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ALASKA BITUMINOUS COAL AND ANTHRACITE

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CONTENTS

CONTENTS (con.)

FIGURES

Page

TABLES

TABLES (con.)

Table | Page

FOREWORD

Coal is the chief energy resource of the world today and for the foreseeable future. With escalating world energy needs and rapidly depleting petroleum resources, coal's share of the world energy mix will continue to increase. Coal is already the primary source of fuel for electrical-power generation in the United States.

Coal undoubtedly constitutes the most important resource in Alaska's energy future. Alaska's total coal resources are estimated at between 5.5 and 6.0 trillion short tons, over half of which are of bituminous rank. The total energy equivalency (in Btu) of the coal in Alaska surmounts by many magnitudes that present in all the oil that ultimately will flow from the State. The energy equivalency of Alaska's bituminous coal resources alone are estimated at over 1000 Prudhoe Bays (original recoverable reserves of about 10 billion barrels).

Because of Alaska's vast resources of coal, it promises to become an important coal-mining and export center for the next decade and for the 21st century. The potential for coal development in Alaska is unlimited, and its strategic position on the northern Pacific Rim places it in the center of projected expanding coal-trade routes. In fact, Alaska is closer to Far East markets than Australia, Canada, or South Africa.

Alaska's resources of very low sulfur coal guarantee to make it an important future source of low-sulfur fuel on the Pacific Rim. The low-sulfur content of Alaska's coal (less than 0.5 percent) is one of its chief attractions. The environmental significance of low-sulfur coal is great, and its importance will increase dramatically in the future. The environmental problems inherent to the mining, preparation, and utilization of high-sulfur coal can be avoided by the use of very low sulfur Alaskan coals.

The content of sulfur in Alaskan coals on average is about half that of the lowest-sulfur coals of the contiguous United States. Alaska's coals are uniquely low in the acid-producing, pyritic form of sulfur that causes acid-mine drainage in other regions of the United States. Alaska's lower mean annual temperatures and local relative aridity act to reduce the oxidation effects on Alaska's coals when exposed to the environment.

Because of their very low sulfur content, Alaska coals have resultant low emissions of sulfur-oxide (SO_x) pollution. Most of Alaska's coals meet the U.S. Environmental Protection Agency's emission standards (1.2 lbs SO_2/MM Btu) for direct combustion. Because nitrogen contents are also low, the combined low emissions of SO_x and NO_x gases during combustion make Alaska's coals among the environmentally safest in the world. Alaska's high-rank coals also possess good ash-fusion characteristics, and low moisture and metallic trace-element contents.

Alaska's coals have already been mined for 130 years. If this long history of coal development proves one thing, it proves that coal mining can exist in harmony with the unique Alaskan environment. The Usibelli Coal Mine, located near Healy in interior Alaska, has shown unequivocally by its long-standing efficiency and revolutionary land-restoration programs that coal mining can be carried on in Alaska with both economic success and environmental restraint. As coal mining increases in the State, Alaska has the opportunity to serve as a model for mining efficiency and prudent land-restoration practices in Arctic and Subarctic regions. Today, Alaska coal is poised on the brink, ready to burst into the world coal-market arena in a major way.

INTRODUCTION

Alaska has abundant resources of coal that are estimated to total between five and six trillion tons. These resources are widely distributed across the State and are found in nearly all areas (fig. 1). The resources are comprised almost equally of high- and low-rank coals. This report summarizes known information about the high-rank coals, which are found to some extent in all the major coal provinces of the State.

It is estimated that as much as 55 percent of Alaska's total coal resources---approximately 3 trillion tons---is of bituminous rank (fig. 2). These deposits are predominantly located on Alaska's North Slope, but important resources are also found in the Matanuska, Bering River, Chignik, and Herendeen Bay fields (fig. 3). Most bituminous coal in Alaska formed in the Cretaceous Period between 65 and 140 million years ago as a result of heat and pressure generated during times of strong structural deformation. The remaining bituminous coals formed in the Tertiary Period. The potential for large yet undiscovered deposits of high-rank coal in Alaska is great.

Alaska contains at least minor resources of all high ranks of coal, including semianthracite, anthracite, and meta-anthracite (table 1). These coals are generally classified according to their volatile matter and fixed carbon contents (table 2). Although the bituminous ranks are abundant in Alaska, anthracitic coals are minor (less than 1 percent of the total). Tertiary-age anthracitic coals are found in the eastern parts of the Matanuska and Bering River fields, and Mississippian-age anthracitic coals are found in northern Alaska.

Identified and hypothetical resources of high-rank coal in Alaska that show the highest potential for near-term development are summarized in table 3, and measured resources are shown in figure 4. Possible development projects of Alaskan high-rank coals are listed in table 4.

Almost all of Alaska's bituminous coals are low sulfur (less than 1 percent), and they exhibit coking characteristics ranging from poor to excellent. Potential coking and metallurgical-grade coals are found in the (1) Chickaloon district, Matanuska field; (2) Western Arctic region, especially at Kukpowruk River; (3) Bering River field; (4) Chignik and Herendeen Bay fields, Alaska Peninsula; (5) Lisburne field; and (6) Lower Yukon basin---Nulato field.

Early studies of Alaska's high-rank coals concerned whether they were suitable for blacksmithing purposes or for use by steamships. As many as 20 coal mines operated in Alaska in 1910, and altogether more than 60 mines have operated and closed in Alaska (Conwell and Triplehorn, 1981). Over seven million tons of bituminous coal has been mined in Alaska, mostly from the Matanuska field prior to 1968.

NORTHERN ALASKA PROVINCE

The Northern Alaska coal province on the North Slope of Alaska probably holds as much as 4.0 trillion tons of coal including resources within the

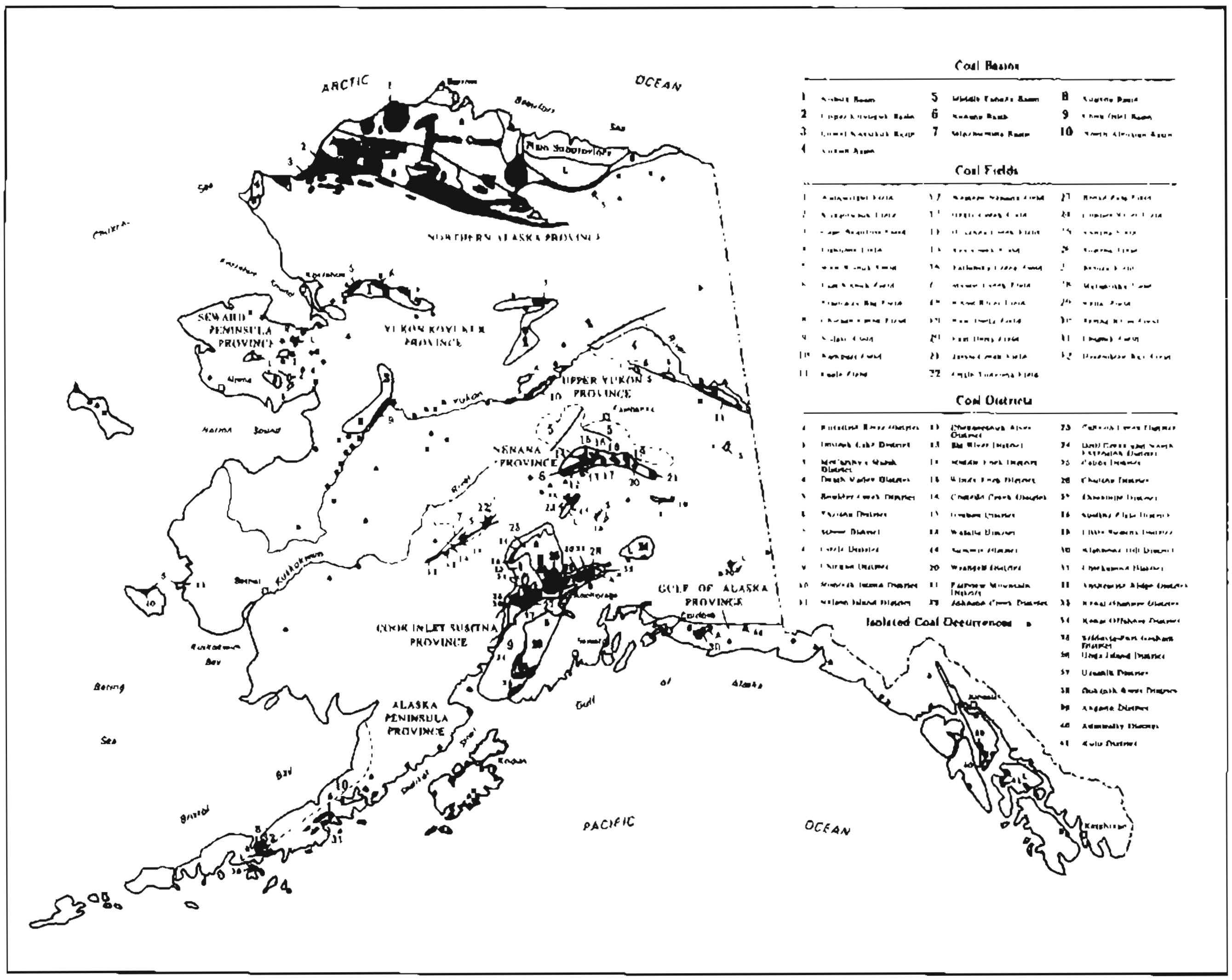

Figure 1. Map of Alaska's coal resources (modified from Merritt and Hawley, 1986).

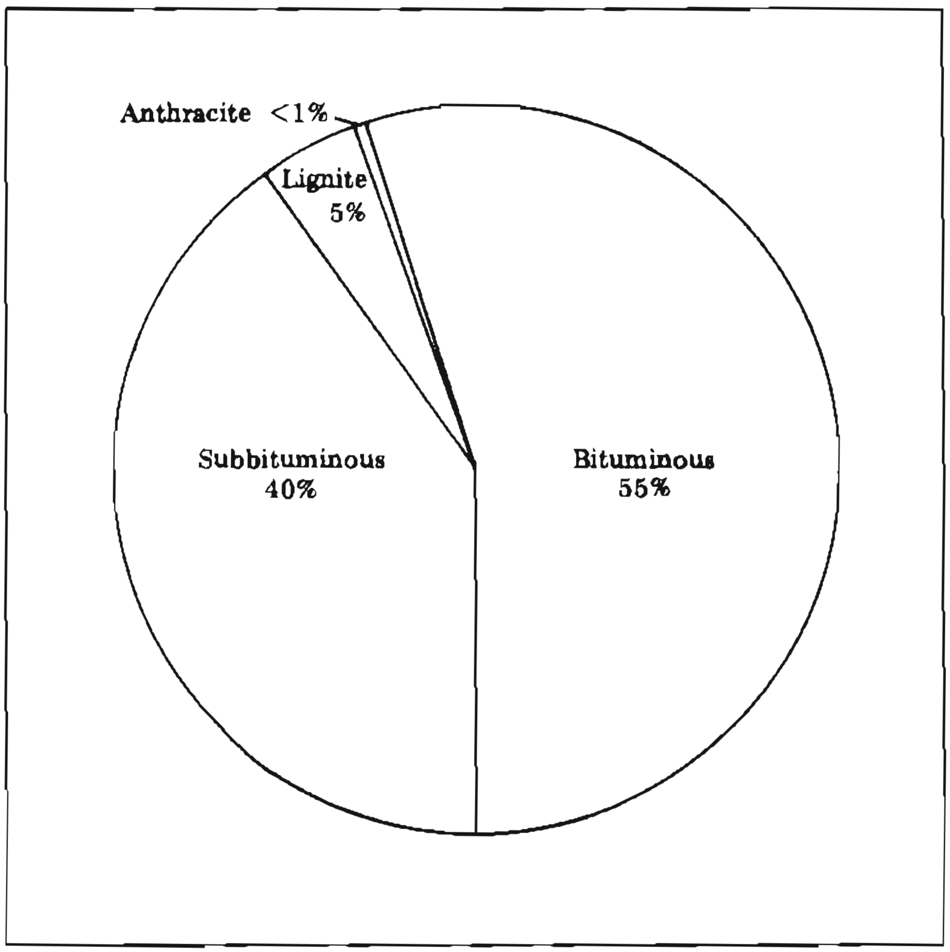

Figure 2. Percentages of Alaska's coal resources by rank.

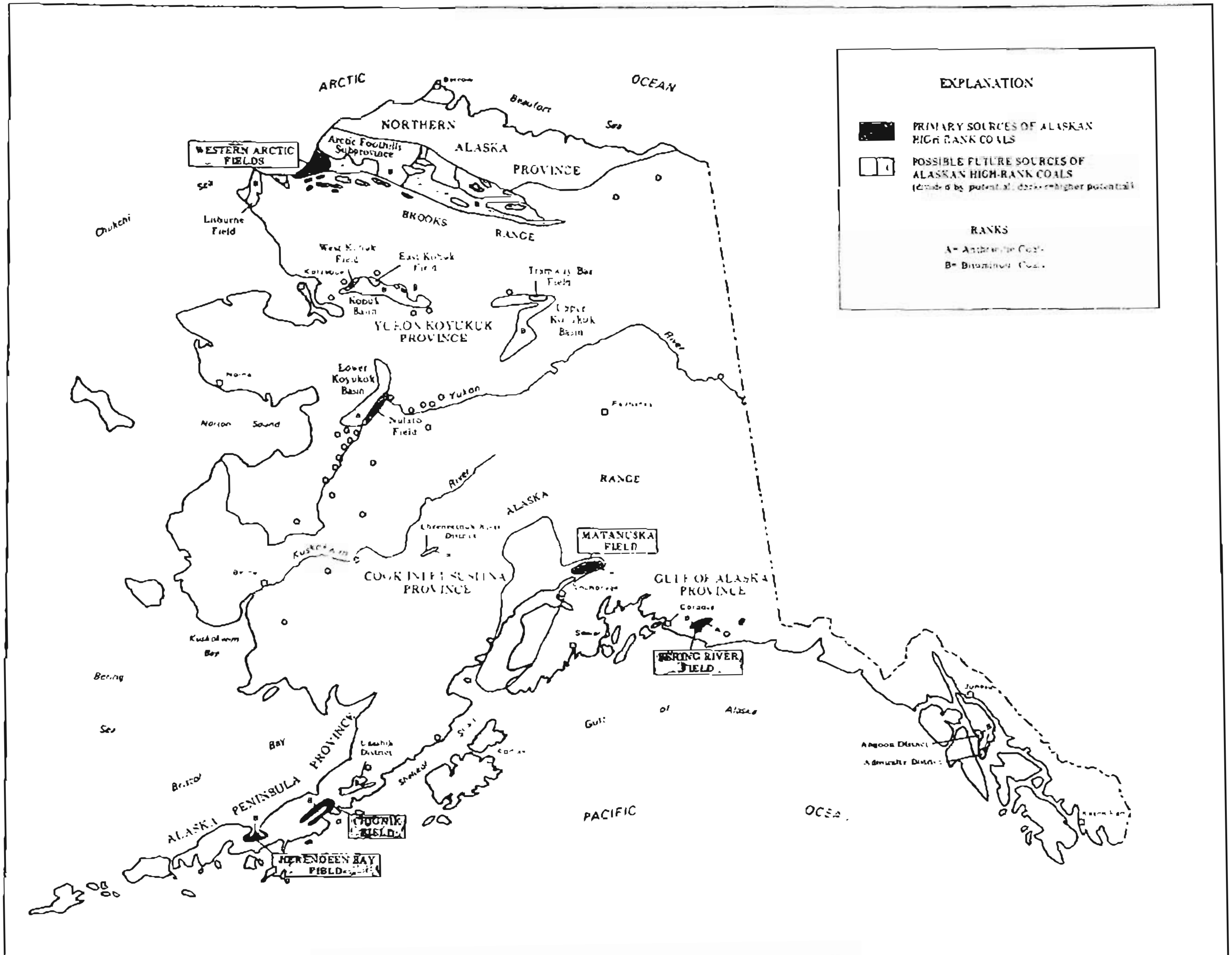

Figure 3. Map showing the general distribution of Alaskan high-rank coal deposits (modified from Merritt and Hawley, 1986).

Table 1. Ranks of bituminous coal and anthracite.

Rank	Abbreviation
Meta-anthracite	ma
Anthracite	an
Semianthracite	sa
Low-volatile bituminous	lvb
Medium-volatile bituminous	mvb
High-volatile A bituminous	hvAb
High-volatile B bituminous	hvBb
High-volatile C bituminous	hvCb

Table 2. Ranges in volatile-matter and fixed-carbon contents in coal as per ASTM.

Volatile Matter (%)	Fixed Carbon (%)	Rank
≤2	≥98	Meta-anthracite
>2, ≤8	≥92, <98	Anthracite
>8, ≤14	≥86, <92	Semianthracite
>14, ≤22	≥78, <86	Low-volatile bituminous
>22, ≤31	≥69, <78	Medium-volatile bituminous
>31	<69	High-volatile bituminous

Table 3. Estimated identified and hypothetical resources of Alaskan high-rank coals for areas considered in detail in this report.

Area	Identified	Hypothetical
Deadfall Syncline	500	5,000
Cape Beaufort	390	1,700
Kukpowruk River	275	1,200
Chignik	230	1,500
Bering River	160	3,500
Herendeen Bay	130	1,500
Wishbone Hill	120	350
Chickaloon	25	100
Anthracite Ridge	4.5	50

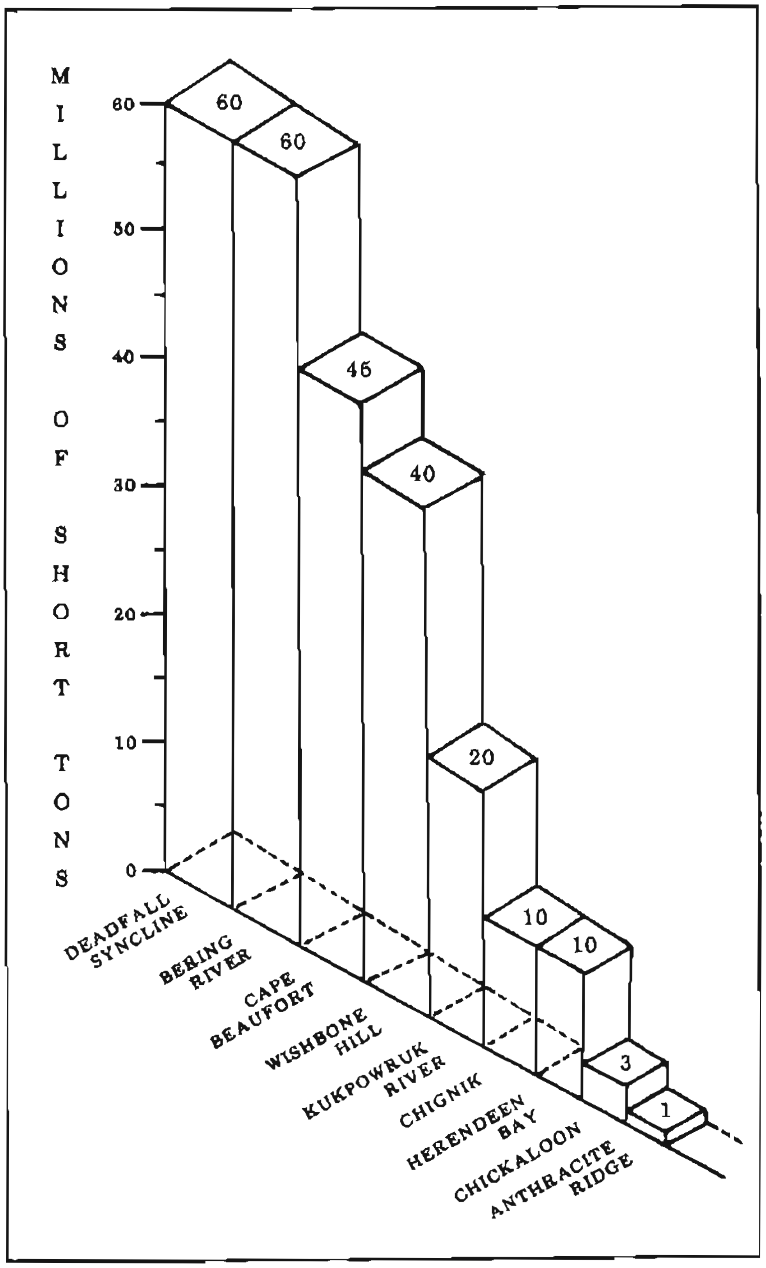

Figure 4. Estimated measured resources of Alaskan high-rank coal.

Table 4. Current development projects of Alaskan high-rank coal.

Company	Location/Project
Union Pacific Resources/ Idemitsu Kosan	Wishbone Hill, Matanuska Field
Arctic Slope Regional Corporation	Western Arctic Coal Development Project
Morgan Coal Company	Kukpowruk River
Chugach Alaska Corporation	Korean-Alaska Development Corporation Project, Bering River Field
Bristol Bay Native Corporation	Chignik Field, Alaska Peninsula

National Petroleum Reserve of Alaska (NPRA) and both east and west of it (fig. 5). As early as 1976, Tailleur and Brosgé estimated total North Slope coal resources as high as 3.35 trillion tons. More recent estimates place hypothetical resources even higher and total identified resources at about 150 billion tons. Approximately 60 percent of North Slope coal is estimated to be of bituminous rank with ten percent or more of the stratigraphic section in some wells composed of coal.

In general, half or more of the coal resources on the North Slope lie on federal lands of the National Petroleum Reserve in Alaska (NPRA). Substantial interests in the high priority coal-development lands are held by the Arctic Slope Regional Corporation.

The large resources of North Slope coal will undoubtedly spur development in the future. Although the coals are amenable to either surface or underground mechanized mining, much depends on the actual total resources of coking coal. The coals may be transported to a partially or wholly ice-free port on the western North Slope. Another possibility is the transportation of the coal as a water or oil slurry after the peak oil production period. The coals may also be used locally in the metal-mining industry or for mine-mouth power plants.

Arctic Foothills' Subprovince

The bituminous coals of northern Alaska occur within the Arctic Foothills' subprovince north of the Brooks Range (fig. 5) and predominantly west of the Itkillik and lower Colville Rivers, a broad upland region of dissected rolling hills south of the nearly flat Arctic Coastal Plain subprovince. The belt of bituminous coal-bearing rocks extends eastward from Cape Lisburne to 149° longitude, chiefly between latitudes 69° and 70°. It includes an extensive area of inadequately known coal fields.

Although the Corwin Formation of the early to late Cretaceous Nanushuk Group contains most of the bituminous coals, the Chandler and Niakogon Formations of the same group and the Late Cretaceous Colville Group also contain bituminous coals (fig. 6). Interbedded with the numerous coal seams

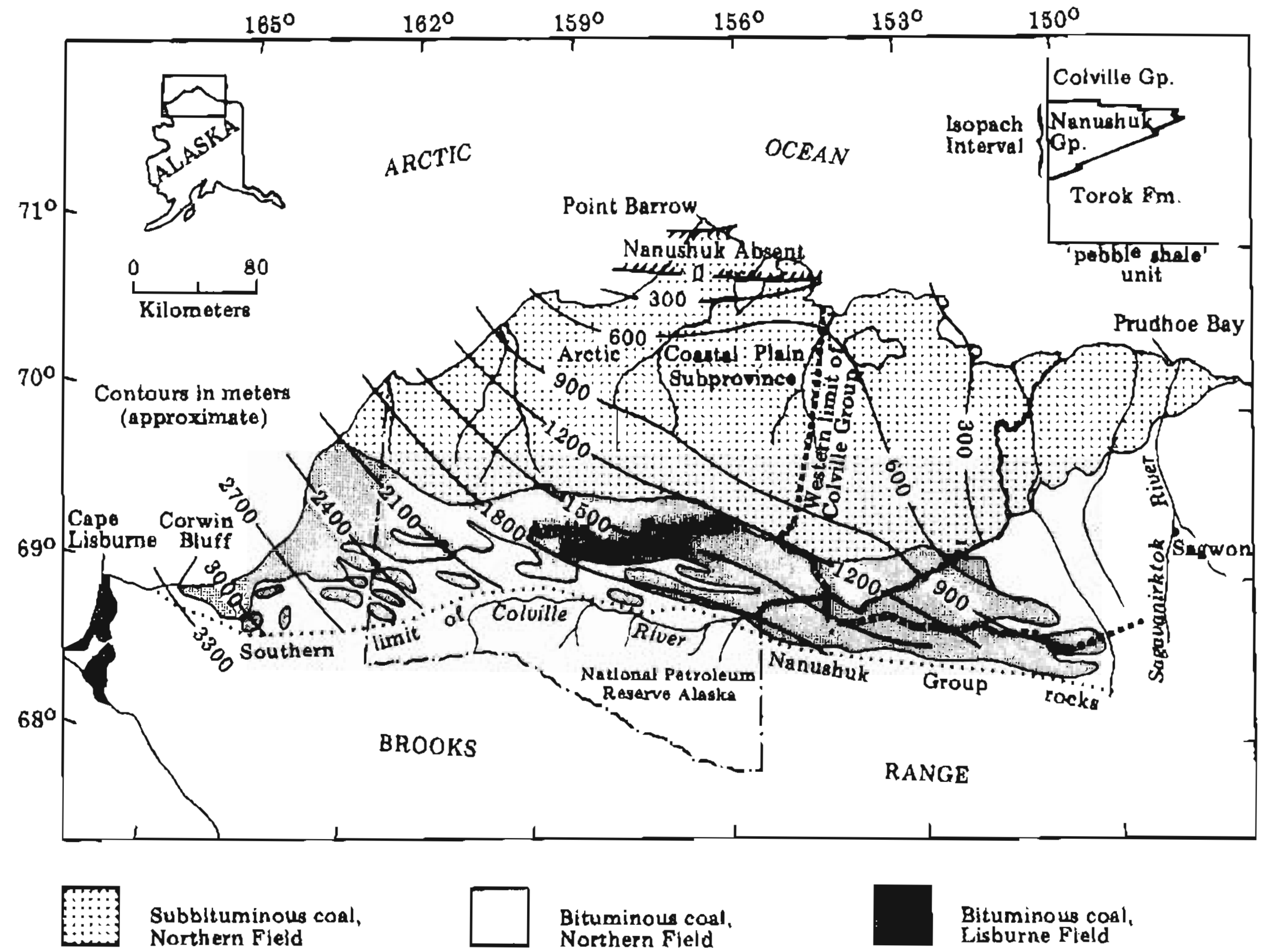

Figure 5. Distribution and extent of coal-bearing rocks of northern Alaska showing coal rank and thickness of the Nanushuk Group (modified from Bird and Andrews, 1979).

