark-gray to black, clayey, locally fissile	1.0	
Coal	4.0	KR1-2
Sandstone, hard and dense	40.0 (approx.)	
Coal	1.0	KR1-1

Table E2. Coal Creek section (CC3).

Unit	Thickness (ft)	Sample
Top of section:		
Claystone, brown, silty, carbonaceous, firm	1.0	
Claystone, dark-brownish-gray, silty, carbonaceous, firm	2.0	CC3-1
Sandstone, siderite-cemented, fine-grained, hard and dense, with leaf impressions	0.2	
Coal	1.5	CC3-2
Sandstone, siderite-cemented	0.3	
Shale, black, carbonaceous, fissile, firm; and claystone, dark-gray to black, carbonaceous, firm	1.3	CC3-3
Shale, dark-gray, sandy, fissile, firm	0.5	
Claystone, grayish-brown, sandy, firm with blocky fracture	4.0	

Table E3. Mrak mine area section (MM1).

Unit	Thickness (ft)	Sample
Top of section:		
Claystone, light-gray, sandy, firm with siderite nodules and bands	1.3	MM1-1
Claystone, medium-gray, sandy, slightly carbonaceous, firm to hard, with ferruginous bands of soft claystone to 1 in. thick and coal pods and lenses to 3 in. thick.	1.4	MM1-2
Shale, black, carbonaceous, fissile; claystone, ferruginous, soft, coaly; coal lense to 2 in.; and sandstone, siderite-cemented, fine-grained, hard, and dense	1.0	MM1-3
Coal	3.3	MM1-4
Claystone, dark-grayish-brown, sandy, firm to hard with coal lenses and pockets; siderite-cemented sandstone lenses to 3 in.	3.0	MM1-5
Coal	6.0	MM1-6
Claystone, medium-grayish-brown, sandy, firm, blocky fracture, carbonaceous plant fossils	1.0	MM1-7

Table E4. Young Creek section (YC3).

Unit	Thickness (ft)	Sample
(4) Young Creek section Site: YC3		
Top of section:		
Shale, black, carbonaceous, fissile	1.0	
Claystone, silty, carbonaceous, fissile	0.6	
Shale, black, carbonaceous, fissile	0.3	
Coal	1.0	YC3-1
Shale, black, carbonaceous, fissile	0.5	
Shale, reddish-brown, sandy, ferruginous, firm	0.2	
Shale, black, carbonaceous, fissile	0.1	
Coal	0.4	
Shale, black, fissile, firm with 1-in.-thick coal lense	0.5	
Claystone, medium-gray, silty, firm, blocky fracture with thin carbonaceous shale lenses to 2 in.	3.5	
Shale, black, carbonaceous, fissile	1.5	
Claystone, medium-gray, sandy, hard	0.5	
Claystone, medium-gray, sandy, with siderite nodules	4.0	

APPENDIX F

Table F1. General outline of coal quality data.

Analysis type	Description
I. Proximate analysis................	Rank, beneficiation, combustible/noncombustible ratio, quality.
A. Moisture.......................	The total moisture content can be determined by the air-loss (drying) weight under set conditions of airflow, temperature, and time. Free or adherent moisture is surficial water on coal. Inherent moisture is that portion of the total moisture that is physically held by vapor pressure or other phenomena. Water in the coal structure itself is chemically bound. Equilibrium or bed moisture (for classification by rank) is the inherent moisture-holding capacity of a given coal (in situ) measured at 30°C and 97 percent relative humidity atmosphere.
B. Volatile matter.................	Consists of vapors and gases which can be driven off during pyrolysis.
C. Ash content.....................	Mineral impurities in a coal. It typically consists of silicates (e.g., calcium, magnesium, iron, and titanium), oxides (silica and iron), sulfides (iron), carbonates (iron, calcium, and magnesium), and minor quantities of phsophates, sulfates, arsenides, etc.
D. Fixed carbon content............	Estimated by difference---subtract the ash content, moisture, and volatile matter from 100 percent.
E. Sulfur content..................	Supplemental analysis to the short proximate. Strictly considered part of the ultimate analysis.
F. Heating value...................	Usually expressed as Btu/lb. Supplemental analysis to the short proximate. Determined by use of adiabatic bomb calorimeter. Measurement of the temperature rise after combustion of a coal sample in an oxygen bomb.

II. Ultimate analysis

A. Carbon	Determination by catalytic burning in oxygen and the subsequent measurement of the amount of carbon dioxide formed. Total organic carbon is equal to the total carbon content less the carbonate carbon. Total carbon in a sample is greater than the fixed carbon content.
B. Hydrogen	Determination by catalytic burning in oxygen and the subsequent measurement of the water formed and absorbed by a desiccant.
C. Sulfur	Total sulfur is composed of organic, sulfide, and sulfur forms. Pyritic (sulfide) sulfur is combined with iron in the minerals pyrite and marcasite. All pyritic sulfur cannot be removed by mechanical cleaning. organic sulfur is bonded to the carbon structure. Common sulfates are calcium and iron. Three methods for sulfur determination are often used: the Eschka method, the high-temperature combustion method, and the bomb-washing method.
D. Nitrogen	Typically a chemical digestion with the contained nitrogen converted to ammonia by the Kjeldahl-Gunning method.
E. Oxygen	Estimated by difference; total carbon, hydrogen, sulfur, nitrogen, and ash are subtracted from 100 percent.
F. Ash content	Determined during proximate analysis.
G. Other	Supplementary measurements of minor or trace elements in inorganic and/or organic constituents. Chlorine, e.g., is sometimes determined by the bomb combustion or Eschka method.

III. Other chemical and physical tests

A. Ash geochemistry................Major oxides---SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, Na_2O, K_2O, P_2O_5, and SO_3. Phosphorous is often determined due to its importance in steelmaking processes. The major oxides compose over 99 percent of coal ash.

B. Trace element analysis...........Among the most important usually determined are B, Be, Co, Cr, Cu, Ga, Ge, La, Mo, Ni, Sn, Ti, V, Y, and Zn. Trace element analysis is of importance due mainly to environmental concerns. Common analytical equipment used include atomic absorption, spark-source mass spectrophotometry, X-ray fluorescence, and neutron activation.

C. Ash fusibility temperatures......Varies with the character of coals, particularly the ash content, and is less for low rank coals. Can perform either a 4-point (reducing atmosphere only) ash fusibility or an 8-point (reducing and oxidizing atmospheres) ash fusibility. The melting temperatures and deformational changes of an ash cone are measured at certain stages. In the 4-point test these are: 1) Point of initial deformation, the tip of the ash cone begins to deform; 2) softening point, as indicated by the point where the ash cone height is equal to ½ of its width; 3) hemispherical stage, the ash cone height is equal to its width; and 4) fluid stage, indicated by the spreading out of the completely melted ash cone into a flat layer.

D. Free-swelling index.............Obtained by the rapid heating of a coal sample in a nonrestraining crucible. Ranges from 0 to 9, with noncaking and nonswelling coals being 0 on this scale (e.g., most Powder River Basin coals). Thus, the FSI gives an indication of the caking characteristics of a given coal.

E. Hardgrove grindability...........Peaks in the bituminous coal groups and is less for lignites and anthracites. Intermediate rank coals are softer and hence easier to grind, while lower and higher rank coals are harder to grind and subsequently have lower grindability indices. Grindability should be measured at different moisture levels, i.e., at two or three temperatures. The index is calculated by measuring the quantity of -200 mesh fine coal produced.

F. Slagging and fouling factors......Obtained by calculation from the ash geochemistry. Relates to the reaction of coal in combustion facilities. Generally is not applicable to western coals.

Table F2. Classification of coals by rank. From the American Society for Testing and Materials, 1981.[a]

Class	Group	Fixed carbon limits, percent (dry, mineral-matter-free): Equal or greater than	Fixed carbon limits: Less than	Volatile matter limits, percent (dry, mineral-matter-free basis): Greater than	Volatile matter limits: Equal or less than	Calorific value limits, Btu per pound (moist,[b] mineral-matter-free basis): Equal or greater than	Calorific value limits: Less than	Agglomerating character
I. Anthracitic	1. Meta-anthracite	98	- -	- -	2	- -	- -	non-agglomerating
	2. Anthracite	92	98	2	8	- -	- -	
	3. Semianthracite[c]	86	92	8	14	- -	- -	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	- -	- -	
	2. Medium volatile bituminous coal	69	78	22	31	- -	- -	
	3. High volatile A bituminous coal	- -	69	31	- -	14 000[d]	- -	commonly agglomerating[e]
	4. High volatile B bituminous coal	- -	- -	- -	- -	13 000[d]	14 000	
	5. High volatile C bituminous coal	- -	- -	- -	- -	11 500	13 000	
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	- -	- -	- -	- -	10 500	11 500	
	2. Subbituminous B coal	- -	- -	- -	- -	9 500	10 500	non-agglomerating
	3. Subbituminous C coal	- -	- -	- -	- -	8 300	9 500	
IV. Lignitic	1. Lignite A	- -	- -	- -	- -	6 300	8 300	
	2. Lignite B	- -	- -	- -	- -	- -	6 300	

[a]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15 500 moist, mineral-matter-free British thermal units per pound.

[b]Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.
[c]If agglomerating, classify in low-volatile group of the bituminous class.
[d]Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.
[e]It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and that there are notable exceptions in high volatile C bituminous group.

Table F3. Proximate and ultimate analyses of Matanuska Valley coal samples. Note that the few samples with over 50-percent ash are carbonaceous shales. See plate 2 and appendixes D and E for sample locations.

Sample	Basis[a]	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	C (%)	H (%)	N (%)	O (%)	Total sulfur (%)
BC1-1	1	4.80	7.66	11.19	76.35	- -	- -	- -	- -	- -	0.14
	2		8.05	11.75	80.20	- -	- -	- -	- -	- -	0.15
	3		40.65	59.35		- -	- -	- -	- -	- -	0.76
CC1-1	1	5.58	20.51	27.32	46.59	6253	- -	- -	- -	- -	0.57
	2		21.73	28.93	49.34	6623	- -	- -	- -	- -	0.61
	3		42.89	57.11		13074	- -	- -	- -	- -	1.20
CC1-2	1	5.56	24.91	37.61	31.92	8630	- -	- -	- -	- -	0.71
	2		26.38	39.83	33.80	9138	- -	- -	- -	- -	0.75
	3		39.84	60.16		13803	- -	- -	- -	- -	1.13
CC1-3	1	6.05	23.48	35.10	35.37	7764	- -	- -	- -	- -	0.77
	2		24.99	37.36	37.65	8264	- -	- -	- -	- -	0.82
	3		40.08	59.92		13254	- -	- -	- -	- -	1.32
CC1-4	1	4.40	23.91	29.37	42.32	7139	40.31	3.85	0.98	12.15	0.40
	2		25.02	30.72	44.26	7467	42.16	3.51	1.02	8.63	0.41
	3		44.88	55.12		13397	75.64	6.30	1.83	15.48	0.74
CC1-5	1	8.91	10.75	75.70	4.63	12704	- -	- -	- -	- -	0.36
	2		11.80	83.11	5.09	13947	- -	- -	- -	- -	0.40
	3		12.44	87.56		14694	- -	- -	- -	- -	0.42

[a]1 - As received
2 - Moisture free
3 - Moisture and ash free
- - Not analyzed

Sample	Basis[a]	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	C (%)	H (%)	N (%)	O (%)	Total sulfur (%)
CC1-6	1	7.00	17.51	73.45	2.04	13273	--	--	--	--	0.43
	2		18.82	78.98	2.19	14272	--	--	--	--	0.47
	3		19.25	80.75		14592	--	--	--	--	0.48
CC3-2	1	4.66	11.37	23.02	60.96	--	--	--	--	--	0.32
	2		11.92	24.14	63.94	--	--	--	--	--	0.33
	3		33.06	66.94		--	--	--	--	--	0.93
CC4-1	1	4.54	18.29	60.41	16.76	11628	--	--	--	--	0.65
	2		19.16	63.28	17.56	12181	--	--	--	--	0.68
	3		23.24	76.76		14775	--	--	--	--	0.82
CC4-2	1	5.04	17.74	54.74	22.48	10597	--	--	--	--	0.58
	2		18.68	57.64	23.68	11159	--	--	--	--	0.61
	3		24.47	75.53		14621	--	--	--	--	0.79
CM1-5	1	4.82	7.18	28.89	59.11	3935	29.95	2.16	1.02	7.58	0.18
	2		7.55	30.35	62.10	4135	31.46	1.70	1.07	3.47	0.19
	3		19.91	80.09		10909	83.02	4.49	2.83	9.16	0.51
CM2-1	1	8.09	7.76	76.04	8.11	12787	--	--	--	--	0.37
	2		8.44	82.73	8.83	13912	--	--	--	--	0.40
	3		9.26	90.74		15259	--	--	--	--	0.44
CM2-2	1	4.16	12.38	70.66	12.80	12541	--	--	--	--	0.52
	2		12.91	73.73	13.36	13085	--	--	--	--	0.54
	3		14.90	85.10		15102	--	--	--	--	0.63
CM2-3	1	3.02	28.09	60.61	8.28	13601	76.17	5.21	1.72	7.96	0.66
	2		28.97	62.50	8.53	14025	78.54	5.02	1.77	5.45	0.68
	3		31.67	68.33		15333	85.87	5.49	1.94	5.95	0.75

