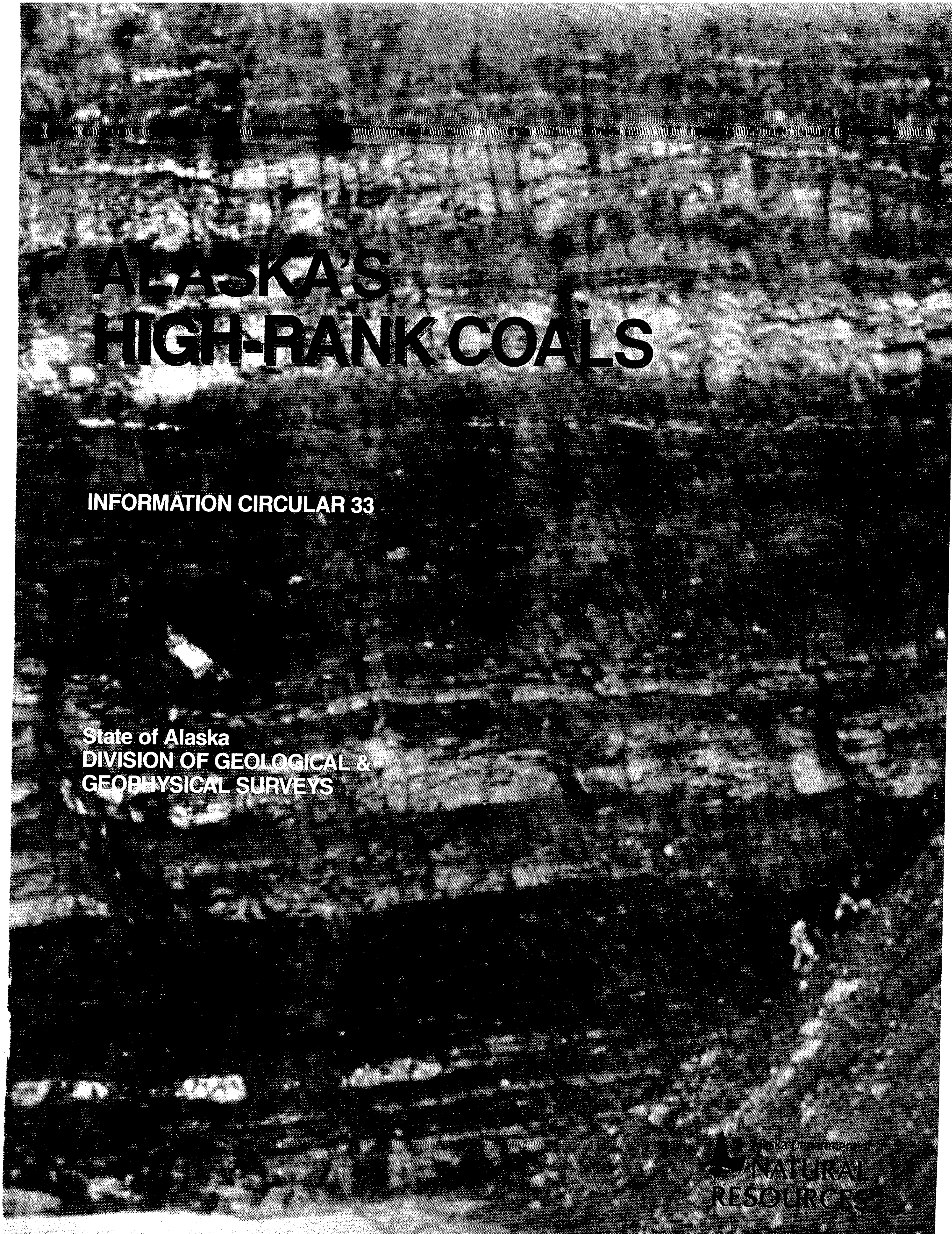

ALASKA'S HIGH-RANK COALS

INFORMATION CIRCULAR 33

State of Alaska
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

Alaska Department of
NATURAL RESOURCES

ALASKA'S HIGH-RANK COALS

A summary of high-rank coal resources in Alaska and their potential for mining and development.

First Edition 1990
Revised Edition 1993

Department of Natural Resources
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
Fairbanks, Alaska

Cover photo: *North limb of Wishbone Hill syncline, Matanuska Valley.* *(See fig. 8, p. 7.)*

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Thomas E. Smith, *State Geologist*

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Alaska Division of Geological & Geophysical Surveys
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FOREWORD

Although current coal production is limited to subbituminous coals, Alaska produced high rank coals from the Matanuska field until 1968. Plans are again under way for production from the Matanuska field. Deadfall syncline coal, being in close proximity to the Bering Sea, is another candidate for development and is receiving renewed attention. For example, seam K3 of this field is of high volatile A bituminous rank and has a maximum thickness of 17 feet, with an average ash content of 9 percent and over 10 feet of this seam averages less than 4 percent ash. Other exposures along Kukpowruk, Kokolik, and Utukok rivers are of similar high quality.

The low volatile bituminous coal of the Bering River field has been well explored. Some seams of this field have unusually low ash content and could be washed to produce clean coal containing less than 0.5 percent ash for special utilization purpose. Coals of the Alaska Peninsula, near Chignik, have been mined in the past for use in fish canneries. Alaska has extensive high rank coal deposits which await development.

P.D. Rao
Associate Director
Mineral Industry Research Laboratory

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- UNIVERSITY OF ALASKA
  Mineral Industry Research Laboratory (MIRL)
  210 O'Neill Resources Building
  Fairbanks, Alaska 99775
  (907) 474-7135 or 474-7136
  Russell Ostermann, *Acting Director*
  P.D. Rao, *Associate Director*

Conducts applied and basic research on the location, development, and use of Alaska's coal resources. Specializes in the mineralogical, chemical, and petrographic characterization of Alaska's coals and their preparation. Publishes reports and general information concerning coal mining and utilization in Alaska.

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CONVERSION FACTORS

To convert	to	multiply by
acres	hectares	0.4047
feet	meters	0.3048
meters	feet	3.281
miles	kilometers	1.609
kilometers	miles	0.6214
square miles	square kilometers	2.590
tons*	metric tons	0.9072
Btu/lb	Kcal/Kg	0.5556

*All tonnages reported here are in short tons (2,000 lb).

ALASKA'S HIGH-RANK COALS

INTRODUCTION

It is estimated that as much as 55 percent of Alaska's abundant coal resources--approximately 3 trillion tons--is high-rank (bituminous) coal (fig. 1). Bituminous coal deposits are found not only on Alaska's North Slope, but also in the Matanuska, Bering River, Chignik, and Herendeen Bay coalfields (fig. 2). Measured resources are summarized in figure 3; identified and hypothetical resources are listed in table 1. Significant potential exists for large, yet-undiscovered deposits of high-rank coal.

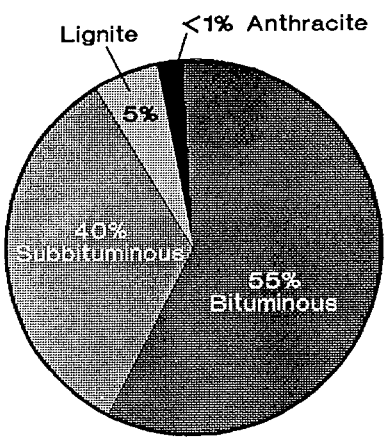


Figure 1. Alaska's coal resources divided by rank.

Early studies of Alaska's high-rank coals were directed at determining suitability for blacksmithing use or for steamship fuel. Investigations now are directed toward developing a market for Alaska coals in Pacific Rim nations, as well as for local heat and power generation (table 2).

Bituminous coals formed in Alaska during the Cretaceous Period (65-140 million years ago) from heat and pressure created by structural deformation of coal-bearing rocks. Most bituminous Alaska coals have a low sulfur content (less than 1 percent) and exhibit coking characteristics that range from poor to excellent. Potential coking and metallurgical-grade coals are found in the Chickaloon district, Matanuska coalfield; Western Arctic region, especially at Kukpowruk River; Bering River coalfield; Chignik and Herendeen Bay coalfields, Alaska Peninsula; Lisburne coalfield; and the Lower Yukon basin-Nulato coalfield. More than 7 million tons of bituminous coal has been mined in Alaska, most of it from the Matanuska coalfield before 1968.

Some of Alaska's coal resources (less than 1 percent) are anthracitic coals--semianthracite, anthracite, and meta-anthracite. Deposits of Tertiary age are found in eastern parts of the Matanuska and Bering River coalfields, and Mississippian-age deposits are found in northern Alaska. High-rank coal has long been known to exist in Mississippian rocks, but mineable resources are small and therefore not discussed here.

Table 1. *Estimate of identified and hypothetical resources of Alaska's high-rank coals (in millions of tons).*

	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
TOTALS	1,834.5	14,900

Table 2. *Current high-rank coal development projects in Alaska.*

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

ACKNOWLEDGMENTS

The Alaska Division of Geological & Geophysical Surveys (DGGS) thanks the Office of International Trade for funding, which initiated this study. The information was collected by R.D. Merritt, formerly of DGGS. Coalfield tables include data compiled by P.D. Rao and published by the University of Alaska Fairbanks, Mineral Industry Research Laboratory (1986). The design and production was by G.M. Laird (DGGS). The agency also wishes to thank the following individuals whose efforts made this brochure possible. We acknowledge technical reviews by John F.M. Sims, Usibelli Coal Mine, Inc., and Gilbert R. Eakins, geologist (retired) DGGS. The report was edited by C.L. Daniels and A.F. Seward (DGGS). Cartography by Nori Bowman and Teresa Imm. Typesetting by Roberta Mann, and paste-up by A-L. Schell.

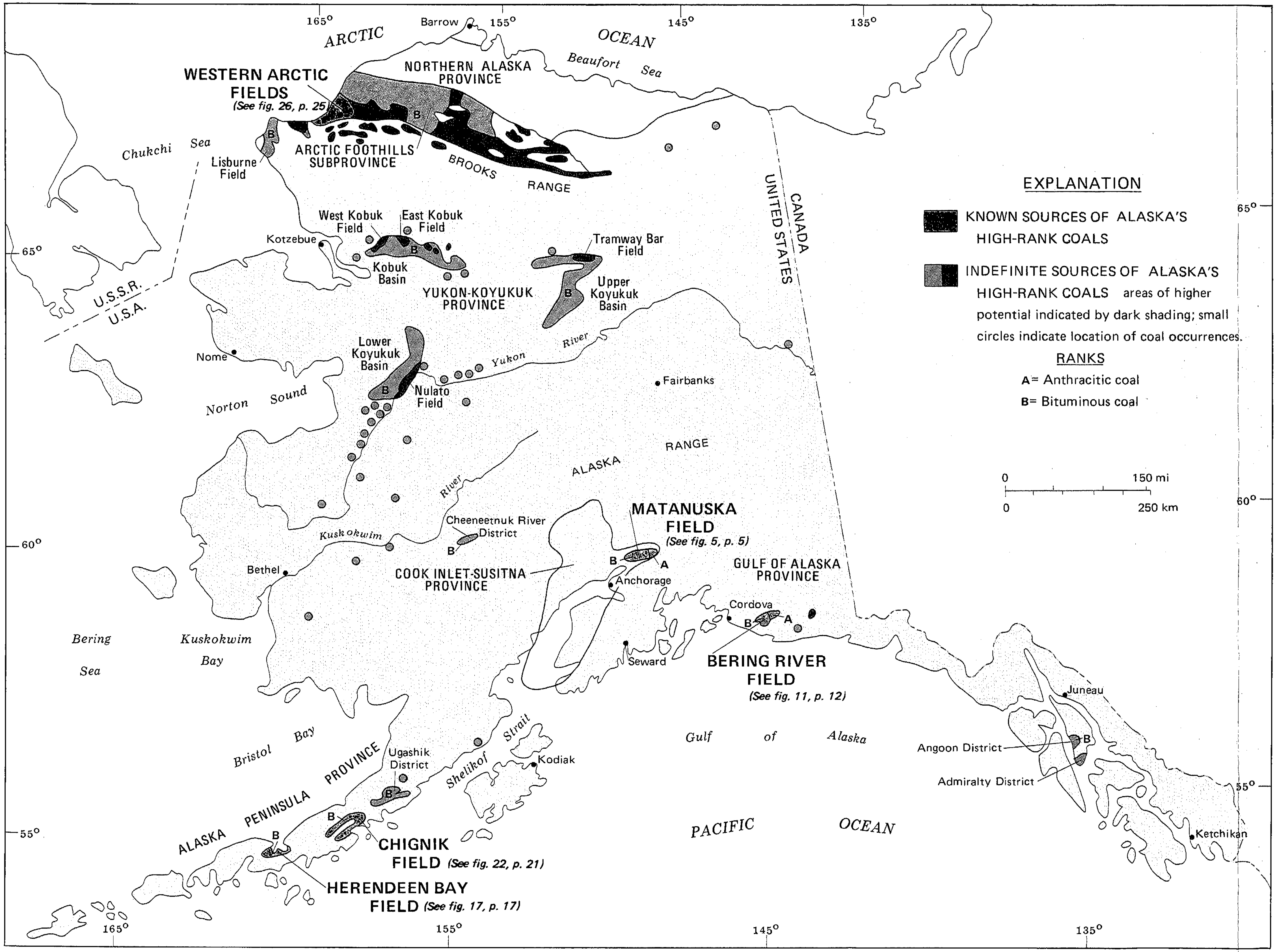


Figure 2. Map showing the general distribution of Alaska's high-rank coal deposits (modified from Merritt and Hawley, 1986).