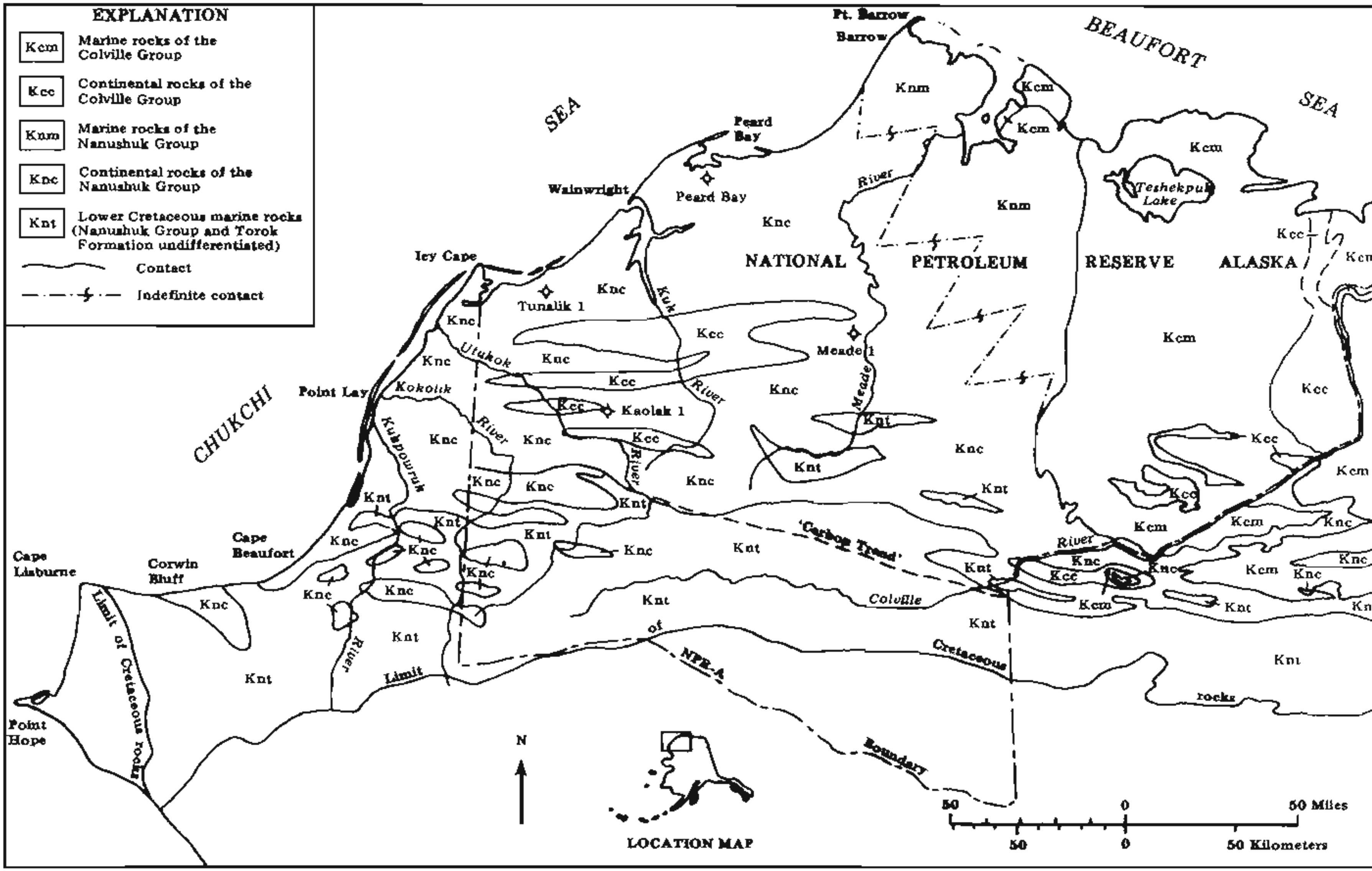

Figure 6. Geologic map of northwestern Alaska showing the distribution and extent of Nanushuk Group and Colville Group continental coal-bearing rocks (from Callahan and Martin, 1981; after Beikman, 1978).

are sandstones, claystones, siltstones, and carbonaceous shales. The intertonguing marine and nonmarine coal-bearing rocks of the Arctic Foothills' subprovince formed in a prograding deltaic depositional system in a swampy coastal lowland.

The geologic structure is relatively simple, overall consisting of a series of east-west trending anticlines and synclines. The synclines contain abundant coal deposits. The coal-bearing strata are flat-lying to gently dipping (10° to 20°).

Coal thicknesses in measured outcrops range to 14.5 ft. Although seams less than 5-ft thick are characteristic, 10-ft thick beds are common and seams greater than 20-ft thick have been recorded in test wells. About 60 percent of the coal beds are over 3.5-ft thick.

The thermal value of the coal overall ranges from 9,300-13,500 Btu/lb. Sulfur ranges from 0.1 - 0.7 percent. Moisture content is low, ranging from 2-7 percent. Although ash varies from 2-25 percent, it has an average content at the low end of the scale. Volatile matter ranges from 31-36 percent and fixed carbon from 53-58 percent. Some coal is of coking quality.

Western Arctic Region

The Western Arctic region west of NPRA may contain up to 1.0 trillion tons of coal. Between 150 and 200 coal beds have been correlated in the Corwin Formation of the Western Arctic (fig. 7). The Corwin Formation correlates with the Chandler Formation to the east.

The coals of the Western Arctic were first explored by the Beechey expedition of 1826-27. A.J. Collier made the first geologic reconnaissance of coastal deposits south of Cape Beaufort in 1904. Kaiser Engineers performed detailed mining and economic evaluations of Western Arctic coal from 1970-77. Subsequently, the State of Alaska and North Slope Borough performed extensive exploration and pre-development site investigations of the coal deposits at Cape Beaufort and Deadfall Syncline.

Tables 5 and 6 summarize the general quality and petrology of coals of the Cape Beaufort, Deadfall Syncline, and Kukpowruk River areas. Figure 8 shows trends in coal petrologic data for the Western Arctic region.

The total resources of stripping coal in the Western Arctic region have not been clearly defined. At a minimum, 125 million short tons of coal reserves are strippable resources amenable to modern mechanized mining and other strippable resources can be defined with further exploration. Abundant additional resources can be developed by underground mining methods. The coal resources of the Western Arctic region are summarized in table 7.

Cape Beaufort

Cape Beaufort is one of the areas of the Western Arctic region that shows high potential for near-term development. The coals of the Cape Beaufort area occur in the Liz-A syncline, located just inland from the

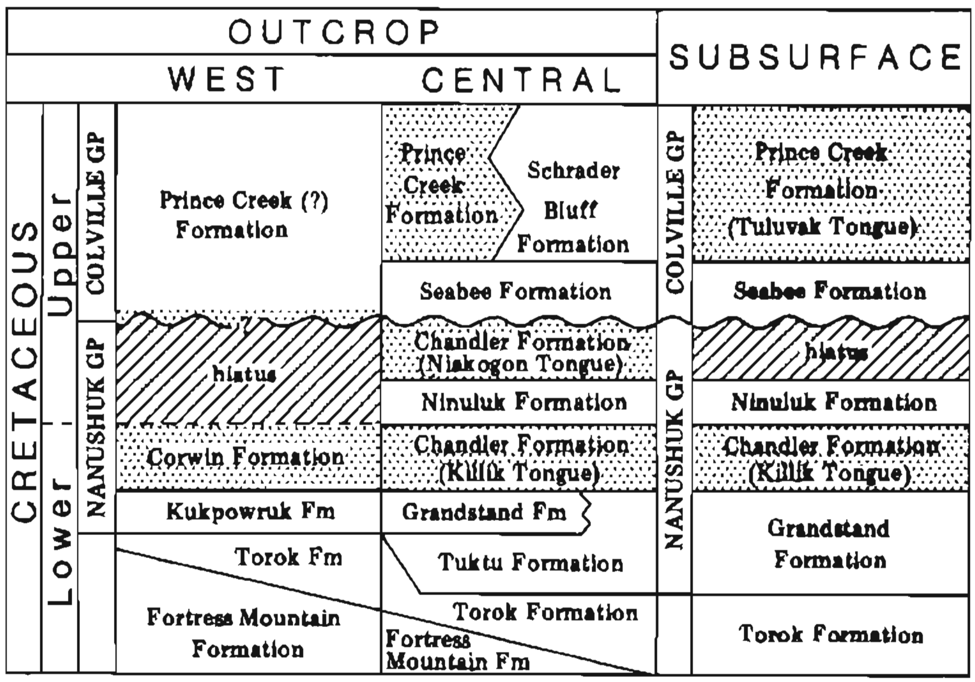

Figure 7. General stratigraphic nomenclature and correlation diagram for the coal-bearing Nanushuk and Colville Groups, northern Alaska (from Ahlbrandt and others, 1979). The dominantly nonmarine units are stippled.

Table 5. Comparison of the quality parameters of Cape Beaufort, Deadfall Syncline, and Kukpowruk River coals, Western Arctic region.

Parameter	Cape Beaufort	Deadfall Syncline	Kukpowruk River
A. Rank:	hvAb-hvCb	hvAb-hvCb	hvAb-hvCb
B. Heating value (Btu/lb):	9,100-12,700 (mean 12,300)	10,900-13,200 (mean 12,900)	11,900-14,100 (mean 13,800)
C. Mean-maximum vitrinite reflectance (Ro_{max}, %):	0.70	0.70	0.73
D. Proximate analysis:			
Moisture	2.5-7 (4.5)	2.5-8 (4.6)	0.8-10 (2.8)
Volatile matter	22-33 (29.7)	22-36 (33.9)	31-40 (35.2)
Fixed carbon	37-55 (46.8)	35-56 (53.9)	52-60 (58.5)
Ash	8-27 (16.0)	5.5-22 (7.6)	2.5-15 (3.5)
E. Ultimate analysis:			
Carbon	46.71 (58.3)	51-65 (59.4)	57-77 (70.0)
Hydrogen	3.5-5 (4.5)	3.7-5.1 (4.6)	4.5-5.6 (5.1)
Nitrogen	0.7-1.5 (1.1)	0.8-1.4 (1.1)	1.0-1.6 (1.3)
Oxygen	13-25 (19.1)	17-27 (23.3)	12-18 (14.5)
Sulfur	0.2-0.4 (0.3)	0.2-0.3 (0.2)	0.2-0.5 (0.3)
Ash	8-27 (16.7)	5.5-22 (11.4)	2.5-15 (8.8)
F. Major-oxide composition of ash (avg., %):			
SiO_2	49.7	30.9	51.5
Al_2O_3	25.1	29.2	25.5
Fe_2O_3	3.2	4.8	4.8
MgO	2.7	6.7	3.0
CaO	6.2	17.5	3.5
Na_2O	2.3	6.8	2.0
K_2O	1.2	0.6	1.0

Table 5 (con.)

Parameter	Cape Beaufort	Deadfall Syncline	Kukpowruk River
TiO_2	1.1	0.7	1.0
SO_3	0.6	1.5	0.5
P_2O_5	0.3	0.8	0.6
MnO	0.1	0.0	0.1
Undet.	7.5	0.5	6.5
G. Trace elements in coal ash (avg., %):			
Boron	440	300	---
Chromium	55	50	40
Cobalt	40	30	35
Copper	40	35	150
Gallium	30	30	50
Lead	55	50	150
Molybdenum	5	5	---
Nickel	40	25	80
Silver	3.5	2	---
Tin	295	180	---
Vanadium	130	95	65
Zinc	110	100	---
Zirconium	500	220	190
H. Trace elements in raw coals (avg., ppm):			
Boron	75	55	---
Chromium	15	12	4
Cobalt	8	8	4
Copper	9	10	12
Gallium	6	5	4
Lead	10	10	14
Molybdenum	1	1	---
Nickel	8	7	7
Silver	1	1	---
Tin	35	25	---
Vanadium	20	20	9
Zinc	25	18	---
Zirconium	100	80	19

Table 5 (con.)

Parameter	Cape Beaufort	Deadfall Syncline	Kukpowruk River
I. Fusibility of ash (reducing atmosphere, temperature °F):			
Initial deformation	2320	2093	2040
Softening	2410	2143	2110
Fluid	2520	2189	2390
J. Free swelling index:	0-6	0-6	0-6
K. Hardgrove grindability index:	58	56	70
L. Coking potential:	Increases with depth; coal from 200-ft shows pronounced coking characteristics.	Similar to Cape Beaufort coals	Significant coking properties; generally soft-coking

Table 6. Comparison of the average distribution of macerals in Cape Beaufort, Deadfall Syncline, and Kukpowruk River coals, Western Arctic region (volume, mmf-basis %; modified from Rao and Smith, 1983).

Maceral	Cape Beaufort	Deadfall Syncline	Kukpowruk River
Vitrinite	62.2	58.1	60.9
Pseudovitrinite	10.0	10.7	16.3
Gelinite	0.7	0.9	1.7
Phlobaphinite	0.4	0.1	0.3
Pseudophlobaphinite	1.0	1.1	1.0
Sporinite	1.2	1.7	1.9
Resinite	0.8	1.0	0.7
Cutinite	0.1	0.2	0.4
Alginite	0.0	0.0	0.1
Exsudatinite	0.1	0.0	0.0
Thick cutinite	0.1	0.3	0.3
Suberinite	0.0	0.0	0.1
Other liptinite	0.0	0.0	0.0
Fusinite	0.8	2.0	0.6
Semifusinite	14.3	16.4	11.4
Macrinite	1.7	2.4	1.1
Globular macrinite	1.3	0.3	0.3
Inertodetrinite	5.3	4.8	2.9
Sclerotinite	0.0	0.0	0.0

Table 7. Summary of the coal resources of the Cape Beaufort, Deadfall Syncline, and Kukpowruk River areas of the Western Arctic.

	Coal resources (millions of short tons; overburden 0-3000 ft)		
	Measured	Identified	Hypothetical
Cape Beaufort	45	390	1,700
Deadfall Syncline	60	500	5,000
Kukpowruk River	20	275	1,200

Chukchi Sea coast (fig. 9). The syncline has an area of almost 30 square miles and exhibits common dips from 15° to 40°. Beds range to 9-ft thick in outcrops (fig. 10) and to 17-ft thick in drill holes. More than 20 beds have been correlated.

Drill samples from a depth of 200 ft have higher heating values and pronounced coking characteristics. Coking properties increase at depth since none of the surface samples show coking properties. Callahan and Sloan (1976) reported a range of free-swelling indexes (FSI) from 0.5 - 6.1 and an average FSI of 2.0 in 47 Cape Beaufort samples. Rao (1980) reported a similar FSI range of 0-6.1 and an average of 2.1 in 30 Cape Beaufort samples.

Arctic Slope Consulting Engineers (1984) found the following ranges in coal-quality criteria based on four seams in the Cape Beaufort project area: heating values from 9,100-12,300 Btu/lb, ash contents from 8-27 percent, moisture contents from 4-6 percent, and ranks of high volatile A bituminous or high volatile B bituminous. They cited reserves at the following stripping ratios: 22.5 million tons at a 10 to 1 stripping ratio, 13.5 million tons at a 7 to 1 stripping ratio, and 8.1 million tons at a 5 to 1 stripping ratio. Additional projected strippable resources were estimated at 25 million tons.

Several specific mining blocks or units can be defined within the Cape Beaufort area. The coals of the Cape Beaufort area are primarily located on Arctic Slope Regional Corporation lands (fig. 11).

Deadfall Syncline

The Deadfall Syncline is located about 6 mi east of the Chukchi Sea (fig. 9) The Cretaceous bituminous coals of the Deadfall Syncline exhibit dips from 0° to 20° (fig. 12) and thicknesses ranging from 4.5 to 13 ft. Denton and others (1987) estimated total indicated coal reserves of the Deadfall Syncline project area at 58 million short tons. Arctic Slope Consulting Engineers (1984) cited the following reserve figures at specified stripping ratios: 15.8 million tons at a 10 to 1 stripping ratio, 7.8 million tons at a 7 to 1 stripping ratio, and 4.0 million tons at a 5 to 1 stripping ratio.

Based on averages of seven seams in the Deadfall Syncline project area, the following general ranges in coal-quality criteria were noted: heating values from 10,900-13,200 Btu/lb, ash contents from 5.5 to 22 percent, moisture contents from 2.5 - 8.0 percent, and a rank of high volatile B bituminous or high volatile C bituminous (Arctic Slope Consulting Engineers, 1984). Although outcrop samples show free-swelling indexes of 0, the swelling properties of coals increase with depth (Callahan and Sloan, 1976).

Access to the Deadfall Syncline coal deposits was examined by the Western Arctic Coal Development Project. It is expected that a 5.4-mi long haul road would be built to connect the mine site with a marine port facility and berthing area for barge traffic. A 2,800 ft lead-in channel and a turning basin in Omalik Lagoon would be dredged to an operational depth of 13

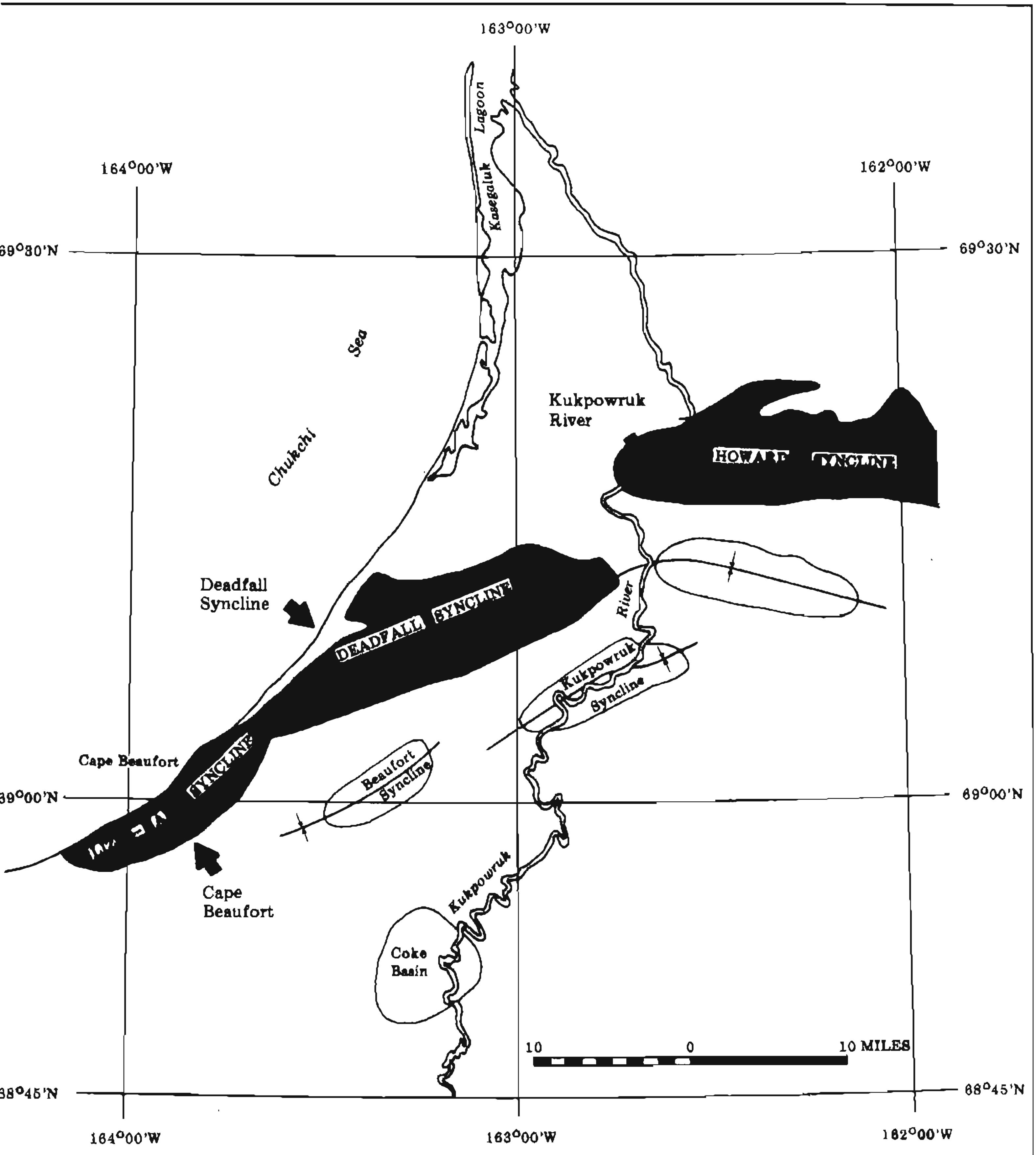

Figure 9. Important bituminous coal-bearing areas and structural features of the Western Arctic region (modified from Chapman and Sable, 1960).

Figure 10. Sampling a thick coal bed north of Cape Beaufort, Western Arctic region, 1981. (Photo courtesy of P.D. Rao, University of Alaska, MIRL.)

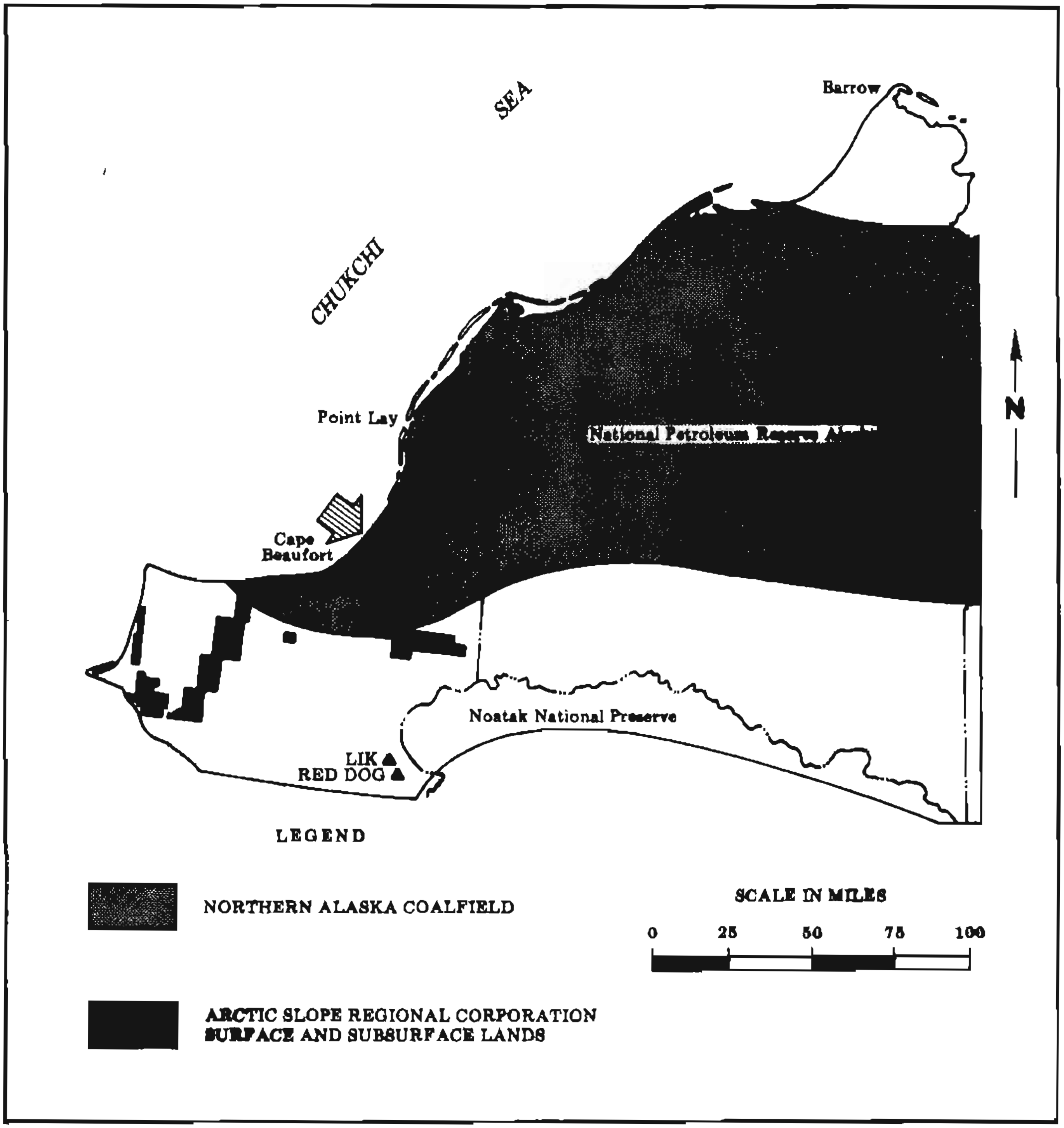

Figure 11. Location of Arctic Slope Regional Corporation lands in the Western Arctic region of the Northern Alaska coal field (modified from Arctic Slope Consulting Engineers, 1986).

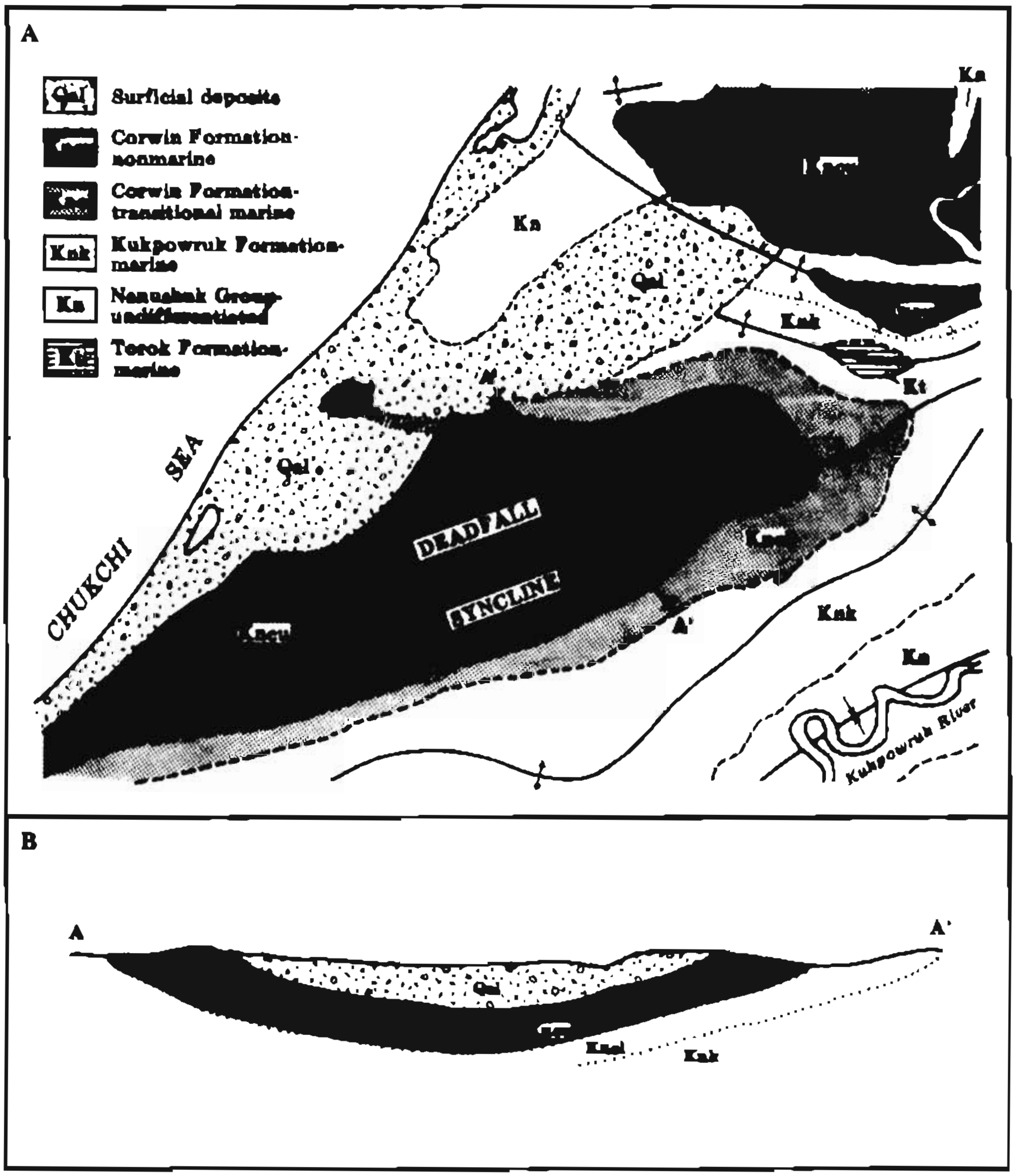

Figure 12. Geologic map and cross section of the Deadfall Syncline, Western Arctic region (modified from Callahan and Eakins, 1987 and Arctic Slope Consulting Engineers, 1986).

ft. Coal would be stockpiled at the barge loading facility for shipment during the ice-free season. Coal for export would most likely have to be transported to a separate ice-free port facility with a large stockpile capacity and a harbor permitting the berthing and loading of bulk carriers. Large-volume shipments from anywhere in the Western Arctic would probably follow a similar plan unless a long-distance rail line was completed to the region.

Kukpowruk River

The Kukpowruk River area of the Western Arctic region occupies some 20-30 square miles at the west end of the Howard Syncline in the northern Arctic Foothills' subprovince (fig. 9). Although coals are exposed for 25 mi or more along the lower Kukpowruk River, the priority area for development lies 28 mi south-southeast of Point Lay, the nearest permanently inhabited community, and 14 mi directly east of the Chukchi Sea coast. Kotzebue is located 170 mi due south. The area contains the thickest identified outcropping seam in the region, a 22-ft thick bed (fig 13). Above the thick seam are 12 other beds from 1-9 ft thick. As many as 40 beds from 1.5 - 13 ft thick crop out along the lower Kukpowruk River.