Sample	Basis[a]	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	C (%)	H (%)	N (%)	O (%)	Total sulfur (%)
CR1-1	1	4.44	17.83	65.59	12.14	12482	- -	- -	- -	- -	0.81
	2		18.66	68.63	12.71	13062	- -	- -	- -	- -	0.85
	3		21.38	78.62		14963	- -	- -	- -	- -	0.97
CR1-2	1	4.02	17.58	61.16	17.24	11766	67.92	4.28	1.37	8.49	0.70
	2		18.32	63.72	17.96	12259	70.76	3.99	1.43	5.13	0.73
	3		22.33	77.67		14943	86.26	4.86	1.74	6.25	0.88
CR1-3	1	5.72	13.89	61.02	19.37	11122	- -	- -	- -	- -	0.51
	2		14.73	64.73	20.54	11797	- -	- -	- -	- -	0.54
	3		18.54	81.46		14847	- -	- -	- -	- -	0.69
CR2-1	1	4.86	12.42	27.16	55.56	5052	30.69	2.83	0.83	9.82	0.27
	2		13.06	28.54	58.40	5310	32.26	2.41	0.87	5.78	0.28
	3		31.39	68.61		12765	77.55	5.79	2.09	13.89	0.68
CR2-2	1	5.28	14.31	43.96	36.45	8403	- -	- -	- -	- -	0.34
	2		15.11	46.41	38.48	8871	- -	- -	- -	- -	0.36
	3		24.57	75.43		14421	- -	- -	- -	- -	0.59
CR2-3	1	4.54	12.24	27.84	55.38	- -	- -	- -	- -	- -	0.26
	2		12.82	29.16	58.02	- -	- -	- -	- -	- -	0.27
	3		30.54	69.46		- -	- -	- -	- -	- -	0.65
EC1-1	1	10.86	30.27	40.66	18.21	9323	- -	- -	- -	- -	0.43
	2		33.96	45.61	20.43	10458	- -	- -	- -	- -	0.48
	3		42.68	57.32		13143	- -	- -	- -	- -	0.61
KM1-1	1	5.38	7.34	3.77	83.51	- -	- -	- -	- -	- -	0.14
	2		7.75	3.99	88.26	- -	- -	- -	- -	- -	0.15
	3		66.03	33.97		- -	- -	- -	- -	- -	1.30

Sample	Basis[a]	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	C (%)	H (%)	N (%)	O (%)	Total sulfur (%)
KM2-1	1	7.21	8.37	53.92	30.50	8436	--	--	--	--	0.55
	2		9.02	58.11	32.86	9092	--	--	--	--	0.59
	3		13.44	86.56		13543	--	--	--	--	0.88
KR1-1	1	3.53	17.62	46.71	32.14	9518	--	--	--	--	0.46
	2		18.26	48.42	33.32	9866	--	--	--	--	0.47
	3		27.39	72.61		14795	--	--	--	--	0.71
KR1-2	1	4.02	11.97	30.05	53.96	--	--	--	--	--	0.29
	2		12.47	31.13	56.22	--	--	--	--	--	0.30
	3		28.47	71.51		--	--	--	--	--	0.69
KR1-3	1	4.85	12.98	45.33	36.84	8483	--	--	--	--	0.41
	2		13.64	47.64	38.71	8916	--	--	--	--	0.43
	3		22.26	77.74		14548	--	--	--	--	0.71
MC1-1	1	3.18	16.07	13.30	67.46	--	--	--	--	--	0.25
	2		16.60	13.73	69.67	--	--	--	--	--	0.26
	3		54.72	45.28		--	--	--	--	--	0.86
MC1-2	1	4.19	20.73	24.99	50.09	--	--	--	--	--	0.44
	2		21.63	26.09	52.28	--	--	--	--	--	0.46
	3		45.34	54.66		--	--	--	--	--	0.97
MC1-3	1	4.58	31.64	53.26	10.52	12424	--	--	--	--	0.79
	2		33.16	55.81	11.03	13021	--	--	--	--	0.83
	3		37.27	62.73		14634	--	--	--	--	0.93
MC1-5	1	5.03	31.74	56.32	6.90	3102	73.37	5.60	1.44	12.10	0.58
	2		33.42	59.31	7.27	13796	77.26	5.30	1.51	8.04	0.62
	3		36.04	63.96		14877	83.32	5.72	1.63	8.67	0.66

Sample	Basis[a]	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	C (%)	H (%)	N (%)	O (%)	Total sulfur (%)
MC1-6	1	4.75	28.98	47.73	18.54	11216	- -	- -	- -	- -	0.54
	2		30.42	50.11	19.47	11775	- -	- -	- -	- -	0.56
	3		37.78	62.22		14622	- -	- -	- -	- -	0.70
MC2-1	1	5.34	28.47	51.94	14.25	11758	66.26	5.00	1.54	12.37	0.57
	2		30.08	54.87	15.05	12421	70.00	4.65	1.63	8.06	0.61
	3		35.41	64.59		14622	82.40	5.48	1.91	9.49	0.71
MC2-2	1	4.48	28.39	51.21	15.93	11678	- -	- -	- -	- -	0.50
	2		29.72	53.61	16.68	12226	- -	- -	- -	- -	0.52
	3		35.66	64.34		14672	- -	- -	- -	- -	0.63
MM1-4	1	5.81	33.65	41.12	19.43	10708	59.46	5.09	1.49	13.97	0.57
	2		35.72	43.66	20.62	11368	63.12	4.71	1.58	9.35	0.61
	3		45.00	55.00		14322	79.53	5.94	1.99	11.78	0.76
MM1-6	1	6.53	34.33	44.94	14.20	11464	- -	- -	- -	- -	0.70
	2		36.73	48.08	15.19	12265	- -	- -	- -	- -	0.75
	3		43.30	56.70		14462	- -	- -	- -	- -	0.88
MR1-1	1	3.64	12.70	54.12	29.55	9981	- -	- -	- -	- -	0.49
	2		13.17	56.16	30.66	10358	- -	- -	- -	- -	0.51
	3		19.00	81.00		14939	- -	- -	- -	- -	0.74
MR2-2	1	3.38	9.04	40.75	46.82	6532	41.72	2.68	0.94	7.54	0.29
	2		9.36	42.18	48.46	6760	43.18	2.38	0.98	4.70	0.30
	3		18.16	81.84		13117	83.77	4.62	1.89	9.12	0.59
MR2-4	1	3.40	7.79	21.73	67.08	- -	- -	- -	- -	- -	0.18
	2		8.06	22.49	69.45	- -	- -	- -	- -	- -	0.18
	3		26.39	73.61		- -	- -	- -	- -	- -	0.59

Sample	Basis[a]	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	C (%)	H (%)	N (%)	O (%)	Total sulfur (%)
MR2-7	1	3.22	11.53	79.80	5.45	14027	- -	- -	- -	- -	0.49
	2		11.91	82.46	5.63	14494	- -	- -	- -	- -	0.50
	3		12.62	87.38		15359	- -	- -	- -	- -	0.53
MR2-10	1	4.27	9.47	35.17	51.10	- -	- -	- -	- -	- -	0.23
	2		9.89	36.73	53.38	- -	- -	- -	- -	- -	0.24
	3		21.21	78.79		- -	- -	- -	- -	- -	0.52
MR2-11	1	3.39	9.60	48.11	38.90	8316	49.45	2.93	1.21	7.22	0.29
	2		9.94	49.80	40.26	8608	51.18	2.64	1.26	4.36	0.30
	3		16.64	83.36		14409	85.68	4.41	2.10	7.30	0.51
MR2-12	1	4.25	8.54	31.73	55.48	- -	- -	- -	- -	- -	0.31
	2		8.91	33.14	57.95	- -	- -	- -	- -	- -	0.32
	3		21.20	78.80		- -	- -	- -	- -	- -	0.77
MR2-13	1	2.67	9.98	68.97	18.38	12049	- -	- -	- -	- -	0.51
	2		10.25	70.86	18.89	12379	- -	- -	- -	- -	0.53
	3		12.64	87.36		15261	- -	- -	- -	- -	0.65
PC1-1	1	8.64	9.78	73.74	7.84	12297	- -	- -	- -	- -	0.21
	2		10.71	80.71	8.58	13460	- -	- -	- -	- -	0.23
	3		11.71	88.29		14724	- -	- -	- -	- -	0.25
PC1-2	1	5.35	7.43	77.95	9.27	13386	- -	- -	- -	- -	0.30
	2		7.85	82.35	9.80	14143	- -	- -	- -	- -	0.31
	3		8.71	91.29		15679	- -	- -	- -	- -	0.35
PC1-3	1	5.75	7.30	82.07	4.88	12863	- -	- -	- -	- -	0.35
	2		7.74	87.08	5.18	13647	- -	- -	- -	- -	0.37
	3		8.17	91.83		14392	- -	- -	- -	- -	0.39

Sample	Basis[a]	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	C (%)	H (%)	N (%)	O (%)	Total sulfur (%)
PC2-1	1	4.26	6.89	80.45	8.39	11526	--	--	--	--	0.63
	2		7.20	84.03	8.77	12039	--	--	--	--	0.66
	3		7.89	92.11		13196	--	--	--	--	0.72
PC3-1	1	4.69	5.98	72.88	16.45	11922	71.95	2.87	1.22	6.81	0.69
	2		6.27	76.47	17.26	12509	75.50	2.46	1.28	2.77	0.73
	3		7.58	92.42		15119	91.24	2.97	1.55	3.35	0.88
PC3-2	1	5.07	6.67	74.69	13.57	12492	--	--	--	--	0.67
	2		7.03	78.68	14.30	13159	--	--	--	--	0.71
	3		8.20	91.80		15354	--	--	--	--	0.83
PC3-3	1	14.75	6.69	68.82	9.74	11015	--	--	--	--	0.72
	2		7.84	80.73	11.43	12920	--	--	--	--	0.85
	3		8.86	91.14		14588	--	--	--	--	0.95
PC4-1	1	7.76	10.55	66.07	15.62	10788	--	--	--	--	0.66
	2		11.44	71.63	16.94	11696	--	--	--	--	0.71
	3		13.77	86.23		14081	--	--	--	--	0.86
PC5-1	1	5.34	8.01	70.53	16.12	11467	--	--	--	--	0.60
	2		8.46	74.51	17.03	12114	--	--	--	--	0.64
	3		10.20	89.80		14600	--	--	--	--	0.77
PC5-2	1	4.44	6.78	72.41	16.37	11704	--	--	--	--	0.67
	2		7.09	75.77	17.14	12248	--	--	--	--	0.70
	3		8.56	91.44		14780	--	--	--	--	0.84
PC6-2	1	11.26	14.89	61.35	12.49	10375	--	--	--	--	0.50
	2		16.78	69.14	14.08	11692	--	--	--	--	0.57
	3		19.53	80.47		13607	--	--	--	--	0.66

Sample	Basis[a]	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	C (%)	H (%)	N (%)	O (%)	Total sulfur (%)
PC6-5	1	9.35	13.77	67.72	9.16	11626	70.39	4.18	1.72	14.15	0.39
	2		15.19	74.70	10.11	12825	77.65	3.46	1.90	6.45	0.43
	3		16.90	83.10		14267	86.38	3.85	2.11	7.18	0.48
PG1-1	1	11.41	26.95	44.70	16.94	9325	--	--	--	--	0.55
	2		30.42	50.46	19.12	10526	--	--	--	--	0.63
	3		37.61	62.39		13015	--	--	--	--	0.77
PG1-2	1	8.91	28.83	51.52	10.74	10946	--	--	--	--	0.71
	2		31.65	56.56	11.79	12017	--	--	--	--	0.78
	3		35.88	64.12		13623	--	--	--	--	0.88
PG1-3	1	5.97	29.94	45.35	18.74	10334	--	--	--	--	0.60
	2		31.84	48.23	19.93	10990	--	--	--	--	0.64
	3		39.76	60.24		13725	--	--	--	--	0.80
PG2-1	1	5.26	22.20	36.02	36.52	8132	--	--	--	--	0.56
	2		23.43	38.02	38.55	8583	--	--	--	--	0.59
	3		38.12	61.88		13967	--	--	--	--	0.95
PG2-2	1	5.14	19.47	28.87	46.52	6631	--	--	--	--	0.35
	2		20.52	30.43	49.05	6990	--	--	--	--	0.37
	3		40.27	59.73		13718	--	--	--	--	0.73
PG3-1	1	8.12	23.95	44.46	23.47	9552	--	--	--	--	0.55
	2		26.07	48.39	25.54	10396	--	--	--	--	0.60
	3		35.01	64.99		13962	--	--	--	--	0.80
PG4-1	1	3.12	7.44	87.23	2.22	14292	--	--	--	--	0.57
	2		7.68	90.04	2.29	14752	--	--	--	--	0.59
	3		7.85	92.15		15097	--	--	--	--	0.60

Sample	Basis[a]	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	C (%)	H (%)	N (%)	O (%)	Total sulfur (%)
PG4-2	1	2.84	7.59	81.86	7.71	13326	--	--	--	--	0.52
	2		7.81	84.25	7.94	13716	--	--	--	--	0.54
	3		8.48	91.52		14898	--	--	--	--	0.58
PG4-3	1	5.47	7.54	41.71	45.27	6425	42.77	2.43	1.15	8.08	0.30
	2		7.98	44.13	47.89	6796	45.24	1.93	1.22	3.41	0.31
	3		15.31	84.69		13043	86.82	3.69	2.33	6.55	0.60
RM1-1	1	10.64	25.64	49.69	14.02	9942	58.69	4.71	1.17	20.89	0.51
	2		28.70	55.61	15.69	11126	65.67	3.94	1.31	12.80	0.58
	3		34.04	65.96		13197	77.90	4.67	1.56	15.19	0.68
RM1-2	1	8.36	29.83	36.56	25.25	9031	--	--	--	--	0.29
	2		32.55	39.89	27.55	9855	--	--	--	--	0.32
	3		44.93	55.07		13604	--	--	--	--	0.44
WH3-2	1	8.08	30.37	38.27	23.27	9524	53.50	4.93	1.06	16.64	0.59
	2		33.04	41.64	25.32	10362	58.20	4.38	1.16	10.30	0.64
	3		44.24	55.76		13875	77.93	5.87	1.55	13.79	0.86
WH3-5	1	6.73	33.72	37.90	21.65	10238	--	--	--	--	0.44
	2		36.15	40.64	23.21	10977	--	--	--	--	0.47
	3		47.08	52.92		14296	--	--	--	--	0.61
WH3-8	1	9.89	28.36	39.76	21.99	9424	--	--	--	--	0.29
	2		31.47	44.13	24.40	10458	--	--	--	--	0.33
	3		41.63	58.37		13833	--	--	--	--	0.43
YC1-1	1	6.49	25.76	60.16	7.59	12509	--	--	--	--	0.51
	2		27.55	64.34	8.12	13377	--	--	--	--	0.55
	3		29.98	70.02		14558	--	--	--	--	0.59

Table F4. Total sulfur content of Matanuska Valley coal samples for different bases.

