Alaska Coal Geology, Resources, and Coalbed Methane Potential

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft.)	0.3048	meter (m)
mile (mi.)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	9,290	square centimeter (cm^2)
square foot (ft^2)	0.0929	square meter (m^2)
square inch (in^2)	6.452	square centimeter (cm^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Weight	
metric ton	1.10	ton, short (2,000 lb)
ton, short (2,000 lb)	0.907	metric ton
pound (lb)	453.59	gram (gm)
gram (gm)	0.0022	pound (lb)
	Energy	
Btu per pound (Btu)	0.0022	mega joules per kilogram

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F= (1.8x°C) +32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C= (°F-32)/1.8

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Alaska Coal Geology, Resources, and Coalbed Methane Potential

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Abstract

Estimated Alaska coal resources are largely in Cretaceous and Tertiary rocks distributed in three major provinces. Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet. Cretaceous resources, predominantly bituminous coal and lignite, are in the Northern Alaska-Slope coal province. Most of the Tertiary resources, mainly lignite to subbituminous coal with minor amounts of bituminous and semianthracite coals, are in the other two provinces. The combined measured, indicated, inferred, and hypothetical coal resources in the three areas are estimated to be 5,526 billion short tons (5,012 billion metric tons), which constitutes about 87 percent of Alaska's coal and surpasses the total coal resources of the conterminous United States by 40 percent.

Coal mining has been intermittent in the Central Alaskan-Nenana and Southern Alaska-Cook Inlet coal provinces, with only a small fraction of the identified coal resource having been produced from some dozen underground and strip mines in these two provinces. Alaskan coal resources have a lower sulfur content (averaging 0.3 percent) than most coals in the conterminous United States and are within or below the minimum sulfur value mandated by the 1990 Clean Air Act amendments. The identified resources are near existing and planned infrastructure to promote development, transportation, and marketing of this low-sulfur coal. The relatively short distances to countries in the west Pacific Rim make them more exportable to these countries than to the lower 48 States of the United States.

Another untapped but potential resource of large magnitude is coalbed methane, which has been estimated to total 1,000 trillion cubic feet (28 trillion cubic meters) by T.N. Smith, 1995, Coalbed methane potential for Alaska and drilling results for the upper Cook Inlet Basin: Intergas, May 15 – 19, 1995, Tuscaloosa, University of Alabama, p. 1 – 21.

Introduction

This report is a synthesis of the largely untapped hypothetical coal resources of Alaska, which are estimated to be as much as 5,526 billion short (or 5.5 trillion) tons (5,012 billion metric tons). The last coal resource assessment in 1974 for the conterminous United States (coal remaining in the ground) estimated a total coal resource of 3,968 billion short tons (3,600 billion metric tons) or 4 trillion short tons (Averitt, 1975). Thus, the Alaska coal resource estimate surpasses the total coal resources of the conterminous United States by 40 percent. This report focuses on an assessment of the coal resources of the three major coal provinces in Alaska: Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet and makes up 87 percent of the total coal resources of the State (fig. 1). Also, it will concentrate on the origin, geologic setting, and depositional environments of the coal, as well as coal rank, quality, and petrology and the amount of the resources. In addition, this report will summarize the coalbed methane potential and prioritize areas for exploration and development in these major coal provinces.

The coal resources of Alaska occur in discrete areas (coalfields) and in isolated, unrelated outcrops (occurrences) (fig. 1). A coalfield may contain coal beds of various ranks, shown in figure 2, and different ages and geologic settings, shown in figure 3. Coal resources and geological settings of minor coalfields not reported here may be found in Stricker (1991) and Wahrhaftig and others (1994).

Before the arrival of the European immigrants, native inhabitants used coal in Alaska (Chapman and Sable, 1960, p. 159). The Beechey expedition of 1826–1827 reported the presence of coal in Alaska (Huish, 1836; Dall, 1896). Whaling shippers mined coal from near Cape Beaufort, north of the Arctic Circle, before the turn of the twentieth century (Conwell and Triplehorn, 1976). The first coal mine was opened in 1855 and closed in 1867 at Port Graham (fig. 2) on the southwestern part of the Kenai Peninsula (Martin, 1915). The Russians opened and operated this coal mine before the United States took possession of the Alaska Territory. The U.S. Congress passed two significant legislative acts in 1914 that led to development of coal resources of Alaska: (1) the Alaska Coal Leasing Act promoted opening mines in the Alaskan coalfields and (2) the Alaska Railroad Enabling Act authorized construction of the railroad from Anchorage to Fairbanks, which encouraged the use of coal by the locomotives and by the gold mining operations to power gold dredges and to fuel steam boilers for thawing the frozen ground.