The Kukpowruk River area has witnessed a great amount of exploration activity and some minor local production. Morgan Coal Company first explored the coking coal on the Kukpowruk River in 1954 by driving a 70 ft tunnel in the over 20-ft thick bed. The company still holds a U.S. Bureau of Mines preference right coal lease on 5,000 acres in the area. Union Carbide investigated the Kukpowruk River coking coal in 1961-63.

The Kukpowruk River bituminous coals are low-ash and low-sulfur and predominantly high-volatile A or B. The 22-ft bed has significant coking properties and is generally soft-coking. It has a free-swelling index of 4.5. Other average coal-quality criteria for the seam are: moisture content 2.8 percent, volatile matter 35.2 percent, fixed carbon 58.5 percent, ash 3.5 percent, sulfur 0.25 percent, and heating value 13,860 Btu/lb.

Dips in outcrops range from 0° to near vertical; the main seam at Kukpowruk River dips at 15° (fig. 14). Strippable coal resources in the area of the main seam are estimated at 20 million tons and inferred resources at 100 million tons. Total estimated resources are over 3 billion short tons.

Other than the lease of Morgan Coal Company, coal rights are held by the Arctic Slope Regional Corporation.

Other Regions

Chuckchi Sea

Coals of the Northern Alaska coal province extend offshore beneath the Chukchi Sea. Deeply buried coal underlies some 10,000 square miles. There are extensive deposits of Cretaceous bituminous coals that may hold potential for liquefaction or gasification (McGee and O'Connor, 1974).

Figure 13. Twenty-ft thick coal seam at Kukpowruk River, Western Arctic region. (Photo by G.R. Eakins, 1982).

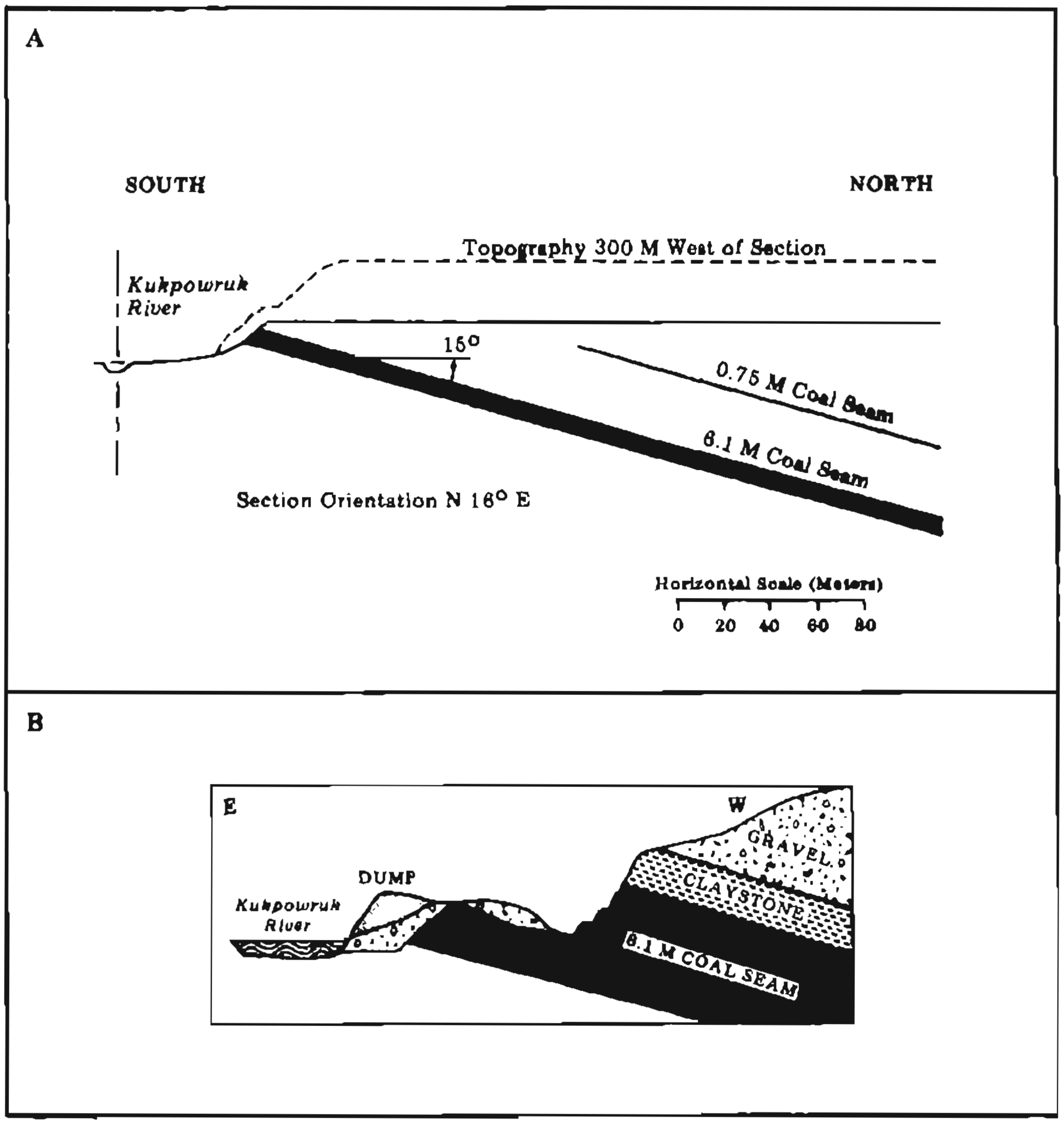

Figure 14. Typical cross sections in Kukpowruk River area of Western Arctic region (from Knutson, 1981).

Corwin Bluff

Corwin Bluff is located on the northwest Alaska Arctic Slope 25 mi east of Cape Lisburne and 35 mi west of Cape Beaufort. Whaling ships and U.S. Revenue cutters started using coal from the Corwin Bluff mines in 1879. Coal was produced from several different beds in Corwin Bluff. Captain C.L. Hooper took on 20 tons of coal for his ship the Corwin at the so-called Corwin Mine in 1881. In 1888-89 coal from the Thetis Mine was supplied to the U.S. Revenue cutter Thetis. In 1900-01, over 1,000 tons of coal were extracted from the mines at Corwin Bluff and shipped to Nome. Other small-scale mines (Alaska Development Company, Arctic Development Company, and Corwin Trading Company) along the Corwin Bluff also extracted coal for shipboard use.

The type locality of the Late Cretaceous Corwin Formation of the Nanushuk Group is at Corwin Bluff, where 80 or more coal beds over 1-ft thick are exposed; 17 beds are between 2.5 and 9.0 ft thick. The beds generally dip from 30° to 45° (fig. 15).

Analysis of the coals yields the following average values: moisture 3-6 percent, volatile matter 28-41 percent, fixed carbon 47-58 percent, ash 4-12 percent, and a free-swelling index of 1.5. Table 8 summarizes average petrologic composition data for Corwin Bluff coal samples.

National Petroleum Reserve in Alaska (NPRA)

Half or more of the coal resources of northern Alaska are located on federal land of the NPRA. Martin and Callahan (1978) cited at least 28 billion short tons of identified subeconomic bituminous coal resources in beds over 14-in thick to a depth of 6,000 ft. In addition, they estimated undiscovered hypothetical bituminous coal resources at 1.9 trillion short tons in beds over 14-in thick to a depth of 6,000 ft. Table 9 summarizes the average quality of NPRA bituminous coals.

Kokolik River - Elusive Creek

The Kokolik River - Elusive Creek area has at least 17 coal beds from 2-12 ft thick. The beds dip from 0°-22°. One seam at Elusive Creek is shown in figure 16. The coals range from medium to high volatile bituminous and exhibit some coking properties. Free-swelling indexes range from 0-4. Coal-quality parameters exhibit the following general ranges: moisture 1.5 - 6.5 percent, volatile matter 25-38 percent, fixed carbon 46-58 percent, ash 2-18 percent, sulfur 0.2 - 0.6 percent, and heating content 10,800-13,650 Btu/lb. Table 10 lists specific data for two coal seams from this area. Washability studies have shown that the coals can be cleaned to produce premium quality, low ash, low sulfur products (Rao and Wolff, 1982).

Utukok River

Bituminous coal beds crop out on the Utukok River between 25 and 80 mi above the mouth of the river. They occur downstream from Archimedes Ridge and Carbon Creek. In surface exposures, beds dip from 0°-25° and thicknesses

Figure 15. Coal outcrop at Corwin Bluffs, Western Arctic region. (Photo by G.D. Stricker, 1982.)

Table 8. Average distribution of macerals in 24 samples of coal from Corwin Bluffs (modified from Rao and Smith, 1983).

Maceral	Content (volume, mmf basis, %)
Vitrinite	65.2
Pseudovitrinite	15.0
Gelinite	1.4
Phlobaphinite	0.7
Pseudophlobaphinite	0.6
Sporinite	2.6
Resinite	1.7
Cutinite	0.6
Alginite	0.2
Exsudatinite	0.0
Thick cutinite	0.1
Suberinite	0.0
Other liptinite	0.0
Fusinite	0.5
Semifusinite	7.4
Macrinite	0.8
Globular macrinite	0.1
Inertodetrinite	3.1
Sclerotinite	0.0

Table 9. Range in major coal-quality parameters for NPRA bituminous coals of northern Alaska (modified from Martin and Callahan, 1978).

Parameter	Range in values
Moist mmf heating value (Btu/lb)	12,400 - 14,900
Moisture (%)	0.8 - 10.0
Volatile matter (%)	23.5 - 37.0
Fixed carbon (%)	42.0 - 59.0
Ash (%)	4.0 - 29.0
Sulfur (%)	0.1 - 0.7

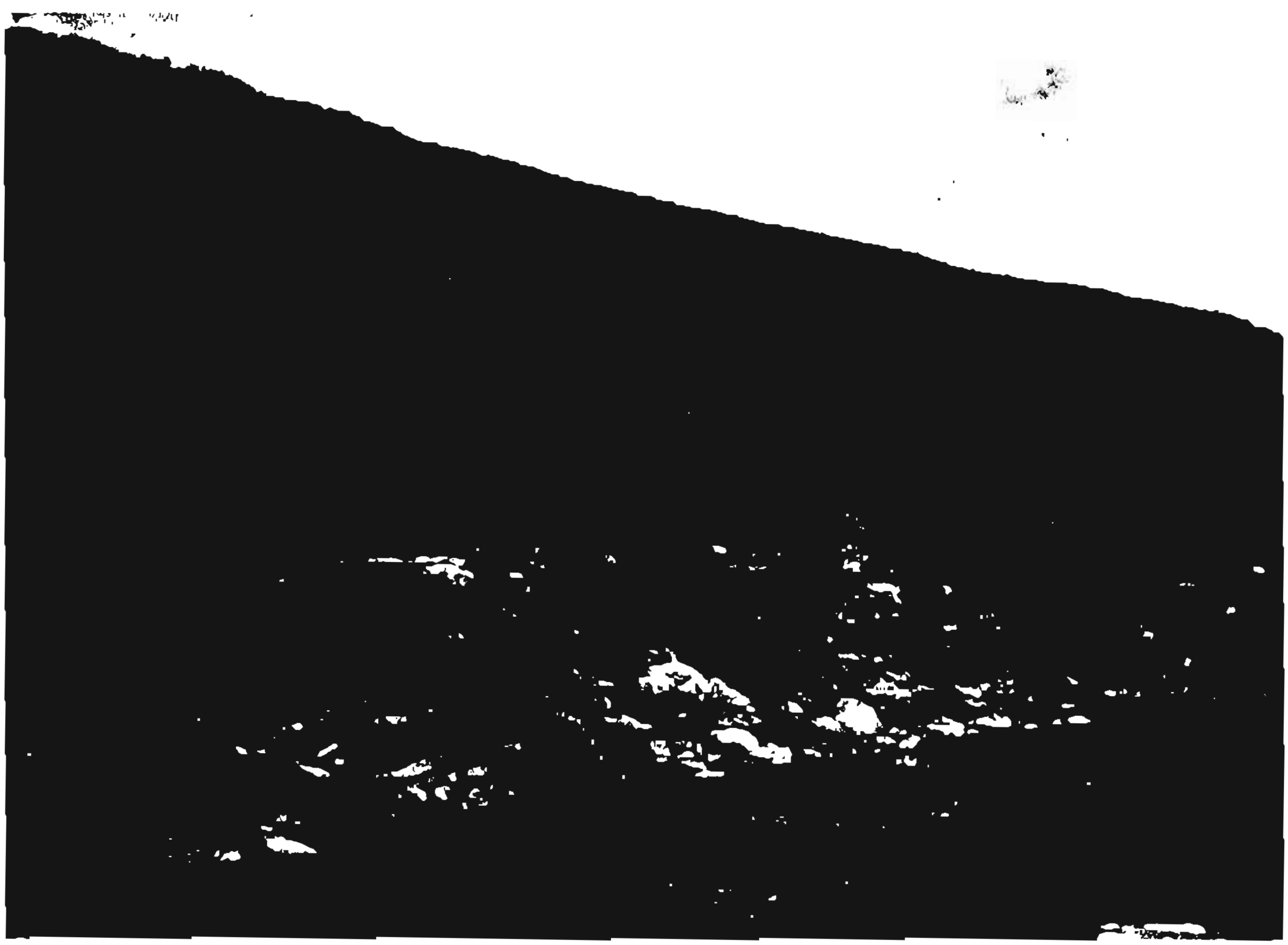

Figure 16. Coal-bearing outcrop at Elusive Creek, NPRA. (Photo by J. Callahan, 1980.)

Table 10. Proximate and ultimate analysis data, major-oxide composition and fusibility of ash, and Hardgrove grindability and free-swelling indexes of Kokolik River and Elusive Creek coals (from Rao and Wolff, 1982, phase III report).

A. Proximate and ultimate analysis data:

	Basis	Moisture (%)	Volatile Matter (%)	Fixed Carbon (%)	Ash (%)	Heating content Btu/lb
No. 3 bed	1	11.95	30.36	55.37	2.37	11,242
Elusive Creek	2	---	34.48	62.88	2.64	12,768
hvBb; 11.5-ft thick	3	---	35.42	64.58	---	13,114
Uncorrelated bed	1	15.58	26.43	52.57	5.42	10,904
Kokolik River	2	---	31.31	62.27	6.42	12,916
hvAb; 11.6-ft thick	3	---	33.46	66.54	---	13,803

1 = equilibrium bed moisture basis; 2 = moisture free basis; and 3 = moisture- and ash-free basis

	Basis	Carbon(%)	Hydrogen(%)	Nitrogen(%)	Oxygen(%)	Sulfur	
						Pyritic	Total
No. 3 bed	1	65.90	5.20	1.31	25.00	0.06	0.27
Elusive Creek	2	74.84	4.39	1.49	16.33	0.07	0.31
hvBb; 11.5-ft thick	3	76.87	4.51	1.53	16.77	0.07	0.32
Uncorrelated bed	1	63.44	5.63	1.03	24.24	0.04	0.24
Kokolik River	2	75.15	4.61	1.22	12.32	0.05	0.28
hvAb; 11.6-ft thick	3	80.31	4.93	1.30	13.17	0.06	0.29

B. Major-oxide composition of ash:

	Elusive Creek	Kokolik River
SiO_2	22.3	42.4
Al_2O_3	26.5	27.1
Fe_2O_3	12.3	5.5
MgO	6.6	3.0
CaO	15.0	6.1
Na_2O	2.14	1.63
K_2O	0.7	1.9
TiO_2	0.8	2.2
SO_3	3.0	4.6
MnO	0.03	0.03
P_2O_5	1.95	2.02

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range to 12-ft. In the Kaolak test well 1 on the Utukok River 60 coal beds aggregating 350 ft occur in the upper 4,600 ft. At a minimum, resources are estimated at 2.7 billion short tons.

The coals are typically high volatile A bituminous with the following ranges in quality parameters: moisture 1.7 - 6.2 percent, volatile matter 33.0 - 37.5 percent, fixed carbon 46.5 - 58.0 percent, ash 2.5 - 17.5 percent, sulfur 0.2 -0.6 percent, and heating values from 11,600-13,650 Btu/lb.

Meade and Ikpikpuk Rivers

Bituminous coals occur near the headwaters of the Meade and Ikpikpuk Rivers in the Arctic Foothills. At least 10 beds occur in outcrops and these range from 2-6 ft thick and have horizontal to shallow dips. The beds have supported minor local production in the past. Average coal-quality criteria are: moisture 3-4 percent, volatile matter 36.5 percent, fixed carbon 46.8 percent, ash 13.3 percent, sulfur 0.7 percent, and heating value 11,660 Btu/lb.

Colville River

Bituminous coals along the Colville River are restricted to moderately folded rocks of the foothills belt. This includes a northeast-trending segment of the river extending from the mouth of Etivluk River downstream to within about 20 mi of Umiat. The Cretaceous Chandler Formation in this area contains at least 25 bituminous coal beds from 2-8 ft thick. General ranges in various coal-quality parameters are: moisture 2.5 - 6.6 percent, volatile matter 30.1 - 43.7 percent, fixed carbon 39.3-62.8 percent, ash 2.6 - 24.3 percent, sulfur 0.3 - 0.7 percent, and heating value 10,430-13,450 Btu/lb.

Awuna, Kurupa, Oolamnagavik, Killik, Chandler, and Anaktuvuk Rivers

There are numerous other occurrences of bituminous coals in the northern Alaska Foothills. As many as five beds from 2 to 5 ft crop out on the Awuna River. Nine beds less than 4.5-ft thick occur on the Kurupa River. Individual beds from 2-3 ft thick each are found on the Oolamnagavik, Killik, Chandler, and Anaktuvuk Rivers (Barnes, 1967).

Sagavanirktok River: Sagwon Bluffs

A 6.5-ft thick coal bed from Sagwon Bluffs was sampled and analyzed by Rao and Wolff (1980). The coal is evidently Cretaceous (?) and of high-volatile C bituminous rank. Table 11 summarizes the quality of the coal.

Lisburne Field

The Lisburne field is located near Point Hope on the Lisburne Peninsula of northwest Alaska. Although its true extent is unknown, coal-bearing rocks are distributed from Cape Dyer to Cape Thompson. The area includes several coal prospects and sites of minor coal extraction. The discovery of gold at Nome in 1898 brought the first interest in developing the Cape Lisburne coals.

Table 11. Proximate and ultimate analyses, major-oxide composition and fusibility of ash, Hardgrove grindability and free-swelling indexes of Sagwon Bluffs coal (from Rao and Wolff, 1980, phase II report).

A. Proximate and ultimate data:

Basis	1	2	3
Moisture (%)	14.71	---	---
Volatile matter (%)	15.74	18.45	50.13
Fixed carbon (%)	15.65	18.36	49.87
Ash (%)	53.90	63.19	---
Heating value (Btu/lb)	3591	4210	11439
Carbon (%)	20.98	24.60	66.83
Hydrogen (%)	3.37	2.02	5.49
Nitrogen (%)	0.53	0.62	1.67
Oxygen (%)	21.16	9.50	25.81
Sulfur (%):			
Pyritic	0.04	0.05	0.14
Total	0.06	0.07	0.20

1 = equilibrium-bed-moisture basis; 2 = moisture-free basis; and 3 = moisture- and ash-free basis.

B. Major-oxide composition of ash (%):

SiO_2	-	66.5
Al_2O_3	-	20.1
Fe_2O_3	-	3.9
MgO	-	2.2
CaO	-	1.8
Na_2O	-	0.16
K_2O	-	3.5
TiO_2	-	1.3
SO_3	-	0.7
MnO	-	0.04

C. Fusibility of ash (°F):

Initial deformation	2670
Softening	2730
Fluid	2840

The coals evidently belong to a member of the Lisburne Group, a Carboniferous (Mississippian) nonmarine unit. Coal seams are found in the upper 1900 ft of section. The coal-bearing rocks of the Lisburne field are distinct from and unassociated with the major Cretaceous-age coal resources of the North Slope basin.

The highly-deformed rocks contain coal beds typically 6-ft thick or less that pinch and swell over short distances (fig. 17). Geologic structure is generally complex with coal beds deformed and broken by faults. Thrusting, shearing, and contorted folding are common (fig. 18). Dips average 40° but range from horizontal to near-vertical.

The coals are typically low-moisture and low-ash (table 12). They range from low-volatile bituminous to semianthracite in rank with heating contents to about 14,000 Btu/lb or higher. They are generally noncoking. Table 13 lists major-oxide composition of ash in Lisburne coals.

Coal occurrences of the Lisburne field include Niak Creek, Cape Lewis, Cape Dyer, Kukpuk River, and Cape Thompson. At Niak Creek, 4-5 ft thick seams of semianthracite occur in a faulted exposure. At Cape Lewis, a 4-ft bed of semianthracite and two thinner seams dip at 40° in outcrop. The Kapaloak Creek section at Cape Dyer includes 13 beds of low volatile bituminous coal ranging from 2.5 to 11 ft thick totalling an aggregate 70 ft of coal; the beds dip from 30° to near-vertical. At Kukpuk River, a site of past local production, a 6-ft thick bed of semianthracite dips at 23° in outcrop; the coal is low-ash (5 percent) and high calorific value (13,750 Btu/lb). At Cape Thompson there is a 1-ft thick bed standing vertically and it is sheared.

Mining potential in the Lisburne field in the near future is unlikely but the deposits are probably more amenable to surface methods. Subsurface rights are controlled by Arctic Slope Regional Corporation and surface rights are held by the village of Point Hope.

YUKON-KOYUKUK PROVINCE

Kobuk Basin

The Kobuk Basin includes what has generally been referred to as the Kobuk fields (or West and East Kobuk fields) and a number of other coal occurrences. In 1908 Captain Theielen opened a mine on the Kobuk River about a mile below the Kallarichuk River; in 1929 Alexander Haralan renewed mining on the site where small quantities of coal were extracted for use by placer-gold miners.

A number of coal outcrops and coal occurrences are found exposed along river bluffs in the Kobuk Basin (fig. 19). The westernmost locality is on the north side of the Kobuk River between Trinity Creek and the Kallarichuk River. Other localities are the Singauruk River (fig. 20), the Hunt River, lower Ambler River, lower Kogoluktuk River, and in the Lockwood Hills near the Pah River (Barnes, 1967). The coals are Cretaceous (Middle or Late?) and were originally included with the upper member of the Bergman Group, now an

Figure 17. Coal-bearing outcrop at Cape Lisburne, northwest Alaska. (Photo by G.R. Eakins, 1983.)

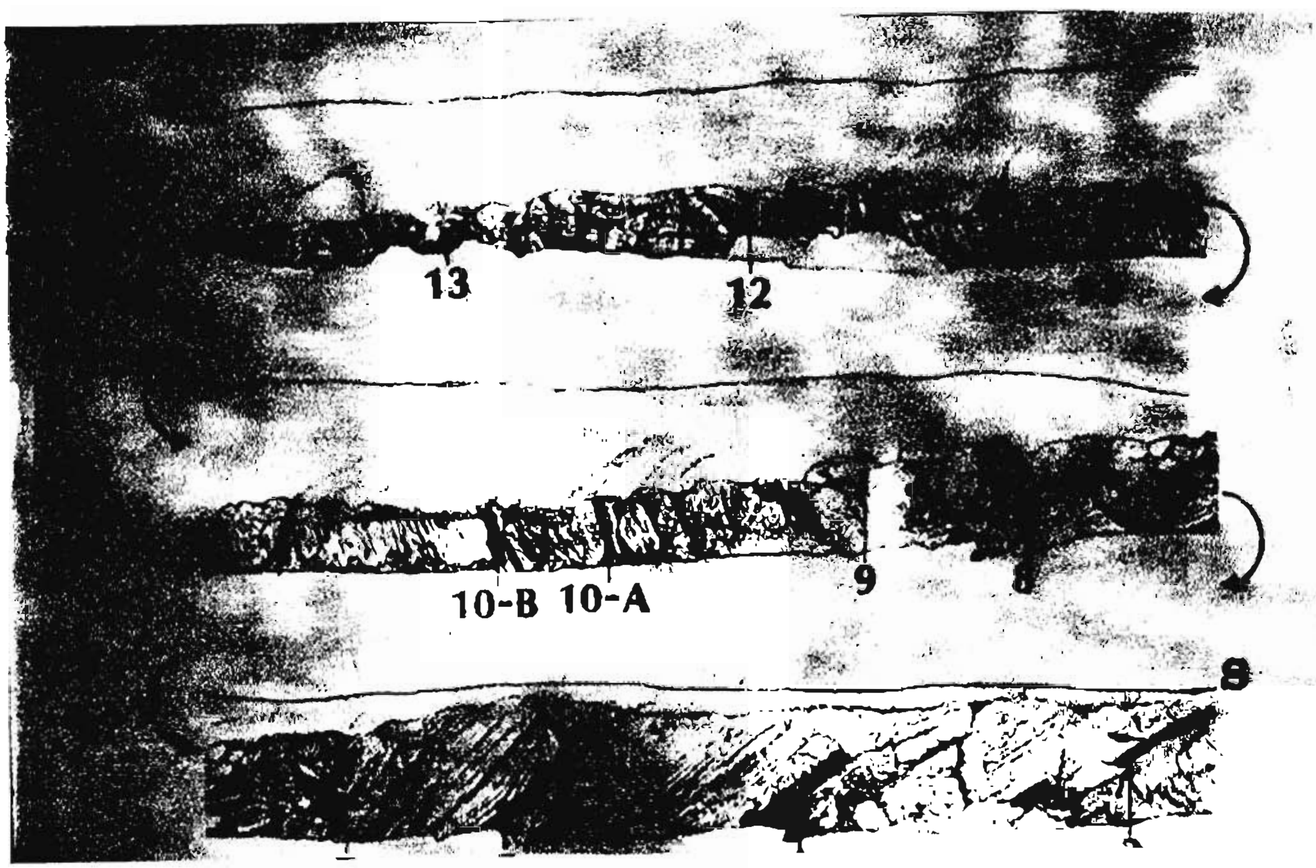


Figure 18. Schematic cross section of coal-bearing beachcrop at Cape Lisburne, northwest Alaska. (Photo by K.M. Goff, 1984.)

Table 12. Range in proximate-analysis data, heating and sulfur contents of 7 Lisburne field coals.

Parameter	Range
Moisture (%)	2 - 13
Volatile matter (%)	11 - 14
Fixed carbon (%)	66.5 - 83.5
Ash (%)	1.6 - 17.0
Heating value (Btu/lb)	11,500 - 14,750
Sulfur (%)	0.4 - 0.8

Table 13. Average ash analysis of Lisburne field coals.