Sample number	Basis[a] 1	2	3
BC1-1*	0.14	0.15	0.76
CC1-1	0.57	0.61	1.20
CC1-2	0.71	0.75	1.13
CC1-3	0.77	0.82	1.32
CC1-4	0.40	0.41	0.74
CC1-5	0.36	0.40	0.42
CC1-6	0.43	0.47	0.48
CC3-2*	0.32	0.33	0.93
CC4-1	0.65	0.68	0.82
CC4-2	0.58	0.61	0.79
CM1-5*	0.18	0.19	0.51
CM2-1	0.37	0.40	0.44
CM2-2	0.52	0.54	0.63
CM2-3	0.66	0.68	0.75
CR1-1	0.81	0.85	0.97
CR1-2	0.70	0.73	0.88
CR1-3	0.51	0.54	0.69
CR2-1*	0.27	0.28	0.68
CR2-2	0.34	0.36	0.59
CR2-3*	0.26	0.27	0.65
EC1-1	0.43	0.48	0.61
KM1-1*	0.14	0.15	1.30
KM2-1	0.55	0.59	0.88
KR1-1	0.46	0.47	0.71
KR1-2*	0.29	0.30	0.69
KR1-3	0.41	0.43	0.71
MC1-1*	0.25	0.26	0.86
MC1-2*	0.44	0.46	0.97
MC1-3	0.79	0.83	0.93
MC1-5	0.58	0.62	0.66
MC1-6	0.54	0.56	0.70
MC2-1	0.57	0.61	0.71
MC2-2	0.50	0.52	0.63
MM1-4	0.57	0.61	0.76
MM1-6	0.70	0.75	0.88
MR1-1	0.49	0.51	0.74
MR2-2	0.29	0.30	0.59
MR2-4*	0.18	0.18	0.59
MR2-7	0.49	0.50	0.53
MR2-10*	0.23	0.24	0.52
MR2-11	0.29	0.30	0.51
MR2-12*	0.31	0.32	0.77
MR2-13	0.51	0.53	0.65
PC1-1	0.21	0.23	0.25
PC1-2	0.30	0.31	0.35

Sample number	Basis[a]		
	1	2	3
PC1-3	0.35	0.37	0.39
PC2-1	0.63	0.66	0.72
PC3-1	0.69	0.73	0.88
PC3-2	0.67	0.71	0.83
PC3-3	0.72	0.85	0.95
PC4-1	0.66	0.71	0.86
PC5-1	0.60	0.64	0.77
PC5-2	0.67	0.70	0.84
PC6-2	0.50	0.57	0.66
PC6-5	0.39	0.43	0.48
PG1-1	0.55	0.63	0.77
PG1-2	0.71	0.78	0.88
PG1-3	0.60	0.64	0.80
PG2-1	0.56	0.59	0.95
PG2-2	0.35	0.37	0.73
PG3-1	0.55	0.60	0.80
PG4-1	0.57	0.59	0.60
PG4-2	0.52	0.54	0.58
PG4-3	0.30	0.31	0.60
RM1-1	0.51	0.58	0.68
RM1-2	0.29	0.32	0.44
WH3-2	0.59	0.64	0.86
WM3-5	0.44	0.47	0.61
WH3-8	0.29	0.33	0.43
YC1-1	0.51	0.55	0.59

[a] 1 = As received; 2 = Moisture free; and 3 = Moisture- and ash-free.
* = Carbonaceous shale

Table F5. Coal-quality calculations from proximate and ultimate analytical data on Matanuska Valley samples.

Sample no.	Fuel ratio F.R. = F.C. / V.M.	Carbon ratio C.R. = F.C. / (F.C. + V.M.) x 100	Perch and Russell ratio R = moist, mm-free Btu / Dry, mm-free Btu	H value (Lord) H = Btu-4050S x 100 / 100-(M+A+S)	Mineral matter M.M. = 1.08A + 0.55S	DuLong's equation (approx. heating value calculated ult. anal. data) Q = 1/100 [14,544 x %C + 62,028 (%H-%O/8) + 4050 x %S]	Dry, mm-free fixed carbon (%) F.C. dmf = F.C.-0.155 x 100 / 100-(M + 1.08A + 0.55S)	Dry, mm-free volatile matter (%) V.M. dmf = 100-F.C. dmf	Moist, mm-free Btu (per lb) Btu-50S x 100 / 100-(1.08A + 0.55S)	Apparent rank (Based A.S.T.M. system)
CC1-1	1.33	57.1	0.96	8339	50.6		62.1	37.9	12600	hvCb
CC1-2	1.51	60.2	0.96	9311	34.9		63.0	37.0	13202	hvBb
CC1-3	1.49	59.9	0.95	8037	38.6		63.1	36.9	12582	hvCb
CC1-4	1.23	55.1	0.98	10433	45.9	7324	59.0	41.0	13159	hvBb
CC1-5	7.04	87.6	0.91	13062	5.2		88.1	11.9	13382	hvBb
CC1-6	4.19	80.8	0.93	12742	12.4		91.1	8.9	13577	hvBb
CC4-1	3.30	76.8	0.96	11533	18.5		78.4	21.6	14228	lvb
CC4-2	3.09	75.5	0.96	13469	24.6		77.7	22.3	14016	mvb
CM2-1	9.80	90.7	0.92	13535	9.0		91.6	8.4	14031	sa
CM2-2	5.71	85.1	0.96	12648	14.1		86.3	13.7	14569	sa
CM2-3	2.16	68.3	0.98	12418	9.3	13716	69.0	31.0	14959	mvb
CR1-1	3.68	78.6	0.96	11240	13.6		80.2	19.8	14400	lvb
CR1-2	3.48	77.7	0.97	11450	19.0	11904	79.3	20.7	14483	lvb
CR1-3	4.39	81.5	0.95	12173	21.2		83.4	16.6	14082	lvb
CR2-2	3.07	75.4	0.96	12135	39.6		79.7	20.3	13884	hvBb
EC1-1	1.34	57.3	0.88	10754	19.9		58.6	42.4	11612	hvCb
KM2-1	6.44	86.6	0.93	10062	33.0		90.0	10.0	12581	hvCb
KR1-1	2.65	72.6	0.99	11980	35.0		75.9	24.1	14608	mvb
KR1-3	3.49	77.7	0.97	11783	40.0		82.1	17.9	14104	lvb
MC1-3	1.68	62.7	0.96	10968	11.8		63.5	36.5	14041	hvAb
MC1-5	1.77	64.0	0.95	12289	7.8	13231	64.5	35.5	14179	hvAb
MC1-6	1.65	62.2	0.96	11849	20.3		63.6	36.4	14039	hvAb
MC2-1	1.82	64.6	0.95	11841	15.7	11800	65.7	34.3	13914	hvBb
MC2-2	1.80	64.3	0.96	12204	17.5		65.5	34.5	14125	hvAb
MM1-4	1.22	55.0	0.95	11320	21.3	10743	56.3	43.7	13570	hvBb
MM1-6	1.31	56.7	0.94	10978	15.7		57.6	42.4	13558	hvBb
MR1-1	4.26	81.0	0.98	12061	32.2		84.2	15.8	14685	lvb
MR2-2	4.51	81.8	1.01	10823	50.8	7159	88.8	11.2	13247	hvBb
MR2-7	6.92	87.4	0.97	13263	6.2		88.0	12.0	14928	sa
MR2-11	5.03	83.3	0.99	12485	42.2	8463	88.3	11.7	14362	sa
MR2-13	6.91	87.4	0.99	12734	20.2		89.3	10.7	15067	sa
PC1-1	7.54	88.3	0.83	13741	8.6		89.1	10.9	12287	hvCb
PC1-2	10.49	91.3	0.95	14302	10.2		92.2	7.8	14890	a
PC1-3	11.24	91.8	0.94	12860	5.5		92.4	7.6	13593	hvBb

Sample no.	Fuel ratio F.R. = F.C. / V.M.	Carbon ratio C.R. = F.C. / F.C. + V.M. x 100	Perch and Russell ratio R = moist, mm-free Btu / Dry, mm-free Btu	H value (Lord) H = Btu-4050S x 100 / 100-(M+A+S)	Mineral matter M.M. = 1.08A + 0.55S	DuLong's equation (approx. heating value calculated ult. anal. data) Q = 1/100 [4,544 x %C + 62,028 (%H-%O/8) + 4,50 x %S)	Dry, mm-free fixed carbon (%) F.C. dmf = F.C.-0.155 x 100 / 100-(M + 1.08A + 0.55S)	Dry, mm-free volatile matter (%) V.M. dmf = 100-F.C. dmf	Moist, mm-free Btu (per lb) Btu-50S x 100 / 100-(1.08A + 0.55S)	Apparent rank (Based A.S.T.M. system)
PC2-1	11.68	92.1	0.96	10351	9.4		93.1	6.9	12687	hvCb
PC3-1	12.19	92.4	0.96	11672	18.2	11745	94.4	5.6	14532	a
PC3-2	11.20	91.8	0.96	12117	15.1		93.4	6.6	14674	a
PC3-3	10.29	91.1	0.84	10828	10.9		92.4	7.6	12322	hvCb
PC4-1	6.26	86.2	0.92	10678	17.3		88.0	12.0	13005	hvBb
PC5-1	8.81	89.8	0.95	12465	17.7		91.5	8.5	13897	hvBb
PC5-2	10.68	91.4	0.96	11453	18.1		93.4	6.6	14250	a
PC6-2	4.12	80.5	0.88	11030	13.8		81.8	18.2	12007	hvCb
PC6-5	4.92	83.1	0.90	12388	10.1	11748	84.0	16.0	12910	hvCb
PG1-1	1.66	62.4	0.88	9982	18.6		63.8	36.2	11422	subA
PG1-2	1.79	64.1	0.91	10139	12.0		65.0	35.0	12398	hvCb
PG1-3	1.51	60.2	0.94	10581	20.5		61.6	38.4	12961	hvCb
PG2-1	1.62	61.9	0.96	10163	39.7		63.7	36.3	13439	hvBb
PG2-2	1.48	59.7	0.97	10861	50.4		64.8	35.2	13334	hvBb
PG3-1	1.86	65.0	0.92	10787	25.6		67.0	33.0	12802	hvCb
PG4-1	11.72	92.1	0.97	12735	2.7		92.5	7.5	14662	a
PG4-2	10.79	91.5	0.98	12621	8.6		92.3	7.7	14551	a
PG4-3	5.53	84.7	0.97	10633	49.1	7120	91.7	8.3	12593	hvCb
RM1-1	1.94	66.0	0.89	10530	15.4	9859	67.1	32.9	11722	hvCb
RM1-2	1.23	55.0	0.91	11868	27.5		56.9	43.1	12437	hvCb
WI3-2	1.26	55.8	0.92	10477	25.4	9573	57.4	42.6	12727	hvCb
WI3-5	1.12	52.9	0.94	11876	23.6		54.3	45.7	13372	hvBb
WI3-8	1.40	58.4	0.89	12167	23.9		60.0	40.0	12365	hvCb
YC1-1	2.34	70.0	0.94	12229	8.5		70.7	29.3	13643	hvBb

Table F6. Mineral analysis of Matanuska Valley coal ash samples (weight percent, ignited basis).