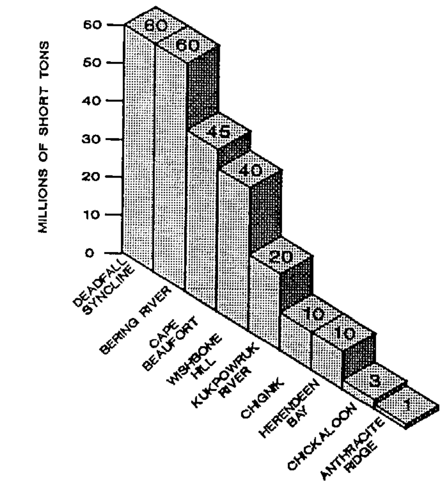
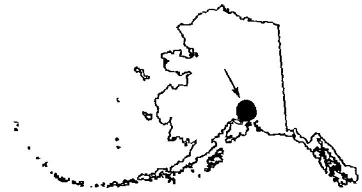


Figure 3. Estimated measured resources of Alaskan high-rank coals.

MATANUSKA COALFIELD



DESCRIPTION

LOCATION

The Matanuska coalfield in south-central Alaska is an eastern extension of the Cook Inlet-Susitna coal province and underlies most of the Matanuska Valley (fig. 2). Its western margin is 45 mi northeast of Anchorage.

The Matanuska field contains five coal districts (fig. 4). The Wishbone Hill district is located about 10 mi northeast of Palmer; its chief coal-bearing feature is the Wishbone Hill syncline. The Young Creek, Castle Mountain, and Chickaloon districts underlie the central Matanuska Valley. The Chickaloon district is centered around the old mining camp at Chickaloon, about 30 mi northeast of Palmer. The Anthracite Ridge district is situated at the east end of the Matanuska Valley about 12 mi east of Chickaloon.

AREA

The Wishbone Hill district occupies about 20 mi² between Moose and Granite Creeks. The Chickaloon district covers a 10-mi² area on lower Chickaloon River and Coal Creek. The Anthracite Ridge district includes a 20-mi² area that extends south from Anthracite Ridge to the Matanuska River.

GEOLOGY

Tertiary coal deposits of the Matanuska field occur within Paleocene-lower Eocene rocks of the Chickaloon Formation. The upper 1,400 ft of this unit contains several series (or groups) of coal beds within layers of claystone, siltstone, sandstone, and conglomerate (fig. 5). Deposition occurred predominantly in a meandering fluvial to paludal paleoenvironment. Stratigraphic structure varies from moderately complex at the west margin of the Matanuska field to complex at its east margin. Beds range in dip from 7° to overturned; typically they dip from 20° to 65°.

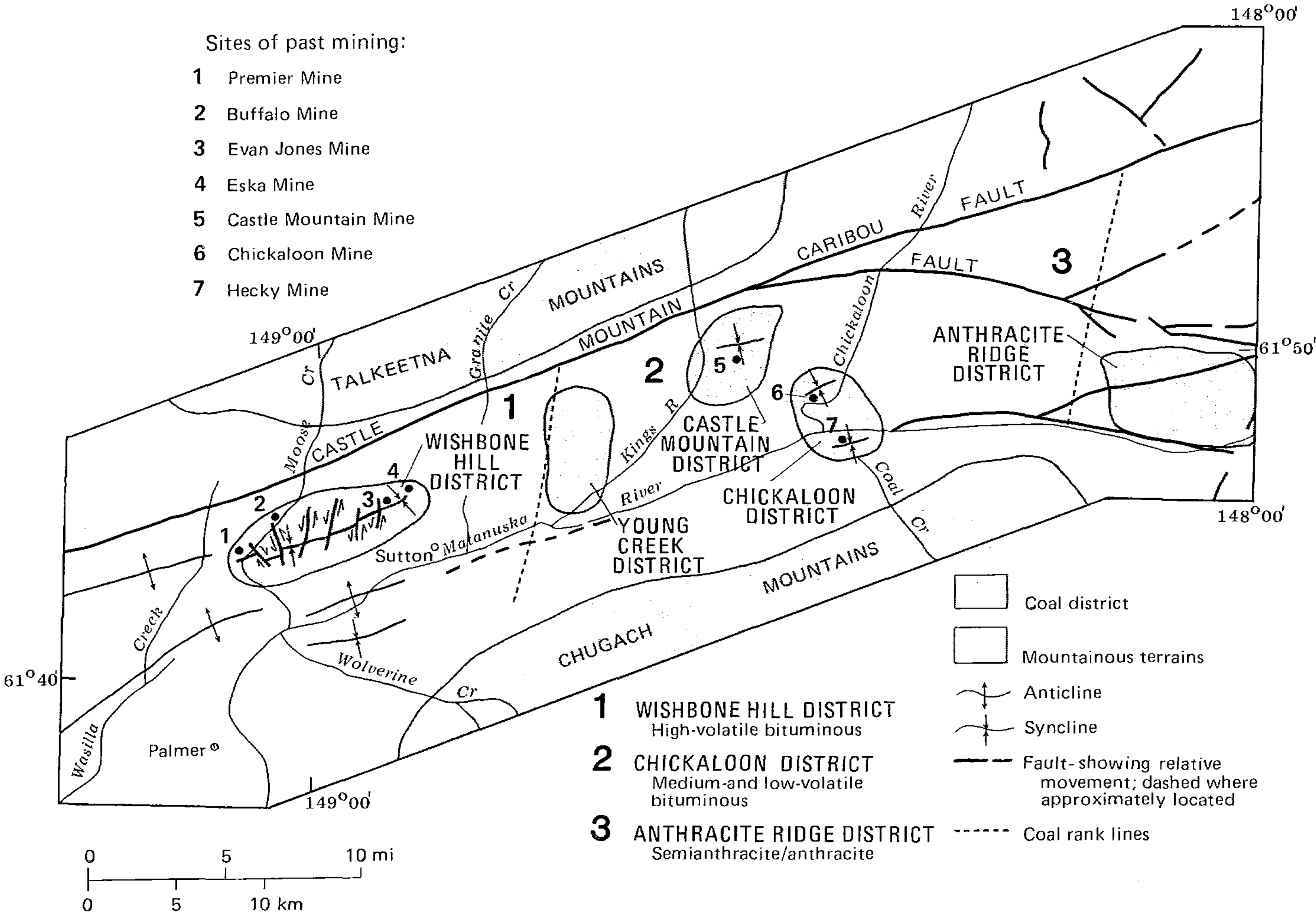


Figure 4. Major districts of the Matanuska coalfield, Matanuska Valley, south-central Alaska (modified from Merritt, 1986).

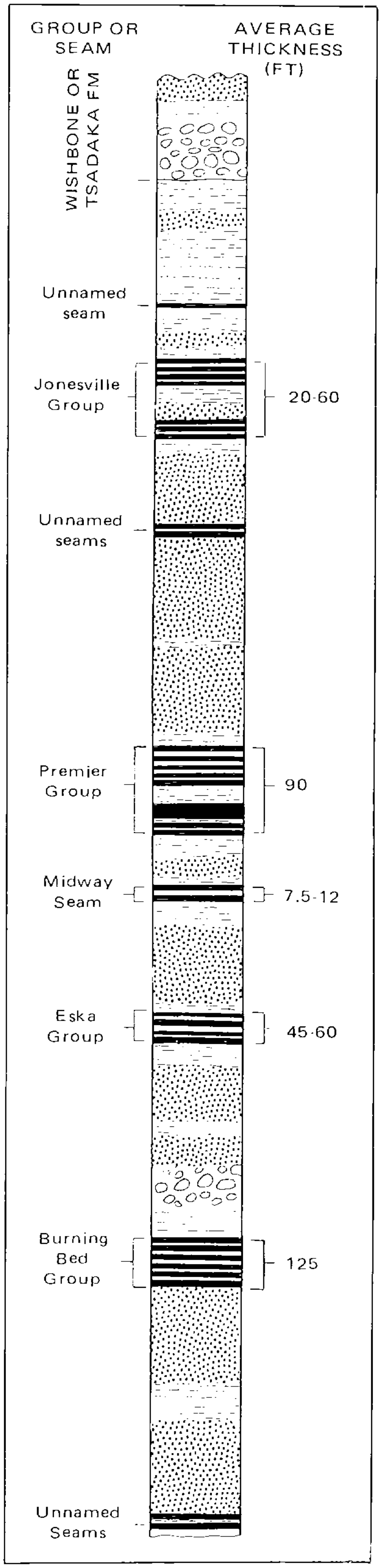


Figure 5. Generalized stratigraphic section of the upper Chickaloon Formation, western Wishbone Hill district, Matanuska field (after Hawley and others, 1984).

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 (fig. 6). The structure of the Chickaloon district is dominantly synclinal, but complicated by faulting and intrusion of dikes and sills. The Anthracite Ridge district also encompasses a synclinal basin that has been sharply folded and faulted and intruded by igneous dikes and sills. Coal rank and structural complexity increase progressively to the east.

MINING HISTORY

Coal was mined in the Matanuska field from 1914 to 1968 (fig. 7). When the Alaska Railroad was completed to the Matanuska field in 1916, mining expanded to 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; the Navy searched for steaming coal, and the Alaska Engineering Commission sought coal supplies for railroad fuel.

Figure 4 locates historical mining operations in the Matanuska field: the Premier Mine, which operated from 1925 to 1971; the Buffalo Mine, 1942-45; the Evan Jones Mine, 1920-65; the Eska Mine, 1917-46; the Castle Mountain Mine, 1958-60; the Chickaloon Mine, 1917-22; and Hecky or Coal Creek Mine, 1925-30. Total past production was about 7.5 million tons, mostly from stripping and underground workings of the Evan Jones Mine at Wishbone Hill (fig. 8). Mining ceased in the Matanuska field in 1968 when Cook Inlet natural gas supplanted coal use in the Anchorage area. Minor production at the Premier Mine continued to provide coal for local needs until 1982. Recent exploration and mine-feasibility studies have been completed by Union Pacific Resources (figs. 9 and 10).

ACCESS

The Matanuska field is favorably located with respect to rail 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 transportation facilities would be required to resume coal-mining operations in the Matanuska field.

COAL RESOURCES

Wishbone Hill district

Bituminous coal beds to 23 ft thick occur in the upper 1,400 ft of the Chickaloon Formation. Most beds are greater than 3.5 ft thick. Total estimated resources (to a depth of 2,000 ft) are:

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

Chickaloon district

Bituminous coal beds up to 14 ft thick yield two main deposits: at Chickaloon north of the Matanuska River and at Coal Creek south of the Matanuska River. Total estimated resources (to a depth of 2,000 ft) are:

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

Anthracite Ridge district

A 20-acre tract in the Purinton Creek area contains an estimated 1 million tons of anthracite and semi-anthracite. Although coal beds are usually less than 5 to 10 ft thick, beds 24 and 34 ft thick have been measured at two exposures. Total estimated resources (to a depth of 2,000 ft) are:

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

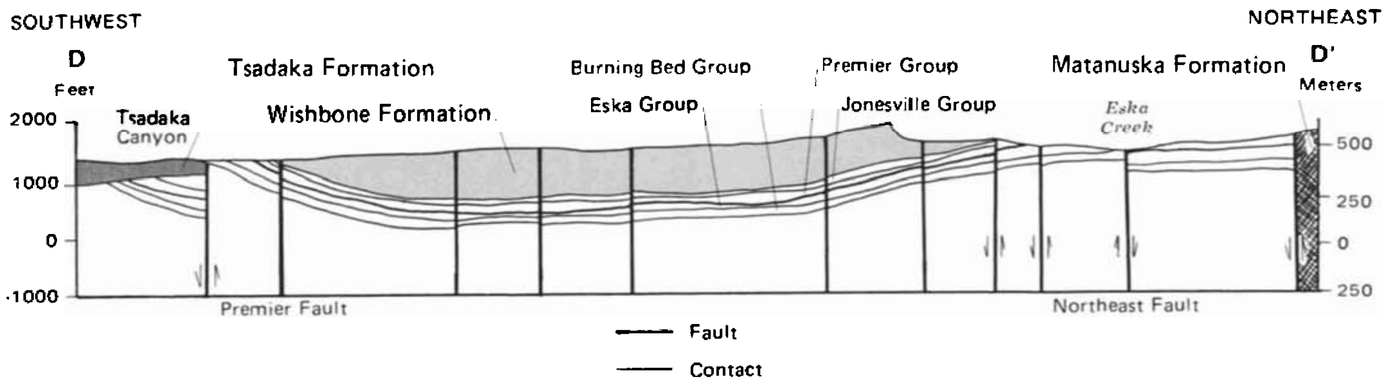


Figure 6. Longitudinal cross section of the Wishbone Hill syncline (from Germer, 1987).

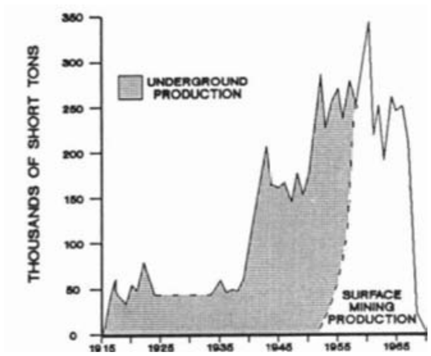


Figure 7. Coal production in Matanuska field, 1915-1970 (from Merritt and Belowich, 1984).

LAND STATUS

Land in the Matanuska coalfield is state-owned.