Major-oxide	Percent
SiO_2	48.5
Al_2O_3	25.0
Fe_2O_3	7.2
K_2O	1.8
SO_3	1.7
CaO	1.4
TiO_2	1.1
P_2O_5	<1.0
MgO	0.7
Na_2O	0.6
MnO	0.1
Undet.	11.0

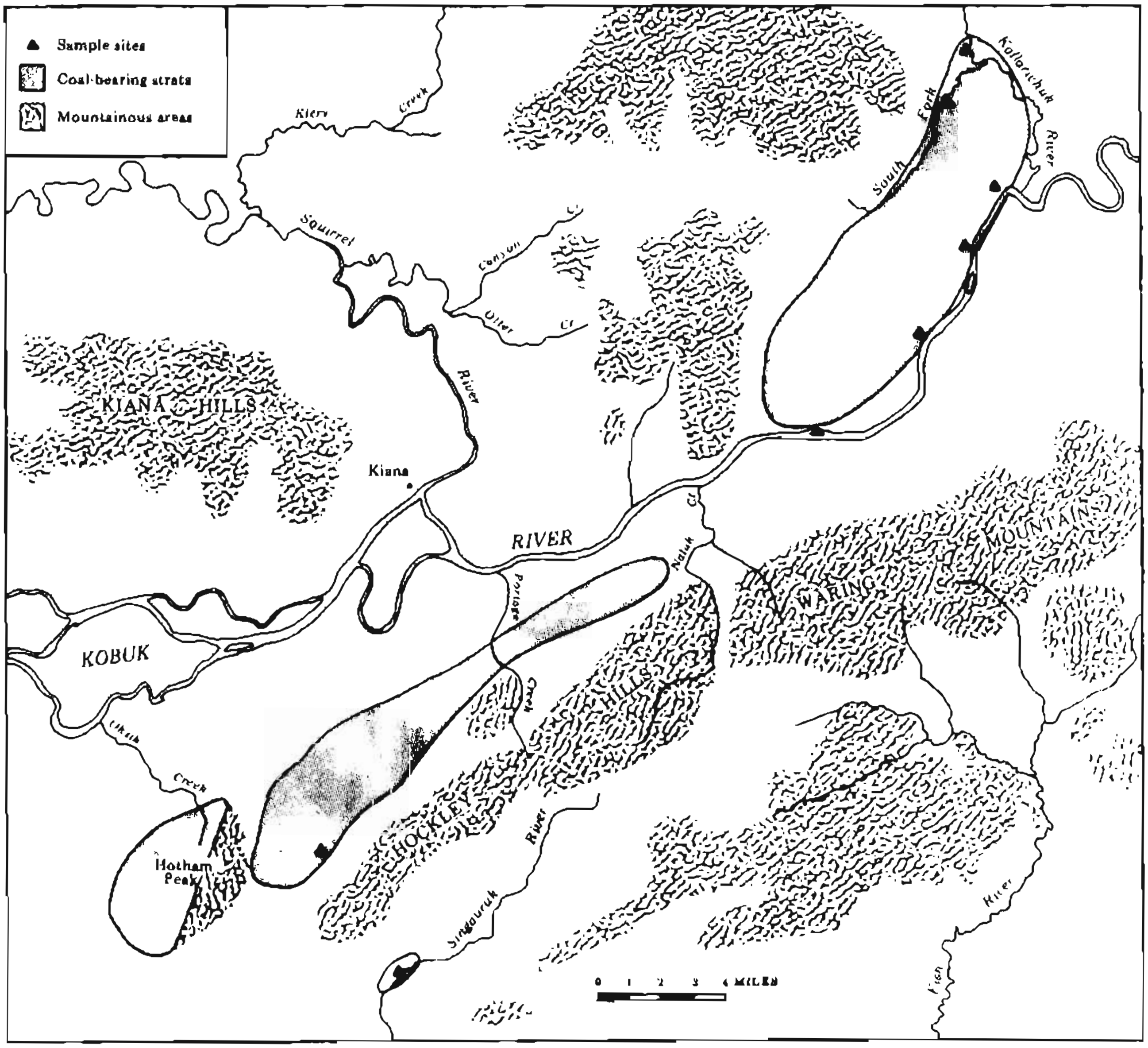


Figure 19. Coal-bearing Cretaceous rocks of the lower Kobuk River region (modified from Patton and Miller, 1986).

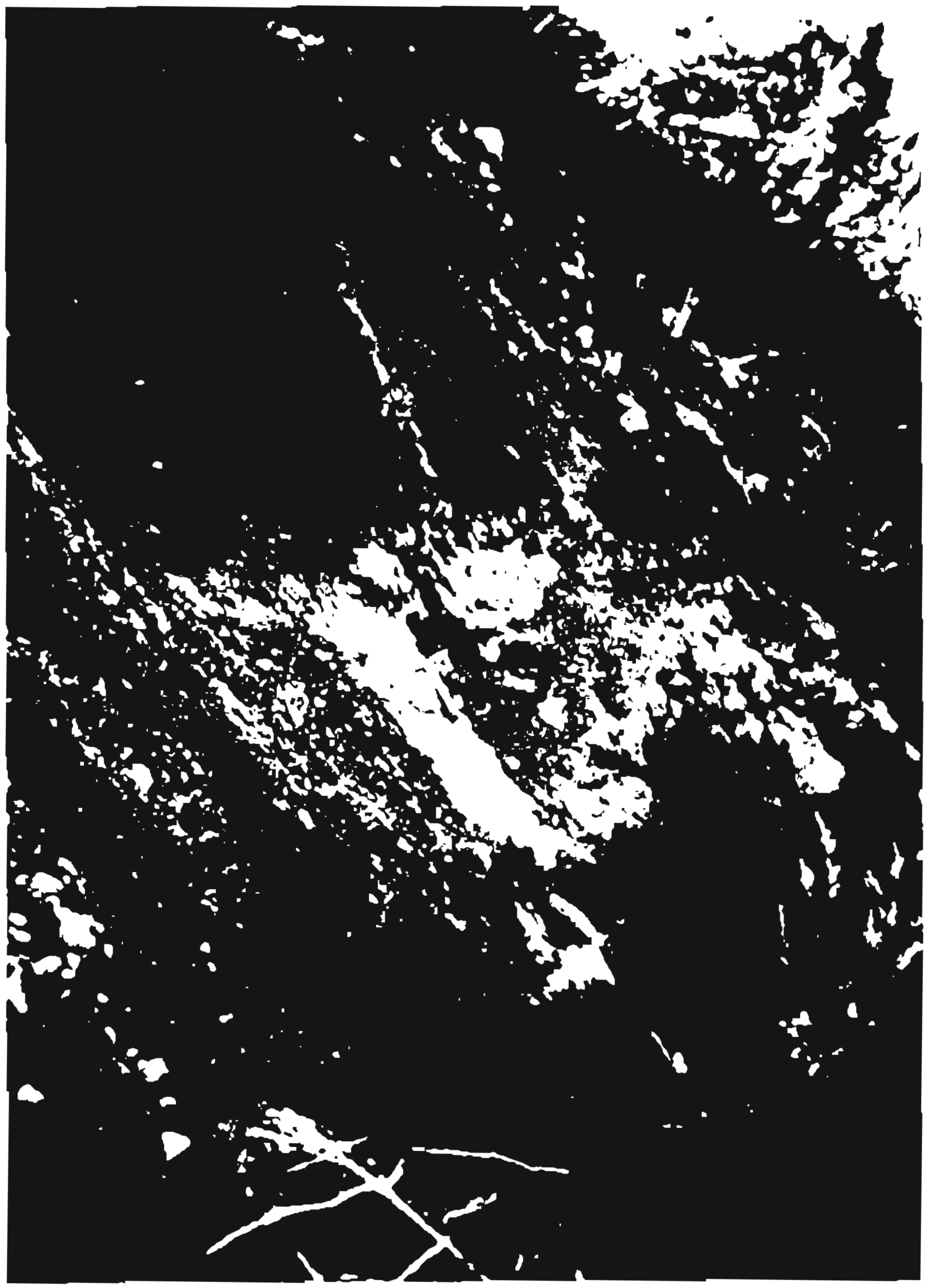


Figure 20. Coal-bearing outcrop at Singauruk River, Kobuk basin. (Photo by G.R. Eakins, 1982.)

obsolete classification. The structure shows generally shallow dips (less than 30°) defining broad open folds, locally steeply dipping near high-angle faults.

More recent reconnaissance surveys in the region have located three main outcrops. One is at the site of minor production on the Kallarichuk River, where two coal beds about 2-ft thick each dip at 20°-45°. Two occurrences were sited on the Kobuk River. At the first were one or more coal beds 2-3 ft thick dipping at 30°, and at the second was an 18-ft thick bed dipping at 25°.

The coals are bituminous in rank, typically high volatile C bituminous. Heating contents range from 9,200 to 10,500 Btu/lb. Sulfur content varies from 0.4 to 1.1 percent, and ash varies from 7 percent to 35 percent.

Future mining potential is low because the area is located within the confines of Kobuk Valley National Park.

Upper Koyukuk Basin

This basin includes the Tramway Bar field and several other scattered minor coal occurrences. Tramway Bar is located about 35 mi northeast of Bettles in Wiseman Quadrangle on the Middle Fork of the Koyukuk River (T. 26 N., R. 14 W.). It encompasses the northeastern part of the Yukon-Koyukuk Province.

The coal-bearing rocks are mid-Cretaceous in age (Albian to Cenomanian, possibly Turonian based on fossil plants) and were formerly originally included with the upper member of the Bergman Group (now obsolete). The unit consists of sandstone, conglomerate, and bituminous coal (fig. 21). Barnes (1967) believed the deposit to be an eastern extension of the coal-bearing rocks of the Kobuk basin.

F.C. Schraeder (1904) first reported the presence of coal at Tramway Bar in 1899. He also found abundant coal float in the river gravels on the John River north of Bettles near the base of the Endicott Mountains, but no in-place coal beds were located. The coals have been used on a small-scale basis by gold prospectors.

Rao and Wolff (1980) sampled and analyzed coal from the main outcrop. They found three seams dipping at 56° cropping out on the north bank of the Koyukuk River, an 8-in bed, a 3-ft bed, and a 17.5-ft bed. They sampled and analyzed the lower 13 ft of the thick seam (table 14). The rank of the coal is high volatile B bituminous. The ash content is high but the sulfur content is very low. Thin dirt bands add to the 35 percent ash content on a raw-coal basis. Rao and Wolff found that washing the coal could very effectively reduce the ash content to acceptable levels.

Lower Koyukuk Basin

This area includes what has classically been referred to as the Nulato field as well as a number of additional coal occurrences that extend for 200

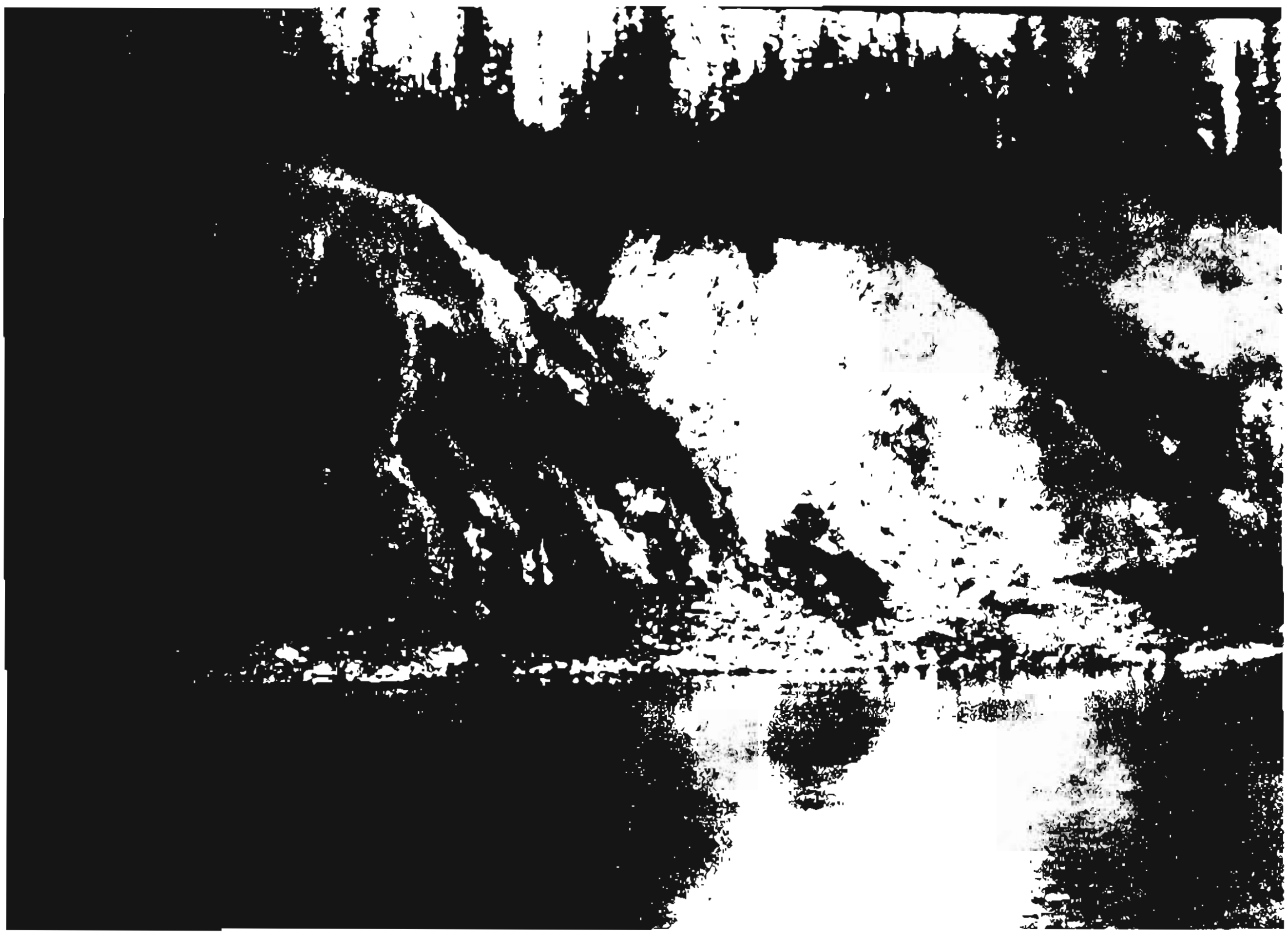


Figure 21. Coal-bearing outcrop at Tramway Bar on the Middle Fork of the Koyukuk River south of Wiseman. (Photo by K.M. Goff, 1984.)

Table 14. Proximate and ultimate analyses, major-oxide composition and fusibility of ash, Hardgrove grindability and free-swelling indexes of Tramway Bar coal (from Rao and Wolff, 1980, phase II report).

A. Proximate and ultimate data:

Basis	1	2	3
Moisture (%)	6.38	---	---
Volatile matter (%)	24.29	25.94	41.99
Fixed carbon (%)	33.54	35.83	58.01
Ash (%)	35.79	38.23	---
Heating value (Btu/lb)	7263	7758	12559
Carbon (%)	42.72	45.64	73.88
Hydrogen (%)	3.62	3.10	5.02
Nitrogen (%)	0.55	0.59	0.95
Oxygen (%)	17.18	12.29	19.90
Sulfur (%):			
Pyritic	0.04	0.04	0.07
Total	0.14	0.15	0.25

1 = equilibrium-bed-moisture basis; 2 = moisture-free basis; and 3 = moisture- and ash-free basis.

B. Major-oxide composition of ash (%):

SiO_2	-	52.8
Al_2O_3	-	30.8
Fe_2O_3	-	5.1
MgO	-	1.4
CaO	-	2.3
Na_2O	-	0.51
K_2O	-	4.0
TiO_2	-	1.7
SO_3	-	0.9
MnO	-	0.05

C. Fusibility of ash (°F):

Initial deformation	2468
Softening	2593
Fluid	2723

D. Hardgrove grindability index = 56

E. Free-swelling index = 0

miles, from Ruby to Anvik, on the Yukon River below the mouth of the Melozitna River. Several of the outcrops from Ruby to Blackburn (fig. 22) were mined for steamboat fuel from 1897-1902 but extracted only a few thousand tons altogether. Some of the coals were exploited for blacksmithing purposes and domestic fuel as well.

The coals belong to the Late Cretaceous Kaltag Formation, a predominantly nonmarine sequence of sandstone, siltstone, and shale containing fossil plants. Structure is locally complex with folding and faulting and beds dipping from 20° to 60°. The thickest coal bed is about 4 ft, and most beds are less than 2-ft thick.

The coals are high-quality bituminous, ranging from high-volatile A bituminous to high volatile C bituminous. Although they have a high ash content, they can be cleaned to give a product with 10 percent ash or less. The coals are potentially some of the best coking in Alaska. Table 15 summarizes coal-quality criteria for one Nulato seam that may be atypical. Sanders (1981) lists the following representative analyses of Nulato coal: moisture 1-11 percent, volatile matter 24-41 percent, fixed carbon 47-65 percent, ash 3-23 percent, sulfur 0.2 - 0.6 percent, heating value (as received) approximately 9,500 Btu/lb, heating value (moist, mineral-matter-free basis) 12,300 Btu/lb, and a rank of high volatile C bituminous.

Among the coal prospects on the lower Yukon River is a 2-3 ft thick bed of possible blacksmithing coal on the Melozitna River, a 1-ft thick bed occurring about 20 mi above Galena, a 3-ft thick bed at Nahoclatilten, a 4.5-ft thick bed dipping 20° at Kaltag (the Adolph-Muller Prospect), and a 0.5-ft coal (the Nulato bed) in a 2.5-ft thick coal zone located a mile above Nulato (Chapman, 1963). The latter coal dips at 40° and was also used in blacksmithing at Nulato.

The so-called Pickart Mine was located on the right or south bank of the Yukon River about 10 mi above Nulato. The coal beds range from 1.5 to 3 ft thick and dip at 35°. The Pickart Brothers originally mined the site in 1898. The Alaska Commercial Company took possession in 1901, but the site was abandoned in 1902 because of floor rolls. At least one 600-ft drift tunnel was driven and several hundreds of tons produced and used for steaming purposes on riverboats from 1898-1902. The coal reportedly produced a good compact coke. An average analysis of the coal is: moisture 1.02 percent, volatile matter 27.33 percent, fixed carbon 65.03 percent, ash 6.62 percent, and sulfur 0.60 percent.

The Bush Mine was located on the right bank of the Yukon about 4 mi below Nulato. The coal beds range from 2-4 ft thick and dip at 40°. A 40 ft tunnel was driven in 1903 and about 400 tons of coal produced for steamboat use.

The Blatchford Mine was located on the right bank of the Yukon about 9 mi below Nulato. Sheared pockets of coal 8-ft across dip at 45°-55°. About 300 tons of coal were mined at the site prior to 1902.

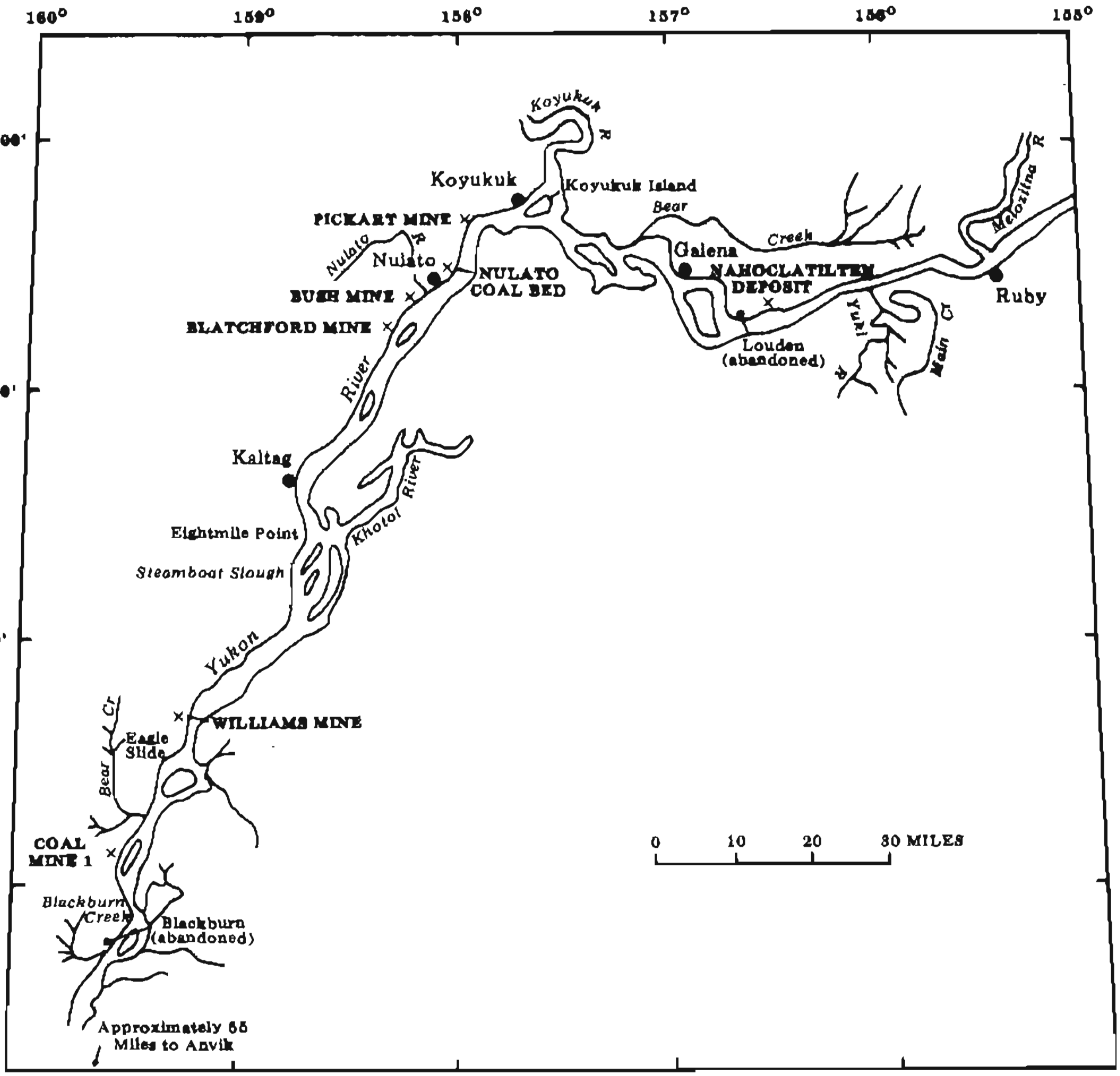


Figure 22. Location of coal deposits along the Yukon River between Ruby and Anvik (modified from Chapman, 1963).

Table 15. Proximate and ultimate analyses, major-oxide composition and fusibility of ash, Hardgrove grindability and free-swelling indexes of a Nulato coal seam (from Rao and Wolff, 1982, phase III report).

A. Proximate and ultimate data:

Basis	1	2	3
Moisture (%)	3.11	---	---
Volatile matter (%)	11.21	11.57	33.41
Fixed carbon (%)	22.35	23.06	66.59
Ash (%)	63.33	65.37	---
Heating value (Btu/lb)	4,762	4,915	14,190
Carbon (%)	26.29	27.13	78.33
Hydrogen (%)	2.31	2.02	5.83
Nitrogen (%)	0.49	0.51	1.16
Oxygen (%)	7.22	4.59	13.30
Sulfur (%):			
Pyritic	0.16	0.16	0.47
Total	0.36	0.38	1.08

1 = equilibrium-bed-moisture basis; 2 = moisture-free basis; and 3 = moisture- and ash-free basis.

B. Major-oxide composition of ash (%):

SiO_2	-	62.7
Al_2O_3	-	21.8
Fe_2O_3	-	3.8
MgO	-	1.5
CaO	-	0.3
Na_2O	-	1.88
K_2O	-	4.4
TiO_2	-	1.1
SO_3	-	0.8
MnO	-	0.01
P_2O_5	-	0.08

C. Fusibility of ash (°F):

Initial deformation	2468
Softening	2593
Fluid	2723

D. Hardgrove grindability index = 56

E. Free-swelling index raw coal = 0

Free-swelling index of 1.60 specific-gravity float = 9.6

The Williams or Thein Mine was located about 50 mi below Kaltag, 90 miles below Nulato, and 100 mi south of the Koyukuk River. It was situated on the west bank of the Yukon River. A 3.25-ft thick bed dips at 45°. The mine opened in 1902 and a 400-ft shaft had been completed in 1902 when Collier visited. About 1700 tons of coal were produced before 1903. The coal reportedly produces a noncoherent coke. Conditions may be favorable at the site for appreciable resources. An average analysis of the coal is: moisture 6.66 percent, volatile matter 36.76 percent, fixed carbon 50.50 percent, ash 6.08 percent, and sulfur 0.46 percent.

Coal Mine No. 1 was located 16 mi below Blackburn and 125 mi below Nulato on the lower Yukon River. Coal beds at the site range from 2.5 - 3 ft thick and dip at 35°. The Alaska Commercial Company opened a mine at the site in 1898 and produced about 900 tons of coal. Conditions may be favorable at the site for appreciable resources.

Total hypothetical resources of the Lower Koyukuk basin are estimated at only 50 million short tons. Economically recoverable seams have not been identified and mining potential is currently rated as low. The relative steep dip of beds precludes strip mining in most cases. The coal could only be moved at high transportation costs, most likely by shallow draft barges of 500 tons or less.

UPPER YUKON PROVINCE

Nation River

The coal-bearing outcrop at Nation River is located on the Nation River about 1.5 mi from its junction with the Yukon River. It is near the Eagle field of east-central Alaska and occupies a very small area. In 1897, the Alaska Commercial Company opened a small coal mine here and extracted about 2,000 tons of coal for use on steamboats prior to 1902.

The coal-bearing rocks are of unknown age, although older reports have assigned them, probably erroneously, to the Late Devonian Nation River Formation. The general consensus now is that they are most likely Tertiary or Cretaceous.

The coal occurs in a fault zone as large pockets or kidneys resulting from intense crushing and shearing. The coal is reported to be bituminous (possibly medium volatile) although no recent and reliable analyses exist.

NENANA PROVINCE

Yanert

Coals are found at Yanert near mile 341 of the Alaska Highway within the confines of Mount McKinley National Park. In 1923-24, the Mount McKinley Bituminous Coal Company operated the Yanert Mine here. A shaft was driven 700 ft into a 5-ft thick bed of coal dipping 40°-60°.

The coal evidently occurs in the Paleocene Cantwell Formation and is typically of medium volatile bituminous rank. Rao and Wolff (1982) found that cleaning the high-ash coals resulted in a poor yield and higher than acceptable ash levels in the product. Detailed analyses of the coal are presented in table 16.

Cheeneetnuk River

Tertiary bituminous coals occur on Cheeneetnuk River, a tributary of the Swift River, at the extreme west end of the Nenana province. The coals range to 6-ft thick and are downfaulted against older rocks in the Farewell fault zone. The potential mineability of these coals has not been investigated.

COOK INLET-SUSITNA PROVINCE

Matanuska Field

Location

The Matanuska coal field of southcentral Alaska forms an eastern extension of the Cook Inlet-Susitna coal province. The field occupies most of the Matanuska River valley (fig. 23). Its western margin is some 45 air miles northeast of Anchorage.

The Matanuska field has been divided into five main districts (fig. 24). The Wishbone Hill district is located about 10 mi northeast of Palmer, Alaska. The chief coal resource of this district is the Wishbone Hill syncline. The Young Creek, Castle Mountain, and Chickaloon districts occupy the central Matanuska Valley. The Chickaloon district is centered about 30 mi northeast of Palmer around the old mining camp at Chickaloon. The Anthracite Ridge district is situated at the east end of the Matanuska Valley about 12 mi east of Chickaloon. The Young Creek and Castle Mountain districts are not considered in detail.

Area

The Wishbone Hill district occupies about 20 square miles between Moose and Granite Creeks. The Chickaloon district includes a 10 mile square area on lower Chickaloon River and Coal Creek. The Anthracite Ridge field includes a 20 mile square area that extends from the south slope of Anthracite Ridge southward to the Matanuska River.

Mining History

Coal was actively mined in the Matanuska field from 1914 to 1968 (fig. 25). The Alaska Railroad was completed to the Matanuska field in 1916, spurring mining in the Moose Creek area of the Wishbone Hill district. Early exploration and development in the Matanuska Valley was carried out by the U.S. government (table 17); the Navy searched for steaming coal, and the Alaska Engineering Commission sought coal supplies for the railroad.

Table 16. Proximate and ultimate analyses, major-oxide composition and fusibility of ash, Hardgrove grindability and free-swelling indexes of Yanert area coal (from Rao and Wolff, 1982, phase III report).

A. Proximate and ultimate data:

Basis	1	2	3
Moisture (%)	5.51	---	---
Volatile matter (%)	17.67	18.70	41.20
Fixed carbon (%)	25.22	26.69	58.80
Ash (%)	51.60	54.61	---
Heating value (Btu/lb)	5,412	5,728	12,650
Carbon (%)	31.73	33.58	73.98
Hydrogen (%)	3.34	2.88	6.35
Nitrogen (%)	0.63	0.66	1.46
Oxygen (%)	12.52	8.08	17.80
Sulfur (%):			
Pyritic	0.07	0.07	0.16
Total	0.18	0.19	0.41

1 = equilibrium-bed-moisture basis; 2 = moisture-free basis; and 3 = moisture- and ash-free basis.