Sample number	Oxide (weight percent)													
	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	P_2O_5	SrO	BaO	Mn_3O_4	Undetermined
CC1-1	62.81	27.85	1.30	2.61	0.33	1.84	1.98	0.94	0.17	0.07	0.00	0.09	0.01	0.00
CC1-2	59.70	30.42	1.53	2.32	0.33	1.49	2.18	0.51	0.15	0.02	0.00	0.07	0.02	1.26
CC1-3	59.53	28.50	1.37	3.05	0.32	1.45	1.97	0.59	0.21	0.08	0.00	0.12	0.00	2.81
CC1-4	58.20	29.68	1.63	3.47	0.66	1.46	1.80	0.36	0.12	0.54	0.03	0.12	0.05	1.88
CC1-6	34.11	28.70	0.94	15.98	7.30	2.20	0.60	1.87	3.03	4.76	0.12	0.34	0.05	0.00
CC3-2*	62.55	26.84	1.13	3.52	0.30	1.87	2.66	0.74	0.21	0.07	0.00	0.08	0.03	0.00
CM1-5	47.72	26.22	1.67	4.65	7.13	2.77	1.19	1.22	4.72	2.04	0.18	0.36	0.13	0.00
CM2-1	55.35	25.04	0.55	4.56	4.70	2.81	0.99	0.65	3.16	0.12	0.05	0.16	0.08	1.78
CM2-2	58.40	27.40	1.33	3.66	2.44	1.89	1.93	0.74	1.31	0.10	0.03	0.25	0.01	0.51
CM2-3	54.96	31.85	1.30	4.24	1.64	1.38	2.07	0.48	1.13	0.09	0.03	0.25	0.01	0.57
CR1-1	52.01	36.01	1.59	2.32	1.92	0.75	0.91	0.58	0.69	0.91	0.13	0.13	0.00	2.05
CR1-2	45.37	37.78	1.38	2.21	3.83	0.53	0.66	0.28	0.76	4.88	0.98	0.49	0.00	0.85
CR1-3	50.70	27.21	1.64	4.54	5.25	0.68	1.59	0.74	0.44	4.54	0.43	0.28	0.02	1.94
CR2-1	58.33	32.93	1.09	2.64	1.09	0.95	1.64	0.32	0.29	0.35	0.02	0.09	0.00	0.26
CR2-2	58.81	30.58	1.16	3.47	0.98	1.22	2.25	0.43	0.25	0.13	0.00	0.11	0.02	0.59
CR2-3*	58.71	31.26	1.09	2.66	1.02	1.10	1.77	0.44	0.22	0.21	0.00	0.10	0.00	1.42
EC1-1	59.42	29.51	1.61	1.92	1.12	1.35	2.12	0.48	0.88	0.17	0.02	0.12	0.01	1.27
KR1-2*	55.13	26.05	1.19	4.48	3.06	2.14	3.16	0.41	0.26	2.85	0.59	0.26	0.02	0.40
MC1-1*	55.11	32.19	1.70	1.69	3.66	0.64	1.00	0.28	0.33	2.34	0.02	0.08	0.02	0.94
MC1-2*	59.03	33.14	1.72	2.38	0.28	0.73	1.37	0.36	0.11	0.04	0.00	0.06	0.00	0.78
MC1-3	48.21	30.24	1.62	2.84	6.58	0.70	1.49	0.43	0.26	6.17	0.57	0.60	0.02	0.27
MC1-5	48.51	38.00	1.52	6.72	1.07	0.64	0.93	0.34	0.24	1.11	0.19	0.25	0.00	0.48
MC1-6	56.23	33.30	1.58	3.34	0.32	0.95	1.58	0.42	0.07	0.26	0.06	0.15	0.00	1.74
MC2-1	22.69	28.55	0.85	2.02	18.63	0.36	0.27	0.20	0.40	19.84	2.02	1.65	0.00	2.52
MC2-2	59.57	28.11	1.49	3.05	1.38	0.96	2.17	0.38	0.08	1.24	0.17	0.25	0.00	1.15
MM1-4	57.47	25.96	1.25	4.54	3.96	1.33	2.03	0.58	1.48	1.00	0.18	0.15	0.07	0.00
MM1-6	53.81	28.02	1.34	4.44	4.61	1.18	1.64	0.33	2.40	0.33	0.08	0.10	0.02	1.70
MR2-2	62.52	24.53	1.37	2.79	2.44	1.51	2.26	0.22	0.24	1.85	0.04	0.21	0.02	0.00
MR2-4*	64.90	25.44	1.18	2.34	0.36	1.54	3.05	0.36	0.10	0.09	0.00	0.08	0.02	0.54
MR2-7	25.15	28.71	1.67	17.07	9.64	2.60	0.51	0.43	4.40	7.72	0.60	1.28	0.14	0.08
MR2-10*	61.52	29.32	1.17	2.75	0.55	1.56	2.30	0.41	0.13	0.22	0.01	0.06	0.00	0.00
MR2-11	63.43	27.28	1.29	2.36	0.63	1.50	2.56	0.29	0.12	0.34	0.03	0.15	0.02	0.00
MR2-12*	60.50	27.42	1.36	2.21	1.41	1.40	2.60	0.87	0.11	0.86	0.02	0.10	0.01	1.13

Sample number	Oxide (weight percent)													
	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	P_2O_5	SrO	BaO	Mn_3O_4	Undetermined
MR2-13	48.96	24.61	1.48	2.39	9.87	0.51	0.85	0.32	0.15	7.81	0.14	0.18	0.00	2.73
PC1-1	36.78	32.38	1.71	6.55	9.51	4.33	0.72	1.45	0.82	4.99	0.35	0.37	0.04	0.00
PC2-1	36.30	31.54	1.75	4.48	9.90	2.62	0.68	1.59	3.91	3.75	0.53	0.78	0.03	2.14
PC3-1	47.73	28.26	1.97	4.20	4.76	2.10	1.36	1.53	1.70	2.68	0.36	0.61	0.04	2.70
PC3-2	37.30	32.11	2.60	2.99	7.28	1.60	0.71	2.07	0.55	7.47	0.97	1.15	0.03	3.17
PC3-3	36.08	32.95	2.39	4.10	8.03	1.90	0.88	1.50	0.70	6.88	0.83	1.24	0.02	2.50
PC6-2	57.88	30.38	1.59	2.23	2.13	1.75	2.06	0.60	0.75	0.33	0.05	0.14	0.01	0.10
PC6-5	51.13	34.76	1.67	3.00	2.66	1.29	1.59	0.51	0.96	0.50	0.08	0.22	0.09	1.54
PG1-2	51.89	32.51	1.46	3.07	3.34	1.08	1.34	0.48	1.10	1.63	0.14	0.14	0.03	1.79
PG4-1	32.20	30.84	0.86	16.21	7.10	2.12	1.02	0.92	5.23	0.26	0.38	0.46	0.05	2.35
PG4-2	47.98	27.78	1.20	5.42	6.34	1.92	2.05	0.78	1.69	2.55	0.30	0.32	0.02	1.65
PG4-3	60.04	24.48	1.15	4.38	0.93	2.30	2.91	1.10	0.00	0.10	0.01	0.11	0.03	2.46
RM1-1	51.81	33.73	2.19	3.77	1.34	0.53	0.92	1.14	0.28	1.82	0.49	0.23	0.02	1.73
WH3-2	53.53	35.38	2.26	1.44	1.57	0.49	0.92	1.25	0.39	1.92	0.54	0.31	0.00	0.00
WH3-5	53.78	28.16	1.42	3.87	2.67	1.51	1.82	0.73	1.36	1.29	0.27	0.27	0.00	2.85
WH3-8	62.79	26.60	1.51	1.59	0.26	0.85	2.63	0.86	0.16	0.04	0.00	0.12	0.00	2.59
YC1-1	40.33	26.94	1.11	8.33	6.26	1.77	2.37	0.55	4.10	4.13	1.01	0.40	0.22	2.48

*Carbonaceous shale.

Table F7. Sulfur forms, free-swelling indices, and ash-fusion temperatures for selected Matanuska Valley coal samples.

Sample number	Sulfur forms (%)				Free swelling index	Fusion temperature of ash (reducing, °F)			
	Pyritic	Sulfate	Organic	Total		Initial deformation	Softening (H=W)	Softening (H=½W)	Fluid
BC1-1	0.06	0.00	0.05	0.11	0				
CC1-1	0.04	0.00	0.47	0.51	0				
CC1-2	0.01	0.01	0.61	0.63	1				
CC1-3	0.04	0.01	0.69	0.74	0				
CC1-4	0.04	0.00	0.31	0.35	½	2700	2700	2700	2700
CC1-5	0.01	0.00	0.32	0.33	0	2100	2130	2180	2210
CC1-6	0.02	0.00	0.39	0.41	0				
CC3-2	0.08	0.00	0.16	0.24	0	2700	2700	2700	2700
CC4-1	0.01	0.00	0.56	0.57	1½				
CC4-2	0.01	0.00	0.50	0.51	1½				
CM1-5	0.04	0.00	0.10	0.14	0	2635	2660	2700	2700
CM2-1	0.01	0.00	0.31	0.32	0	2370	2450	2540	2620
CM2-2	0.03	0.00	0.47	0.50	0				
CM2-3	0.01	0.00	0.57	0.58	7½	2700	2700	2700	2700
CR1-1	0.01	0.00	0.74	0.75	½				
CR1-2	0.01	0.00	0.67	0.68	½	2700	2700	2700	2700
CR1-3	0.05	0.01	0.42	0.48	0	2380	2580	2700	2700
CR2-1	0.03	0.00	0.19	0.22	½	2700	2700	2700	2700
CR2-2	0.03	0.00	0.27	0.30	1	2700	2700	2700	2700
CR2-3	0.03	0.00	0.19	0.21	½				
EC1-1	0.01	0.00	0.37	0.38	0	2700	2700	2700	2700
KM1-1	0.08	0.06	0.87	1.01	0				
KM2-1	0.03	0.00	0.46	0.49	0				
KR1-1	0.03	0.00	0.39	0.42	1				
KR1-2	0.05	0.00	0.18	0.23	0	2475	2545	2660	2700
KR1-3	0.05	0.00	0.29	0.34	0				
MC1-1	0.03	0.00	0.14	0.17	0				
MC1-2	0.04	0.00	0.32	0.36	1				
MC1-3	0.02	0.00	0.69	0.71	1				
MC1-5	0.01	0.00	0.50	0.51	2½				
MC1-6	0.07	0.00	0.41	0.48	1	2700	2700	2700	2700
MC2-1	0.02	0.00	0.48	0.50	1½	2700	2700	2700	2700
MC2-2	0.01	0.00	0.43	0.44	1				

Sample number	Sulfur forms (%)				Free swelling index	Fusion temperature of ash (reducing, °F)			
	Pyritic	Sulfate	Organic	Total		Initial deformation	Softening (H=W)	Softening (H=½W)	Fluid
MM1-4	0.08	0.00	0.45	0.53	1				
MM1-6	0.10	0.02	0.52	0.64	2	2490	2510	2530	2555
MR1-1	0.05	0.00	0.39	0.44	½				
MR2-2	0.04	0.00	0.18	0.22	0	2620	2700	2700	2700
MR2-4	0.03	0.03	0.06	0.12	0				
MR2-7	0.03	0.00	0.42	0.45	0				
MR2-10	0.04	0.00	0.13	0.17	0				
MR2-11	0.03	0.00	0.20	0.23	0				
MR2-12	0.03	0.00	0.22	0.25	0				
MR2-13	0.02	0.00	0.42	0.44	0				
PC1-1	0.03	0.00	0.15	0.18	0	2310	2330	2360	2420
PC1-2	0.01	0.00	0.18	0.19	0	2390	2420	2440	2480
PC1-3	0.01	0.00	0.27	0.28	0				
PC2-1	0.01	0.00	0.50	0.51	0	2350	2370	2410	2440
PC3-1	0.02	0.00	0.61	0.63	0	2580	2680	2700	2700
PC3-2	0.01	0.00	0.55	0.56	0				
PC3-3	0.01	0.00	0.59	0.60	0				
PC4-1	0.06	0.00	0.54	0.60	0				
PC5-1	0.02	0.00	0.49	0.51	0	2700	2700	2700	2700
PC5-2	0.01	0.00	0.57	0.58	0				
PC6-2	0.02	0.00	0.47	0.49	0				
PC6-5	0.02	0.00	0.32	0.34	0	2700	2700	2700	2700
PG1-1	0.02	0.00	0.46	0.48	0				
PG1-2	0.01	0.00	0.50	0.61	0	2700	2700	2700	2700
PG1-3	0.01	0.00	0.52	0.53	½				
PG2-1	0.01	0.00	0.46	0.47	0				
PG2-2	0.01	0.00	0.27	0.28	0	2580	2700	2700	2700
PG3-1	0.01	0.00	0.49	0.50	0	2700	2700	2700	2700
PG4-1	0.00	0.00	0.46	0.46	0				
PG4-2	0.28	0.00	0.16	0.44	0				
PG4-3	0.04	0.00	0.18	0.22	0	2600	2700	2700	2700
RM1-1	0.02	0.00	0.46	0.48	0	2310	2360	2455	2595
RM1-2	0.07	0.00	0.16	0.23	0				
WH3-2	0.01	0.00	0.49	0.50	½	2700	2700	2700	2700
WH3-5	0.01	0.00	0.33	0.34	½				
WH3-8	0.01	0.00	0.24	0.25	½				
YC1-1	0.03	0.00	0.40	0.43	½	2250	2270	2330	2400

Table F8. Coal-ash characteristics related to slagging and fouling factors for selected Matanuska Valley samples.