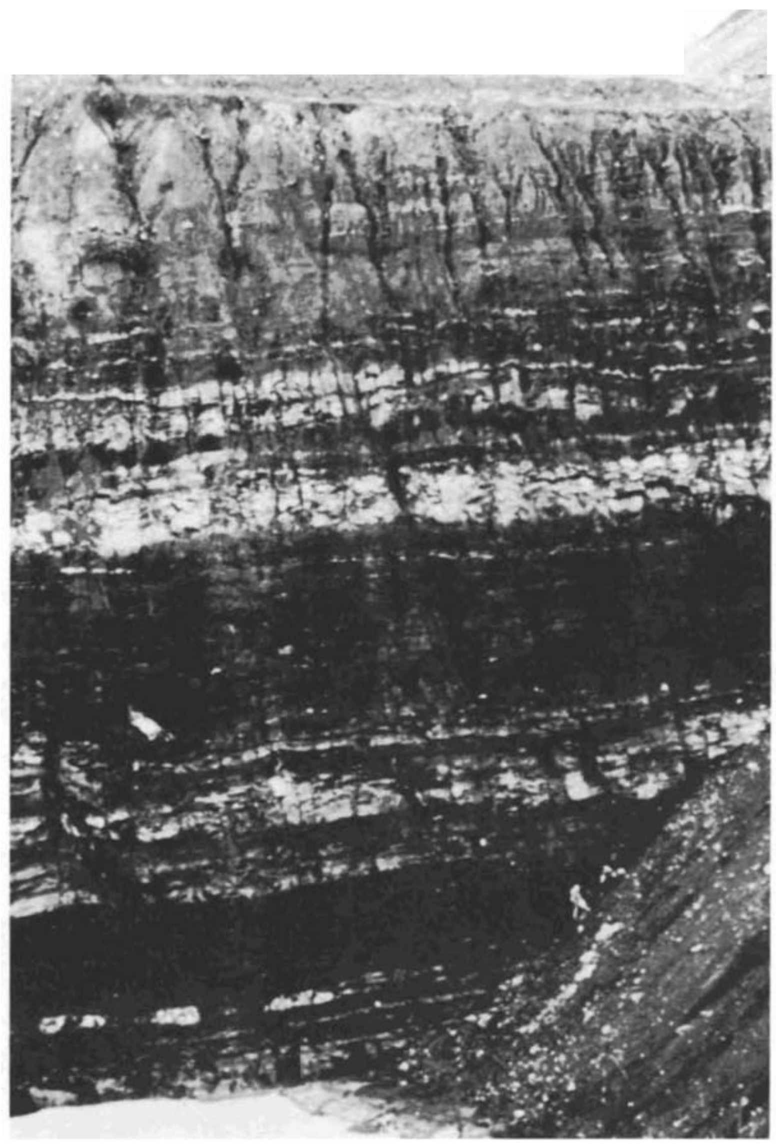


Figure 8. Highwall face at Evan Jones surface mine, north limb of Wishbone Hill syncline, Matanuska Valley. (Photo by G.R. Eakins, 1981.)

Figure 9. Drilling for coal at the Wishbone Hill project of Union Pacific Resources. (Photo by R.D. Merritt, 1983.)

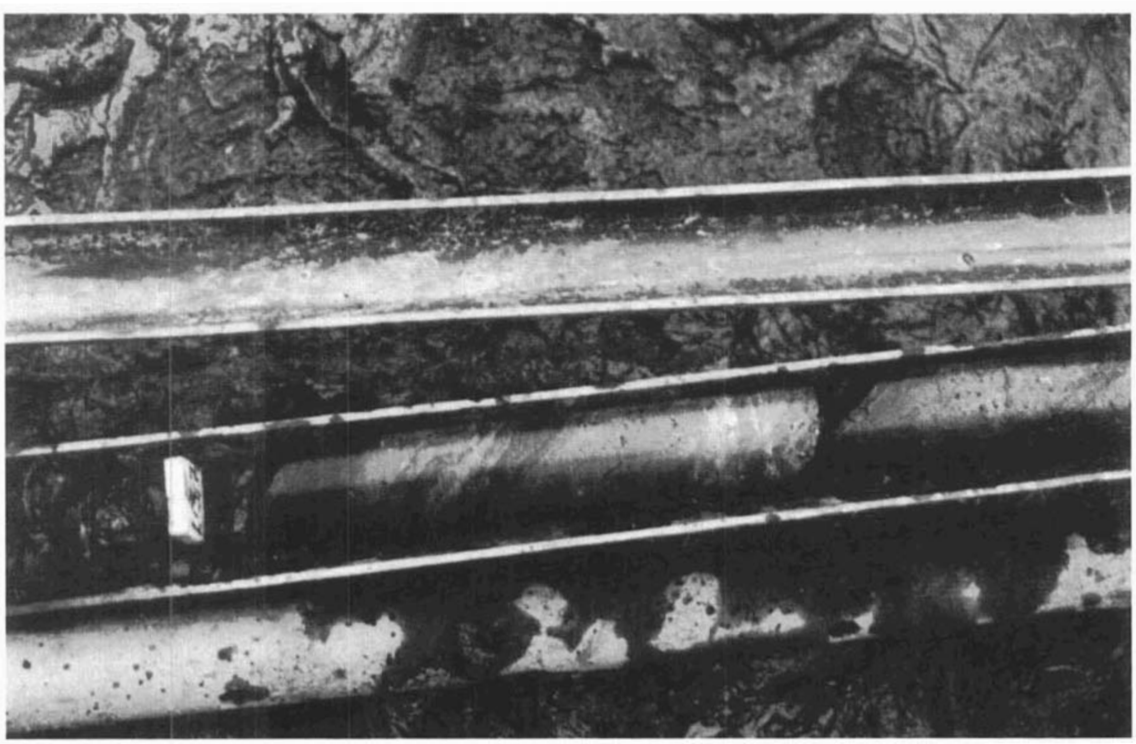


Figure 10. Drill core from the Wishbone Hill project of Union Pacific Resources. (Photo by R.D. Merritt, 1983.)

Matanuska Coalfield Data
WISHBONE HILL

COAL QUALITY

Rank: hvBb

Heating content: Range 10,400-13,200 Btu/lb

Proximate analysis (range in %):

Moisture	3-9	Fixed carbon	38-51
Volatile matter	32-45	Ash	4-24

Ultimate analysis (range in %):

Carbon	50-70	Oxygen	10-17
Hydrogen	4.5-5.5	Sulfur	0.2-0.6
Nitrogen	1.0-1.4	Ash	4-24

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

SiO_2	56.81	SO_3	1.11
Al_2O_3	28.94	P_2O_5	0.79
Fe_2O_3	2.97	Na_2O	0.70
CaO	2.36	SrO	0.18
K_2O	1.86	BaO	0.18
TiO_2	1.56	MnO	0.02
MgO	1.12	Undet.	1.40

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

Antimony	2	Lithium	334
Arsenic	8	Molybdenum	3
Beryllium	0.5	Neodymium	4
Boron	77	Nickel	8
Bromine	2	Niobium	7
Cadmium	1	Praseodymium	4
Cerium	19	Rubidium	9
Cesium	3	Samarium	4
Chlorine	8	Scandium	19
Chromium	14	Selenium	2
Cobalt	16	Tellurium	1
Copper	27	Thorium	6
Europium	0.5	Tin	3
Fluorine	230	Uranium	4
Gallium	22	Vanadium	90
Germanium	1.1	Yttrium	22
Iodine	2	Zinc	14
Lanthanum	19	Zirconium	74
Lead	6		

Fusibility of ash (°F):

Initial deformation	2380
Softening temperature (H=W)	2600
Hemispherical temperature (H= W)	2640
Fluid temperature	2700

Free-swelling index: 0-2

Hardgrove grindability index: 47

Coking potential: *Poor to fair strongly coking; possible metallurgical.*

COAL PETROLOGY

Avg. composition, volume, mineral-matter-free basis, in %:

Vitrinite	78.0
Pseudovitrinite	0.1
Gelinite	1.1
Corpocollinite	0.2
Vitrodetrinite	12.8
Total vitrinite	92.2
Fusinite	0.3
Semifusinite	0.2
Sclerotinite	0.5
Macrinite	0.1
Inertodetrinite	1.2
Total inertinite	2.3
Cutinite	0.5
Sporinite	0.1
Resinite	3.2
Suberinite	0.1
Liptodetrinite	1.6
Total liptinite	5.5

Mean-maximum vitrinite reflectance (Ro_{max}, %): 0.5-0.6

CHICKALOON

COAL QUALITY

Rank: mvb-lvb

Heating content: Range 11,960-14,400 Btu/lb

Proximate analysis (range in %):

Moisture	1-5	Fixed carbon	60-72
Volatile matter	14-24	Ash	5-18

Ultimate analysis (range in %):

Carbon	65-77	Oxygen	6-10
Hydrogen	4.2-5.2	Sulfur	0.2-0.7
Nitrogen	1.3-1.7	Ash	5-18

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

SiO_2	53.92	SO_3	1.13
Al_2O_3	29.73	P_2O_5	1.46
Fe_2O_3	4.34	Na_2O	0.68
CaO	2.63	SrO	0.22
K_2O	1.72	BaO	0.21
TiO_2	1.32	MnO	0.04
MgO	1.52	Undet.	1.08

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

Antimony	1	Lithium	222
Arsenic	4	Molybdenum	8
Beryllium	0.9	Neodymium	7
Boron	66	Nickel	9
Bromine	4	Niobium	11
Cadmium	2	Praseodymium	4
Cerium	36	Rubidium	28
Cesium	4	Samarium	5
Chlorine	32	Scandium	22
Chromium	18	Selenium	5
Cobalt	6	Tellurium	1
Copper	40	Thorium	10
Europium	0.9	Tin	8
Fluorine	425	Uranium	5
Gallium	18	Vanadium	85
Germanium	1.7	Yttrium	18
Iodine	5	Zinc	30
Lanthanum	27	Zirconium	80
Lead	14		

Fusibility of ash (°F):

Initial deformation	2360
Softening temperature (H=W)	2430
Hemispherical temperature (H= W)	2510
Fluid temperature	2560

Free-swelling index: 0-8

Hardgrove grindability index: 72

Coking potential: Noncoking to strongly coking; possible metallurgical.

COAL PETROLOGY

Avg. composition, volume, mineral-matter-free basis, in %:

Vitrinite	80.5
Pseudovitrinite	0.5
Gelinite	0.0
Corpocollinite	0.3
Vitrodetrinite	15.8
Total vitrinite	97.1
Fusinite	0.3
Semifusinite	0.3
Sclerotinite	0.2
Macrinite	0.1
Inertodetrinite	0.4
Total inertinite	1.3
Cutinite	0.0
Sporinite	0.0
Resinite	0.4
Suberinite	0.5
Liptodetrinite	0.7
Total liptinite	1.6

Mean-maximum vitrinite reflectance (Ro_{max}, %): 1.1-2.1

ANTHRACITE RIDGE

COAL QUALITY

Rank: sa-an

Heating content: Range 10,720-14,000 Btu/lb

Proximate analysis (range in %):

Moisture	3-9	Fixed carbon	65-81
Volatile matter	7-11	Ash	6-17

Ultimate analysis (range in %):

Carbon	66-75	Oxygen	6-15
Hydrogen	2.8-5.6	Sulfur	0.2-0.7
Nitrogen	1.2-1.7	Ash	6-17

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

SiO_2	49.26	SO_3	0.97
Al_2O_3	29.95	P_2O_5	3.24
Fe_2O_3	4.46	Na_2O	0.71
CaO	4.75	SrO	0.31
K_2O	1.53	BaO	0.42
TiO_2	1.53	MnO	0.02
MgO	1.54	Undet.	1.31

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

Antimony	1	Lithium	84
Arsenic	7	Molybdenum	6
Beryllium	1.0	Neodymium	34
Boron	85	Nickel	58
Bromine	52	Niobium	7
Cadmium	2	Praseodymium	4
Cerium	35	Rubidium	12
Cesium	4	Samarium	3
Chlorine	66	Scandium	26
Chromium	9	Selenium	2
Cobalt	10	Tellurium	2
Copper	22	Thorium	7
Europium	0.5	Tin	2
Fluorine	361	Uranium	4
Gallium	17	Vanadium	79
Germanium	1.1	Yttrium	17
Iodine	3	Zinc	17
Lanthanum	22	Zirconium	61
Lead	7		

Fusibility of ash (°F):

Initial deformation	2490
Softening temperature (H=W)	2560
Hemispherical temperature (H= W)	2570
Fluid temperature	2590

Free-swelling index: 0-2

Hardgrove grindability index: --

Coking potential: Some coking properties in bituminous coals only.

COAL PETROLOGY

Avg. composition, volume, mineral-matter-free basis, in %:

Vitrinite	84.5
Pseudovitrinite	0.0
Gelinite	0.0
Corpocollinite	0.2
Vitrodetrinite	11.8
Total vitrinite	96.5
Fusinite	0.2
Semifusinite	0.1
Sclerotinite	0.4
Macrinite	0.0
Inertodetrinite	0.2
Total inertinite	0.9
Cutinite	0.1
Sporinite	0.0
Resinite	0.8
Suberinite	0.4
Liptodetrinite	1.3
Total liptinite	2.6

Mean-maximum vitrinite reflectance (Ro_{max}, %): 2.0-5.0

BERING RIVER COALFIELD

DESCRIPTION

LOCATION

The Bering River coalfield is located in south-central Alaska and constitutes the most important resource of the Gulf of Alaska coal province (fig. 11). The field is 12 mi northeast of Katalla, 50 mi east of Cordova, and 200 mi east of Anchorage.

AREA

The belt of coal-bearing rocks extends 20 mi northeast from the eastern shore of Bering Lake and disappears under ice fields in the Chugach Range. The Bering River coalfield width varies from 2 to 6 mi and covers an estimated area of 80 mi^2 (fig. 11).