B. Major-oxide composition of ash (%):

SiO_2	-	64.0
Al_2O_3	-	22.7
Fe_2O_3	-	4.0
MgO	-	1.2
CaO	-	1.1
Na_2O	-	0.49
K_2O	-	2.8
TiO_2	-	1.0
SO_3	-	0.6
MnO	-	0.02
P_2O_5	-	0.32

C. Fusibility of ash (°F):

Initial deformation	2742
Softening	2800+
Fluid	2800+

D. Hardgrove grindability index = 48

E. Free-swelling index = 1

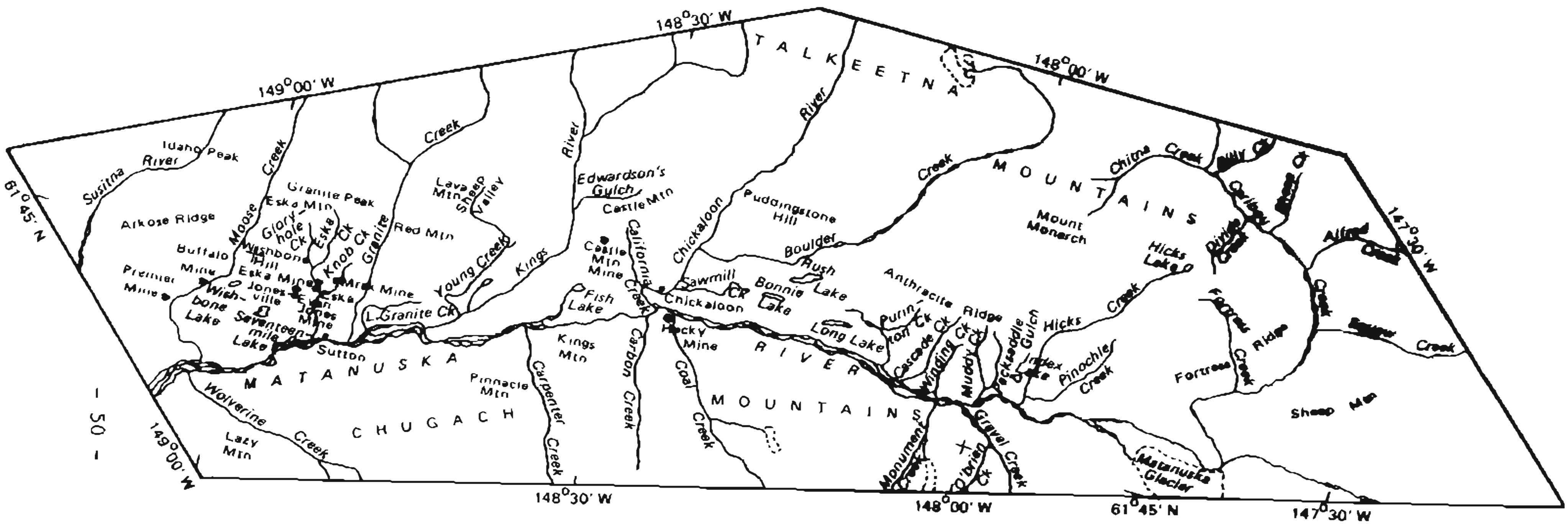


Figure 23. General location, boundaries and geographic features of the Matanuska Valley.

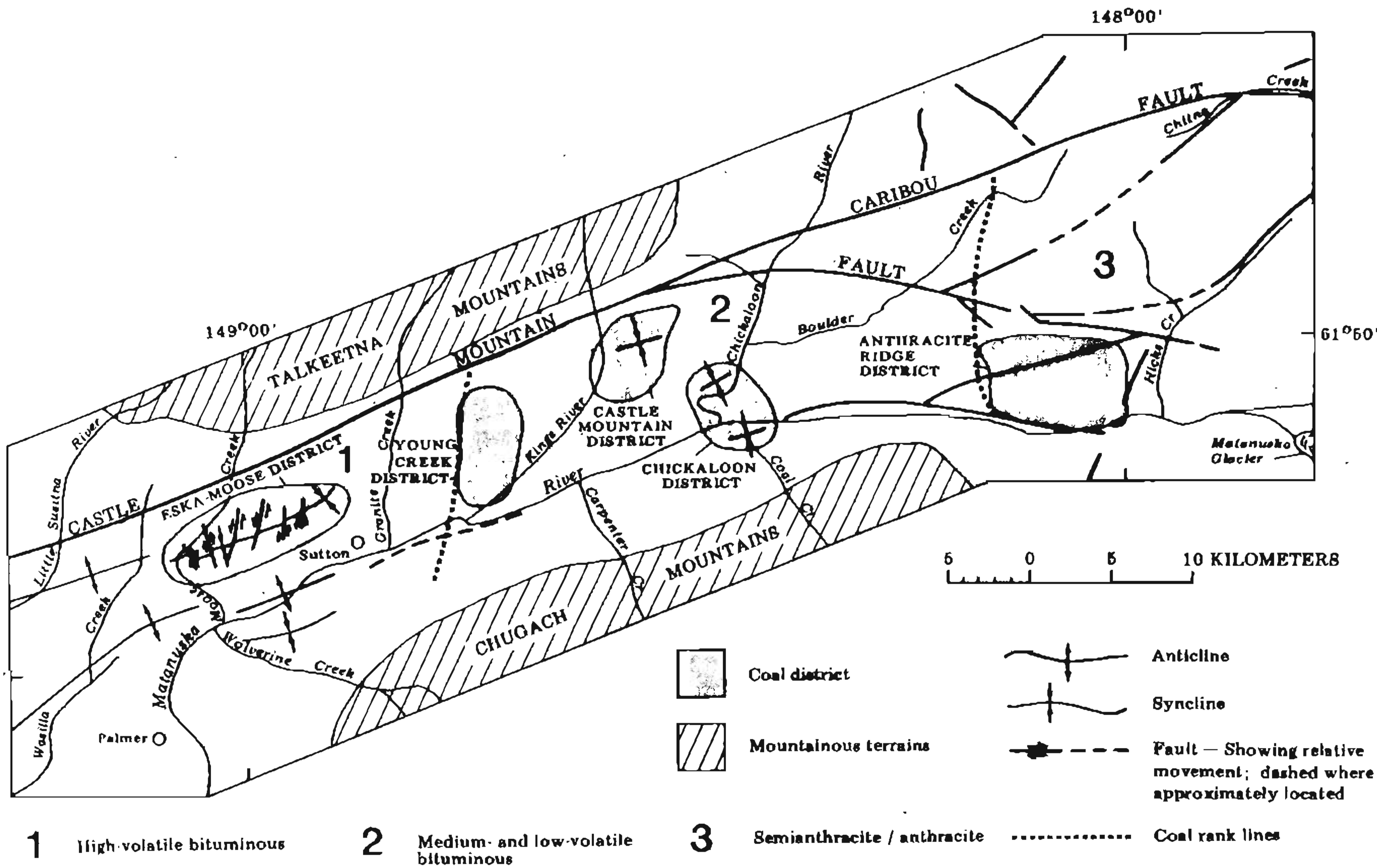


Figure 24. Major districts, rank, and geologic structure in the Matanuska coal field (modified from Merritt and Belowich, 1984).

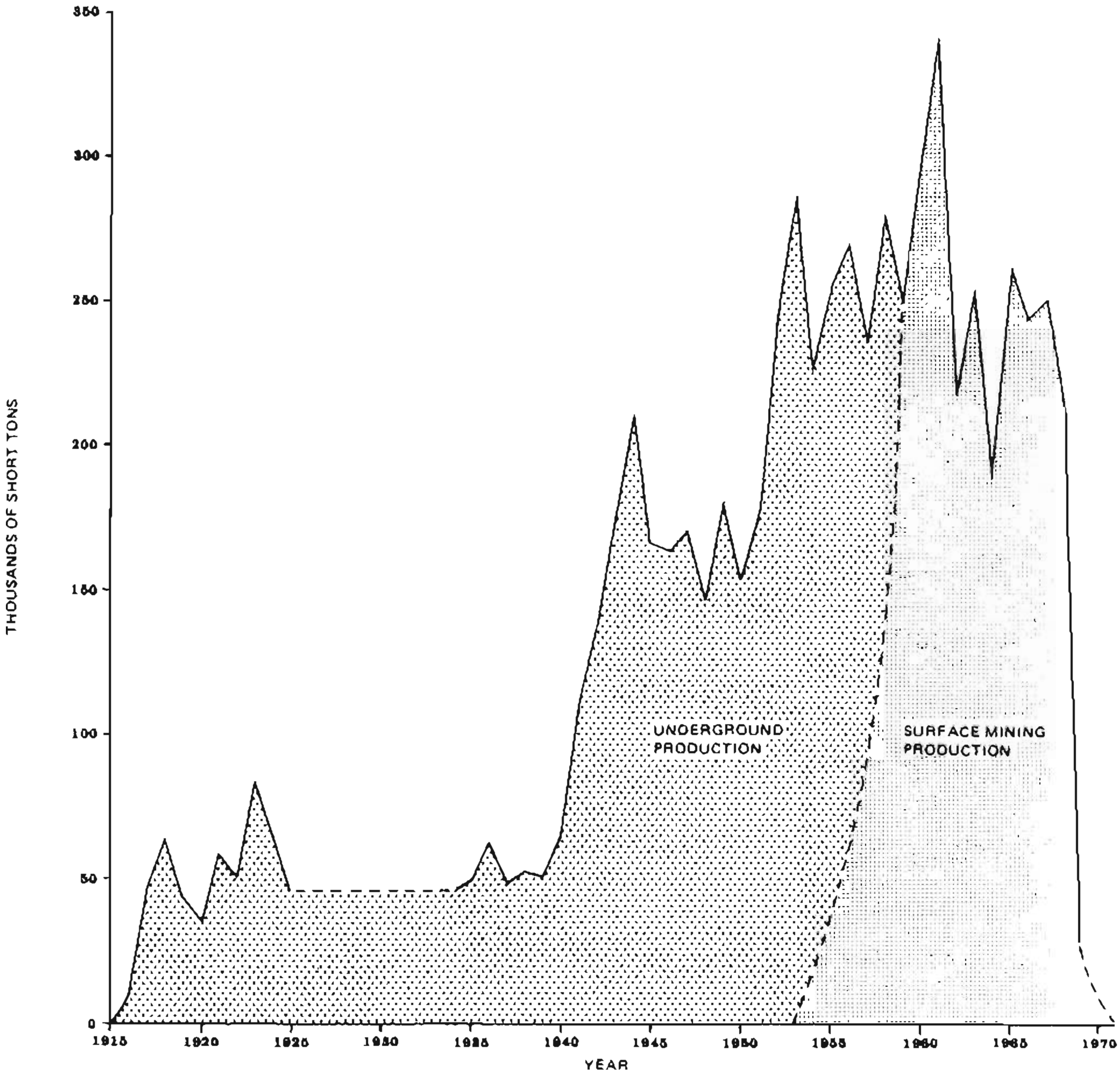


Figure 25. Coal production in the Matanuska field, 1915-1970 (from Merritt and Belowich, 1984).

Table 17. Chronology of events in coal-development history of Matanuska Valley.

1894	Early prospectors and traders learn of coal deposits in the Matanuska Valley from the Indians.
1898-99	Geologist W.C. Mendenhall accompanies Army exploration parties into the Matanuska Valley.
1912-14	The U.S. Navy tests Matanuska Valley coal for naval use.
1913	Over 1,000 tons of coal are extracted by the U.S. Bureau of Mines in the Chickaloon area.
1914	About 600 tons of Chickaloon coal are used in a steaming test aboard the U.S.S. Maryland.
1916	The Alaska Railroad is built to the Matanuska coal field. Mining begins in the Moose Creek district of lower Matanuska Valley.
1916-18	The Doherty Mine of the Matanuska field produces some 50,000 tons of coal.
1917	The Eska Mine is opened and a railroad spur is constructed. The Alaska Railroad is extended to Chickaloon.
1919	The Alaska Railroad purchases the Eska Mine of the Matanuska Valley. Two coal mines are operated by the U.S. government at Eska and Chickaloon. Thirty-five men work at the Chickaloon Mine and over 4,000 tons of coal are mined incidental to development.
1920	The underground operations of the Evan Jones Mine of the Matanuska field begin. The U.S. Navy constructs a coal-mining town at Chickaloon.
1920-21	The U.S. Navy drives two exploratory tunnels at a site 8 miles above the mouth of the Kings River of the Matanuska Valley.
1920-22	The Naval Alaskan Coal Commission performs exploratory work on coal beds at Chickaloon.
1921	A rail spur is completed to the Evan Jones Mine from the Eska branch of the Alaska Railroad.
1921-22	The Sutton Coal Washery is constructed by the U.S. Navy Alaskan Coal Commission and Alaska Engineering Commission. About 5,000 tons of coal are washed before it is closed and dismantled. The Navy prospects for coal on Coal Creek (south side of Matanuska River) and completes eight diamond-drill holes on the bench east of the creek.
1922	The Chickaloon Coal Mine and townsite are prepared for abandonment after a determination is made that the coal in the area cannot be mined economically.
1925	The Premier Mine is opened by the Alaska Matanuska Coal Co. Ross S. Hecky opens the Hecky (or Coal Creek) Mine on the west side of Coal Creek opposite the mouth of the Chickaloon River. 1,650 tons are produced in the next 5 years and sold to the railroad; the coal is converted to coke in ovens at Anchorage and the product used in the foundry of the railroad shop.
1932	The Wishbone Hill Coal Co. produces a small quantity of coal from the Rawson Mine.
1937	A coal mine explosion at the Evan Jones Mine kills 14 men and curtails production.

Table 17 (con.)

1942	The Alaska Railroad reopens the Eska Mine. Drilling begins on the Buffalo property of the Wishbone Hill district, Matanuska Valley.
1945	The Eska Mine of the Matanuska field is closed.
1953	Maximum underground production in the Matanuska field reaches over 285,000 tons.
1958-1960	Two strip pits are excavated at the Castle Mountain Mine in the Matanuska Valley removing 20,700 tons of coal which is sold for power generation purposes at military bases in Anchorage.
1959	Underground coal mining at the Evan Jones Mine ceases.
1967	Cook Inlet natural gas from Swanson River field begins to supplant Matanuska coal.
1968	Matanuska field coal mining shuts down except for small mines filling local needs.

The most important mining operations in the Matanuska field were the Premier Mine, which operated from 1925 until 1982, the Buffalo Mine (1942-1945), the Evan Jones Mine (1920-1965), the Eska Mine (1917-1922), and the Hecky or Coal Creek Mine (1925-1930; fig. 26). Total past production was about 7.5 million tons, mostly from stripping and underground workings of the Evan Jones Mine at Wishbone Hill (fig. 27). Mining ceased in the Matanuska field in 1968 when Cook Inlet natural gas supplanted coal use in the Anchorage area. Minor production continued at the Premier Mine to provide coal for local needs until 1982. Recent exploration and mine feasibility studies at Wishbone Hill have been completed by Union Pacific Resources (figs. 28 and 29).

Access

The Matanuska field is favorably located with respect to railroad and road links, and hence is not a 'green-field' energy development. The Glenn Highway passes along its southern edge, and the western part of the field is served by the Alaska Railroad. No major construction of transportational facilities would be required to resume coal-mining operations in the Matanuska field.

Geology

Coal deposits of the Matanuska field occur within the Tertiary (Paleocene-early Eocene) Chickaloon Formation (fig. 30). The upper coal-bearing part of this unit includes about 1400 ft of claystone, siltstone, sandstone, conglomerate, and several series (or groups) of coal beds (fig. 31). The strata indicate deposition in a dominantly fluvial meandering to paludal depositional paleoenvironment. Structure varies from moderately complex at the west end of the Matanuska field to complex at the east end. Although beds range in dip from 7° to overturned, they typically dip at 20° to 65°.

The main structural feature of the Wishbone Hill district is the northeast-trending Wishbone Hill syncline, which has moderately-dipping limbs and is cut by several transverse faults (figs. 32 and 33). The structure of the Chickaloon district is dominantly synclinal, but is further complicated by faulting and intrusion of dikes and sills. Both coal rank and complexity in structure increases progressively eastward.

Coal Quality and Petrology

The quality of Matanuska field bituminous and anthracitic coals from the Wishbone Hill, Chickaloon, and Anthracite Ridge districts are summarized in table 18. Average petrologic compositions of coals from the same areas are listed in table 19.

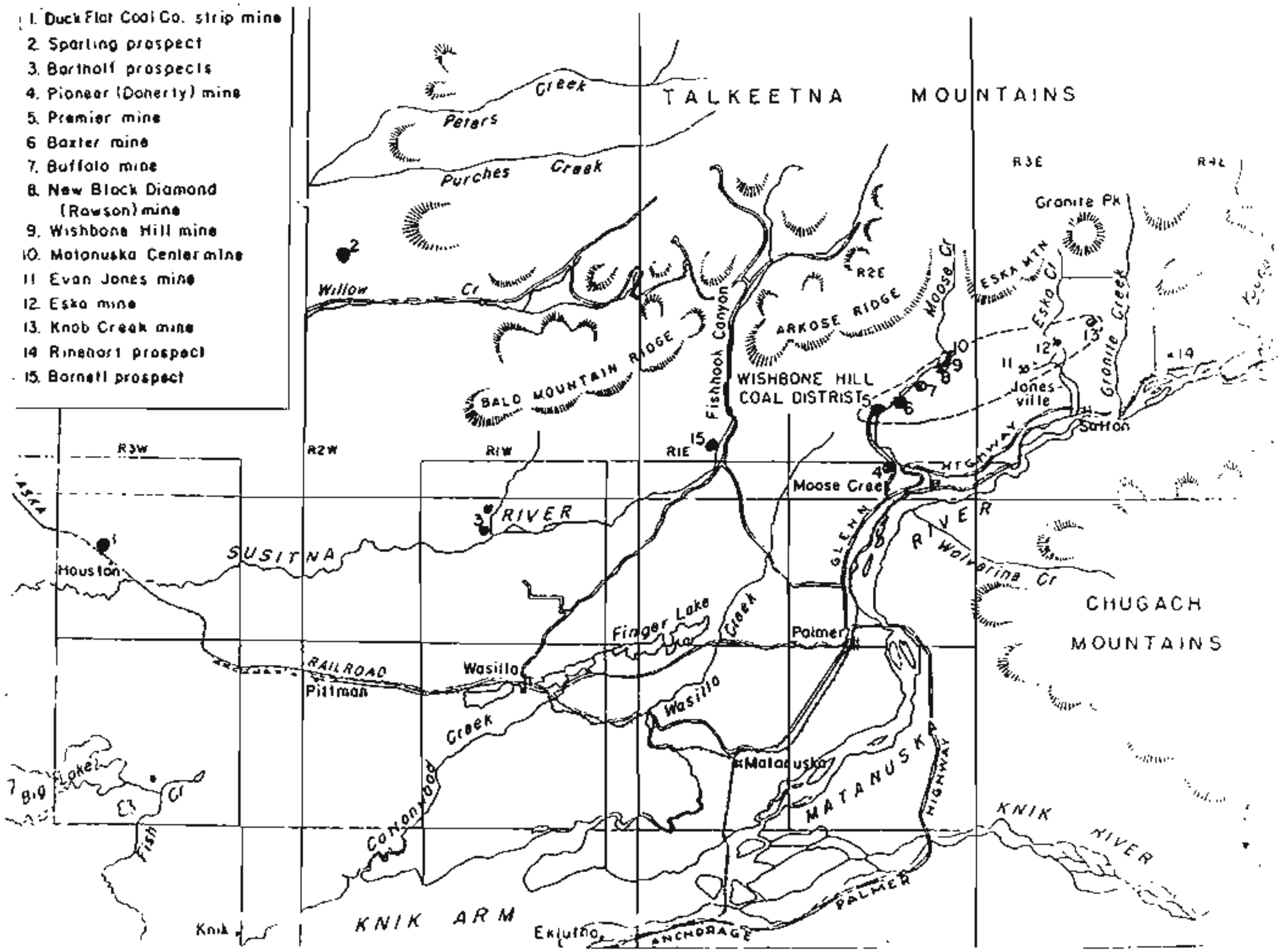


Figure 26. Locations of important former coal mines and prospects of western Matanuska Valley and vicinity (from Barnes and Ford, 1952).

Figure 27. Highwall face at Evan Jones surface mine, north limb of Wishbone Hill syncline, Matanuska Valley. (Photo by G.R. Eakins, 1981.)

Figure 28. Drilling for coal at the Wishbone Hill project of Union Pacific Resources. (Photo by R.D. Merritt, 1983.)

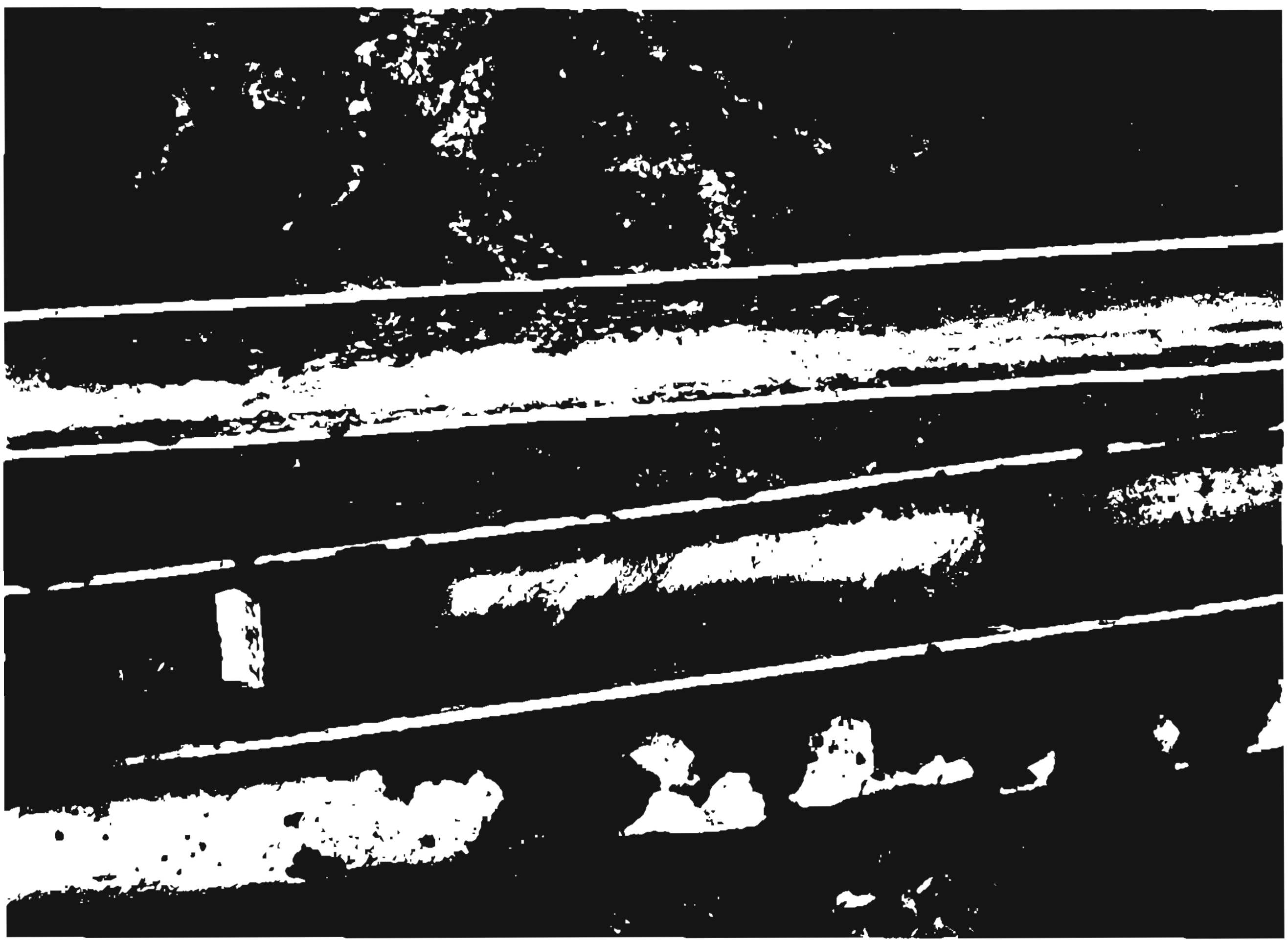
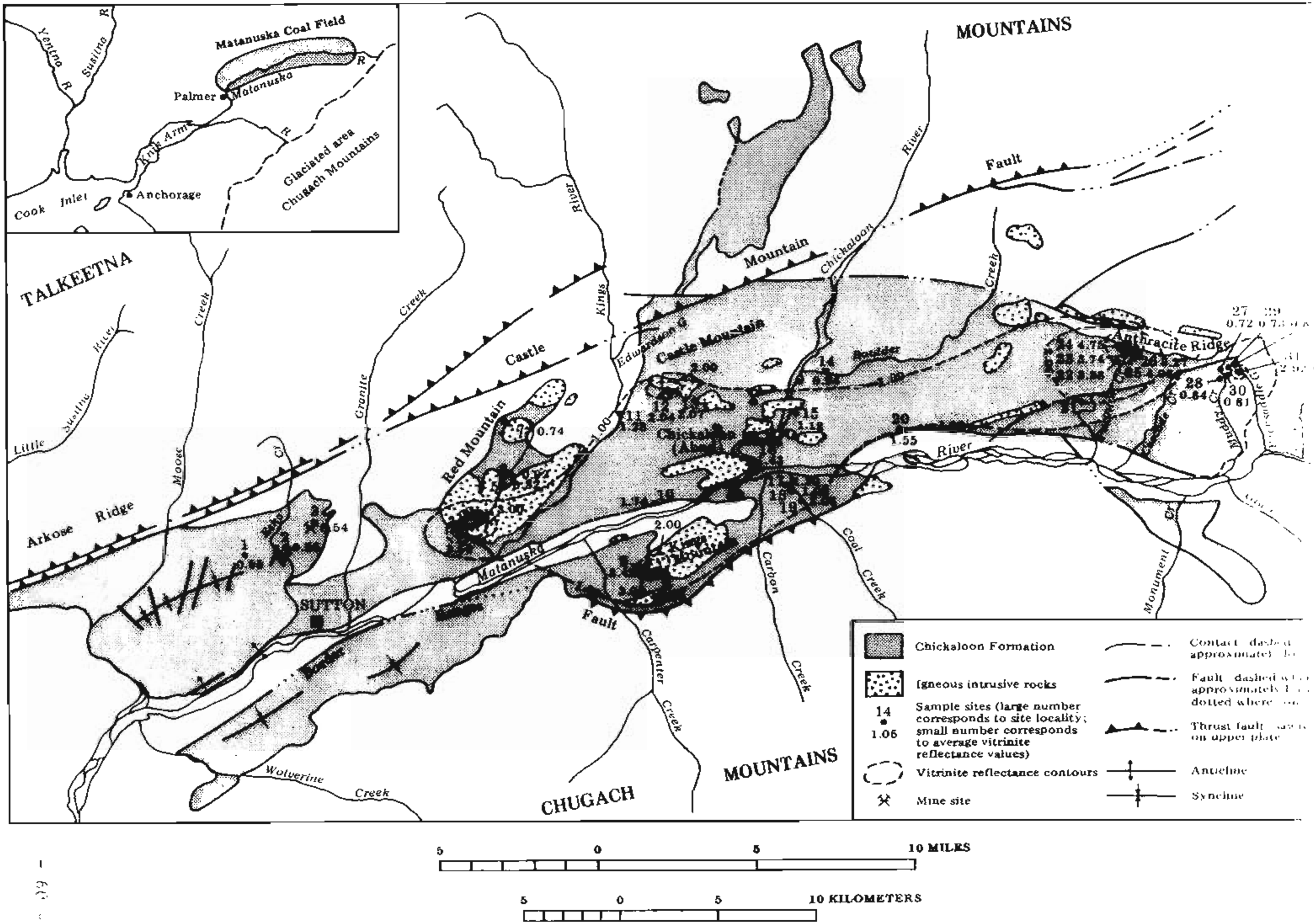


Figure 29. Drill core from the Wishbone Hill project of Union Pacific Resources. (Photo by R.D. Merritt, 1983.)



...ure 30. Geology map of the Matanuska Valley showing the general distribution and outcrop extent of the ... Chickaloon Formation, igneous intrusive bodies, and vitrinite reflectance data for sample localities (modified from ... and ... 197...).