Sample number	Alkalies as Na_2O, dry coal basis	Silica value	Base: acid ratio	Fouling index	Slagging index	Estimated viscosity at critical viscosity: Temperature of xxxx deg F = xxxx poises	Estimated viscosity at critical viscosity: T250 temperature deg F
CC1-1	1.11	92.93	0.08	-0.2	-0.6		+2900
CC1-2	0.69	93.52	0.07	-0.2	-0.6		+2900
CC1-3	0.64	92.51	0.08	-0.2	-0.6		+2900
CC1-4	0.67	91.24	0.09	-0.2	-0.6	+2900/-580	+2900
CC1-6	0.06	57.26	0.44	0.8	-0.6		2367
CC3-2	1.58	91.66	0.10	-0.2	-0.6	+2900/-580	+2900
CM1-5	1.21	76.64	0.22	0.3	-0.6	+2900/-36	2671
CM2-1	0.12	82.10	0.17	-0.2	-0.6	2740/400	2834
CM2-2	0.31	87.97	0.12	-0.2	-0.6		+2900
CM2-3	0.16	88.33	0.11	-0.2	-0.6	+2900/-280	+2900
CR1-1	0.14	91.25	0.07	-0.2	-0.6		+2900
CR1-2	0.12	87.35	0.09	-0.2	-0.6	+2900/-300	+2900
CR1-3	0.33	82.88	0.16	-0.2	-0.6	+2900/-130	2828
CR2-1	0.81	92.57	0.07	-0.2	-0.6	+2900/-500	+2900
CR2-2	0.71	91.21	0.09	-0.2	-0.6	+2900/-480	+2900
CR2-3	0.93	92.47	0.08	-0.2	-0.6		+2900
EC1-1	0.39	93.12	0.08	-0.2	-0.6	+2900/-600	+2900
KR1-2	1.39	85.06	0.16	-0.2	-0.6	2860/250	2853
MC1-1	0.65	90.20	0.08	-0.2	-0.6		+2900
MC1-2	0.65	94.57	0.05	-0.2	-0.6		+2900
MC1-3	0.15	82.65	0.15	-0.2	-0.6		2841
MC1-5	0.07	85.19	0.11	-0.2	-0.6		+2900
MC1-6	0.27	92.42	0.07	-0.2	-0.6	+2900/-600	+2900
MC2-1	0.06	51.92	0.41	-0.2	-0.6	2600/11	2396
MC2-2	0.31	91.70	0.09	-0.2	-0.6		+2900
MM1-4	0.39	85.40	0.15	-0.2	-0.6		+2900
MM1-6	0.23	84.03	0.15	-0.2	-0.6	2730/520	2881
MR2-2	0.88	90.27	0.10	-0.2	-0.6	+2900/-420	+2900
MR2-4	1.65	93.87	0.08	-0.2	-0.6		+2900
MR2-7	0.05	46.18	0.54	0.2	-0.6		2278
MR2-10	1.04	92.68	0.08	-0.2	-0.6		+2900
MR2-11	0.80	93.39	0.08	-0.2	-0.6		+2900

Sample number	Alkalies as Na_2O, dry coal basis	Silica value	Base: acid ratio	Fouling index	Slagging index	Estimated viscosity at critical viscosity: Temperature of xxxx deg F = xxxx poises	Estimated viscosity at critical viscosity: T250 temperature deg F
MR2-12	1.49	92.34	0.10	-0.2	-0.6		+2900
MR2-13	0.15	79.31	0.19	-0.2	-0.6		2761
PC1-1	0.18	64.35	0.32	0.5	-0.6	2560/90	2514
PC2-1	0.19	68.11	0.28	0.4	-0.6	2610/120	2575
PC3-1	0.39	81.19	0.18	0.3	-0.6	+2900/-110	2768
PC3-2	0.37	75.86	0.20	0.4	-0.6		2699
PC3-3	0.22	72.00	0.23	0.3	-0.6		2652
PC6-2	0.29	90.45	0.10	-0.2	-0.6		+2900
PC6-5	0.16	88.03	0.10	-0.2	-0.6	+2900/-300	+2900
PG1-2	0.16	87.39	0.11	-0.2	-0.6	+2900/-320	+2900
PG4-1	0.04	55.87	0.43	0.4	-0.6		2378
PG4-2	0.19	77.81	0.21	0.2	-0.6		2688
PG4-3	1.45	88.75	0.14	0.2	-0.6	+2900/-350	+2900
RM1-1	0.27	90.18	0.09	-0.2	-0.6	2655/+2000	+2900
WH3-2	0.47	93.85	0.06	-0.2	-0.6	+2900/-700	+2900
WH3-5	0.42	86.98	0.13	-0.2	-0.6		+2900
WH3-8	0.63	95.88	0.07	-0.2	-0.6		+2900
YC1-1	0.17	71.14	0.28	0.2	-0.6	2530/370	2571

Table F9. Matanuska Valley coal-ash calculations and characteristic values based on major oxide geochemistry.

Sample	Na_2O content (%)	Total coal alkali %Na_2O + 0.6589 (% K_2O x % ash)	Total ash alkali %Na_2O + 0.6589 (%K_2O)	Total acid $SiO_2 + TiO_2 + Al_2O_3$	Total base $Fe_2O_3 + CaO + MgO + K_2O + Na_2O$	Base/acid ratio $\frac{Fe_2O + CaO + MgO + K_2O + Na_2O}{SiO_2 + TiO_2 + Al_2O_3}$	Ferric/lime ratio Fe_2O_3/CaO	Dolomite percent $\frac{CaO + MgO}{Fe_2O_3 + CaO + MgO + Na_2O + K_2O} \times 100$
CC1-1	0.94	61.72	2.24	91.96	7.70	.084	7.91	28.18
CC1-2	0.51	46.36	1.95	91.65	6.83	.075	7.03	26.66
CC1-3	0.59	46.50	1.89	89.40	7.38	.083	9.53	23.98
CC1-4	0.36	50.55	1.55	89.51	7.75	.087	5.26	27.35
CC1-6	1.87	2.68	2.27	63.75	27.95	.438	2.19	33.99
CM2-1	0.65	5.94	1.30	80.94	13.71	.169	0.97	54.78
CM2-2	0.74	17.02	2.01	87.13	10.66	.122	1.50	40.62
CM2-3	0.48	11.77	1.84	88.11	9.81	.111	2.59	30.78
CR1-1	0.58	7.86	1.18	89.61	6.48	.072	1.21	41.20
CR1-2	0.28	7.78	0.71	84.53	7.51	.089	0.58	58.05
CR1-3	0.74	21.03	1.79	79.55	12.80	.161	0.86	46.33
CR2-2	0.43	54.47	1.91	90.55	8.35	.092	3.54	26.35
EC1-1	0.48	25.92	1.88	90.54	6.99	.077	1.71	35.34
MC1-3	0.43	10.76	1.41	80.07	12.04	.150	0.43	60.47
MC1-5	0.34	4.57	0.95	88.03	9.70	.110	6.28	17.63
MC1-6	0.42	19.72	1.46	91.11	6.61	.073	10.44	19.21
MC2-1	0.20	2.74	0.38	52.09	21.49	.413	0.11	88.37
MC2-2	0.38	23.16	1.81	89.17	7.94	.089	2.21	29.47
MM1-4	0.58	26.57	1.92	84.68	12.19	.144	1.15	43.40
MM1-6	0.33	15.67	1.41	83.17	12.20	.147	0.96	47.46
MR2-2	0.22	69.94	1.71	88.42	9.22	.104	1.14	42.84
MR2-7	0.43	2.26	0.77	55.53	30.25	.545	1.77	40.46
MR2-11	0.29	65.91	1.98	92.00	7.34	.080	3.75	29.02
MR2-13	0.32	10.61	0.88	75.05	13.94	.186	0.24	74.46
PC1-1	1.45	5.17	1.92	70.87	22.56	.318	0.69	61.35
PC2-1	1.59	5.35	2.04	69.59	19.27	.277	0.45	64.97
PC3-1	1.53	16.27	2.43	77.96	13.95	.179	0.88	49.18
PC3-2	2.07	8.42	2.54	72.01	14.65	.203	0.41	60.61
PC3-3	1.50	7.15	2.08	71.42	16.41	.230	0.51	60.51
PC6-2	0.60	17.55	1.96	89.85	8.77	.098	1.05	44.24
PC6-5	0.51	10.11	1.56	87.56	9.05	.103	1.13	43.65
PG1-2	0.48	9.96	1.36	85.86	9.31	.108	0.92	47.48
PC4-1	0.92	2.41	1.59	63.90	27.37	.428	2.28	33.69
PC4-2	0.78	11.19	2.13	76.96	16.51	.215	0.85	50.03
PG4-3	1.10	87.90	3.02	85.67	11.62	.136	4.71	27.80
RM1-1	1.14	9.64	1.75	87.73	7.70	.088	2.81	24.29
WH3-2	1.25	15.36	1.86	91.17	5.67	.062	0.92	36.33
WH3-5	0.73	26.69	1.93	83.36	10.60	.127	1.45	39.43
WH3-8	0.86	38.97	2.59	90.90	6.19	.068	6.12	17.93
YC1-1	0.55	12.40	2.11	68.38	19.28	.282	1.33	41.65

Table F9. (continued)

Sample	Ferric/dolomite ratio Fe_2O_3/ $CaO + MgO$	Silica/alumina ratio SiO_2/ Al_2O_3	Silica ratio SiO_2/ $SiO_2 + Fe_2O_3 + CaO + MgO$	Slagging factor (Rs) Base/acid ratio x S	Fouling factor (Rf) base/acid ratio x Na_2O	Ash type bituminous: $Fe_2O_3 > CaO + MgO$ lignite: $Fe_2O_3 < CaO + MgO$
CC1-1	1.20	2.26	0.93	0.04	0.08	Bituminous
CC1-2	1.27	1.96	0.94	0.05	0.04	Bituminous
CC1-3	1.72	2.09	0.93	0.06	0.05	Bituminous
CC1-4	1.64	1.96	0.93	0.03	0.03	Bituminous
CC1-6	1.68	1.19	0.57	0.18	0.82	Bituminous
CM2-1	0.61	2.21	0.82	0.05	0.11	Lignite
CM2-2	0.85	2.13	0.88	0.06	0.09	Lignite
CM2-3	1.40	1.73	0.88	0.06	0.05	Bituminous
CR1-1	0.87	1.44	0.91	0.05	0.04	Lignite
CR1-2	0.51	1.20	0.87	0.06	0.02	Lignite
CR1-3	0.77	1.86	0.83	0.08	0.12	Lignite
CR2-2	1.58	1.92	0.91	0.03	0.04	Bituminous
EC1-1	0.78	2.01	0.93	0.03	0.04	Lignite
MC1-3	0.39	1.59	0.83	0.11	0.06	lignite
MC1-5	3.93	1.28	0.85	0.06	0.04	Bituminous
MC1-6	2.63	1.69	0.92	0.04	0.03	Bituminous
MC2-1	0.11	0.79	0.52	0.21	0.08	Lignite
MC2-2	1.30	2.12	0.92	0.04	0.03	Bituminous
MM1-4	0.86	2.21	0.85	0.08	0.08	Lignite
MM1-6	0.77	1.92	0.84	0.09	0.05	Lignite
MR2-2	0.71	2.55	0.90	0.02	0.02	Lignite
MR2-7	1.39	0.88	0.46	0.25	0.23	Bituminous
MR2-11	1.11	2.33	0.93	0.02	0.02	Bituminous
MR2-13	0.23	1.99	0.79	0.08	0.06	Lignite
PC1-1	0.47	1.14	0.64	0.06	0.46	Lignite
PC2-1	0.36	1.15	0.72	0.14	0.44	Lignite
PC3-1	0.61	1.69	0.81	0.11	0.27	Lignite
PC3-2	0.34	1.16	0.76	0.11	0.42	Lignite
PC3-3	0.41	1.09	0.72	0.14	0.35	Lignite
PC6-2	0.57	1.91	0.90	0.05	0.06	Lignite
PC6-5	0.76	1.47	0.88	0.04	0.05	Lignite
PG1-2	0.69	1.60	0.87	0.07	0.05	Lignite
PG4-1	1.76	1.04	0.56	0.20	0.39	Bituminous
PG4-2	0.66	1.73	0.78	0.09	0.17	Lignite
PG4-3	1.36	2.45	0.89	0.03	0.15	Bituminous
RM1-1	2.02	1.54	0.90	0.04	0.10	Bituminous
WH3-2	0.70	1.51	0.94	0.03	0.08	Lignite
WH3-5	0.93	1.91	0.87	0.04	0.09	Lignite
WH3-8	1.43	2.36	0.96	0.02	0.06	Bituminous
YC1-1	1.04	1.50	0.71	0.12	0.16	Bituminous

Table F10. Evaluation criteria for various coal-ash parameters related to fouling and slagging types. From Schmidt, 1979, after ASME Research Committee on Corrosion and Deposits from Combustion Gases.

Parameter	Low	Medium	High	Severe
		Fouling type		
$R_f = \frac{base}{acid} \times \% Na_2O$	<0.2	0.2-0.5	0.5-1.0	>1.0
Na_2O content, %	<0.5	0.5-1.0	1.0-2.5	>2.5
Total alkali on coal, %	<0.3	0.3-0.45	0.45-0.6	>0.6
Chlorine on coal, %	<0.2	0.2-0.3	0.3-0.5	>0.5
Ash sintering strength =				
At 925°C = mPa	6.89	6.89-34.47	34.47-110.32	>110.32
At 1700°F = psi	1,000	1,000-5,000	5,000-16,000	>16,000
		Slagging type		
T_{250}:				
°C	>1,275	1,400-1,150	1,245-1,120	<1,200
°F	>2,325	2,550-2,100	2,275-2,050	<2,200
$R_s = \frac{base}{acid} \times \% S$	<0.6	0.6-2.0	2.0-2.6	>2.6

Table F11. Concentration of trace elements in Matanuska Valley coal ash samples (ppm). Determined by spark source mass spectrographic analysis.