GEOLOGY

The coalfield is defined by the outcrop of the Kushtaka Formation, a 2,000-ft-thick arkosic Tertiary (Eocene-early Miocene) sequence that also includes feldspathic sandstones, siltstones, shales, and coal beds (fig. 12; table 3). Its geologic structure

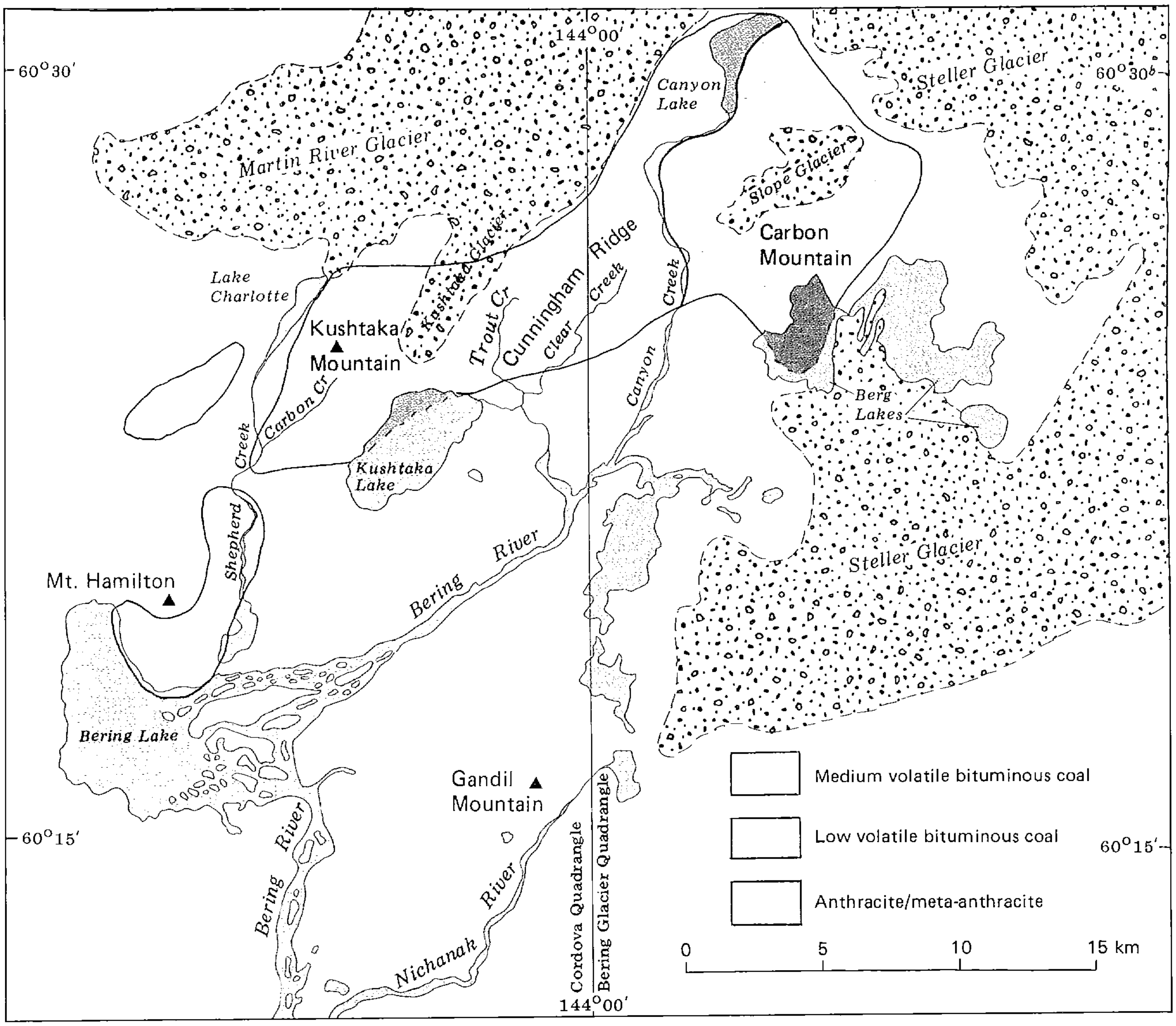


Figure 11. Generalized outcrop extent of the Kushtaka Formation of the Bering River coalfield showing the eastward gradation in coal rank (from Merritt, 1986).

Table 3. *Generalized stratigraphy in the Bering River coalfield (after Barnes, 1951).*

Age	Formation	Lithology	Sedimentation
Quaternary		fresh-water, glacial, marine origin sediments	fresh-water, glacial, marine
Tertiary or Post-Tertiary		diabase, basalt, dikes	
Tertiary	Tokun Formation	sandstone, sandy shale, shale	marine origin
	Kushtaka Formation	arkose, sandstone, sandy shale, shale, coal, coaly shale	fresh-water
	Stillwater Formation	shale, sandstone, sandy shale	partial saline partial fresh-water
	Katalla Formation	conglomerate, sandstone, shale, nodular shale, inter-bedded glauconitic sand	marine origin
Tertiary or Pre-Tertiary		graywacke, slate, igneous rock	

is complex; average dip of beds is 40° (fig. 13). 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. The beds are thinned by tectonic lensing to form 'schlieren,' and thickened at the axes of folds (figs. 14 and 15). Coal rank increases with intensity of deformation to the east.

MINING HISTORY

The Bering River field was discovered in 1896. Extensive exploration and testing of the coals were conducted during the early 1900s. Despite the identification of numerous surface and underground prospects, no commercial mines have been developed. The total amount of coal produced to date is estimated at only a few thousand tons.

In recent years, the Chugach Alaska Corporation, in association with the Korea-Alaska Development Corporation, has been studying the

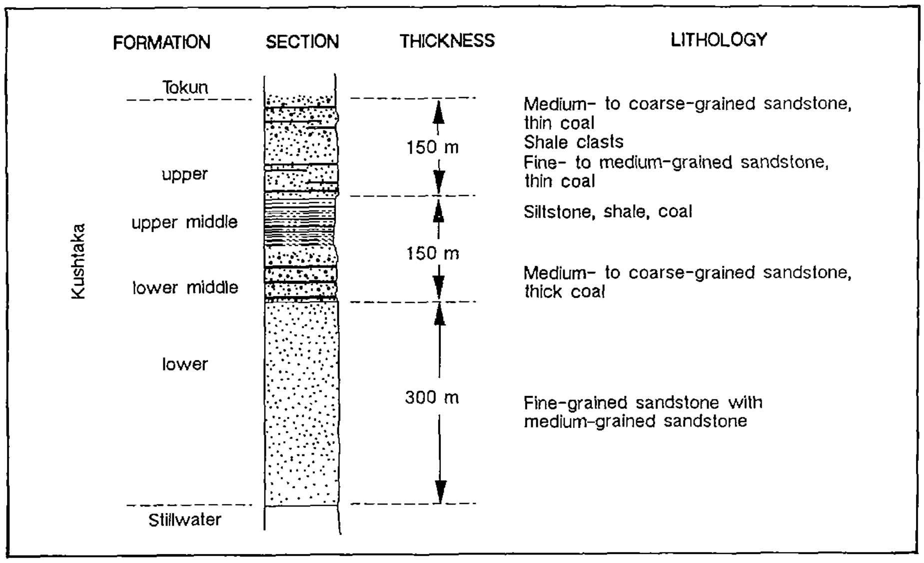


Figure 12. Stratigraphy of the Kushtaka Formation (after Smith and Rao, 1987).

feasibility of developing a coal mine in the Bering River field to produce coal for export. Thousands of feet of core drilling have been completed in the last few years (fig. 16). A tentative mine plan proposes a combination of open-pit and underground mining methods.

ACCESS

The Bering River field is about 25 mi from tidewater. It would be considered a 'green-field' energy project, since it has no infrastructure or overland transportation access system. Such a system would likely consist of a conveyor or aerial tramway to transport 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. An access road would connect the mine-site facilities with the road to Cordova.

COAL RESOURCES

Coal resources 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 ranging from 5 to 10 ft thick have been confirmed. Lenses 30 to 60 ft thick occur locally.

Resources are summarized as follows (with overburden depths of 0 to 3,000 ft):

Measured	60 million tons
Identified	160 million tons
Hypothetical	3,500 million tons

LAND STATUS

Lands in the Bering River coalfield are owned by Chugach Alaska Corporation.

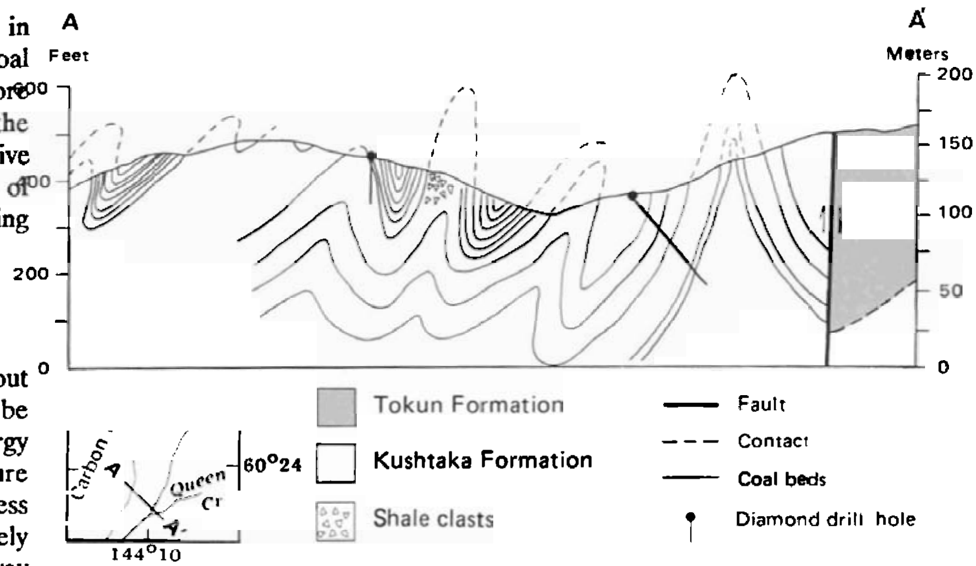


Figure 13. Cross section of the Carbon Ridge area (modified from Smith and Rao, 1987).

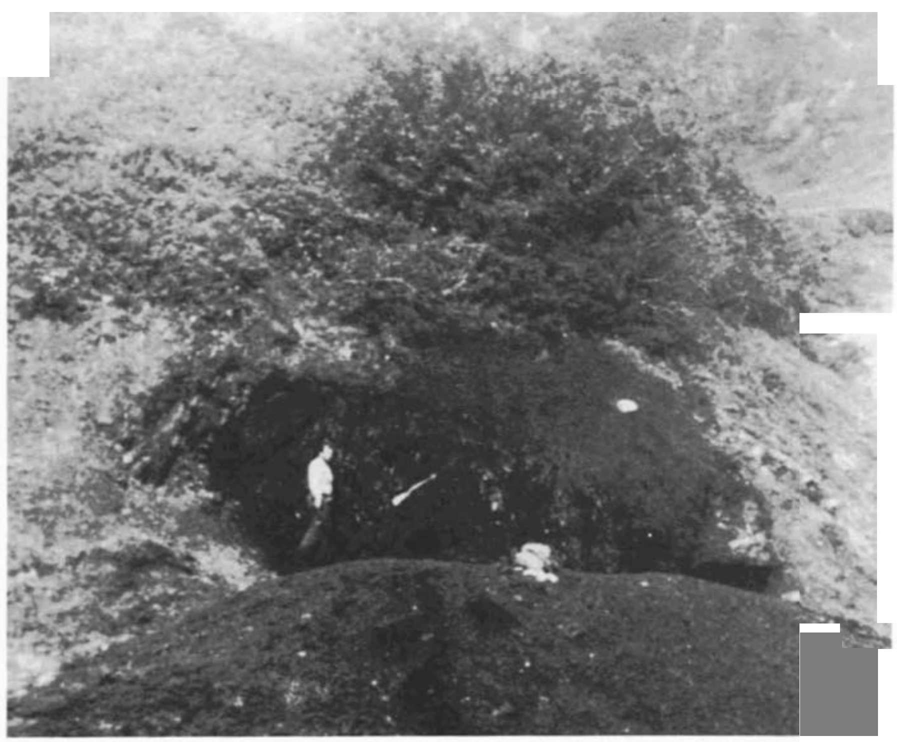


Figure 14. The 'Queen Vein,' a 28-foot thick coal seam of the Bering River field. (Photo by R.B. Sanders, 1973.)

Figure 15. Folding in coal beds in the Carbon Mountain area, Bering River field. (Photo by R.B. Sanders, 1973.)