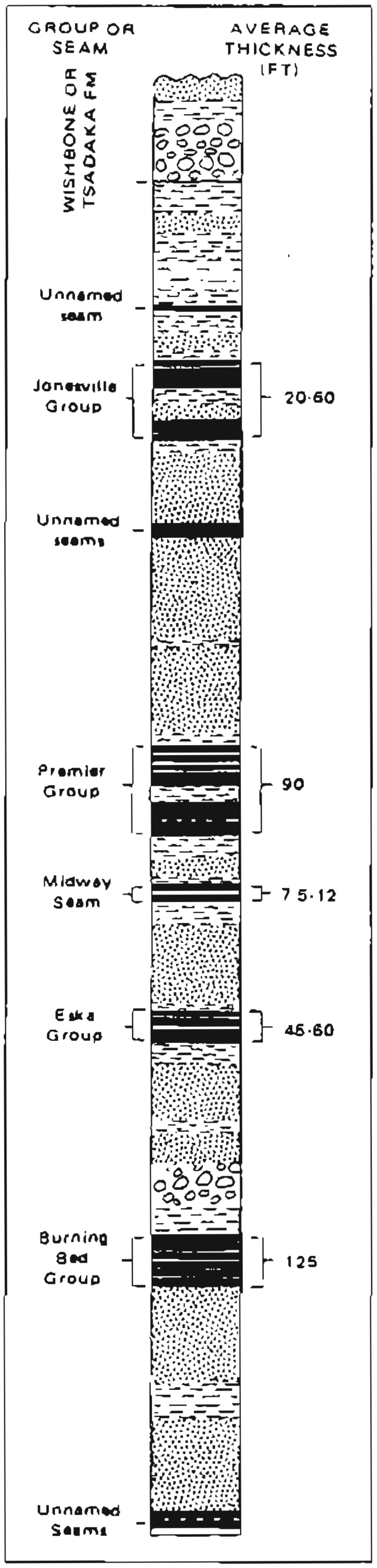


Figure 31. Generalized stratigraphic section of upper Chickaloon Formation in western part of the Wishbone Hill district, Matanuska coal field (after Hawley and others, 1984).

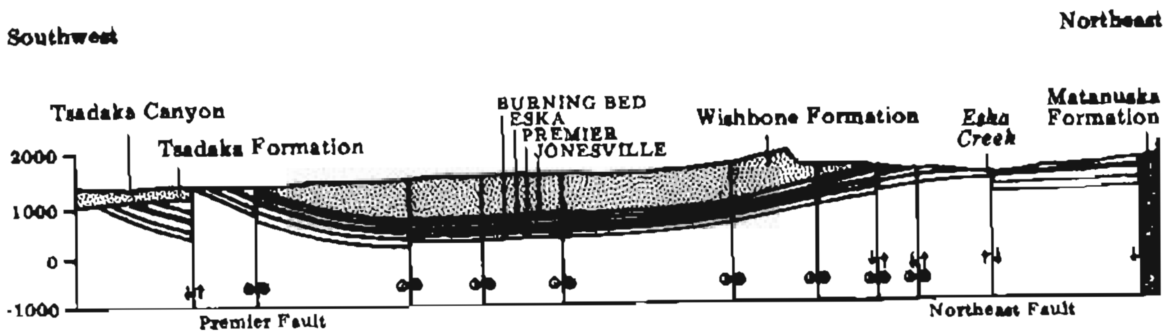


Figure 32. Longitudinal cross section of the Wishbone Hill syncline (from Germer, 1987).

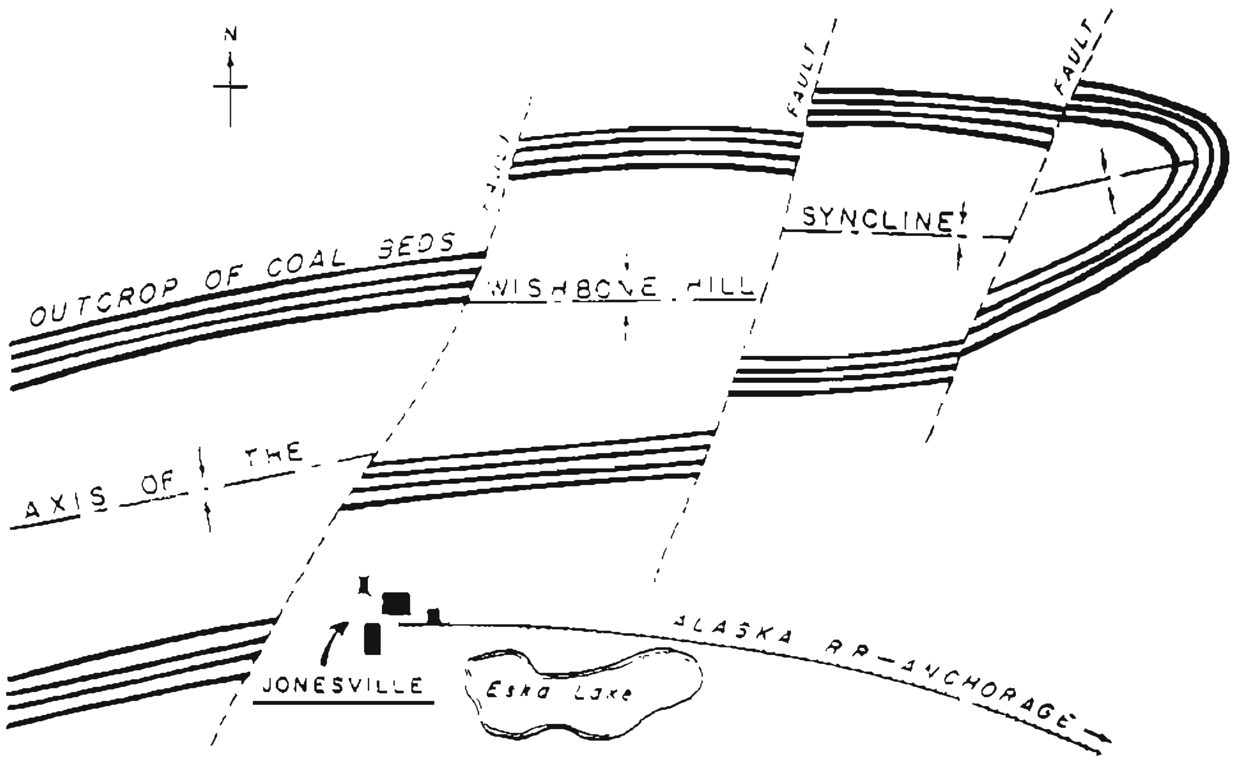


Figure [illegible] field (modified

Table 18. Comparison of quality parameters of Wishbone Hill, Chickaloon, and Anthracite Ridge coals, Matanuska field.

	Wishbone Hill	Chickaloon	Anthracite Ridge
Rank:	hvBb	mvb-lvb	sa-an
Heating content (Btu/lb):	10,400-13,200	11,960-14,400	10,720-14,000
Mean-maximum vitrinite reflectance (Ro_{max}, %):	0.5-0.6	1.1-2.1	2.0-5.0
Proximate analysis (range in %):			
Moisture	3-9	1-5	3-9
Volatile matter	32-45	14-24	7-11
Fixed carbon	38-51	60-72	65-81
Ash	4-24	5-18	6-17
Ultimate analysis (range in %):			
Carbon	50-70	65-77	66-75
Hydrogen	4.5-5.5	4.2-5.2	2.8-5.6
Nitrogen	1.0-1.4	1.3-1.7	1.2-1.7
Oxygen	10-17	6-10	6-15
Sulfur	0.2-0.6	0.2-0.7	0.2-0.7
Ash	4-24	5-18	6-17
Major-oxide composition of ash (avg., %):			
SiO_2	56.81	53.92	49.26
Al_2O_3	28.94	29.73	29.95
Fe_2O_3	2.97	4.34	4.46
CaO	2.36	2.63	4.75
K_2O	1.86	1.72	1.53
TiO_2	1.56	1.32	1.53
MgO	1.12	1.52	1.54
SO_3	1.11	1.13	0.97
P_2O_5	0.79	1.46	3.24
Na_2O	0.70	0.68	0.71
SrO	0.18	0.22	0.31
BaO	0.18	0.21	0.42
MnO	0.02	0.04	0.02
Undet.	1.40	1.08	1.31

Table 18 (con).

Trace elements in coal ash (avg., ppm):			
Antimony	2	1	1
Arsenic	8	4	7
Beryllium	0.5	0.9	1.0
Boron	77	66	85
Bromine	2	4	52
Cadmium	1	2	2
Cerium	19	36	35
Cesium	3	4	4
Chlorine	8	32	66
Chromium	14	18	9
Cobalt	16	6	10
Copper	27	40	22
Europium	0.5	0.9	0.5
Fluorine	230	425	361
Gallium	22	18	17
Germanium	1.1	1.7	1.1
Iodine	2	5	3
Lanthanum	19	27	22
Lead	6	14	7
Lithium	334	222	84
Molybdenum	3	8	6
Neodymium	4	7	3
Nickel	8	9	5
Niobium	7	11	7
Praseodymium	4	4	4
Rubidium	9	28	12
Samarium	4	5	3
Scandium	19	22	26
Selenium	2	5	2
Tellurium	1	1	2
Thorium	6	10	7
Tin	3	8	2
Uranium	4	5	4
Vanadium	90	85	79
Yttrium	22	18	17
Zinc	14	30	17
Zirconium	74	80	61
Fusibility of ash (°F):			
Initial deformation	2380	2360	2490
Softening temperature (H=W)	2600	2430	2560
Hemispherical temperature (H=½W)	2640	2510	2570
Fluid temperature	2700	2560	2590

Table 18 (con.)

Free-swelling index:	0-2	0-8	0-2
Hardgrove grindability index:	47	72	---
Coking potential:	Poor to fair coking and caking properties	Noncoking to strongly coking; possible metallurgical	Some coking properties in bituminous coals only

Table 19. Comparison of the average distribution of macerals in Wishbone Hill, Chickaloon, and Anthracite Ridge coals, Matanuska field (volume, mmf-basis %).

	Wishbone Hill	Chickaloon	Anthracite Ridge
Average composition, volume, mineral-matter-free basis, %:			
Vitrinite	78.0	80.5	84.5
Pseudovitrinite	0.1	0.5	0.0
Gelinite	1.1	0.0	0.0
Corpocollinite	0.2	0.3	0.2
Vitrodetrinite	12.8	15.8	11.8
Total vitrinite	92.2	97.1	96.5
Fusinite	0.3	0.3	0.2
Semifusinite	0.2	0.3	0.1
Sclerotinite	0.5	0.2	0.4
Macrinite	0.1	0.1	0.0
Inertodetrinite	1.2	0.4	0.2
Total inertinite	2.3	1.3	0.9
Cutinite	0.5	0.0	0.1
Sporinite	0.1	0.0	0.0
Resinite	3.2	0.4	0.8
Suberinite	0.1	0.5	0.4
Liptodetrinite	1.6	0.7	1.3
Total liptinite	5.5	1.6	2.6

Coal Resources

Wishbone Hill District

Bituminous coal beds to 23-ft thick are confined largely to the upper 1400 ft of the Chickaloon Formation. Most resources are in beds greater than 3.5-ft thick. Total estimated resources (0-2,000 ft) are:

Measured:	40 million short tons
Identified:	120 million short tons
Hypothetical:	350 million short tons

Chickaloon District

Bituminous coal beds to 14-ft thick comprise two principal deposits: (1) at Chickaloon north of Matanuska River (fig. 34), and (2) at Coal Creek, south of the Matanuska River. Total estimated resources (0-2,000 ft) are:

Measured:	3 million short tons
Identified:	25 million short tons
Hypothetical:	100 million short tons

Anthracite Ridge District

A 20-acre tract in the Purinton Creek area contains an estimated 1.0 million tons of anthracite and semianthracite. Beds of 34 and 24 ft thickness have been measured at two exposures (fig. 35), although beds are predominantly 5-10 ft thick or less. Total estimated resources (0-2,000 ft) are:

Measured:	1 million short tons
Identified:	4.5 million short tons
Hypothetical:	50 million short tons

Mining Potential

Large-scale mines with annual productions in excess of 1.0 million tons per year are unlikely in the Matanuska field. Surface mining will occur initially in areas at the east and west ends of Wishbone Hill followed thereafter by underground mining of additional reserves. Shipping of large tonnages of coal will require upgrading the rail system. A factor favoring development is that most of the region lies on State lands.

Mine-mouth electrical power-generating facilities are feasible at the west end of Matanuska Valley. Specific mineral industries could also develop near the coal deposits; for example, a Portland cement plant using limestone (marble) and argillite from the Kings River marble deposits.

Figure 34. Coal-bearing outcrop on the lower Chickaloon River, central Matanuska Valley. (Photo by R.D. Merritt, 1983.)

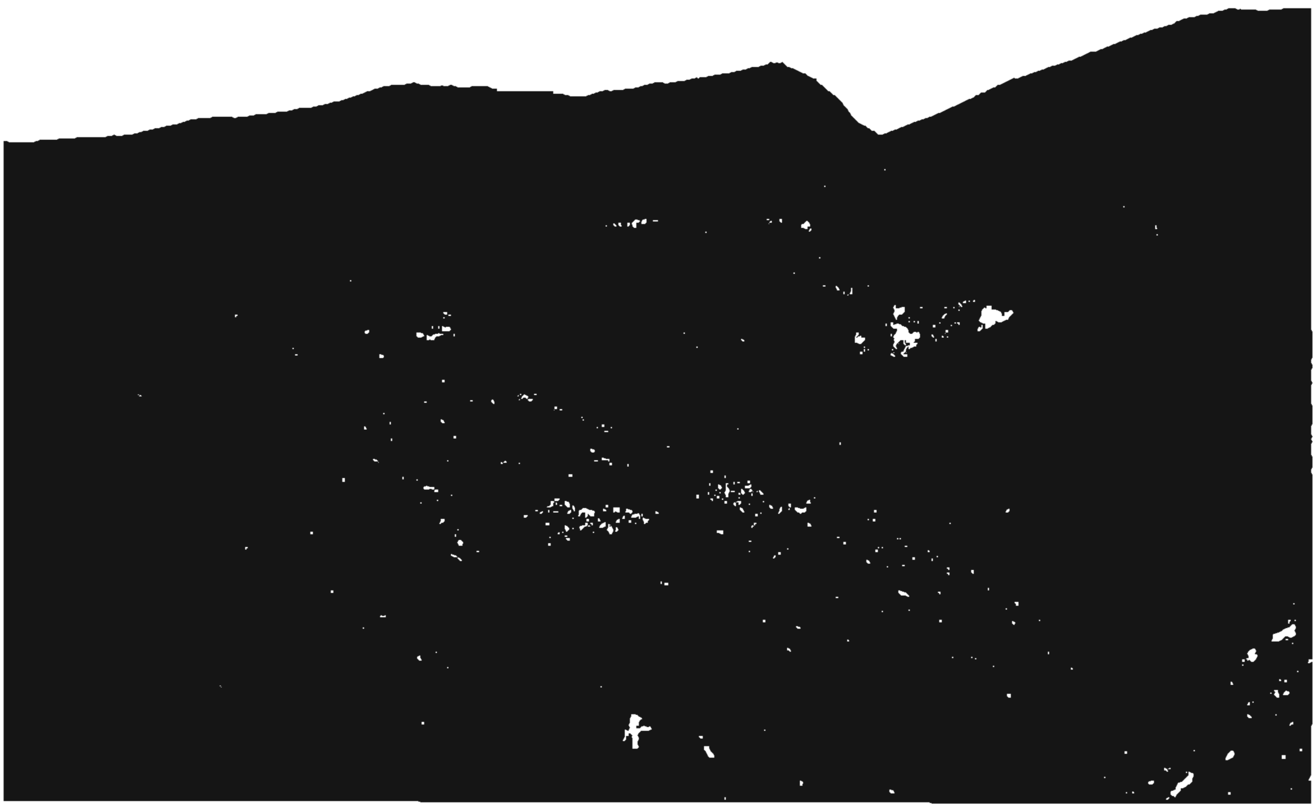


Figure 35. Anthracite-bearing outcrop on Purinton Creek, Anthracite Ridge district, eastern Matanuska Valley. One seam at left is present in an over 30-ft thick lense. (Photo by R.D. Merritt, 1983.)

GULF OF ALASKA PROVINCE

Bering River Field

Location

The Bering River field is located in southcentral Alaska and constitutes the most important resource of the Gulf of Alaska coal province. It straddles the border between the Cordova and Bering Glacier Quadrangles (fig. 36). The field is 12 mi northeast of Katalla, 50 miles east of Cordova, and 200 mi east of Anchorage.

Area

The belt of coal-bearing rocks extends northeast from the east shore of Bering Lake 20 mi and disappears under the ice fields of the Chugach Range. The coal field varies from 2 - 6 mi wide and incorporates a total estimated area of 80 square miles (fig. 36).

Mining History

The Bering River field was discovered in 1896 (table 20). Extensive exploration and testing of the coals was conducted during the early 1900's. Despite numerous surface and underground prospects, no commercial mines have been developed. Total production from the field to date is estimated at a few thousand short tons.

In recent years, the Chugach Alaska Corporation, in association with the Korea-Alaska Development Corporation, has been studying the feasibility of developing a coal mine in the Bering River field to produce coal for export (fig. 37). A tentative mine plan calls for the use of a combination of open-pit and underground mining methods.

Geology

The Bering River field is defined by the outcrop extent of the Kushtaka Formation, a dominantly arkosic Tertiary (Eocene-early Miocene) sequence that also includes feldspathic sandstones, siltstones, shales, and coal beds (table 21). The formation is about 2,000-ft thick (fig. 38).

The geologic structure of the coal field is complex with dips of beds averaging 40°. The coals occur in a highly compressed series of isoclinal, chevron-like folds incorporated into an imbrication or pinching-and-swelling selvage along one of numerous bedding-plane faults (fig. 39). The beds are thinned by tectonic lensing to form "schlieren" (fig. 40) and tectonically thickened at the axes of folds (fig. 41).

Access

The Bering River field is about 25 miles from tidewater. It can be considered a "green-field" energy development since it lacks existing

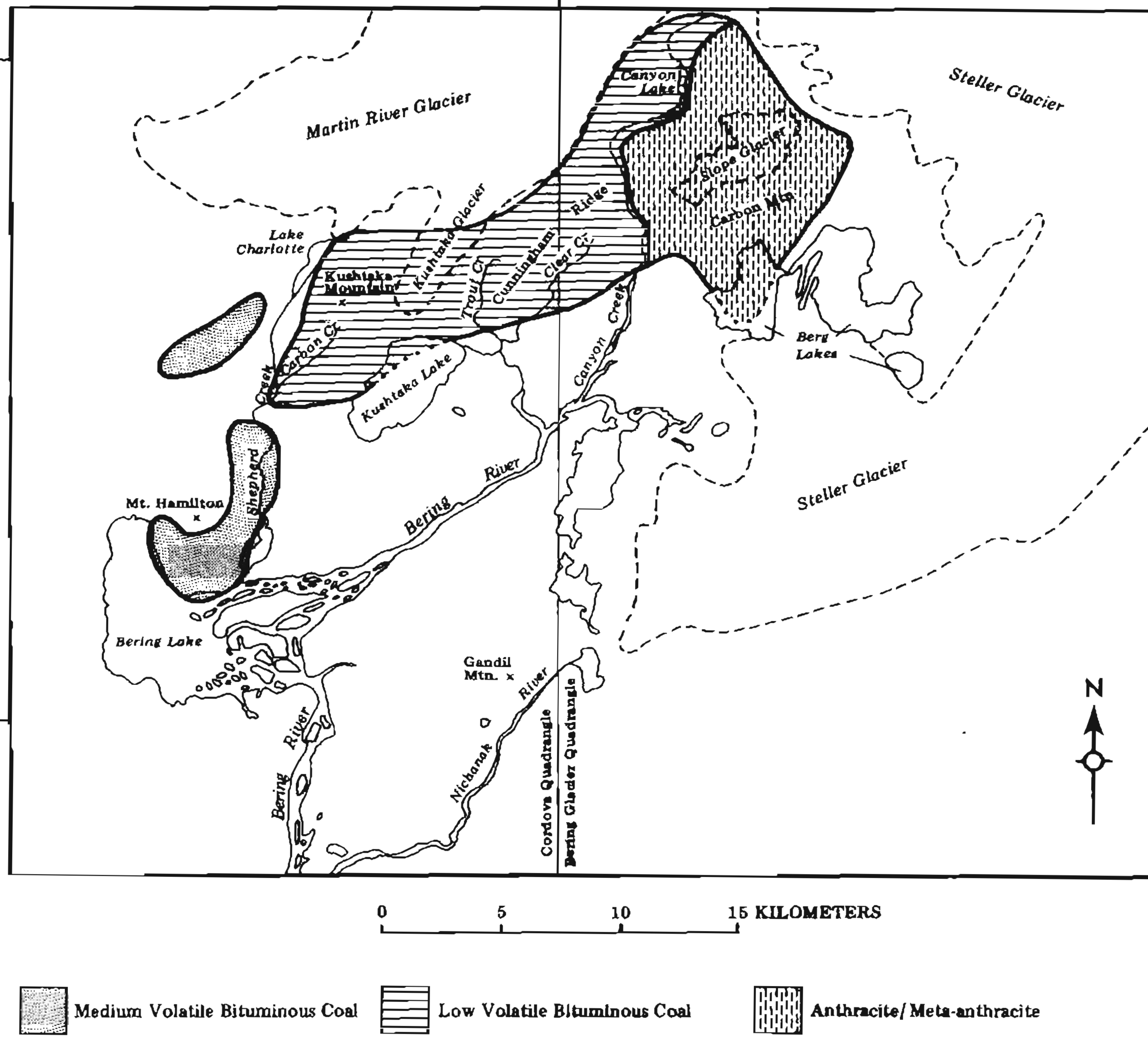


Figure 36. Generalized outcrop extent of the Kushtaka Formation of the Bering River coal field showing the eastward gradation in coal rank (from Merritt, 1986).

Table 20. Chronology of events in coal-development history of the Bering River field.

1896	Coal is discovered in the area of the Bering River field.
1904	Coal Claims Act is ratified allowing coal-claim locations without prior surveys. Coal claims in the Bering River field are refiled under the act.
1906	President Theodore Roosevelt closes Alaska public land to entry under coal laws due to the Ballinger-Pinchot feud over the Bering River field coal claims.
1906-12	U.S. Bureau of Mines, Forest Service, and Geological Survey conduct extensive studies on the Bering River field coals for the Navy. Six major tunnels are driven in the Carbon Creek area, and over 150 prospects are opened. Six railroads are surveyed to develop the Bering River field.
1907	Six hundred tons of coal are mined from the McDonald Property on Bering Lake and used in Cordova.
1910	Alaska Coal and Petroleum Company drives a 1,000-ft tunnel at the Davis Mine on the A.B. Hunt Claim, Bering River field.
1911	Cordova 'Coal Party' is held in which imported coal is shoveled into the harbor by angry residents in protest of federal coal policies. Pinchot is burned in effigy at Katalla.
1912	The U.S. Navy begins coal investigations in the Bering River field.
1912-14	The U.S. Navy tests Bering River coal for naval use.
1958-59	The Jewel Ridge Coal Company of Tazewell, Virginia reopens the old underground workings on Carbon and Trout Creeks in the Bering River field.
1981-present	Exploration and mine feasibility studies by Bering Development Corporation.

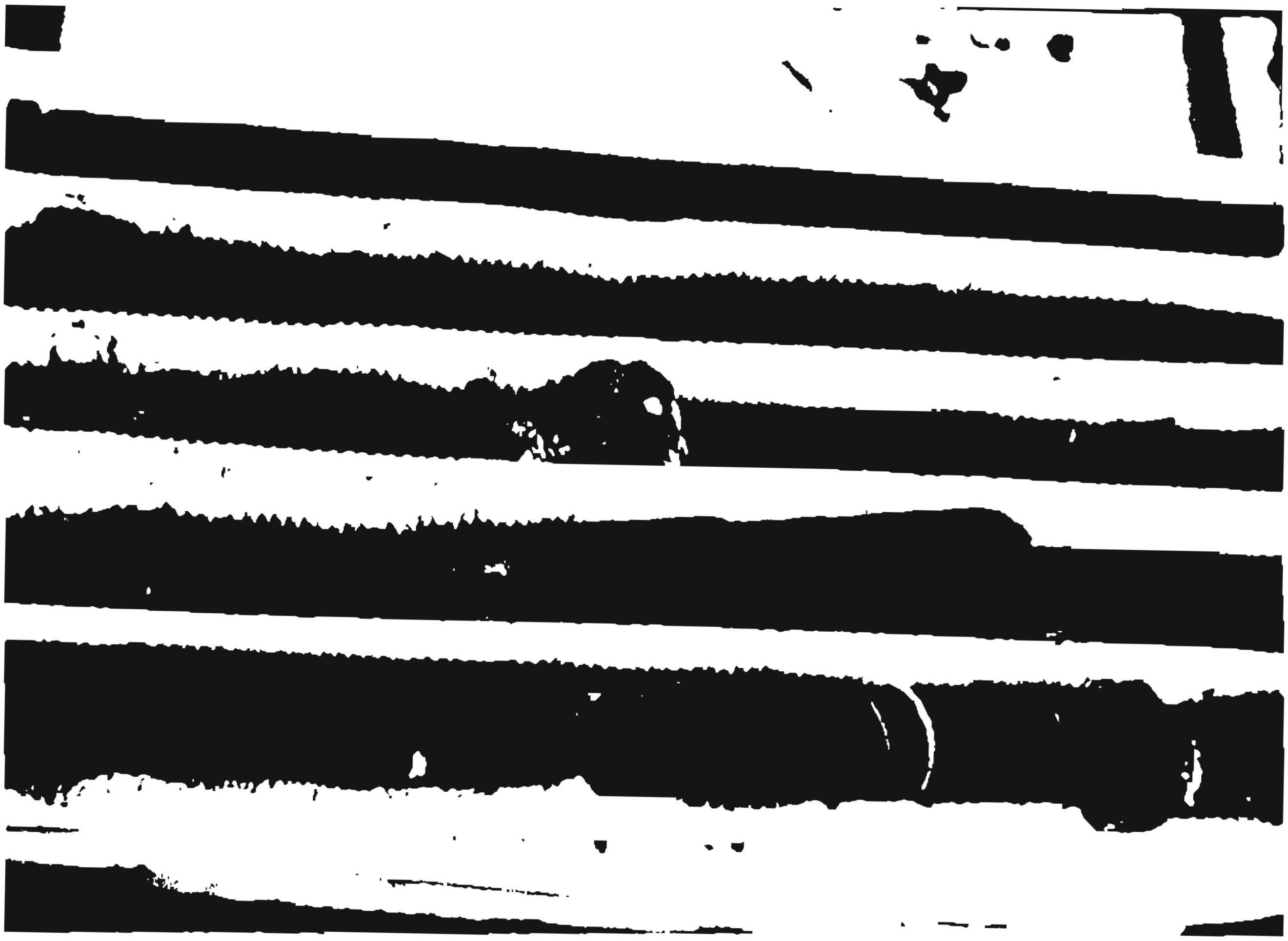


Figure 37. Coal core from Bering Development Corporation's drilling project in the Bering River field, 1984. (Photo courtesy of Bering Development Corporation.)

Table 21. Generalized section of rocks in the Bering River coal field (modified from Barnes, 1951).