Sample no.	(3) Lithium (Li)	(4) Beryllium (Be)	(5) Boron (B)	(9) Fluorine (F)	(15) Phosphorous (P)	(17) Chlorine (Cl)	(21) Scandium (Sc)	(23) Vanadium (V)	(24) Chromium (Cr)	(25) Manganese (Mn)	(27) Cobalt (Co)	(28) Nickel (Ni)	(29) Copper (Cu)	(30) Zinc (Zn)	(31) Gallium (Ga)	(32) Germanium (Ge)	(33) Arsenic (As)	(34) Selenium (Se)
CC1-4	MC	3	110	700	MC	34	65	340	51	230	9	19	61	30	37	1	9[a]	14
CC1-5	11	<0.1	6	290	560	5	0.5	2	2	7	2	3	4	5	1	0.7	3	1
CC3-2	110	0.5	31	560	560	81	19	250	37	41	6	13	44	43	27	2	3	4
CH1-5	28	0.1	47	710	350	11	29	67	23	45	7	8	68	59	30	1	3	2
CM2-1	46	0.2	1	51	56	18	5	25	2	17	2	1	4	5	3	0.3	2	4
CM2-3	110[a]	0.1	9	91	140	8	5	25	9	7	10	6	11	21	5	0.3	2	2
CR1-2	230	3	76	630	NR	NR	24	31	12	2	3	17	22	12	13	2	2	22
CR1-3	300	1	31	510	NR	NR	5	61	9	22	6	13	19	10	11	7	3	4
CR2-1	300	0.5	14	290	NR	NR	8	25	17	17	11	13	19	86	48	0.7	3	≤ 2
CR2-2	330	1	33	550	NR	NR	20	66	18	18	11	6	47	58	29	2	2	≤ 1
EC1-1	46	0.5	14	290	NR	NR	5	110	17	7	25	13	19	10	27	0.7	5	≤ 1
KR1-2	>910	2	76	NR	NR	NR	8	24	37	41	2	13	22	53	22	3	7	2
MC1-6	110	1	31	110	NR	NR	19	200	9	7	25	6	44	21	27	0.7	7	≤ 1
MC2-1	110	0.2	3	NR	NR	NR	2	2	0.9	2	6	13	11	21	11	0.7	7	NR
MM1-6	46	0.5	140	110	NR	NR	5	61	17	17	11	6	44	21	11	0.7	17	NR
MR2-2	300	0.2	31	NR	NR	NR	8	61	17	41	6	13	19	53	27	3	0.3	NR
PC1-1	20	0.5	140	250	MC	37	5	61	0.7	17	6	1	11	5	11	0.7	0.2	1
PC1-2	46	0.5	310	290	MC	15	5	25	0.9	41	2	3	19	21	11	0.6	17	2
PC2-1	46	3	69	260	MC	41	19	25	2	15	6	3	25	12	24	0.7	15	2
PC3-1	100	3	69	640	MC	100	100	55	4	37	14	3	0.3	12	24	1	15	NR
PC3-3	180	2	47	440	MC	86	29	38	5	11	17	2	30	8	17	≤ 0.5	5	2
PC5-1	110	0.5	120	510	NR	NR	5	25	17	41	6	6	19	21	11	0.7	7	NR
PC6-5	110	0.2	31	290	NR	NR	19	61	9	22	6	6	19	21	11	0.3	7	NR
PG1-2	71	0.1	42	310	NR	NR	12	38	6	5	4	4	12	6	3	0.5	4	NR
PG2-2	110	0.2	140	MC	MC	46	47	250	9	41	6	6	44	21	24	3	3	4
PG3-1	46	1	76	510	MC	25	47	61	4	17	11	3	11	10	11	0.7	3	4
PG4-3	110	1	76	MC	250	180	47	200	37	73	25	6	44	3	27	2	3	4
RM1-1	110	<0.1	31	290	MC	18	19	54	17	73	2	6	190	21	11	2	7	1
RM1-2	300	0.5	310	MC	MC	56	47	98	4	170	6	3	19	5	11	0.7	2	4
WH3-2	>910	0.5	76	290	MC	8	47	98	9	4	11	6	19	10	27	2	0.7	4
YC1-1	100	1	150	MC	MC	56	43	120	8	37	6	3	25	5	6	NR	4	NR

NR = Not reported
MC = Major component 1,000 ppm
[a]Heterogeneous

Table F11. (continued)

Sample no.	(35) Bromine (Br)	(37) Rubidium (Rb)	(38) Strontium (Sr)	(39) Yttrium (Y)	(40) Zirconium (Zr)	(41) Niobium (Nb)	(42) Molybdenum (Mo)	(47) Silver (Ag)	(48) Cadmium (Cd)	(50) Tin (Sn)	(51) Antimony (Sb)	(52) Tellurium (Te)	(53) Iodine (I)	(55) Cesium (Cs)	(56) Barium (Ba)	(57) Lanthanum (La)	(58) Cerium (Ce)
CC1-4	8	97	180	37	130	23	5	NR	1	2	0.9	0.8	2	0.7	MC	47	66
CC1-5	3	21	23	1	5	16	NR	NR	NR	7[a]	1	0.6	4	NR	35	2	2
CC3-2	3	28	52	27	170	17	4	NR	0.6	3	3	2	15	12	MC	34	25
CM1-5	2	78	72	17	130	10	15	NR	0.4	5	0.7	0.4	2	7	960	52	120
CM2-1	3	3	13	5	47	2	9	NR	0.6	3	1	1	0.4	0.2	150	3	4
CM2-3	0.7	28	120	11	47	2	9	NR	1	3	NR	0.6	0.7	1	350	8	8
CR1-2	8	8	650	33	120	5	4	NR	7	1	NR	NR	≤ 2	0.6	NR	42	59
CR1-3	3	13	520	11	53	7	9	NR	6	NR	NR	NR	4	2	NR	15	19
CR2-1	1	28	13	27	70	17	9	NR	1	74[a]	3	1	2	12	870	84	63
CR2-2	3	30	56	29	100	18	10	NR	2	3	1	1	7	12	380	36	51
EC1-1	3	13	130	27	84	7	2	NR	1	1	2	1	5	5	350	15	19
KR1-2	1	28	NR	27	53	17	9	NR	2	3	1	≤ 0.6	10	0.5	NR	34	38
MC1-6	3	7	110	11	53	7	9	NR	1	1	2	1	0.7	2	150	15	19
MC2-1	1	3	NR	27	53	2	4	NR	11	1	NR	2	2	0.5	NR	34	25
MM1-6	3	7	130	27	84	7	4	NR	1	1	NR	0.6	1	2	350	27	19
MR2-2	3	28	210	11	53	17	2	NR	1	1	NR	NR	1	5	870	34	47
PC1-1	7	3	230	11	21	4	4	NR	0.6	1	0.6	5	3	NR	350	15	19
PC1-2	3	1	230	11	42	2	9	NR	1	7	0.6	1	2	≤ 0.1	870	15	19
PC2-1	6	3	290	24	120	9	8	NR	1	2	NR	NR	3	NR	780	8	19
PC3-1	NR	6	290	24	120	9	4	NR	2	1	NR	14	3	0.5	MC	34	43
PC3-3	4	2	360	7	33	7	3	NR	0.9	2	NR	2	2	NR	MC	13	13
PC5-1	7	6	130	27	93	7	4	NR	1	3	NR	1	15	2	870	34	25
PC6-5	1	7	52	11	53	7	4	NR	0.6	NR	0.6	0.6	0.7	1	770	15	19
PG1-2	2	4	140	15	58	5	10	NR	1	0.8	0.5	0.4	2	1	540	21	26
PG2-2	3	28	130	11	53	7	4	NR	0.6	3	1	1	2	NR	870	15	19
PG3-1	3	13	100	23	53	7	9	NR	1	0.7	0.6	1	3	12	350	27	19
PG4-3	630	63	130	24	52	7	4	NR	0.6	3	1	0.6	4	12	870	34	42
RM1-1	7	7	130	11	53	4	MC	0.6	1	4	NR	2	4	5	350	3	8
RM1-2	7	13	520	11	93	7	2	NR	2	3	0.6	1	2	1	870	15	19
WH3-2	1	7	230	11	53	7	4	NR	2	6	0.6	2	0.4	2	MC	15	19
YC1-1	6	6	520	6	47	4	8	NR	5	2	NR	NR	9	0.5	780	8	27

Table F11. (continued)

Sample no.	(59) Praseodynium (Pr)	(60) Neodymium (Nd)	(62) Samarium (Sm)	(63) Europium (Eu)	(64) Gadolinium (Gd)	(65) Terbium (Tb)	(72) Hafnium (Hf)	(74) Tungsten (W)	(82) Lead (Pb)	(90) Thorium (Th)	(92) Uranium (U)
CC1-4	2	2	4	0.7	NR	NR	NR	NR	21	8	6
CC1-5	0.4	NR	NR	NR	NR	NR	NR	NR	3	≤3	≤2
CC3-2	0.8	7	7	0.8	NR	NR	≤3	NR	15	14	5
CM1-5	10	10	4	0.5	1	0.4	≤1	NR	16	9	3
CM2-1	0.4	NR	NR	NR	NR	NR	NR	NR	12[a]	3	≤2
CM2-3	2	0.9	NR	NR	NR	NR	≤3	NR	6	6	3
CR1-2	4	5	8	0.6	NR	NR	NR	≤2	19	8	6
CR1-3	4	9	7	0.8	2	NR	NR	≤3	6	6	3
CR2-1	17	36	17	2	4	NR	NR	NR	26	14	11
CR2-2	5	10	7	0.9	≤1	NR	NR	NR	28	15	5
EC1-1	4	4	3	0.5	NR	NR	NR	NR	6	6	3
KR1-2	8	16	7	2	≤2	NR	NR	NR	26	35	9
MC1-6	4	4	3	0.5	NR	NR	NR	NR	6	6	3
MC2-1	4	4	7	0.8	4	NR	NR	NR	3	6	3
MM1-6	4	4	7	0.8	NR	NR	NR	NR	6	6	5
MR2-2	4	4	3	0.5	NR	NR	NR	NR	15	6	5
PC1-1	4	2	2	NR	NR	NR	NR	NR	6	3	≤2
PC1-2	2	2	3	0.5	NR	NR	NR	NR	8	3	NR
PC2-1	4	4	4	NR	NR	NR	NR	NR	6	≤6	≤5
PC3-1	3	4	4	NR	NR	NR	NR	NR	13	≤6	≤5
PC3-3	3	3	4	0.7	NR	NR	NR	NR	9	≤4	≤4
PC5-1	4	4	3	0.5	NR	NR	NR	NR	6	6	3
PC6-5	2	2	3	0.5	NR	NR	NR	NR	6	3	≤3
PG1-2	5	5	2	0.3	NR	NR	NR	NR	4	9	3
PG2-2	4	2	3	0.5	NR	NR	NR	NR	6	14	5
PG3-1	2	2	3	0.5	NR	NR	NR	NR	6	14	3
PG4-3	4	4	3	0.5	NR	NR	NR	NR	6	6	5
RM1-1	2	2	3	0.5	NR	NR	NR	NR	6	6	3
RM1-2	2	2	3	0.5	NR	NR	NR	NR	6	6	5
WH3-2	4	4	3	0.5	NR	NR	NR	NR	6	6	5
YC1-1	2	4	7	≤1	NR	NR	NR	NR	6	8	6

Table F12. Petrology of Matanuska Valley subbituminous coals.

Maceral group/ maceral	Sample (volume %, mineral-matter-free basis)							
	CC1-4	EC1-1	MM1-4	MM1-6	RM1-2	WH3-2	WH3-5	WH3-8
Ulminite/vitrinite	68.2	80.0	76.8	78.7	78.2	75.6	76.0	79.4
Pseudovitrinite	0.0	0.0	0.0	0.7	0.0	0.0	0.1	0.0
Gelinite	0.0	0.5	1.0	0.5	0.4	2.2	0.0	2.2
Phlobaphinite	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.0
Pseudophlobaphinite	0.0	0.2	0.0	0.0	0.4	0.2	0.0	0.0
Humodetrinite	25.2	10.8	13.6	13.2	9.8	11.4	15.9	12.2
Total huminite	93.4	91.5	91.4	93.3	89.0	89.6	92.0	93.8
Fusinite	0.2	0.0	0.6	0.4	0.0	0.4	0.2	0.0
Semifusinite	0.4	0.0	0.2	0.0	0.8	0.4	0.7	0.0
Sclerotinite	1.4	0.1	0.6	0.3	0.6	1.4	0.6	0.2
Macrinite	0.4	0.2	0.2	0.2	0.0	0.0	0.0	0.2
Inertodetrinite	2.0	0.5	2.0	1.6	0.8	1.4	1.6	0.4
Total inertinite	4.4	0.8	3.6	2.5	2.2	3.6	3.1	0.8
Cutinite	0.2	0.0	0.0	0.9	0.6	0.4	1.4	0.2
Sporinite	0.0	0.0	0.0	0.2	0.0	0.0	0.3	0.2
Resinite	1.2	5.2	4.2	0.7	5.4	4.6	1.0	3.2
Suberinite	0.0	0.0	0.0	0.4	0.2	0.0	0.1	0.2
Alginite	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Liptodetrinite	0.8	2.5	0.8	1.0	2.6	1.8	1.9	1.6
Total liptinite	2.2	7.7	5.0	4.2	8.8	6.8	4.9	5.4

Table F13. Petrology of Matanuska Valley bituminous coals.