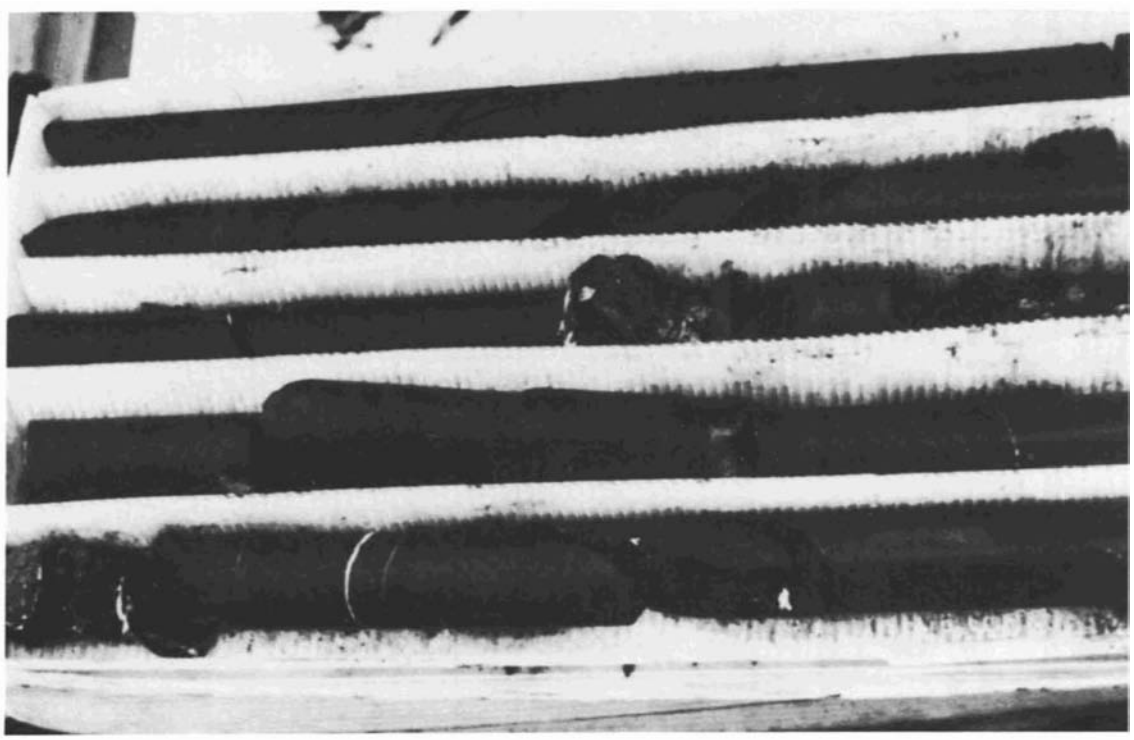


Figure 16. Coal core from Bering Development Corporation's drilling project in the Bering River field, 1984. (Photo courtesy of Bering Development Corporation.)

Bering River Coalfield Data

COAL QUALITY

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

Heating content:

Range	11,000-15,000 Btu/lb	
Average	14,000 Btu/lb	

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:

	Range (%)	Average (%)
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
Sulfur	0.21-4.49	1.25
Ash	1.14-22.46	8.48

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

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

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

Barium	1,850	Nickel	273
Beryllium	10.5	Strontium	4,282
Chromium	246	Vanadium	198
Cobalt	86	Zinc	677
Copper	166	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 potential: Possible source of high-grade metallurgical coal.

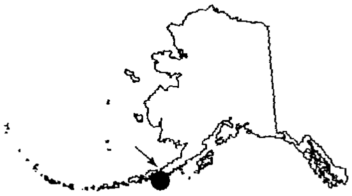
COAL PETROLOGY

Maceral Composition

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.

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

HERENDEEN BAY COALFIELD



DESCRIPTION

LOCATION

The Herendeen Bay coalfield is located along the shore of the Bering Sea on the northern Alaska Peninsula, between Herendeen Bay and Port Moller, about 350 mi southwest of Kodiak and 100 mi southwest of the Chignik coalfield (fig. 17).

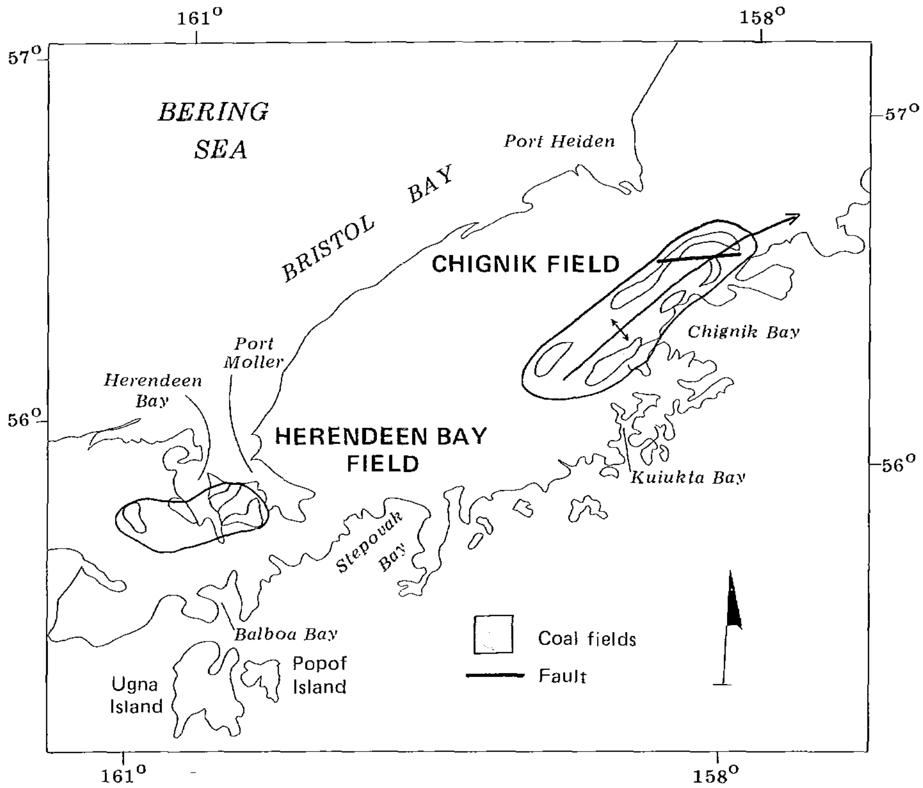


Figure 17. Index map of the southern Alaska Peninsula showing the locations of the Herendeen Bay and Chignik coalfields (modified from Merritt and Hawley, 1986).

AREA

The belt of coal-bearing rocks is about 25 mi long and 5 mi wide. The field covers an area of 100 mi^2 (fig. 18).

GEOLOGY

The high-rank coal deposits of the Herendeen Bay field occur mainly in the Coal Valley Member of the Upper Cretaceous Chignik Formation (fig. 19), which is over 1,500 ft thick. Typical sections of coal-bearing strata are shown in figure 20, and a seam at Mine Harbor in figure 21. Beds are moderately folded and locally broken by small-scale faults.

MINING HISTORY

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

The mining potential of the coalfield has not been thoroughly investigated, and it may hold considerable potential for development of small mines.

ACCESS

The Herendeen Bay field is 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) 15 mi through a low pass to Balboa Bay, on the Pacific side of the Alaska Peninsula (fig. 17).

COAL RESOURCES

Coal resources are concentrated in five main areas: Mine Creek/Mine Harbor, Coal Bluff, Coal Valley, Lawrence Valley, and Coal Point. A large number of closely-spaced coal beds up to 7 ft thick have been found within these areas; however, thickness of beds averages 2 to 4 ft. One 200-ft section contains an aggregate 26 ft of coal.

Resources are summarized as follows (overburden depth to 2,000 ft):

Measured	10 million tons
Identified	130 million tons
Hypothetical	1,500 million tons

LAND STATUS

The Herendeen Bay coalfield occupies land owned by the state of Alaska and the Aleut Native Corporation.

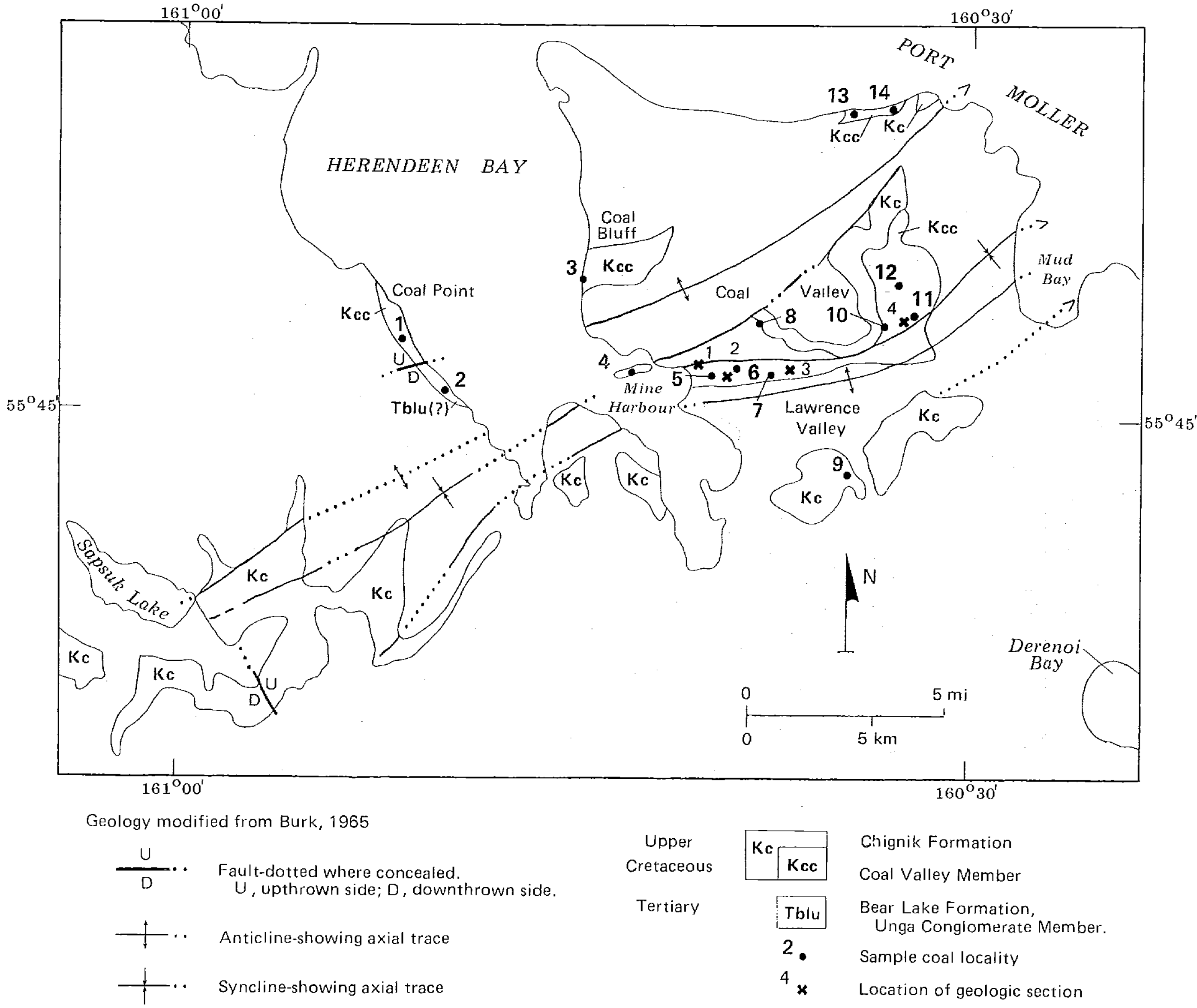


Figure 18. Generalized geologic map of the Herendeen Bay coalfield, Alaska Peninsula (from Merritt and McGee, 1986).

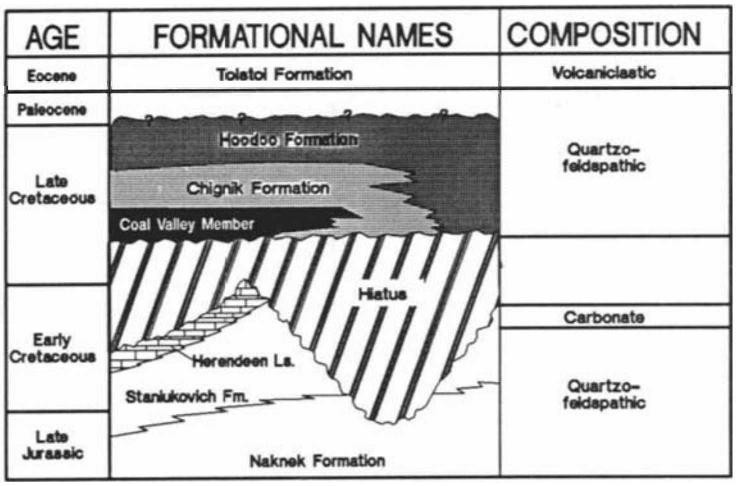


Figure 19. Generalized stratigraphy in the Herendeen Bay coalfield (modified after Burk, 1965; Moore, 1974; and Mancini and others, 1978).