Age	Formation	Character of rocks	Thickness (feet)
Quaternary		Stream deposits, lake sediments, morainal deposits, marine silt and clay	
Tertiary or later		Diabase and basalt dikes	
Tertiary	Tokun	Sandstone	500
		Shale	2,000+
	Kushtaka	Arkose with many coal beds	2,500±
	Stillwater	Shale and sandstone	1,000±
	Katalla[1]	Conglomerates, sandstones, and shales	2,500
		Sandstone	500
		Shale, concretionary	2,000
		Sandstone	1,000
		Shale	500+
Pre-Tertiary		Graywacke, slates, and igneous rocks	

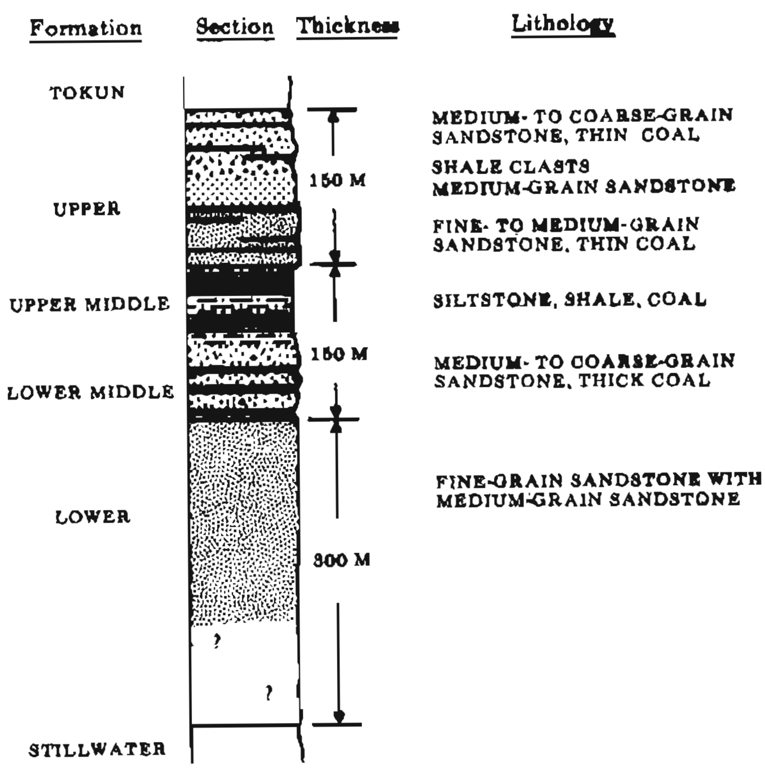


Figure 38. Stratigraphy of the Kushtaka Formation (after Smith and Rao, 1987).

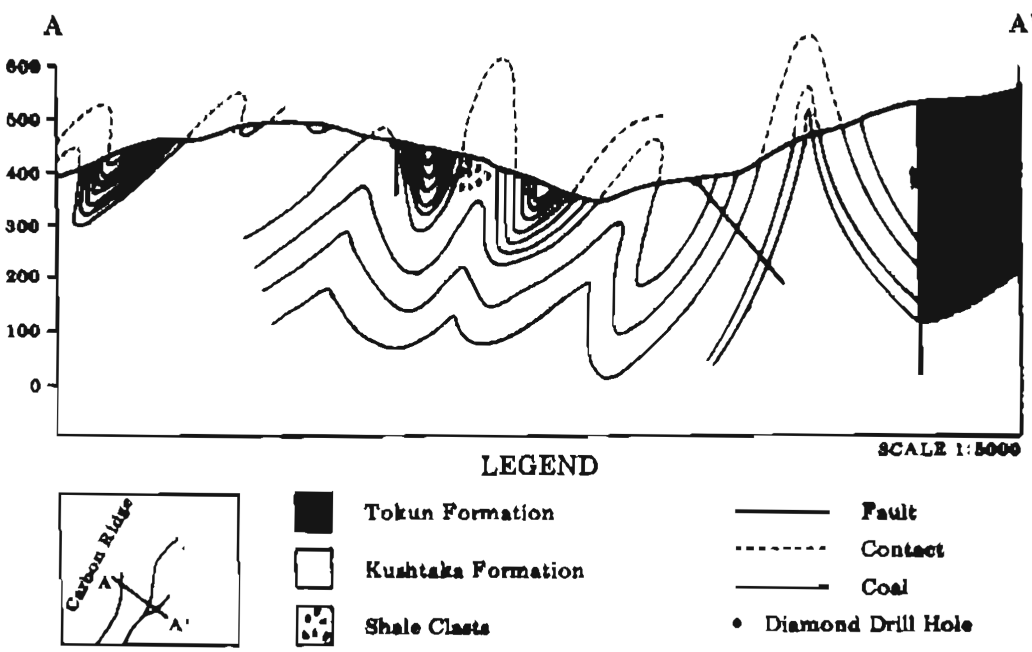


Figure 39. Cross section from the Carbon Ridge area (modified from Smith and Rao, 1987).

Figure 40. Folding in coal beds in the Carbon Mountain area, Bering River field. (Photo by R.B. Sanders, 1973.)

Figure 41. The 'Queen Vein,' a 28-ft thick coal seam of the Bering River field. (Photo by R.B. Sanders, 1973.)

infrastructure and will require the construction of an overland transportation system. This system would likely consist of a conveyor or aerial tramway to transport the coal from the mine to a storage facility at a marine terminal on the southeast tip of Kanak Island where it would be loaded on ships for export. In addition, an access road would be built to connect the mine facilities with the road to Cordova.

Coal Quality

The coals of the Bering River are greatly devolatilized due to low-grade regional metamorphism. The rank of the coals increases to the east with the intensity of deformation. Table 22 summarizes the overall quality of Bering River field bituminous coals and anthracites.

Coal Petrology

Because of the high-rank of the coals of the Bering River field, maceral analyses are of little benefit (Smith and Rao, 1987). Although some samples retain remnant morphological structures of various macerals, the coals are overall petrologically similar and morphologically homogeneous.

Coal Resources

Coal resources of the Bering River field are concentrated in four main areas: Carbon Creek, Trout Creek, Clear Creek/Cunningham Ridge, and Carbon Mountain. The Carbon Creek area is the most promising in size and physical condition of beds. At least 20 coal beds are confirmed ranging from 5 ft to 10 ft thick. Lenses 30-60 ft thick occur locally.

Resources are summarized as follows (overburden 0-3,000 ft):

Measured:	60 million short tons
Identified:	160 million short tons
Hypothetical:	3.5 billion short tons

Mining Potential

Because of the structural complexity of the Bering River field, resources typically have to be calculated based on a coal/country rock ratio. Mass mining of large blocks may be required followed by subsequent separation of the coals by flotation or other washing systems.

The Chugach Alaska Corporation has been studying the feasibility of developing a coal mine in the field. The Korea Alaska Development Corporation has been formed as a joint venture partnership to pursue development. A preliminary study by Wheelabrator Coal Services Company (1984) estimated an FOB loading terminal price of $62 per ton for coal produced at the mine.

Table 22. Summary of quality parameters of Bering River field coals.

Rank: Ranges from low-volatile bituminous in the western part of the field to seminanthracite and anthracite in the eastern part.

Heating content: Range---11,000-15,000 Btu/lb
Average---14,000 Btu/lb

Mean-maximum vitrinite reflectance (Ro_{max}, %): 1.63-2.66; locally to 9.46

Proximate analysis:	Range (%)	Average
Moisture	0.01-1.80	0.52
Volatile matter	2.67-16.15	12.45
Fixed carbon	63.51-85.03	78.55
Ash	1.14-22.46	8.48

Ultimate analysis:

Sulfur	0.21-4.49	1.25
Carbon	68.02-89.14	82.14
Hydrogen	0.76-4.49	3.82
Nitrogen	0.81-1.66	1.31
Oxygen	1.40-4.17	3.00
Ash	1.14-22.46	8.48

Major-oxide composition of ash (avg., %):

SiO_2	- 40.03
Fe_2O_3	- 14.26
CaO	- 7.02
MgO	- 1.78
Na_2O	- 1.00
TiO_2	- 1.00
Al_2O_3	- 20.82
K_2O	- 1.29
P_2O_5	- 1.84
MnO	- 0.10
Undet.	- 10.86

Trace elements in coal ash (avg., ppm):

Barium	1850
Beryllium	10.5
Chromium	246
Cobalt	86
Copper	166

Table 22 (con.)

Nickel	273
Strontium	4282
Vanadium	198
Zinc	677
Zirconium	232

Free-swelling index: 0-2.5

Coking potential: It is questionable whether the low-volatile bituminous coals possess coking properties, but it is expected that a good coke can be produced by blending the low-volatile bituminous coals with other high-volatile bituminous coals.

Metallurgical character: Possible source of high-grade metallurgical coal.

ALASKA PENINSULA PROVINCE

Chignik Field

Location

The Chignik field is located on the northwest shore of Chignik Bay, indenting the southern (Pacific Ocean) side of the Alaska Peninsula (fig. 42). It is about 250 mi southwest of Kodiak, Alaska and 100 mi northeast of the Herendeen Bay field.

Area

The belt of coal-bearing rocks is about 30 mi long and 1-6 mi wide. The field incorporates a total estimated area of 100 square miles (fig. 43).

Mining History

Coal was first discovered on the banks of the Chignik River in 1885. In 1893, the Alaska Mining and Development Company opened a small coal mine on Anchorage Bay near Chignik Lagoon, and the Alaska Packer's Association opened the Chignik River Mine to produce coal for the local fish cannery and for steamers (fig. 44). The Chignik River Mine operated until 1911. The Alaska Peninsula Mining and Trading Company opened the Hook Bay Mine in 1908 (fig. 45). Several other small underground mines and prospects were opened in the early 1900's including Thompson Valley (fig. 46) and Whaler's Creek but accounted for very little production. There has been no mining activity since.

Although there has been limited exploration in recent years, the mineability of most areas has not been thoroughly investigated. In 1980-81, Resource Associates of Alaska, Inc. (a subsidiary of NERCO Minerals Company) explored several areas in the Chignik field for the Bristol Bay Native Corporation, the chief landholder in the area, and outlined several small potential mining blocks.

Access

Although the Chignik field is accessible to tidewater, Chignik Bay itself currently offers no suitable harbor facilities for large-draft vessels. The most likely scenario for coal shipment would require the construction of an overland transportation system (access road and conveyor or aerial tramway) through a low pass to the head of Kuiukta Bay, located about 5 mi south of the southwest end of the coal belt (fig. 42).

Geology

The coal deposits of the Chignik field are confined largely to the Coal Valley Member of the Late Cretaceous Chignik Formation (fig. 47). This cyclic nearshore marine and nonmarine unit is composed of sandstone, pebble-cobble conglomerate, siltstone, shale, and numerous coal beds (fig. 48). The

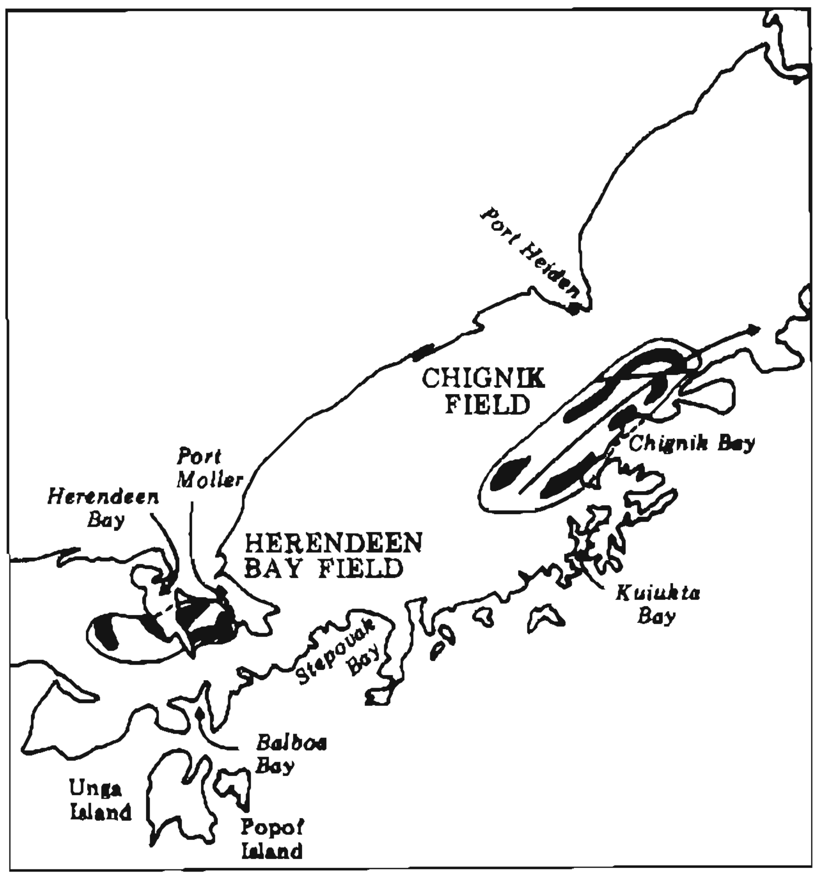


Figure 42. Index map of the southern Alaska Peninsula showing the locations of the Herendeen Bay and Chignik coal fields (modified from Merritt and Hawley, 1986).

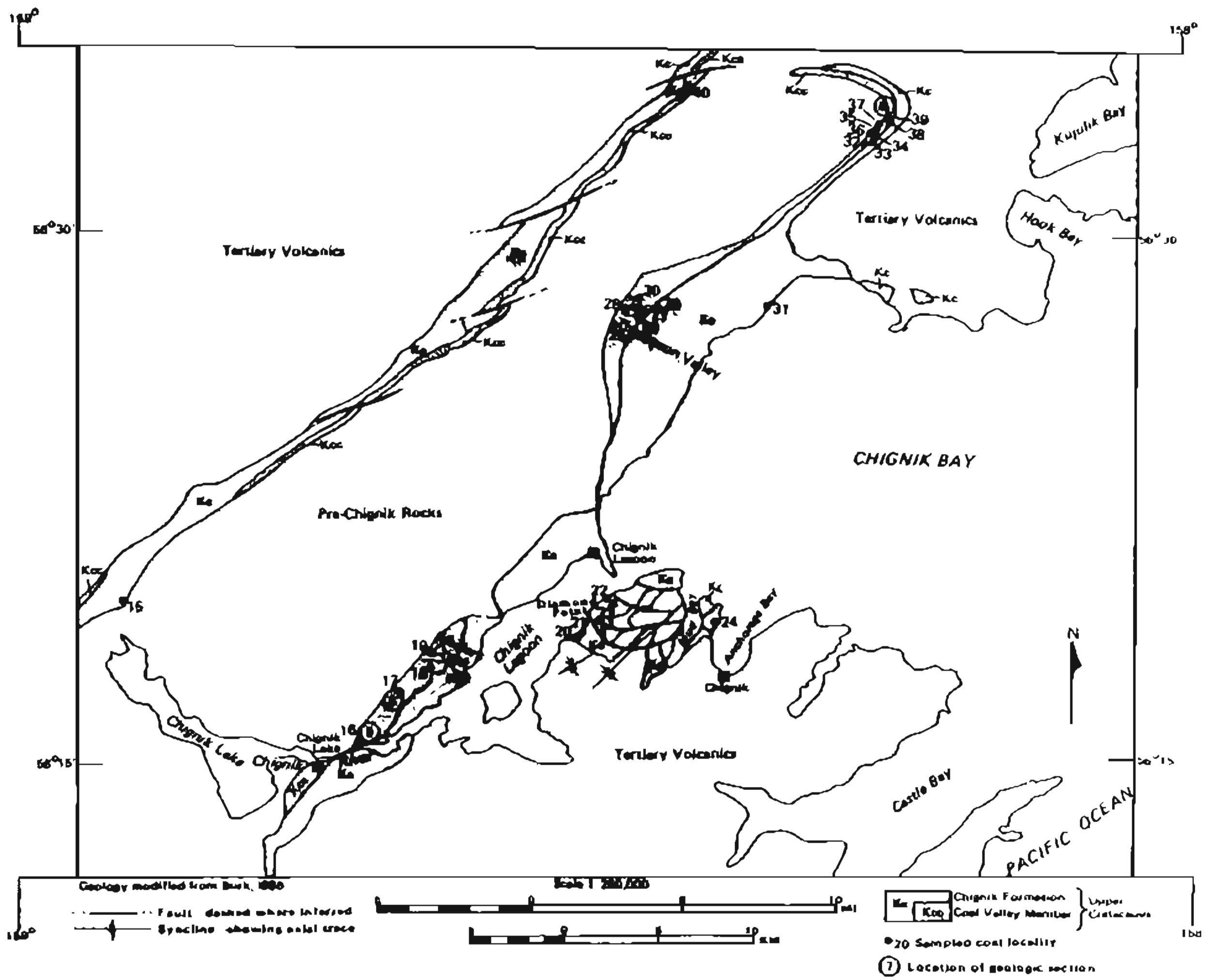


Figure 43. Generalized geologic map of the Chignik coal field, Alaska Peninsula (from Merritt and McGee, 1986).

Figure 44. Chignik Bay mine adit, Chignik field. (Photo by J.G. Clough, 1984.)

Figure 45. Hook Bay, Chignik field coal-bearing outcrop near the site of the Hook Bay mine opened in 1908. (Photo by R.D. Merritt, 1984.)

Figure 46. Lower coal horizon at Thompson Valley, Chignik field, Alaska Peninsula. This seam previously supported a small mine. (Photo by R.D. Merritt, 1984.)

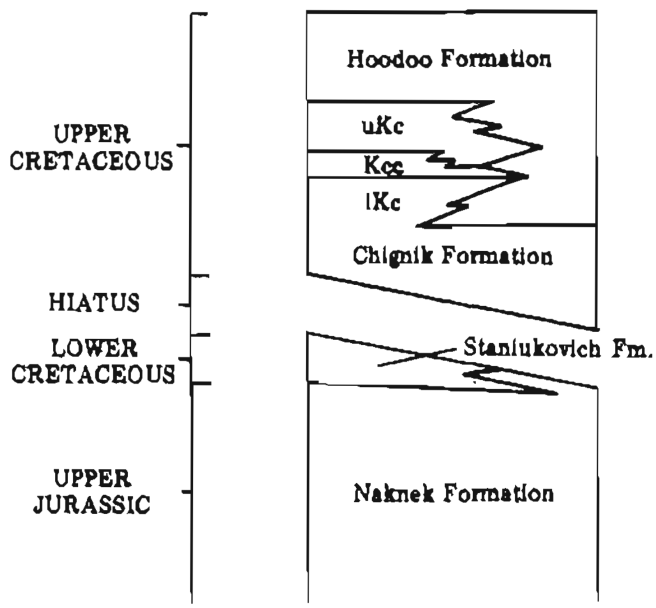


Figure 47. Generalized stratigraphy in the Chignik coal field. Kcc = Coal Valley Member, Chignik Formation (after Vorobik and others, 1981).

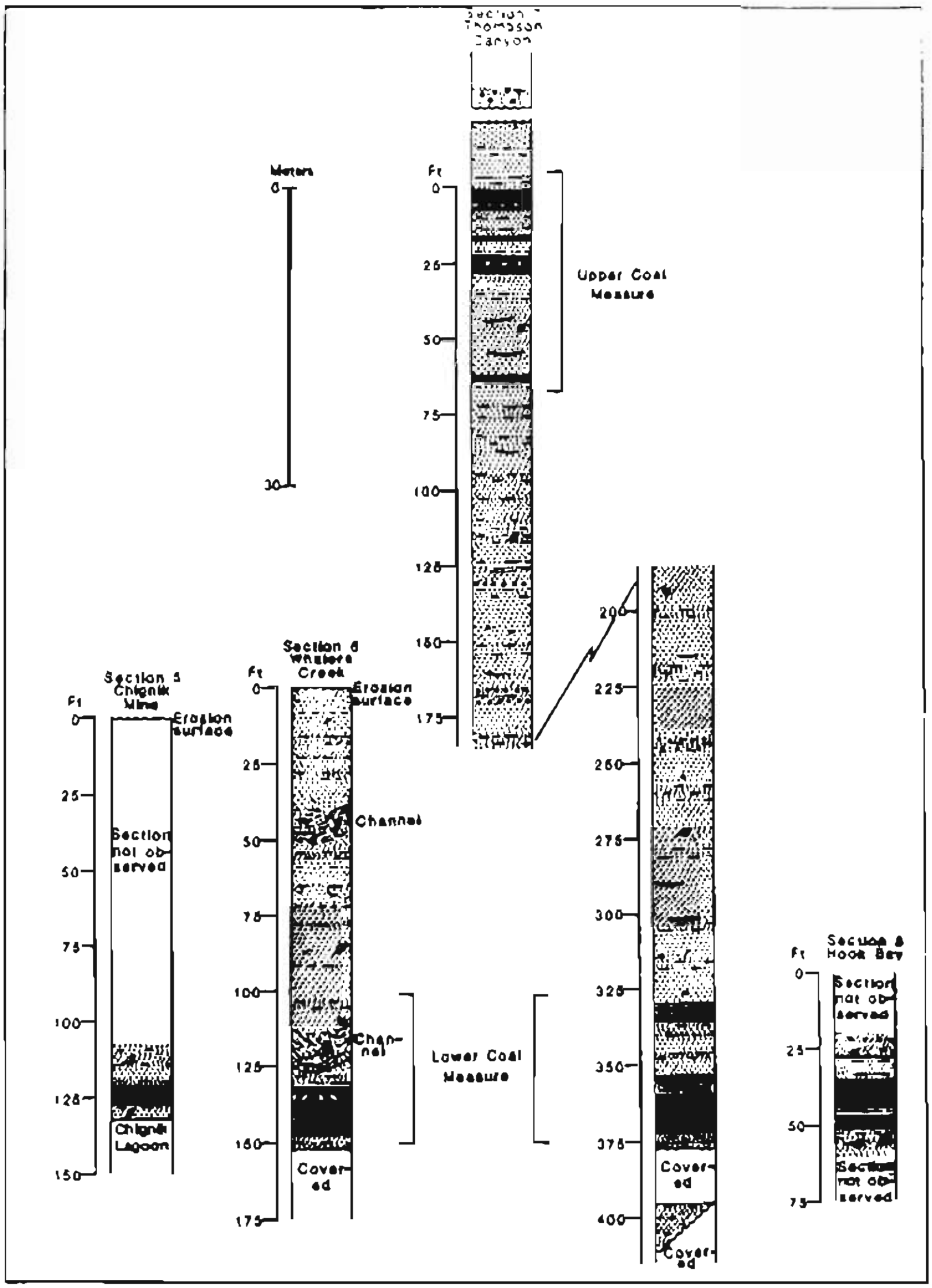


Figure 48. Detailed correlation sections of Chignik coal field (from Merritt and McGee, 1986).

strata are moderately folded and locally faulted. Dips vary generally from 20° to 35°.

Coal Quality and Petrology

Tables 23 through 25 summarize the quality and petrologic composition of Chignik field coals, including vitrinite reflectance data for rank assessment.

Coal Resources

Coal resources are concentrated in four main areas: Chignik River, Whaler's Creek, Thompson Valley, and Hook Bay. Coal beds range to 7-ft thick, but are typically about 3-ft thick.

Resources are summarized as follows (overburden 0-2,000 ft):

Measured:	10 million short tons
Identified:	230 million short tons
Hypothetical:	1.5 billion short tons

Herendeen Bay Field

Location

The Herendeen Bay field is located on the north shore (Bering Sea side) of the Alaska Peninsula between Herendeen Bay and Port Moller (fig. 42). It is about 350 mi southwest of Kodiak and 100 mi southwest of the Chignik field.

Area

The belt of coal-bearing rocks is about 25 mi long and 5 mi wide. The field incorporates a total area of 100 square miles (fig. 49).

Mining History

Between 1889-1904 the Herendeen Bay field was the site of local coal development, small-scale mining, and underground exploration. Mine Harbor was the main focus of activity. However, very little commercial production occurred.

Access

The Herendeen Bay field is readily accessible to tidewater, but Herendeen Bay is blocked by ice several months each year. The most likely scenario for coal shipment would require the construction of an overland transportation system (road, rail, conveyor, aerial tramway, or slurry pipeline) some 15 mi through a low pass to Balboa Bay on the Pacific side of the peninsula (fig. 42).

Table 23. Summary of quality parameters of Chignik field, Alaska Peninsula coals.

Rank: High volatile bituminous, typically hvBb

Heating content: Range---8,800-13,750 Btu/lb
Average---11,800 Btu/lb

Mean-maximum vitrinite reflectance ($\bar{R}o_{max}$, %):

Range---0.57-1.76% Average---0.73%

Proximate analysis:	Range (%)	Average (%)
Moisture	1.09-6.97	4.40
Volatile matter	25.54-40.61	36.33
Fixed carbon	37.86-57.08	47.66
Ash	4.15-30.56	11.61
Ultimate analysis:		
Sulfur	0.28-4.79	1.36
Carbon	56.59-68.45	62.15
Hydrogen	0.68-0.78	0.71
Nitrogen	4.12-5.10	4.71
Oxygen	14.14-24.65	17.46
Ash	4.15-30.56	11.61

Major-oxide composition of ash (avg., %):

SiO_2	- 42.0
Al_2O_3	- 29.3
SO_3	- 5.9
Fe_2O_3	- 5.6
CaO	- 4.0
MgO	- 2.2
TiO_2	- 1.7
K_2O	- 0.5
P_2O_5	- 0.5
Na_2O	- 0.2
MnO	- 0.1
Undet.	- 8.0

Table 23 (con.)

Trace elements in coal ash (avg., ppm):

Barium	367
Boron	400
Cadmium	1
Chromium	55
Cobalt	13
Copper	78
Gallium	30
Lead	32
Lithium	192
Manganese	455
Molybdenum	7
Nickel	27
Scandium	30
Strontium	150
Vanadium	173
Ytterbium	6
Yttrium	57
Zinc	83
Zirconium	217

Trace elements in coal (avg., ppm):

Antimony	0.3
Arsenic	3.7
Fluorine	65
Mercury	0.09
Selenium	0.4
Thorium	4.0
Uranium	1.1

Fusibility of ash (°F):

Initial deformation	2794
Softening temperature	2800+
Fluid temperature	2800+

Free-swelling index: 0-1.5

Hardgrove grindability index: 46

Coking potential: Poor caking and coking properties.

Table 24. Average petrologic composition of Chignik field, Alaska Peninsula coals (volume, mineral-matter-free basis).

Maceral	Content (%)
Vitrinite	78.3
Gelinite	2.0
Corpocollinite	0.4
Vitrodetrinite	10.9
Total vitrinite	91.6
Fusinite	2.0
Semifusinite	1.0
Sclerotinite	0.4
Macrinite	0.5
Inertodetrinite	1.8
Total inertinite	5.7
Cutinite	0.3
Sporinite	0.8
Resinite	0.6
Exsudatinite	0.1
Suberinite	0.1
Alginite	0.1
Liptodetrinite	0.7
Total liptinite	2.7

Table 25. Mean-maximum vitrinite reflectance values of Chignik field coals. See figure 43 for locations.