Sample	Vitri-nite	Pseudo-vitri-nite	Geli-nite	Phlobaphi-nite	Pseudo-phlo-baphi-	Vitro-detri-nite	Total vitri-nite	Fusi-nite	Semi-fusi-nite	Scleroti-nite	Macri-nite	Inerto-detri-nite	Total inerti-nite	Cuti-nite	Spori-nite	Resi-nite	Suberi-nite	Algi-nite	Lipto-detri-nite	Exudati-nite	Total lipti-nite
BC1-2	57.0	0.0	0.0	0.0	0.0	41.6	98.6	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
CC1-1	77.2	0.2	0.0	0.0	0.6	20.0	98.0	0.0	0.2	0.4	0.0	0.0	0.6	0.0	0.0	0.8	0.6	0.0	0.0	0.0	1.4
CC1-2	58.0	0.0	0.0	0.0	3.6	29.2	90.8	0.0	0.0	0.6	0.0	0.0	0.6	0.0	0.0	1.8	5.8	0.0	1.0	0.0	8.6
CC1-3	84.0	0.0	0.0	0.0	2.8	10.4	97.2	0.0	0.2	0.4	0.0	0.0	0.6	0.0	0.0	2.2	0.0	0.0	0.0	0.0	2.2
CC1-6	93.8	0.0	0.0	0.0	0.0	4.2	98.0	1.8	0.0	0.0	0.0	0.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CC4-1	79.2	0.0	0.0	0.0	0.0	14.7	93.9	0.1	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.5	0.0	5.3	0.0	5.9
CC4-2	73.2	0.0	0.0	0.0	0.0	20.2	93.4	0.8	2.0	0.2	0.0	0.4	3.4	0.0	0.0	0.2	1.0	0.0	2.0	0.0	3.2
CM2-2	81.8	0.0	0.0	0.0	0.0	16.8	98.6	0.2	0.0	0.2	0.4	0.0	0.8	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.6
CR1-1	89.8	0.0	0.0	0.0	0.2	7.8	97.8	0.2	0.8	0.0	0.2	0.4	1.6	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.6
CR1-2	82.4	0.0	0.0	0.0	0.0	13.8	96.2	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.4	0.0	0.0	2.2	0.0	3.6
CR1-3	82.6	0.0	0.0	0.0	0.0	15.8	98.4	0.2	0.0	0.4	0.0	0.2	0.8	0.0	0.0	0.2	0.0	0.0	0.6	0.0	0.8
CR2-1	74.8	0.0	0.0	0.0	0.0	25.0	99.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2
CR2-2	89.6	0.0	0.0	0.0	0.0	8.8	98.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.8	0.0	1.6
CR2-3	69.6	0.0	0.0	0.0	0.0	27.0	96.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	2.0	0.0	3.4
KR1-1	71.6	0.0	0.0	0.0	0.0	27.2	98.8	0.0	0.0	0.0	0.2	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.8
KR1-3	97.0	0.0	0.0	0.0	0.0	2.0	99.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.8
MC1-3	91.0	0.0	0.0	0.0	0.8	5.8	97.6	0.0	0.0	0.6	0.0	1.0	1.6	0.2	0.0	0.4	0.2	0.0	0.0	0.0	0.8
MC1-4	80.8	0.0	0.4	0.0	0.2	11.6	93.0	0.2	0.0	0.6	0.2	0.2	1.2	0.0	0.0	4.4	0.0	0.0	1.4	0.0	5.8
MC1-5	89.4	0.0	1.0	0.0	0.0	6.8	97.2	0.0	0.0	0.6	0.0	0.0	0.6	0.0	0.0	1.0	0.0	0.0	1.2	0.0	2.2
MC1-6	80.0	0.0	0.2	0.0	1.4	9.4	91.0	0.0	0.4	0.6	0.2	0.2	1.4	0.2	0.0	1.6	0.0	0.0	5.8	0.0	7.6
MC2-1	87.4	0.0	0.0	0.0	0.0	6.4	93.8	0.4	0.0	0.4	0.2	0.6	1.6	0.2	0.0	4.4	0.0	0.0	0.0	0.0	4.6
MC2-2	83.8	0.0	0.2	0.0	0.8	5.6	90.4	0.0	0.0	0.2	0.0	0.0	0.2	0.2	0.2	1.8	0.0	0.0	7.2	0.0	9.4
MR1-1	81.4	0.0	0.0	0.0	0.0	14.0	95.4	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	2.2	0.0	0.0	1.4	0.8	4.4
MR2-2	75.0	0.0	0.0	0.0	0.0	20.0	95.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.4	0.0	3.4	0.0	5.0
MR2-7	94.4	0.0	0.0	0.0	0.0	4.8	99.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6
MR2-11	70.8	0.0	0.0	0.0	0.0	28.4	99.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.6	0.0	0.8
MR2-13	77.8	0.0	0.0	0.0	0.0	20.6	98.4	0.0	0.0	0.6	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PC6-2	83.0	0.0	0.0	0.0	0.0	14.2	97.2	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.8	0.0	1.8	0.0	2.6
PC6-5	86.0	0.0	0.0	0.0	0.0	10.4	96.4	0.6	0.2	1.0	0.2	1.0	3.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.6
PC1-1	75.8	0.0	0.0	0.0	1.6	13.2	90.6	0.4	0.0	0.6	0.2	0.0	1.2	2.2	0.2	2.0	1.6	0.0	2.2	0.0	8.2
PG1-2	87.0	0.0	0.0	0.0	0.4	8.8	96.2	0.2	0.0	1.0	0.0	0.4	1.6	0.0	0.0	0.4	0.6	0.0	1.0	0.2	2.2
PG1-3	84.0	0.0	0.0	0.2	0.4	7.8	92.4	0.4	0.2	1.2	0.0	0.4	2.2	0.2	0.0	1.0	1.2	0.0	3.0	0.0	5.4
PG2-1	69.0	0.0	0.0	0.0	0.4	21.4	90.8	0.0	0.0	0.2	0.0	0.2	0.4	0.0	0.0	0.6	5.8	0.0	2.4	0.0	8.8
PG2-2	68.6	0.0	0.0	0.0	0.0	22.4	91.0	0.2	1.6	0.0	0.0	1.0	2.8	0.0	0.0	0.6	1.0	0.0	4.6	0.0	6.2
PG3-1	71.0	0.0	0.0	0.0	0.0	18.4	89.4	0.4	0.6	0.4	0.2	0.4	2.0	0.0	0.2	0.2	2.4	0.2	5.6	0.0	8.6
RM1-1	92.4	0.0	0.0	0.0	0.0	5.0	97.4	0.0	0.0	1.2	0.0	0.0	1.2	0.0	0.0	1.2	0.0	0.0	0.0	0.2	1.4
YC1-1	85.0	0.0	0.0	0.0	0.0	10.4	95.4	0.4	0.6	0.0	0.4	1.8	3.2	0.0	0.0	1.0	0.0	0.0	0.4	0.0	1.4
YC2-1	79.6	0.0	0.0	0.0	0.0	14.4	94.0	0.6	0.6	0.0	0.4	3.2	4.8	0.0	0.0	0.6	0.0	0.0	0.6	0.0	1.2

Table F14. Petrology of Matanuska Valley semianthracite, anthracite, and meta-anthracite coals.

Sample	Vitrinite	Pseudovitrinite	Gelinite	Phlobaphinite	Pseudophlobaphinite	Vitrodetrinite	Total vitrinite	Fusinite	Semifusinite	Sclerotinite	Macrinite	Inertodetrinite	Total inertinite	Cutinite	Sporinite	Resinite	Suberinite	Alginite	Liptodetrinite	Total liptinite	Other: Heat-affected coal-coke
CC1-5	65.6	7.8	0.0	0.0	0.0	5.2	78.6	0.6	1.6	0.0	1.0	0.6	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
CM2-1	52.8	1.2	0.0	0.0	0.0	12.4	76.4	0.0	0.0	0.2	0.4	0.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.6
KM2-1	76.8	0.2	0.0	0.0	0.0	21.8	98.8	0.4	0.0	0.8	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PC1-1	92.4	0.0	0.0	0.0	0.0	6.2	98.6	0.2	0.0	0.4	0.0	0.4	1.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0
PC1-2	61.2	0.0	0.0	0.0	0.0	4.8	66.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.0
PC1-3	95.2	0.0	0.0	0.0	0.0	4.4	99.6	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PC2-1	85.4	0.0	0.0	0.0	0.0	4.8	90.2	0.0	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2
PC3-1	94.4	0.0	0.0	0.0	0.0	5.0	99.4	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.0
PC3-2	79.0	0.0	0.0	0.0	0.0	19.2	98.2	1.0	0.2	0.0	0.0	0.0	1.2	0.0	0.0	0.6	0.0	0.0	0.0	0.6	0.0
PC3-3	88.2	0.0	0.0	0.0	0.0	6.4	94.6	2.6	0.0	0.2	0.2	1.2	4.2	0.0	0.0	0.8	0.0	0.0	0.4	1.2	0.0
PC4-1	90.4	0.0	0.0	0.0	0.0	9.2	99.6	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PC5-1	89.4	0.0	0.0	0.0	0.0	8.2	97.6	0.4	0.0	1.2	0.2	0.6	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PC5-2	79.6	0.0	0.0	0.0	0.0	20.4	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PG4-1	98.0	0.0	0.0	0.0	0.0	2.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PG4-2	95.2	0.0	0.0	0.0	0.0	4.8	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PG4-3	64.6	0.4	0.0	0.0	0.0	33.6	98.6	0.0	0.0	1.4	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YC3-1	86.6	1.8	0.0	0.0	0.0	9.6	98.0	0.4	0.0	0.0	0.0	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table F15. Mean-maximum vitrinite reflectance, class frequency data, and corresponding rank of Matanuska Valley coal samples.

Sample number	Romax	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
		Frequency																
BC1-1	0.99						2	6	24	36	18	10	4					
BC1-2	0.89						2	12	38	32	14	2						
CC1-1	0.67					18	52	30										
CC1-2	0.64					12	74	14										
CC1-3	0.76						18	56	24	2								
CC1-4	0.62				6	32	54	6	2									
CC1-5	2.40															2	4	10
CC1-6	1.28											28	28	40	4			
CC3-2	1.08								2	14	38	36	10					
CC4-3	1.33												30	54	16			
CC4-2	1.27										4	16	38	38	4			
CM1-5	2.07																2	
CM2-1	2.94																	
CM2-2	2.09																	2
CM2-3	1.08									6	58	32	4					
CR1-1	1.42										2	2	2	28	50	16		
CR1-2	1.22										8	18	64	10				
CR1-3	1.66										2	2	6	10	20	8	16	2
CR2-1	1.09								2	14	34	28	14	8				
CR2-2	1.14								2	4	16	60	16	2				
CR2-3	1.12								4	6	32	36	18	4				
EC1-1	0.55				16	56	28											
KM1-1	2.85													2		4		
KM2-1	3.42																	
KR1-1	1.09								2	16	26	48	8					
KR1-2	1.27											12	48	38	2			
KR1-3	1.47												2	12	44	36	6	
MC1-1	0.64					24	54	22										
MC1-2	0.65					26	44	28	2									
MC1-3	0.79						8	38	52	2								
MC1-4	0.73						26	62	12									
MC1-5	0.74					4	14	64	16	2								
MC1-6	0.78					4	8	40	48									
MC2-1	0.84							22	64	14								
MC2-2	0.85							18	66	16								
MM1-4	0.51				38	62												
MM1-6	0.57				2	74	24											
MR1-1	1.55													18	16	26	26	12
MR2-2	1.87															8	18	22
MR2-4	1.75														6	10	10	28
MR2-7	1.90																2	6
MR2-10	1.70													2	4	6	30	38
MR2-11	1.80															6	18	22
MR2-12	1.59											2		10	16	24	20	14
MR2-13	1.55													2	32	28	32	6
PC1-1	4.07																	
PC1-2	5.34																	

Sample number	V18	V19	V20	V21	V22	V23	V24	V25	V26	V27	V28	V29	V30	V31	V32	V33	V34	V35
BC1-1																		
BC1-2																		
CC1-1																		
CC1-2																		
CC1-3																		
CC1-4																		
CC1-5	10	10	18	6	4	2	2	4	2	4	4	2				2	4	4
CC1-6																		
CC3-2																		
CC4-3																		
CC4-2																		
CM1-5	6	20	26	28	14	4												
CM2-1						2	6	4	6	10	8	16	14	20	10	2	2	
CM2-2	4	12	30	28	22	2												
CM2-3																		
CR1-1																		
CR1-2																		
CR1-3	6	12	2	4	8	2												
CR2-1																		
CR2-2																		
CR2-3																		
EC1-1																		
KM1-1				4	2	4	4	4	6	8	8	10	12	8	10	2	2	4
KM2-1												2	6	6	14	10	8	14
KR1-1																		
KR1-2																		
KR1-3																		
MC1-1																		
MC1-2																		
MC1-3																		
MC1-4																		
MC1-5																		
MC1-6																		
MC2-1																		
MC2-2																		
MM1-4																		
MM1-6																		
MR1-1	2																	
MR2-2	44	6	2															
MR2-4	28	18																
MR2-7	32	54	4	2														
MR2-10	18	2																
MR2-11	34	18	2															
MR2-12	10	4																
MR2-13																		
PC1-1													4	2			2	2
PC1-2																		

[1] $V_{51} = 4$; $V_{52} = 12$; $V_{53} = 2$.
[2] $V_{51} = 12$; $V_{52} = 10$; $V_{53} = 22$; $V_{54} = 20$; $V_{55} = 6$; $V_{56} = 2$; $V_{57} = 2$; $V_{58} = 4$; $V_{60} = 2$; $V_{61} = 2$.
[3] $V_{54} = 2$.

Sample number	Romax	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21	V22	V23	V24	V25	V26	V27	V28	V29	V30	V31	V32	V33	V34	V35
															Frequency																					
PC1-3	4.85																																			
PC2-1	3.74																															2	6	10	24	10
PC3-1	4.12																																			
PC3-2	3.89																																		2	6
PC3-3	3.64																													8	4	6	6	6	4	10
PC4-1	4.08																																		2	
PC5-1	3.02																											4	4	32	32	26	2			
PC5-2	3.52																															2	2	18	24	20
PC6-2	2.08																	2	8	14	34	20	14	6	2											
PC6-5	1.93																	4	28	54	12	2														
PG1-1	0.74				2	4	16	50	28																											
PG1-2	0.68					10	54	28	8																											
PG1-3	0.76						22	44	32	2																										
PG2-1	0.78						2	54	44																											
PG2-2	0.84							18	76	6																										
PG3-1	0.81							38	54	8																										
PG4-1	2.56																						2	4	24	32	24	12	2							
PG4-2	2.91																										6	8	26	34	26					
PG4-3	3.29																											2	2	4	8	16	12	18	26	10
RM1-1	0.89							8	38	52	2																									
RM1-2	0.60					46	52	2																												
WH3-2	0.60					40	58	2																												
WH3-5	0.58				6	48	46																													
WH3-8	0.47				76	24																														
YC1-1	0.92								32	62	6																									
YC2-1	0.82						2	38	46	14																										
YC3-1	3.69																															4	2		6	12

Sample number	V36	V37	V38	V39	V40	V41	V42	V43	V44	V45	V46	V47	V48	V49	V50	Rank
							Frequency									
BC1-1																hvAb
BC1-2																hvAb
CC1-1																hvCb
CC1-2																hvCb
CC1-3																hvBb
CC1-4																subA
CC1-5						2				2						sa[3]
CC1-6																mvb
CC3-2																hvAb
CC4-1																mvb
CC4-2																mvb
CM1-5																lvb
CM2-1																a
CM2-2																lvb
CM2-3																hvAb
CR1-1																mvb
CR1-2																mvb
CR1-3																mvb
CR2-1																hvAb
CR2-2																hvAb
CR2-3																hvAb
EC1-1																subA
KM1-1	4	2														a
KM2-1	14	6	14	4		2										a
KR1-1																hvAb
KR1-2																mvb
KR1-3																mvb
MC1-1																hvCb
MC1-2																hvCb
MC1-3																hvBb
MC1-4																hvBb
MC1-5																hvBb
MC1-6																hvBb
MC2-1																hvAb
MC2-2																hvAb
MM1-4																subA
MM1-6																subA
MR1-1																mvb
MR2-2																lvb
MR2-4																lvb
MR2-7																lvb
MR2-10																lvb
MR2-11																lvb
MR2-12																mvb
MR2-13																mvb
PC1-1	2	8	6	6	6	16	22	6	12	6						a
PC1-2												2	2	8	6	ma[2]

[2] $V_{51} = 12$; $V_{52} = 10$; $V_{53} = 22$; $V_{54} = 20$; $V_{55} = 6$; $V_{56} = 2$; $V_{57} = 2$; $V_{58} = 4$; $V_{60} = 2$; $V_{61} = 2$.