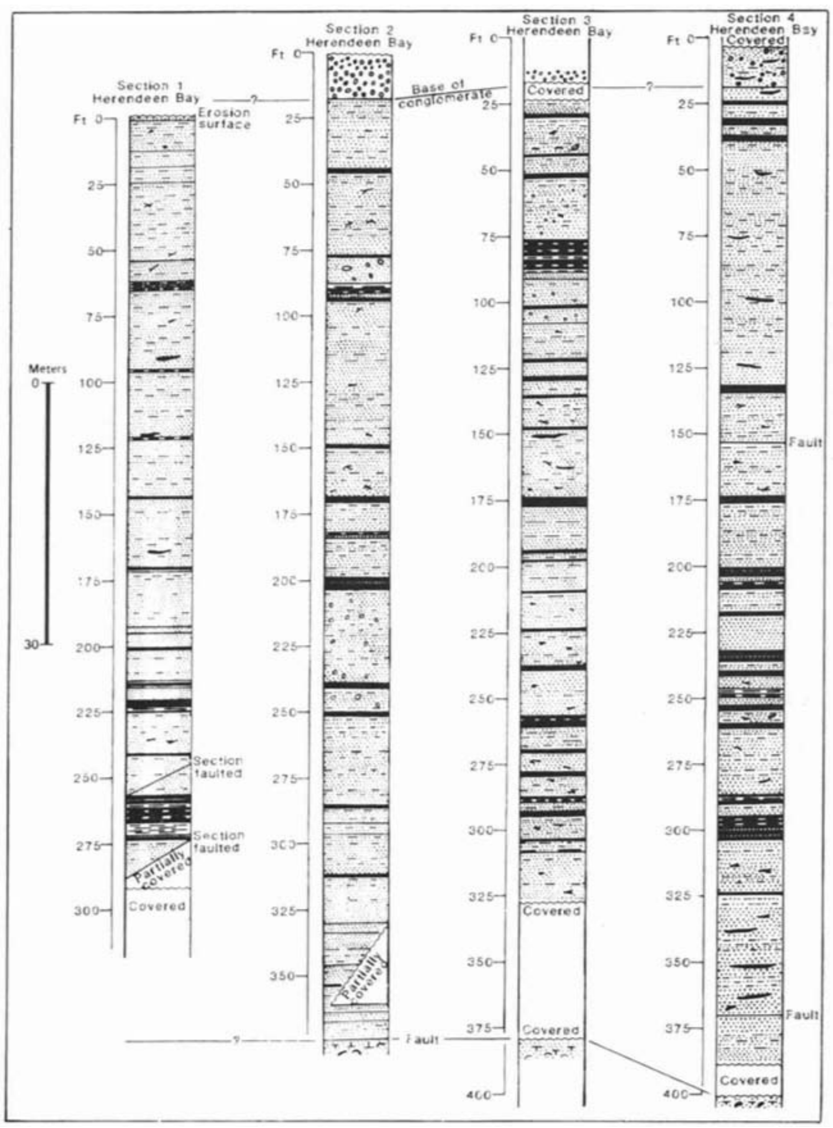


Figure 20. Detailed correlation sections of Herendeen Bay coalfield (from Merritt and McGee, 1986).

Figure 21. One of the thicker coal seams at Mine Harbor, Herendeen Bay field. (Photo by R.D. Merritt, 1984.)

Herendeen Bay Coalfield Data

COAL QUALITY

Rank: High volatile bituminous, typically hvBb.

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

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:

Carbon	56.71-64.52	59.08
Hydrogen	4.38-5.09	4.64
Nitrogen	0.35-0.90	0.74
Oxygen	18.47-24.10	22.00
Sulfur	0.29-4.68	0.76
Ash	2.52-33.23	12.78

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

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

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

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

Trace elements in coal (avg. in ppm):

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

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.

COAL PETROLOGY

Avg. composition, volume, mineral-matter-free basis, in %:

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
Liptodeterinite	0.6
Total liptinite	2.8

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

Range	0.55-0.90
Average	0.65

Locality (See figure 18)	Ro_{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

CHIGNIK COALFIELD

DESCRIPTION

LOCATION

The Chignik field, about 250 mi southwest of Kodiak and 100 mi northeast of the Herendeen Bay field, lies on the northwest shore of Chignik Bay, which indents the south side of the Alaska Peninsula (fig. 17).

AREA

The belt of coal-bearing rocks is about 30 mi long and 1 to 6 mi wide, an estimated area of 100 mi² (fig. 22).

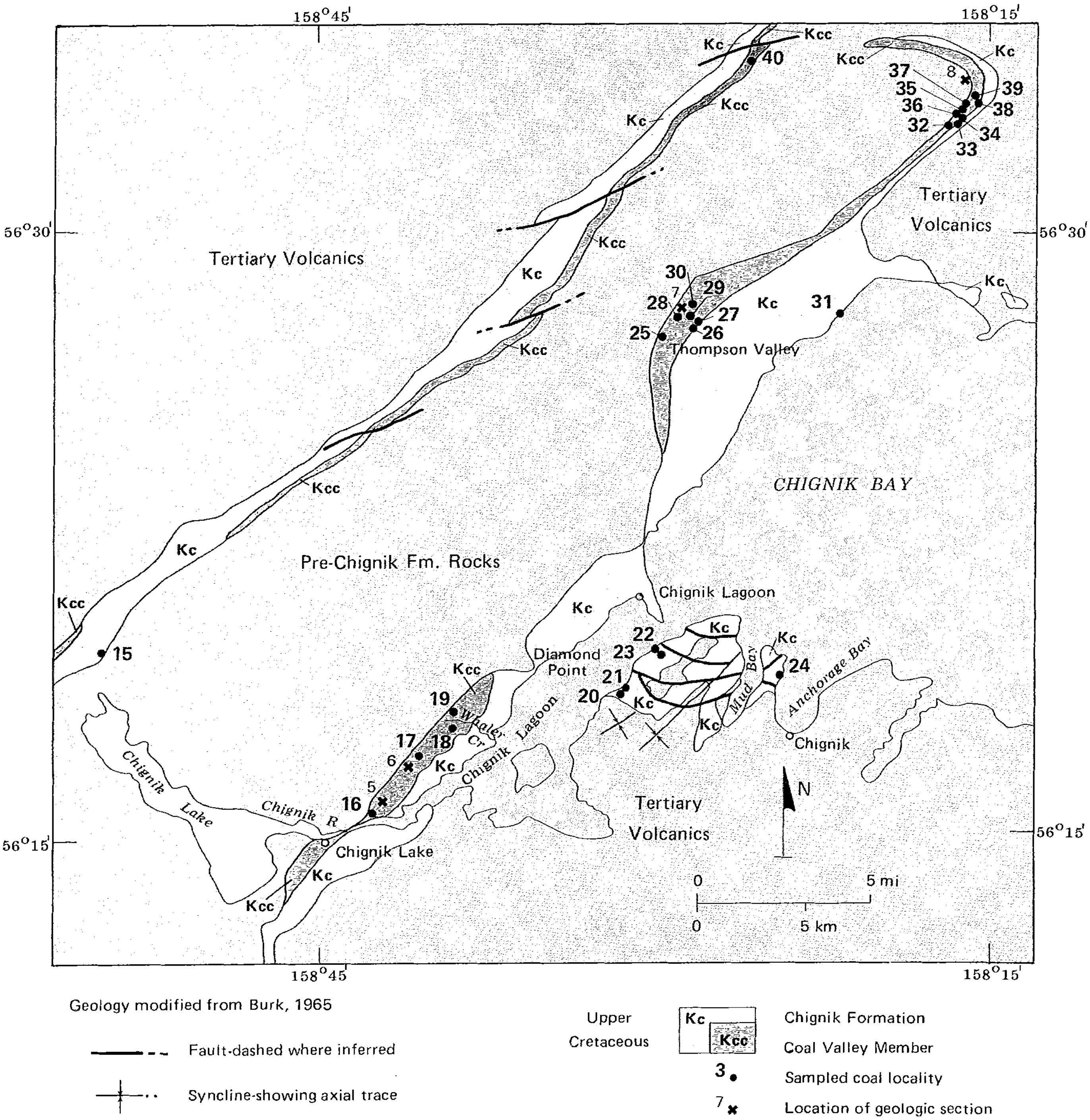


Figure 22. Generalized geologic map of the Chignik coalfield, Alaska Peninsula (from Merritt and McGee, 1986).

GEOLOGY

Coal deposits of the Chignik field lie within the Coal Valley member of the Upper Cretaceous Chignik Formation (fig. 23). This unit of cyclic nearshore marine and nonmarine sedimentation ranges in thickness to 1,500 ft and is composed of sandstone, pebble-cobble conglomerate, siltstone, shale, and numerous coal beds (fig. 24). Strata are moderately folded and locally faulted. Dips vary from 20° to 35°.

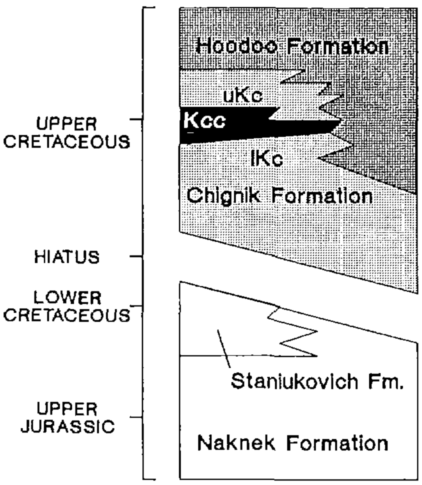


Figure 23. Generalized stratigraphy in the Chignik coalfield. Kcc = Coal Valley Member, Chignik Formation (after Vorobik and others, 1981).

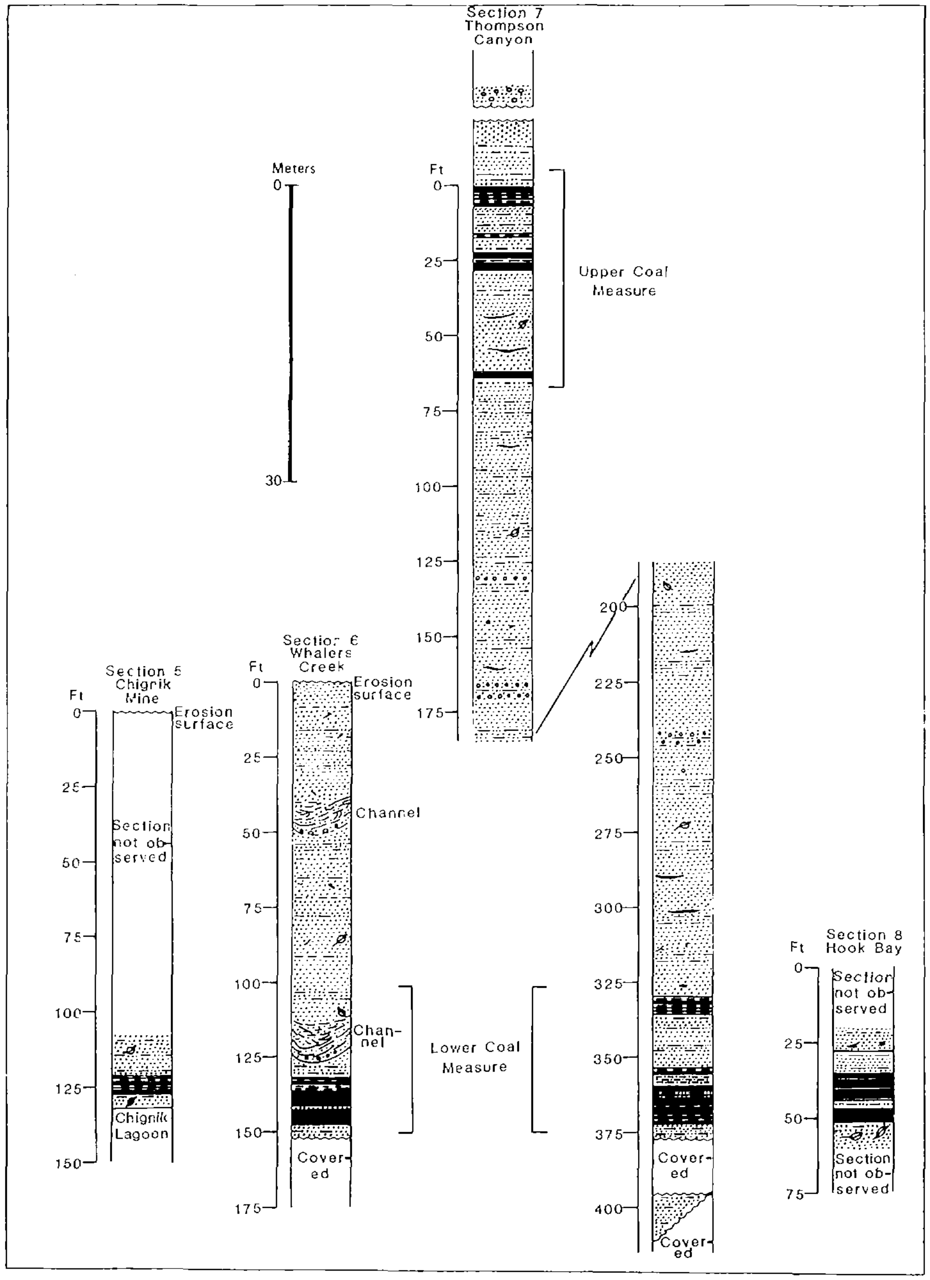


Figure 24. Detailed correlation sections of Chignik coalfield (from Merritt and McGee, 1986).

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. The Chignik River Mine operated until 1911. Several other small underground mines and prospects were opened in the early 1900s at Thompson Valley (fig. 25), Whaler's Creek, and Hook Bay, but they accounted for very little production. There has been no mining activity since.

Although some exploration has been conducted in recent years, the mineability of most areas has not been thoroughly investigated. During 1980-81, Resource Associates of Alaska, Inc. (a subsidiary of NERCO Minerals Co.), explored several areas owned by the Bristol Bay Native Corporation in the Chignik field and outlined small potential mining blocks.

ACCESS

Although the Chignik field is accessible to tidewater, Chignik Bay itself has no suitable harbor facilities for large vessels. It would be necessary to construct coal shipment facilities, including overland transportation system (access road and conveyor or aerial tramway) through a low pass to the head of Kuiukta Bay, about 5 mi south of the coal belt.

COAL RESOURCES

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

Resources are summarized as follows (depths of 0 to 2,000 ft):

Measured	10 million tons
Identified	230 million tons
Hypothetical	1,500 million tons

LAND STATUS

The Chignik coalfield lies within lands owned by the Bristol Bay Native Corporation.

Figure 25. Lower coal horizon at Thompson Valley, Chignik field, Alaska Peninsula. This seam previously supported a small mine. (Photo by R.D. Merritt, 1984.)