Locality	$\bar{R}o_{max}$ (%)
15	0.57
16	0.62
17	0.62
18	0.67
19	0.64
20	0.82
21	1.01
22	0.95
23	0.79
24	1.76
25	0.58
26	0.62
27	0.60
28	0.60
29	0.66
30	0.58
31	0.68
32	0.69
33	0.70
34	0.71
35	0.78
36	0.60
37	0.66
38	0.65
39	0.65
40	0.70

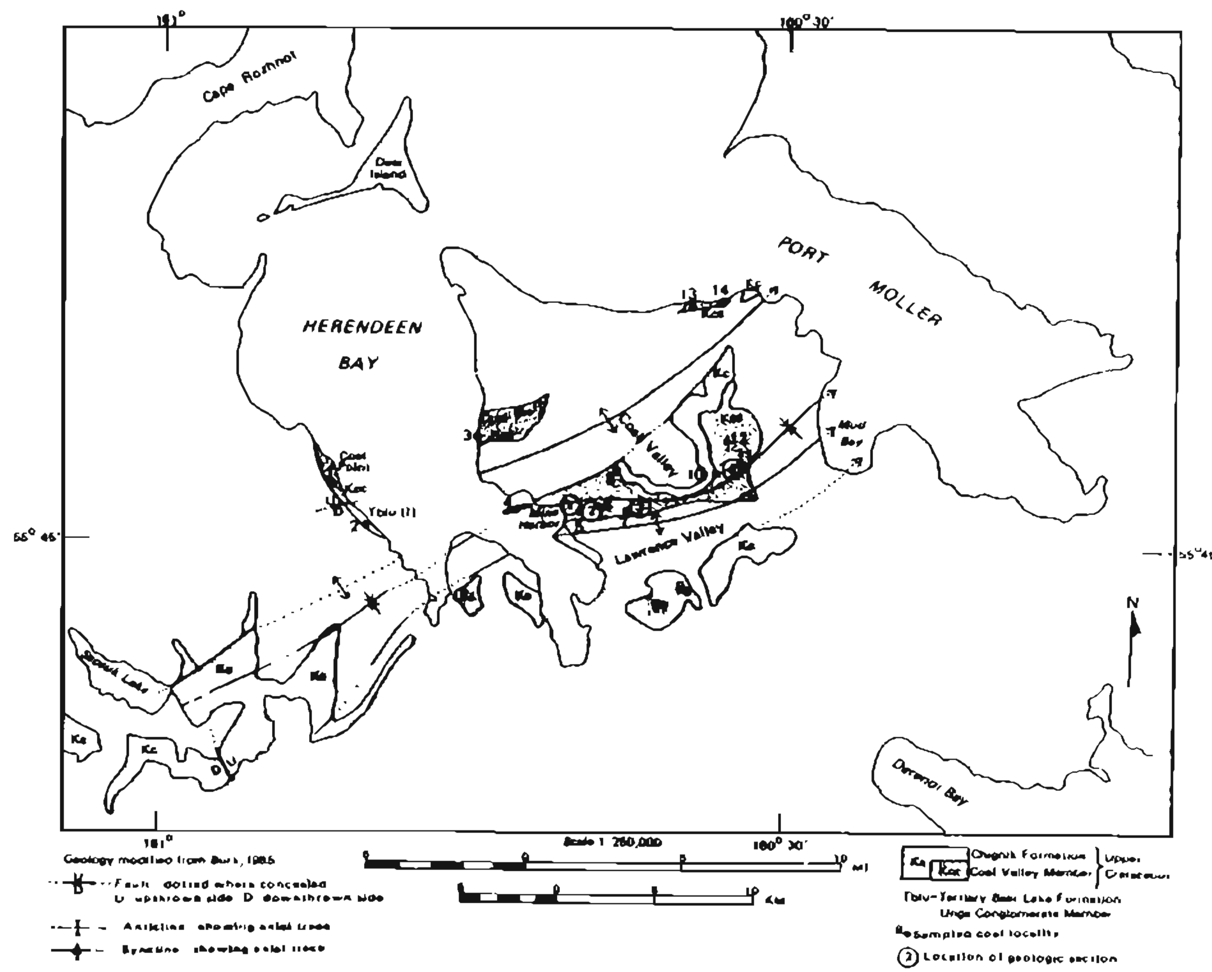


Figure 49. Generalized geologic map of the Herendeen Bay coal field, Alaska Peninsula (from Merritt and McGee, 1986).

Geology

The high-rank coal deposits of the Herendeen Bay field are confined largely to the Coal Valley Member of the Late Cretaceous Chignik Formation (fig. 50). Typical sections of coal-bearing strata are shown in figure 51, and several seams from the Mine Harbor area in figure 52. Beds are moderately folded and locally broken by small-scale faults.

Coal Quality and Petrology

Tables 26 through 28 summarize the quality and petrology of Herendeen Bay field coals, including vitrinite reflectance data for coal rank assessment.

Coal Resources

Coal resources are concentrated in five main areas: Main Creek/Mine Harbor, Coal Bluff (fig. 53), Coal Valley/Staniukovich Mountain (fig. 54), Lawrence Valley and Coal Point. There are a large number of closely spaced coal beds to 7-ft thick. Beds generally average 2-4 ft thick (fig. 41). One section includes an aggregate 26 ft of coal in 200 ft of strata.

Resources are summarized as follows (overburden 0-2,000 ft):

Measured:	10 million short tons
Identified:	130 million short tons
Hypothetical:	1.5 billion short tons

SOUTHWEST ALASKA/KUSKOKWIM REGION

Flat

Coal is found at Flat in southwest Alaska, south of the Yukon River. Coal was mined at one site, the Iditarod Mine, from 1914 to 1916. The mine produced coal from two shallow shafts and transported it on a tramway between Flat and Iditarod.

The Cretaceous anthracitic coals range to over 3-ft thick and occur in a shear zone; some surfaces are slickensided.

The mineability of the coals has not been thoroughly investigated although transportation costs would be high. The coal would have to be carried by shallow-draft river barges of 500 tons or less.

Eek River

Coal was discovered by placer miners on the Eek River of the lower Kuskokwim region, southwest Alaska in 1912 (Holzheimer, 1926). Isolated coal-bearing outcrops are located on the north fork of Eek River 45 miles in a straight line from its mouth and about 125 mi upstream. The Eek River flows west into Kuskokwim Bay about 50 mi below Bethel at Eek Island.

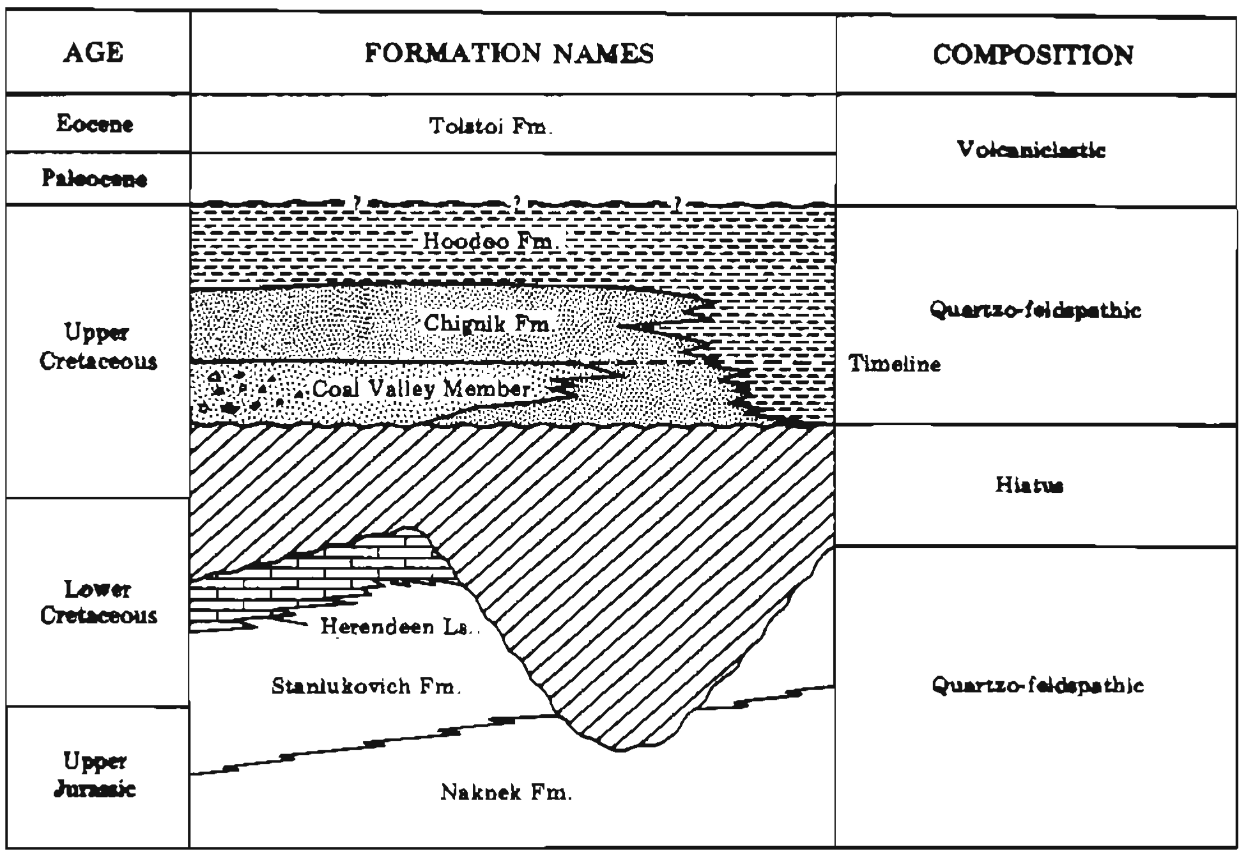


Figure 50. Generalized stratigraphy in the Herendeen Bay coal field (modified after Burk, 1965; Moore, 1974; and Mancini and others, 1978).

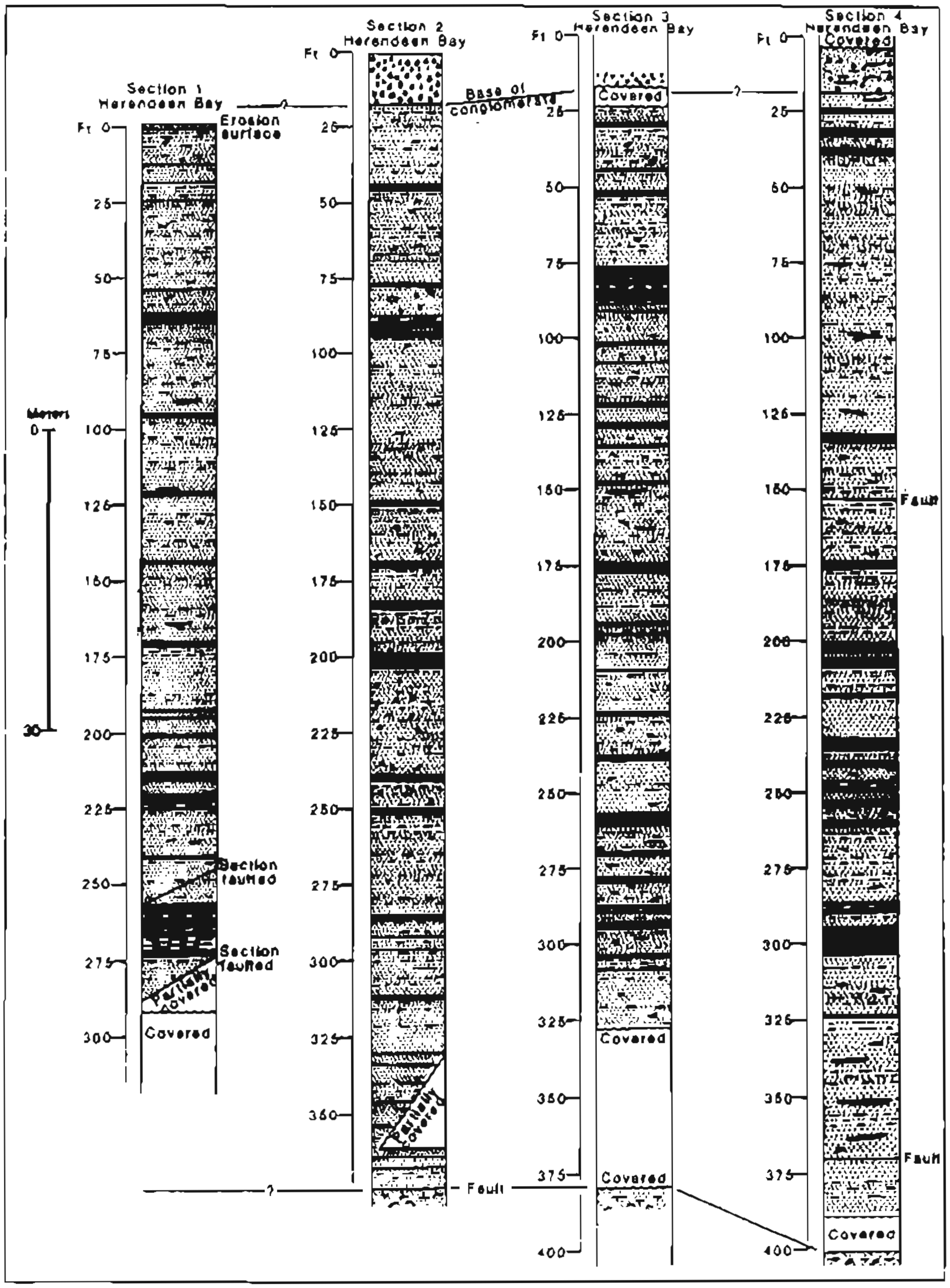


Figure 51. Detailed correlation sections of the Herendeen Bay coal field.

Figure 52. Coal seams at Mine Harbor, Herendeen Bay field.

Table 26. Summary of quality parameters of Herendeen Bay field, Alaska Peninsula coals.

Rank: High volatile bituminous, typically hvBb

Heating content: Range---8,400-12,900 Btu/lb
Average---11,060 Btu/lb

Mean-maximum vitrinite reflectance (Ro_{max}, %):

Range---0.55-0.90 Average---0.65

Proximate analysis:	Range (%)	Average (%)
Moisture	1.80-10.09	4.29
Volatile matter	28.41-48.95	34.13
Fixed carbon	29.88-57.89	48.80
Ash	2.52-33.23	12.78

Ultimate analysis:

Sulfur	0.29-4.68	0.76
Carbon	56.71-64.52	59.08
Nitrogen	0.32-0.90	0.74
Hydrogen	4.38-5.09	4.64
Oxygen	18.47-24.10	22.00
Ash	2.52-33.23	12.78

Major-oxide composition of ash (avg., %):

SiO_2	- 45.2
Al_2O_3	- 27.6
CaO	- 5.4
Fe_2O_3	- 2.8
TiO_2	- 2.0
MgO	- 1.8
SO_3	- 1.7
K_2O	- 0.7
P_2O_5	- 0.6
Na_2O	- 0.5
MnO	- 0.1
Undet.	- 11.6

Trace elements in coal ash (avg., ppm):

Barium	860
Boron	168
Cadmium	1
Chromium	226
Cobalt	282
Copper	81
Gallium	27
Lead	38
Lithium	88
Manganese	269
Molybdenum	63
Nickel	43
Scandium	23
Strontium	600
Vanadium	154
Ytterbium	5
Yttrium	51
Zinc	138
Zirconium	250

Trace elements in coal (avg., ppm):

Antimony	0.9
Arsenic	4.8
Fluorine	143
Mercury	0.05
Selenium	0.7
Thorium	3
Uranium	1.6

Fusibility of ash (°F):

Initial deformation	2701
Softening temperature	2800+
Fluid temperature	2800+

Free-swelling index: 0-1.5

Hardgrove grindability index: 52

Coking potential: Poor caking and coking properties.

Table 27. Average petrologic composition of Herendeen Bay field coals (volume, mineral-matter-free basis).

Maceral	Content (%)
Vitrinite	78.5
Pseudovitrinite	0.1
Gelinite	2.7
Corpocollinite	0.7
Vitrodetrinite	8.4
Total vitrinite	90.4
Fusinite	2.5
Semifusinite	1.1
Sclerotinite	0.4
Macrinite	0.6
Inertodetrinite	2.2
Total inertinite	6.8
Cutinite	0.4
Sporinite	0.8
Resinite	0.7
Exsudatinite	0.2
Suberinite	0.1
Liptodetrinite	0.6
Total liptinite	2.8

Table 28. Mean-maximum vitrinite reflectance values of Herendeen Bay field coals. See figure 49 for sample locations.

Locality	$\bar{R}o_{max}$ (%)
1	0.66
2	0.27
3	0.67
4	0.62
5	0.60
6	0.66
7	0.59
8	0.67
9	0.90
10	0.69
11	0.58
12	0.61
13	0.60
14	0.55

Figure 53. Coal Bluff, Herendeen Bay field coal-bearing section. (Photo by R.D. Merritt, 1984.)

Figure 54. Stanivkovich Mountain coal-bearing section, Herendeen Bay field. (Photo by R.D. Merritt, 1984.)

The coals of the Cretaceous Kuskokwim Group are less than 3-ft thick and dip at 45°. They are high-ash and low-moisture bituminous coals. Overburden consists of medium-grained, siliceous sandstone, conglomerate, black carbonaceous shale and siltstone.

Nunivak and Nelson Islands

Two districts of southwest Alaska are Nunivak Island and Nelson Island. The Nelson Island district is located on the west side of the island including occurrences at Tanunak and Toksook Bay. The Nunivak Island district is located at Mekoryuk on its north shore about 10 mi southwest of Cape Etolin. Coal occurrences here were reported about 1900 and a few tons of coal have been mined in the past for local use.

The coals are of Cretaceous age and are generally less than 2-ft thick. They dip from 5° to 10° in outcrop. The high-ash bituminous coals exhibit fair to good agglomerating properties.

Total resources are apparently small. The mineability of the coals have not been thoroughly investigated largely due to land-status problems.

Anvik River

At least one 10-ft bituminous coal bed and several other 2-ft beds are found on the Anvik River, about 100 mi above its mouth. The beds are of Cretaceous age and have had some minor local production.

SOUTHEAST ALASKA

Angoon District

The Angoon district is located on the north and south sides of Kootznahoo Inlet, west side of Admiralty Island, some 60 mi south of Juneau. Coal-bearing rocks underlie approximately 20 square miles within the confines of the Tongass National Forest.

In 1862, the first coal mined in southeast Alaska and some of the first mined in Alaska was at the Sepphagen Mine located on Kootznahoo Inlet. In 1869 the U.S.S. Saginaw obtained coal here for fuel. The Harkrader Mine opened in 1928 on an inclined shaft several hundred ft deep and extracted coal throughout 1929 but it closed thereafter due to financial problems. A small amount of coal from the mine was shipped to Juneau. Total past production was less than 1,000 tons.

The Tertiary-aged coal-bearing rocks are moderately deformed and faulted but locally only gently folded and nearly horizontal. Coal beds vary from 2-3 ft thick but often contain shale partings. The coals are of bituminous rank, typically high volatile B bituminous. General coal-quality is as follows:

Moisture	3.8-6.5%
Volatile matter	34-35%
Fixed carbon	36-40%
Ash	21.5-23%
Sulfur	0.9-1.3%
Heating content (as rec'd)	9,930-10,630 Btu/lb
Heating content (moist, mmf)	13,900 Btu/lb

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APPENDIX - EXPLANATION

A. Elements of Coal Quality

Rank. Rank refers to the degree of metamorphism of coal. It is the basis of coal classification in the natural series from lignite to anthracite. Higher rank reflects greater metamorphism. Bituminous coals and anthracites are considered to be of high-rank, and subbituminous coals and lignites are low-rank. The classes of high-rank coals are listed in the table below:

ASTM* Abbreviation	Rank**
ma	meta-anthracite
an	anthracite
sa	semianthracite
lvb	low volatile bituminous
mvb	medium volatile bituminous
hvAb	high volatile A bituminous
hvBb	high volatile B bituminous
hvCb	high volatile C bituminous

* American Society for Testing and Materials.
**Rank decreases in order from top to bottom.

Heating content or heating value. Heating content refers to the amount of heat obtainable from coal expressed in British thermal units per pound. It is determined by the use of an adiabatic bomb calorimeter, and represents a measurement of the temperature rise after the combustion of a coal sample in an oxygen bomb.

Vitrinite reflectance. Vitrinite reflectance is a measurement of the extent to which light is reflected from the surface of a polished coal sample. The measurements are made on the vitrinitic maceral components of the coal substance and are used in the determination of rank and coking characteristics of coal. Maximum reflectances are measured in oil for at least 100 vitrinite particles.

Proximate analysis. A proximate analysis of coal includes determinations of the moisture, volatile matter, ash, and fixed carbon (by difference) contents by prescribed methods. A complete proximate analysis is reported on as-received, moisture-free, and moisture- and ash-free bases and totals 100 percent. Sometimes, they are reported on an equilibrium-bed-moisture basis as well. Unless otherwise stated, they should generally be assumed to be on an as-received basis.

Moisture content. Moisture includes the surface moisture that can be removed by natural drying, and the inherent moisture that is structurally contained in the coal substance. Surficial water on coal is free or adherent. Inherent moisture is physically held by vapor pressure or other phenomena. The total moisture content also includes chemically-bound water. The equilibrium or bed moisture (for classification by rank) is the inherent moisture-holding capacity of a given coal (in situ) measured at 30°C with a 97 percent relative humidity atmosphere.

Volatile matter content. Volatile matter includes substances in coal other than moisture that are given off as gas and vapor during combustion.

Ash content. The ash content of a coal is the percentage of incombustible material in coal determined under standardized conditions by burning a sample and measuring the ash.

Fixed carbon content. Fixed carbon is the solid combustible matter of coal remaining after the removal of moisture, volatile matter, and ash. It is determined by difference and is expressed as a percentage.

Ultimate analysis. An ultimate analysis of coal determines the contents of the elements carbon, hydrogen, sulfur, nitrogen, oxygen (by difference), and ash. These quantities always total 100 percent.

Carbon. Carbon is determined 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.

Hydrogen. Hydrogen is determined by catalytic burning in oxygen and the subsequent measurement of the water formed and absorbed by a desiccant.

Sulfur. Total sulfur is composed of pyritic (or sulfide), organic, and sulfate forms. Pyritic sulfur is combined with iron in the minerals pyrite and marcasite. Pyritic sulfur is usually the most abundant form in coals and it is chiefly responsible for acid-mine drainage. Organic sulfur, which is typically the most abundant form in Alaskan coals, is bonded to the carbon structure. Sulfates form mainly by weathering and commonly include calcium and iron varieties. The three methods usually used for sulfur determinations are Eschka, high-temperature combustion, and bomb-washing.

Nitrogen. Nitrogen is determined typically by a chemical digestion with the contained nitrogen converted to ammonia by the Kjeldahl-Gunning method.

Ash. Ash is determined during the proximate analysis, but also forms an integral part of the ultimate analysis.

Oxygen. Oxygen is estimated by difference; total carbon, hydrogen, sulfur, nitrogen, and ash are subtracted from 100 percent.

Major-oxide composition of ash. Major oxides include SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, Na_2O, K_2O, P_2O_5, and SO_3. These compounds typically compose over 99 percent of coal ash.

Trace elements in coal and coal ash. Trace element analysis is of importance due mainly to environmental concerns attendant to coal mining and utilization. The number of trace elements determined varies. Among the most important are arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, fluorine, gallium, germanium, indium, lanthanum, lead, mercury, molybdenum, nickel, selenium, thallium, titanium, uranium, vanadium, yttrium, and zinc. Common analytical equipment used for trace-element analysis include atomic absorption, spark-source mass spectrophotometry, X-ray fluorescence, and neutron activation.

Fusibility of ash (°F). Ash-fusibility temperatures vary with the character of coals, particularly the ash content, and is less for low-rank coals. Among the types performed are either a 3-point or 4-point (reducing atmosphere only) ash fusibility. The melting temperatures and deformational changes of an ash cone are measured at various stages. In the 3-point test, temperatures are measured at the point of initial deformation, softening point, and fluid stage. In the 4-point test, an additional measurement is taken at the hemispherical stage, as follows:

Point of initial deformation. The tip of the ash cone begins to deform.
Softening point. The point where the ash cone height is equal to ½ its width.
Hemispherical stage. The point where the ash cone height is equal to its width.
Fluid temperature. The point indicated by the spreading out of the completely melted ash cone into a flat layer.

Free-swelling index (FSI). FSI is a measurement obtained by the rapid heating of a coal sample in a nonrestraining crucible. It ranges from zero to nine, with noncaking and nonswelling coals being zero on this scale. The FSI gives an indication of the caking characteristics of a given coal.

Hardgrove grindability index (HGI). HGI is a measurement that peaks in the bituminous ranks and is less for lignites and anthracites. Intermediate-rank coals are softer and easier to grind, whereas lower and higher rank coals are more difficult to grind and hence have lower grindability indexes. The grindability index is calculated by measuring the quantity of -200 mesh fine coal produced at different moisture levels, that is, at two or three temperatures. The relative ease of pulverization is compared to a standard coal having an HGI of 100.

Coking and metallurgical potential. Coking and metallurgical potentials refer to the degree to which coals swell, fuse, and run together to produce a strong coke substance under certain specified conditions. Coking or caking coals are the most important of the bituminous coals because of their suitability for the production of coke for metallurgical uses. Coking coals are typically low-ash, low-sulfur, and low- to medium-volatile bituminous rank.

B. Elements of Coal Petrology

Petrographic characterization of coal is used to determine its maceral composition and ultimate suitability for a particular purpose. The concentrations and relative proportions of macerals determine a coal's quality and energy value and its potential coking and metallurgical properties. Petrologic data are used in blending various types of coals for making coke or for other industrial purposes. In coal-conversion technology, for example, those coals that can be most readily hydrogenated are preferred, and these are usually coals high in liptinites or the hydrogen-rich maceral components.

The organic components of coal occur as macerals, which are essentially analogous to minerals in rocks. The maceral composition of a coal though reveals only a part of the overall picture because of its complex mineral-matter content and chemical composition. Both structurally intact cell walls and relatively unstructured fine granular material (for example, mineral matter, fragmented charcoal, and fungal debris) are observed when examining a coal microscopically. Although the maceral compositions usually reflect changes in the primary vegetational types forming the coals, postdepositional effects may remove less resistant macerals as liptinites from the assemblage. The plant materials are subjected to different conditions before and after their burial beneath a sediment cover. The changes that occur in the coals are reflected in varying maceral compositions and ultimately in their physical and chemical qualities.

There are three major maceral groups---vitrinite, liptinite (or exinite), and inertinite. Most coals, including Alaska's high-rank coals, are dominated by a large percentage of vitrinite and minor liptinite and inertinite.

The inertinites are derived from the same general components as vitrinites, but they have been strongly altered and degraded in the peat stage of coal formation, for example, fossil charcoal. The inertinites have the highest reflectances of all macerals. They usually compose 5-15 percent of most coals, and characteristically fluoresce when excited by ultraviolet light. They have the lowest carbon and highest hydrogen contents of all macerals.

The liptinites are derived mainly from the waxy and resinous parts of plants such as spores, cuticles, and resins, and have the lowest reflectances of all macerals. They compose from less than five percent in most coals up to 40 percent in some coals. They do not fluoresce in ultraviolet light. They possess the highest carbon and lowest hydrogen contents of all macerals.

Macerals of the Vitrinite Group

Vitrinite is a group name that composes collinite and telinite in bituminous coals. Because collinite and telinite are difficult to distinguish in reflected light, they are usually combined under the general term vitrinite. Telinite includes the cellular structures and collinite the structureless constituents of vitrinite. Corpocollinite, a variety of collinite, is sometimes distinguished in Alaska bituminous coals in two forms---phlobaphinite and pseudophlobaphinite. Phlobaphinites are primary cell infillings liberated as excretions from living plant cell walls, and pseudophlobaphinites are produced as secondary cell infillings from humic gels.

Pseudovitrinite is a variety of vitrinite that differs in its reflectance (which is higher), its morphology (presence of cell structures and stepped boundaries, marked fissuration, and curved slit-like openings), relief (somewhat higher), and absence of pyrite. Pseudovitrinite has less coking power than vitrinite and it is sometimes inert (Stach and others, 1982).

Gelinite occurs in lower-rank coals as two main varieties---porigelinite and levigelinite---that are often grouped simply as gelinite in higher-rank coals. Porigelinite consists of finely porous to granular gels originating from colloidal humic solutions. Levigelinite occurs as cavity fillings of shrinkage cracks, cleats, or root ducts.

Vitrodetrinite is correlative with humodetrinite (including attrinite and densinite) of lower-rank coals that are usually combined under the general term vitrodetrinite in higher-rank coals. Attrinite consists of humic detrital particles and finely divided and mainly porous gels that are loosely packed and well differentiated from one another. Densinite consists of individual humic detrital particles and finely divided humic gels that are cemented tightly together.

Macerals of the Inertinite Group

Fusinite is a charcoal-like substance with a cellular texture. It is sometimes broken into small shards and fragments called bogen.

Semifusinite has the same cellular texture as fusinite but is of lower reflectance.

Macrinite is typically a minor component that occurs as structureless ovoid or subangular bodies with the same reflectance as fusinite. They may have a globular appearance.

Sclerotinite is formed of hard fungal remains and occurs as ovoid bodies with a cellular texture.

Inertodetrinite is a clastic form of inertinite. It includes fragments of different inertinite macerals occurring as dispersed particles.

Macerals of the Liptinite Group

Sporinite includes spore and pollen perines and exines that take the form of a flattened spheroid, with upper and lower hemispheres compressed until they come together.

Alginite includes rare algal remains that fluoresce with a brilliant yellow color in ultraviolet light.

Cutinite includes cuticles of leaves and stems. It occurs as long stringers that have one fairly flat surface and one that is crenulated.

Resinite includes resins and plant secretions occurring as ovoid bodies or fissure-filling material.

Exsudatinite is secondary 'resinite' occurring in vein-form, joint fillings, or occasionally in empty cell lumens.

Suberinite includes cork cell walls that are mainly derived from bark tissues.

Liptodetrinite consists of finely detrital, unidentifiable liptinitic constituents of extremely small particle size.