[3] $V_{54} = 2$.

Sample number	V36	V37	V38	V39	V40	V41	V42	V43	V44	V45	V46	V47	V48	V49	V50	Rank
								Frequency								
PC1-3						2			6	6	12	20	10	14	12	a[1]
PC2-1	4		4	6	6	12	8	6	2							a
PC3-1	2	4	12	4	20	24	10	14	10							a
PC3-2	6	22	26	28	6											a
PC3-3	8	8	14	6	6	8	2	2		2						a
PC4-1	4	2	6	4	16	20	20	14	4	4						a
PC5-1																a
PC5-2	24	8	2													a
PC6-2																lvb
PC6-5																lvb
PG1-1																hvBb
PG1-2																hvCb
PG1-3																hvBb
PG2-1																hvBb
PG2-2																hvAb
PG3-1																hvAb
PG4-1																sa
PG4-2																a
PG4-3	2															a
RM1-1																hvAb
RM1-2																subA
WH3-2																subA
WH3-5																subA
WH3-8																subB
YC1-1																hvAb
YC2-1																hvAb
YC3-1	18	24	26	8												a

[1] $V_{51} = 4$; $V_{52} = 12$; $V_{53} = 2$.

Table F16. Relationship between ASTM rank and vitrinite reflectance. After Rao, 1976; and Ting, 1978.

Class	Rank	Mean maximum reflectance of vitrinite, Rom (%)
Anthracite	Meta-anthracite	>5.0
	Anthracite	2.5–5.0
	Semianthracite	2.0–2.5
Bituminous	Low-volatile bituminous	1.5–2.0
	Medium-volatile bituminous	1.1–1.5
	High-volatile A bituminous	0.8–1.1
	High-volatile B bituminous	0.6–0.8
	High-volatile C bituminous	0.4–0.6
	Subbituminous	0.3–0.4
Lignite	Lignite	0.2–0.3

APPENDIX G

Table G1. Matanuska Valley coal-overburden characterization. Refer to plate 2 and appendixes B and C for sample locations.

Sample	$CaCO_3$ (%)[3]	pH paste	EC (umho/cm)[a]	Na (meq/1)[b]	Ca (meq/1)[b]	Mg (meq/1)[b]	SAR[c]	K sat. paste (mg/1)	Sand (%)	Silt (%)	Clay (%)	Class	ESP[d]	Sat. (%)
CC3-1	0.4	8.04	480	0.67	0.81	4.12	0.43	6.5	70	12	18	SL	2.36	33
CC3-3	0.3	7.77	350	0.42	0.46	2.93	0.32	2.5	64	29	7	SL	2.94	27
CM1-1	0.5	6.10	170	0.99	0.52	0.12	1.75	3.0	73	13	14	SL	2.99	33
CM1-2	0.9	6.15	160	0.78	0.53	0.20	1.29	2.8	66	14	20	SCL/SL	2.20	28
CM1-3	0.6	6.06	130	0.45	0.51	0.26	0.73	6.3	70	12	18	SL	1.87	27
CM1-4	0.6	6.62	260	0.90	0.85	0.32	1.18	5.2	68	9	23	SCL	2.29	27
MM1-1	0.7	8.13	340	0.73	0.96	1.71	0.63	17.2	9	53	38	SiCL	3.27	51
MM1-2	<0.6	8.02	410	0.60	1.16	2.46	0.45	16.1	24	31	45	C	2.74	46
MM1-3	0.3	7.61	590	0.51	2.32	3.61	0.30	11.0	76	10	14	SL	3.09	38
MM1-5	0.7	6.92	1200	0.56	9.85	6.97	0.19	15.3	56	20	24	SCL	2.82	39
MM1-7	0.3	7.86	390	0.52	1.45	2.27	0.38	10.7	45	30	25	L	3.64	33
MR2-1	0.1	8.31	480	1.93	0.72	2.86	1.44	6.4	77	17	6	SL/LS	4.34	25
MR2-3	0.4	8.10	490	0.82	0.97	3.75	0.70	8.6	56	21	23	SCL	3.16	35
MR2-5	0.3	8.20	480	0.77	0.71	4.18	0.49	11.0	64	18	18	SL	2.92	33
MR2-6	0.5	7.42	240	0.64	0.68	0.92	0.72	5.1	41	27	32	CL	2.15	32
MR2-8	0.9	8.11	420	0.86	0.82	3.09	0.62	10.6	52	22	26	SCL	2.13	39
MR2-9	1.3	8.14	470	0.87	1.04	3.68	0.57	7.6	63	9	28	SCL	2.88	31
PC6-1	1.5	5.81	140	0.67	0.54	0.32	1.02	1.4	83	12	5	LS	1.02	56
PC6-3	0.5	5.12	160	0.77	0.41	0.27	1.32	2.5	66	14	20	SCL/SL	1.26	29
PC6-4	<1.3	4.69	230	0.74	0.61	0.73	0.90	3.9	82	11	7	LS	0.96	37
PC6-6	0.4	5.20	140	0.39	0.42	0.45	0.59	2.9	85	9	6	LS	1.61	38
WH3-1	0.3	7.33	1900	17.42	0.43	0.18	31.54	7.0	68	11	21	SCL	51.60	48
WH3-3	1.4	9.03	2200	24.01	0.53	0.32	36.83	9.0	24	33	43	C	55.69	54
WH3-4	0.1	8.11	1500	14.35	0.43	0.25	24.61	9.2	65	9	26	SCL	29.17	36
WH3-6	0.4	8.38	780	7.03	0.33	0.13	14.66	5.9	20	31	49	C	42.14	50
WH3-7	0.3	8.08	730	6.52	0.38	0.09	13.45	3.5	74	9	17	SL	52.18	34
WH3-9	0.5	8.66	1000	9.64	0.38	0.17	18.38	7.4	57	23	20	SCL/SL	45.13	20

[a]Micromhos per centimeter.
[b]Milliequivalents per liter.
[c]Sodium adsorption ratio.
[d]Exchangeable sodium percentage.

Sample no.	Tot-S (%)	Pyr-S (%)	SO4-S (%)	Org-S (%)	OM (%)	NO3-N (ppm)	PO4-P (ppm)	K (ppm)	B (ppm)	Cu (ppm)	Pb (ppm)	Mo (ppm)	Se (ppm)	ABP Tot-S	ABP Pyr-S
CC3-1	0.08	0.03	<0.01	0.05	1.7	3.0	<1.0	133	3.8	0.40	0.14	<0.10	<0.012	1.5	3.1
CC3-3	0.09	0.02	<0.01	0.07	5.0	1.5	<1.0	95	3.3	1.12	0.24	<0.10	<0.012	0.2	2.4
CM1-1	0.13	0.01	<0.01	0.12	3.1	1.5	5.0	127	2.5	1.88	1.15	0.20	<0.012	0.9	4.7
CM1-2	0.07	<0.01	<0.01	0.07	2.0	1.5	1.0	140	1.8	3.60	1.51	<0.10	<0.012	6.8	9.0
CM1-3	0.10	<0.01	<0.01	0.10	1.9	1.5	1.0	164	2.3	5.00	1.28	<0.10	<0.012	2.9	6.0
CM1-4	0.04	<0.01	<0.01	0.04	1.3	1.5	<1.0	178	2.5	3.16	2.08	<0.10	<0.012	4.8	6.0
MM1-1	0.02	<0.01	<0.01	0.02	1.4	1.5	<1.0	170	4.3	2.52	0.66	<0.10	<0.012	6.4	7.0
MM1-2	0.08	0.02	<0.01	0.06	2.8	2.0	1.0	153	3.3	8.12	1.17	1.45	<0.012	3.5	5.4
MM1-3	0.15	0.03	<0.01	0.12	9.1	2.0	<1.0	93	4.3	5.00	0.23	0.12	<0.012	-1.7	2.1
MM1-5	0.10	0.02	0.01	0.07	3.0	1.5	<1.0	78	3.3	3.28	0.50	<0.10	<0.012	4.2	6.4
MM1-7	0.05	0.02	<0.01	0.03	2.2	2.0	<1.0	91	5.0	1.76	0.52	<0.10	<0.012	1.4	2.4
MR2-1	0.05	0.02	<0.01	0.03	1.3	1.5	<1.0	99	1.8	1.40	0.50	<0.10	<0.012	-1.6	-0.6
MR2-3	0.04	0.01	<0.01	0.03	1.9	5.0	<1.0	112	2.0	0.68	0.68	<0.10	<0.012	2.8	3.7
MR2-5	0.02	<0.01	<0.01	0.02	1.3	3.5	<1.0	143	2.0	0.64	0.72	<0.10	<0.012	2.4	3.0
MR2-6	<0.01	<0.01	<0.01	<0.01	1.0	3.5	<1.0	86	1.8	17.32	7.04	0.15	<0.012	5.0	5.0
MR2-8	0.02	0.01	<0.01	0.01	0.9	2.5	<1.0	132	1.5	0.64	0.46	<0.10	<0.012	8.4	8.7
MR2-9	0.02	0.03	<0.01	<0.01	1.6	3.5	<1.0	89	3.2	0.24	0.28	<0.10	<0.012	12.4	12.1
PC6-1	0.35	0.02	<0.01	0.33	31.0	1.5	<1.0	39	3.2	1.24	1.35	<0.10	<0.012	4.1	14.4
PC6-3	0.06	0.02	<0.01	0.04	3.7	0.5	5.0	82	3.5	2.24	0.57	<0.10	<0.012	3.1	4.4
PC6-4	0.19	0.02	<0.01	0.17	32.0	0.5	<1.0	42	3.0	0.92	1.17	<0.10	<0.012	7.1	12.4
PC6-6	0.17	0.02	<0.01	0.15	7.7	2.0	10.4	79	5.3	1.28	0.28	<0.10	<0.012	-1.3	3.4
WH3-1	0.38	0.02	0.01	0.35	6.2	2.5	<1.0	169	2.5	18.88	1.26	<0.10	<0.012	-8.6	2.4
WH3-3	0.06	0.04	<0.01	0.02	1.3	4.5	<1.0	184	2.8	2.88	1.15	<0.10	<0.012	12.1	12.8
WH3-4	0.13	0.03	<0.01	0.10	2.6	4.5	<1.0	171	3.8	2.00	0.68	0.11	<0.012	-9.7	-0.9
WH3-6	0.04	<0.01	<0.01	0.04	1.2	2.0	<1.0	252	2.8	2.04	1.66	0.10	<0.012	2.8	4.0
WH3-7	0.10	0.01	<0.01	0.09	7.5	2.0	<1.0	158	3.5	2.44	1.54	0.22	<0.012	-0.1	2.7
WH3-9	0.78	0.02	<0.01	0.76	3.7	3.5	<1.0	209	3.3	4.52	1.51	<0.10	<0.012	-19.4	4.4

Table G2. Suitability ratings for soils as sources of topsoiling material. From Wyoming Department of Environmental Quality, 1978.

Soil parameter	Degree of soil suitability: Good	Fair	Poor	Unsuitable
pH	6.0-8.4	5.5-6.0 8.4-8.8	5.0-5.5 8.8-9.0	Under 5.0 Over 9.0
Conductivity (Ec) mmhos/cm at 25°	Under 4	4-8	8-16	Over 16
Saturation percentage (SP)	25-80		Over 80; under 25	
Texture class	sl, l, sil, scl	cl, sicl, sc, ls	c, sic, s	
Sodium adsorption ratio (SAR)	Under 6	6-10	10-15	Over 15
Calcium carbonate	low (none-slight) 0-15%	moderate 15-30%	high Over 30%	
Moist consistence	friable	loose, firm	very firm	
Dry consistence	loose, soft	slightly hard, hard	very hard	
Selenium	2 ppm or less		greater than 2 ppm	
Boron	5 ppm or less		greater than 5 ppm	
Molybdenum	5 ppm or less		greater than 5 ppm	
NO_3-N	50 ppm or less (suspect)		greater than 50 ppm (suspect)	

Table G3. Guideline for suspect levels in overburden material. (Montana Department of State Lands; from Dollhopl and others, 1978, v. 1, p. 43).

Parameter	Suspect level
Conductance (Ec)	>4-6 mmhos/cm
Sodium adsorption ratio (SAR)	>12
Mechanical analysis	
Clay	>40%
Sand	>70%
Saturation %	None
pH	>8.8-9.0
PO_4-P	None
NO_3-N	>10-20 ppm
NH_4-N	>10-20 ppm
Cd	>0.1-1.0 ppm
Cu	>40 ppm
Fe	Unknown
Pb	(1) pH<6, >10-15 ppm (2) pH>6, >15-20 ppm
Mn	>60 ppm
Hg	>0.4-0.5 ppm
Se	>2.0 ppm
Mo	>0.3 ppm
B	>8.0 ppm
Zn	>30-40 ppm
Ni (1) DTPA extraction	>1.0 ppm
(2) Acid extraction	>5.0 ppm