WESTERN ARCTIC COALFIELDS

DESCRIPTION

LOCATION

The Western Arctic region forms a part of the Foothills subprovince in northern Alaska (fig. 26). Three specific areas that show the highest potential for near-term development of bituminous coal deposits are Cape Beaufort (or Liz-A syncline), Deadfall syncline, and Kukpowruk River, west of Howard syncline (fig. 27). The Liz-A syncline is just inland from Cape Beaufort on the Chukchi Sea coast. The Deadfall syncline is 6 mi east of the Chukchi Sea, and the Kukpowruk River area is about 14 mi east of the Chukchi Sea and 25 mi upstream from the mouth of the Kukpowruk River.

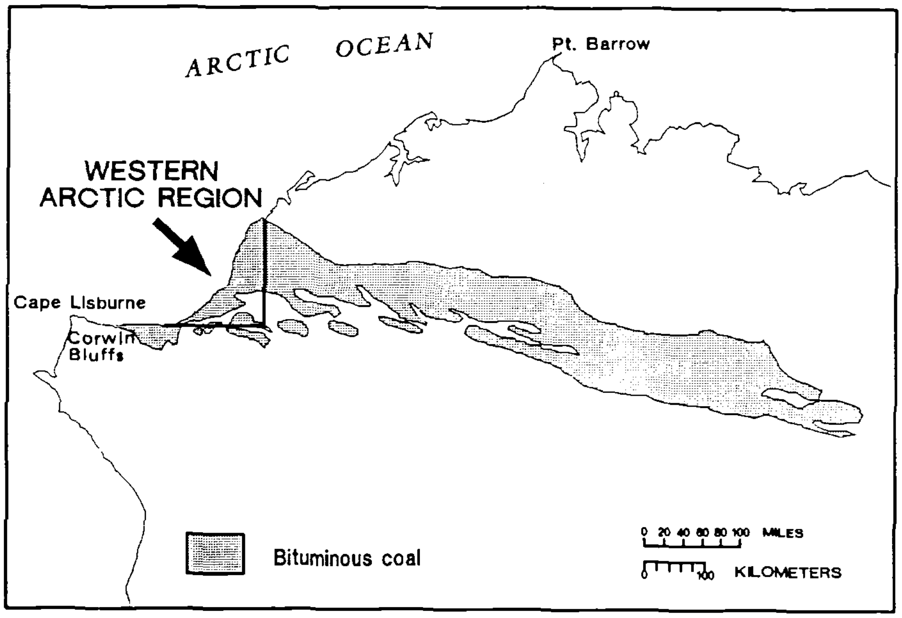


Figure 26. Distribution of bituminous coal deposits in northern Alaska (modified from Knutson, 1981).

AREA

The Cape Beaufort area covers about 30 mi². The Deadfall syncline encompasses less than 100 mi², and that portion of the Kukpowruk River area under consideration here--the western end of the Howard syncline--has an area of 20 to 30 mi². Within these broad areas, several specific mining blocks or units can be defined.

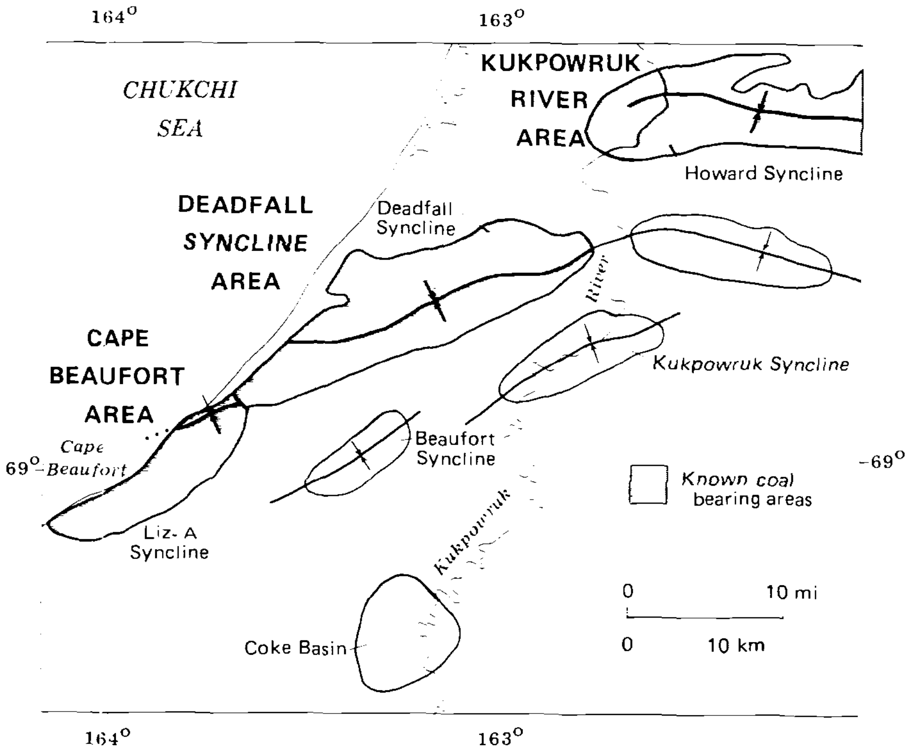


Figure 27. Important bituminous coal-bearing areas and structural features of the Western Arctic region (modified from Chapman and Sable, 1960).

GEOLOGY

The geology of the Western Arctic region is dominated by a series of east-west-trending synclines and anticlines. The synclines contain bituminous coal beds in the Corwin Formation of the Cretaceous-age Nanushuk Group (figs. 28 and 29). In the Western Arctic region, the Corwin Formation varies in thickness from 7,000 to 10,000 ft. The type locality of the Corwin Formation is at Corwin Bluffs (fig. 26), 35 mi west of Cape Beaufort, where 80 or more coal beds over 1 ft thick are exposed. Interbedded with coal seams are sandstones, claystones, siltstones, and carbonaceous shales that formed in a prograding deltaic system in swampy coastal lowlands. The strata are flat-lying to gently dipping (10° to 20°) and their structure is relatively simple (figs. 29 and 30). Rank of the coals increases with the complexity in structure from north to south in the foothills of the Brooks Range.

MINING HISTORY

The coals of the Western Arctic region were first reported by the Beechey expedition of 1826-27. In the late 1800s and early 1900s, coal from the Corwin Bluffs and Cape Beaufort areas was used to fuel whaling ships. A.J. Collier conducted the first geologic reconnaissance of coastal deposits south of Cape Beaufort in 1904.

Morgan Coal Company first explored the coking coal deposit on the Kukpowruk River in 1954, by driving a 70-ft tunnel in the 20-ft-thick bed. The company still holds a U.S. Bureau of Mines preference-right coal lease on 5,000 acres in that area. Union Carbide investigated the Kukpowruk River coking coal deposit from 1961 to 1963,

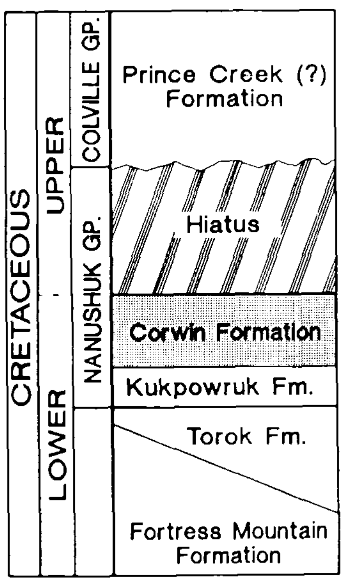


Figure 28. Generalized stratigraphy of the Western Arctic region (modified from Ahlbrandt and others, 1979).

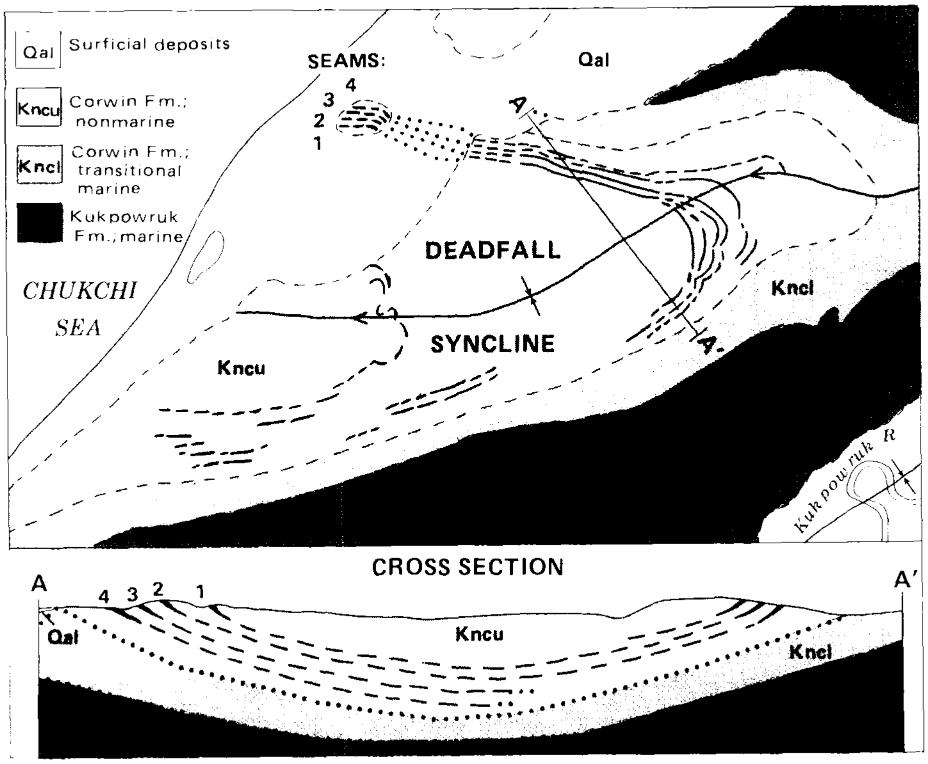


Figure 29. Geologic map and cross section of the Deadfall syncline, Western Arctic region (modified from Callahan and Eakins, 1987).

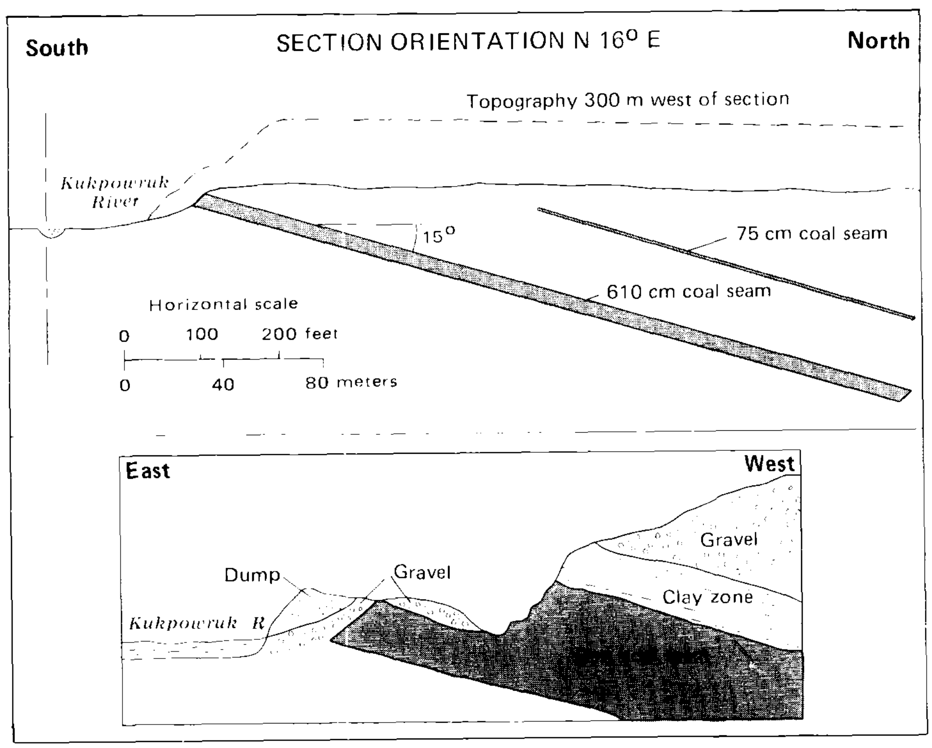


Figure 30. Typical cross sections in the Kukpowruk River area of the Western Arctic (from Knutson, 1981).

and Kaiser Engineers performed detailed mining and economic evaluations from 1970 to 1977. From 1981 to 1986, the State of Alaska and the North Slope Borough conducted extensive exploration and predevelopment site investigations of coal deposits at Cape Beaufort and in the Deadfall syncline area.

ACCESS

Access to the Deadfall syncline deposits was thoroughly studied by the Western Arctic Coal Development Project (Arctic Slope Consulting Engineers, 1986). A 5.4-mi haul road would connect the mine site with a port facility and berthing area for barge traffic. A 2,800-ft lead-in channel would be dredged to an operating depth of 13 ft. Coal would be stored at the barge loading facility for domestic shipment during the ice-free season. Coal for foreign export would be transported to a separate ice-free port facility with a large storage capacity and a harbor for berthing and loading of seagoing carriers. Large-volume shipments from either the Cape Beaufort or Kukpowruk River areas would probably follow a similar plan, unless a long-distance rail line were completed to the Western Arctic region.

COAL RESOURCES

The North Slope, including the National Petroleum Reserve of Alaska (NPRA) and bordering areas to the east and west of it, holds as much as 4 trillion tons of coal. The Western Arctic region west of NPRA may contain up to 1 trillion tons of coal. Approximately 60 percent of North Slope coal is estimated to be of bituminous rank. Ten percent or more of the stratigraphic section from some wells consists of coal. Between 150 and 200 coal beds, 60 percent of which are over 3.5 ft thick, have been correlated in the Corwin Formation of the Western Arctic. The thickest identified outcropping seam in the region is at Kukpowruk River (fig. 31). At Cape Beaufort, coal beds range in thickness to 9 ft in outcrops (fig. 32) and to 17 ft in drill holes; at Deadfall syncline, coal beds range in thickness from 4.5 to 13 ft.

Figure 31. Twenty-foot thick coal seam at Kukpowruk River, Western Arctic region. (Photo by G.R. Eakins, 1982.)

At a minimum, the Western Arctic region contains 125 million tons of strippable coal resources amenable to modern mechanized mining; further exploration will delineate other strippable resources. Plentiful additional resources can be developed by underground mining methods. Domestic uses of Western Arctic coal are heat and power generation for villages in northwest Alaska and power production for other large-scale mining such as the Red Dog zinc mine north of Kotzebue.

Coal resources at Cape Beaufort, Deadfall syncline, and Kukpowruk River are listed below in millions of tons (overburden depths from 0 to 3,000 ft):

	Cape Beaufort	Deadfall syncline	Kukpowruk River
Measured	45	60	20
Identified	390	500	275
Hypothetical	1,700	5,000	1,200

LAND STATUS

Lands in the Western Arctic coalfields region are owned by Arctic Slope Regional Corporation, and leased by the Morgan Coal Company (U.S. Bureau of Mines preference-right lease to 5,000 acres in the Kukpowruk River area).

Figure 32. Sampling a thick coal bed north of Cape Beaufort, Western Arctic region, 1981. (Photo courtesy of P.D. Rao, University of Alaska MIRL.)

Western Arctic Coalfields Data
CAPE BEAUFORT

COAL QUALITY

Rank: hvAb-hvCb

Heating content:		
	Range	9,100-12,700 Btu/lb
	Average	12,300 Btu/lb

Proximate analysis (range in %, mean in parentheses):

Moisture	2.5-7 (4.5)	Fixed carbon	37-55 (46.8)
Volatile matter	22-33 (29.7)	Ash	8-27 (16.0)

Ultimate analysis (range in %, mean in parentheses):

Carbon	46-71 (58.3)	Oxygen	13-25 (19.1)
Hydrogen	3.5-5 (4.5)	Sulfur	0.2-0.4 (0.3)
Nitrogen	0.7-1.5 (1.1)	Ash	8-27 (16.7)

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

SiO_2	49.7	MgO	2.7
Al_2O_3	25.1	SO_3	0.6
Fe_2O_3	3.2	P_2O_5	0.3
CaO	6.2	MnO	0.1
TiO_2	1.1	Undet.	7.5

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

Boron	440	Nickel	40
Chromium	55	Silver	3.5
Cobalt	40	Tin	295
Copper	40	Vanadium	130
Gallium	30	Zinc	110
Lead	55	Zirconium	500
Molybdenum	5		

Trace elements in raw coals (avg. in ppm):

Boron	75	Nickel	8
Chromium	15	Silver	1
Cobalt	8	Tin	35
Copper	9	Vanadium	30
Gallium	6	Zinc	25
Lead	10	Zirconium	100
Molybdenum	1		

Fusibility of ash (reducing temperature, °F):

Initial deformation	2320
Softening temperature	2410
Fluid temperature	2520

Free-swelling index: 0-6

Hardgrove grindability index: 58

Coking potential: Increased with depth; coal from 200-ft shows pronounced coking characteristics.

COAL PETROLOGY

Avg. composition, volume, mineral-matter-free basis, in %:

Vitrinite	62.2
Pseudovitrinite	10.0
Gelinite	0.7
Phlobaphinite	0.4
Pseudophlobaphinite	1.0
Sporinite	1.2
Resinite	0.8
Cutinite	0.1
Alginite	0.0
Exsudatinite	0.1
Thick cutinite	0.1
Suberinite	0.0
Other liptinite	0.0
Fusinite	0.8
Semifusinite	14.3
Macrinite	1.7
Globular macrinite	1.3
Inertodetrinite	5.3
Sclerotinite	0.0

Mean-maximum vitrinite reflectance (Ro_{max}, %): 0.70

DEADFALL SYNCLINE

COAL QUALITY

Rank: hvAb-hvCb

Heating content:		
	Range	10,900-13,200 Btu/lb
	Average	12,900 Btu/lb

Proximate analysis (range in %, mean in parentheses):

Moisture	2.5-8 (4.6)	Fixed carbon	35-56 (53.9)
Volatile matter	22-36 (33.9)	Ash	5.5-22 (7.6)

Ultimate analysis (range in %, mean in parentheses):

Carbon	451-65 (59.4)	Oxygen	17-27 (23.3)
Hydrogen	3.7-5.1 (4.6)	Sulfur	0.2-0.3 (0.2)
Nitrogen	0.8-1.4 (1.1)	Ash	5.5-22 (11.4)

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

SiO_2	30.9	MgO	6.7
Al_2O_3	29.2	SO_3	1.5
Fe_2O_3	4.8	P_2O_5	0.8
CaO	17.5	MnO	0.0
TiO_2	0.7	Undet.	0.5

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

Boron	300	Nickel	25
Chromium	50	Silver	2
Cobalt	30	Tin	180
Copper	35	Vanadium	95
Gallium	30	Zinc	100
Lead	50	Zirconium	220
Molybdenum	5		

Trace elements in raw coals (avg. in ppm):

Boron	55	Nickel	7
Chromium	12	Silver	1
Cobalt	8	Tin	25
Copper	10	Vanadium	20
Gallium	5	Zinc	18
Lead	10	Zirconium	80
Molybdenum	1		

Fusibility of ash (reducing temperature, °F):

Initial deformation	2093
Softening temperature	2143
Fluid temperature	2189

Free-swelling index: 0-6

Hardgrove grindability index: 56

Coking potential: Similar to Cape Beaufort coals.

COAL PETROLOGY

Avg. composition, volume, mineral-matter-free basis, in %:

Vitrinite	58.1
Pseudovitrinite	10.7
Gelinite	0.9
Phlobaphinite	0.1
Pseudophlobaphinite	1.1
Sporinite	1.7
Resinite	1.0
Cutinite	0.2
Alginite	0.0
Exsudatinite	0.0
Thick cutinite	0.3
Suberinite	0.0
Other liptinite	0.0
Fusinite	2.0
Semifusinite	16.4
Macrinite	2.4
Globular macrinite	0.3
Inertodetrinite	4.8
Sclerotinite	0.0

Mean-maximum vitrinite reflectance (Ro_{max}, %): 0.70

KUKPOWRUK RIVER

COAL QUALITY

Rank: hvAb-hvCb

Heating content:	Range	11,900-14,100 Btu/lb
	Average	13,800 Btu/lb

Proximate analysis (range in %, mean in parentheses):

Moisture	0.8-10 (2.8)	Fixed carbon	52-60 (58.5)
Volatile matter	31-40 (35.2)	Ash	2.5-15 (3.5)

Ultimate analysis (range in %, mean in parentheses):

Carbon	57-77 (70.0)	Oxygen	12-18 (14.5)
Hydrogen	4.5-5.6 (5.1)	Sulfur	0.2-0.5 (0.3)
Nitrogen	1.0-1.6 (1.3)	Ash	2.5-15 (8.8)

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

SiO_2	51.5	MgO	3.0
Al_2O_3	25.5	SO_3	0.5
Fe_2O_3	4.8	P_2O_5	0.6
CaO	3.5	MnO	0.1
TiO_2	1.0	Undet.	6.5

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

Boron	--	Nickel	80
Chromium	40	Silver	--
Cobalt	35	Tin	--
Copper	150	Vanadium	65
Gallium	50	Zinc	--
Lead	150	Zirconium	190
Molybdenum	--		

Trace elements in raw coals (avg. in ppm):

Boron	--	Nickel	7
Chromium	4	Silver	--
Cobalt	4	Tin	--
Copper	12	Vanadium	9
Gallium	4	Zinc	--
Lead	14	Zirconium	19
Molybdenum	--		

Fusibility of ash (reducing temperature, °F):

Initial deformation	2040
Softening temperature	2110
Fluid temperature	2390

Free-swelling index: 0-6

Hardgrove grindability index: --

Coking potential: Significant coking, properties; generally soft-coking.

COAL PETROLOGY

Avg. composition, volume, mineral-matter-free basis, in %:

Vitrinite	60.9
Pseudovitrinite	16.3
Gelinite	1.7
Phlobaphinite	0.3
Pseudophlobaphinite	1.0
Sporinite	1.9
Resinite	0.7
Cutinite	0.4
Alginite	0.1
Exsudatinite	0.0
Thick cutinite	0.3
Suberinite	0.1
Other liptinite	0.0
Fusinite	0.6
Semifusinite	11.4
Macrinite	1.1
Globular macrinite	0.3
Inertodetrinite	2.9
Sclerotinite	0.0

Mean-maximum vitrinite reflectance (Ro_{max}, %): 0.73

OUTLOOK FOR COAL DEVELOPMENT IN ALASKA

As the chief energy resource of the world today, where escalating energy needs sap rapidly declining petroleum resources, coal will play an increasing part in the world energy supply. Coal is the primary source of fuel for electrical-power generation in the United States.

Alaska's total coal resources are estimated at between 5.5 and 6.0 trillion tons, over half of which are of bituminous rank. The total energy equivalent (in Btu) of all the coal in Alaska exceeds by several orders of magnitude that of all known oil reserves in the State. The energy equivalent of Alaska's bituminous coal resources alone is estimated to be more than 1,000 Prudhoe Bays (original recoverable reserves of about 10 billion barrels).

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

The low sulfur content of Alaska's coal (less than 0.5 percent) is a chief attraction for Pacific Rim industrial buyers. The environmental significance of low-sulfur coal will increase dramatically in the future; environmental problems encountered in mining, preparation, and use of high-sulfur coal can be avoided with low-sulfur Alaska coal.

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

Alaska coals produce low sulfur-oxide (SO_x) emissions. Most Alaska coals meet the USEPA emission standards (1.2 lb SO_2/MM Btu) for direct combustion. Because nitrogen content is also low, the low combined emission of SO_x and NO_x gases during combustion make Alaska's coals among the most environmentally safe in the world. Alaska's high-rank coals also possess good ash-fusion characteristics and low moisture and metallic trace-element content.

Coal mining has taken place in Alaska for 130 yr. If this long history of coal development proves one thing, it is that coal mining can exist in harmony with the unique Alaska environment. The Usibelli Coal Mine near Healy (in interior Alaska) provides an example--from its longstanding commitment to land-restoration programs--that coal mining can be conducted in Alaska with both economic success and environmental restraint. As coal mining activities increase 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.

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GLOSSARY OF TERMS

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

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. (See Proximate analysis.)

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. (See Ultimate analysis.)

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.

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. (See Proximate analysis.)

Fluid temperature The point indicated by the spreading out of the completely melted ash cone into a flat layer. (See Fusibility of ash.)

Free-swelling index (FSI) FSI is a measurement obtained by the rapid heating of a coal sample in a non-restraining crucible. It ranges on a scale of 0 to 9, where noncaking and nonswelling coals are 0 on the scale. FSI gives an indication of the caking characteristics of a given coal.

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 or an 8-point (reducing and oxidizing atmospheres) ash fusibility. The melting temperature 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 one-half 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.

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 indices. 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.

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

Hemispherical stage The point where the ash cone height is equal to its width. (See Fusibility of ash.)

Hydrogen Hydrogen is determined by catalytic burning in oxygen and the subsequent measurement of the water formed and absorbed by a desiccant. (See Ultimate analysis.)

Major-oxide composition of ash Major oxides include $Si0_2$, $A1_20_3$, Fe_20_3, $Ti0_2$, Ca0, Mg0, Na_20, K_20, P_20_5, and $S0_3$. These compounds typically compose over 99 percent of coal ash.

Moisture content Moisture content includes surface moisture that can be removed by natural drying, and inherent moisture that is contained structurally in the coal substance. Surficial water on coal is free or adherent. Inherent moisture is held physically 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. (See Proximate analysis.)

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

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

Point of initial deformation The tip of the ash cone begins to deform. (See Fusibility of ash.)

Proximate analysis A proximate analysis of coal includes determinations of the moisture, volatile matter, ash, and fixed carbon (by difference) content 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, analyses are reported on an equilibrium-bed-moisture basis as well. Unless otherwise stated, analyses are assumed to be on an as-received basis.

Rank Rank is the basis of coal classification in the natural series from lignite to anthracite and refers to the degree of metamorphism of coal. Higher rank indicates greater metamorphism. Bituminous coals and anthracites are considered to be high-rank; subbituminous coals and lignites, low-rank. Classes of high-rank coals are:

ASTM* abbreviation	Rank (in decreasing order)
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.

Softening point The point where the ash cone height is equal to one-half its width. (See Fusibility of ash.)

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 is chiefly responsible for acid mine drainage. Organic sulfur, typically the most abundant form in Alaskan coals, is bonded to the carbon structure. Sulfates form mainly by weathering, into calcium and iron varieties. Three methods used for sulfur determinations are Eschka, high-temperature combustion, and bomb-washing. (See Ultimate analysis.)

Trace elements in coal and coal ash Trace element analysis is important for environmental concerns attendant to coal mining and use. The most important trace elements 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. Trace-element analysis is performed by atomic absorption, spark-source mass spectrophotometry, X-ray fluorescence, and neutron activation.

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.

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.

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

ALASKA'S HIGH-RANK COALS