Many coal mines in the Nenana and Matanuska coalfields were active after Congress authorized the construction of the Alaska Railroad, which promoted large-scale production, transportation, and marketing. The first coal-lease sale was held in conjunction with an oil-lease sale in 1983. In 1984, export of Alaskan coal began with shipments to South Korea from Nenana coalfield. Other developments included construction of a coal terminal at the deep-water port at Seward, new loading facilities at the Usibelli coal mine, and upgrading of the Alaska Railroad to handle hauling coal to Seward. In 1985, coal production increased by 60 percent over 1984, with a gross value on production of 1.4×10^6 short tons (1.27×10^6 metric tons) valued at $39.7 million (Bundtzen and others, 1986). Coal production for the year 2000 was estimated by Szumigala and Swainbank (2001) at 1,473,000 short tons valued at $38.7 million with 708,000 short tons being exported to Korea. An estimate of total coal in place is 10.4×10^{12} short tons (9.4×10^{12} metric tons), or about 50 percent of total of conterminous U.S. resources.

The coal resources of Alaska, have been only minimally exploited or developed. Mined coal is presently utilized for domestic electric power-generating plants, and approximately one-half of the production from the Usibelli mine is shipped to Korea and potentially to other countries bordering the western Pacific Rim.

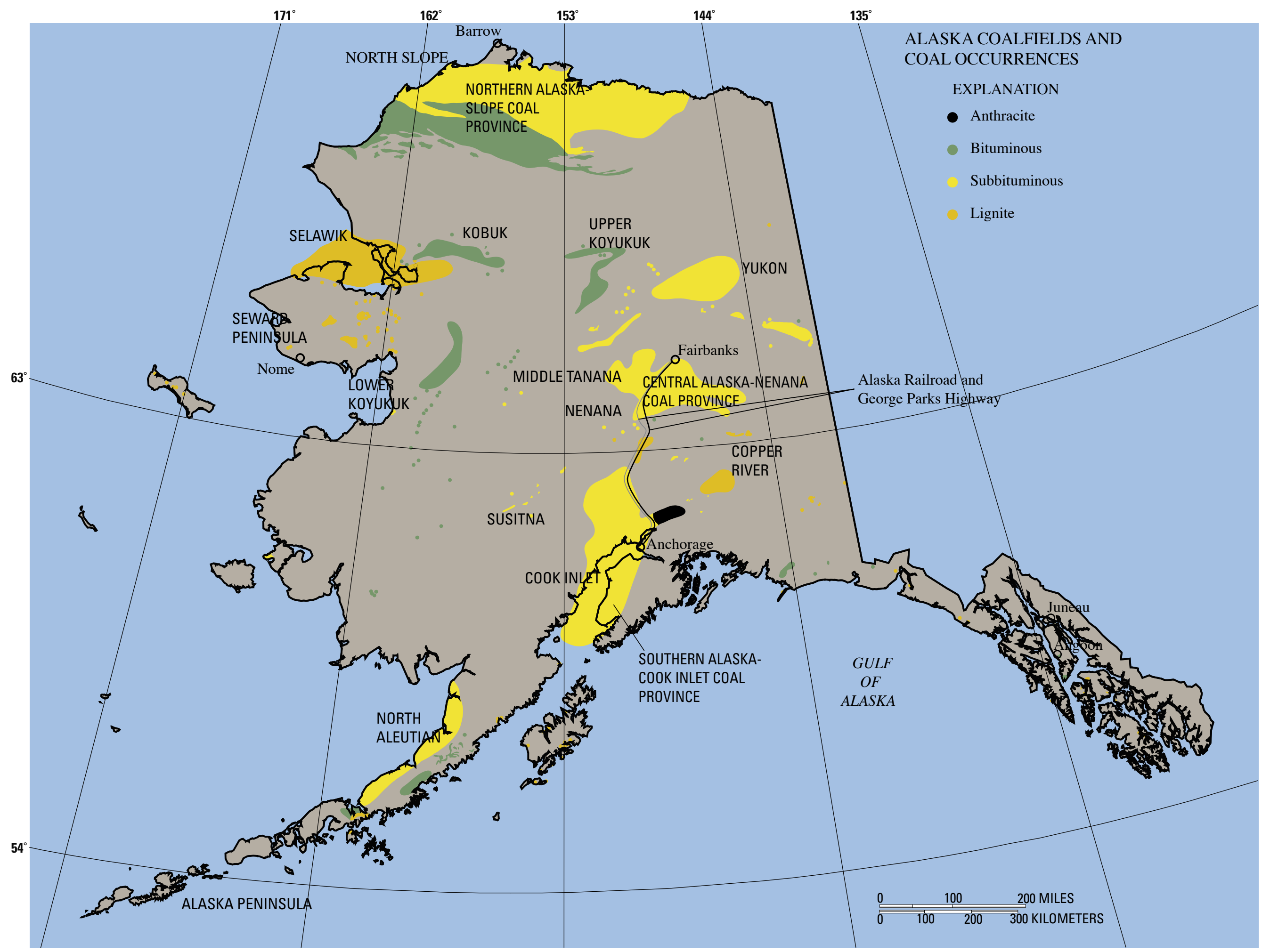


Figure 1. Coal ranks in coal basins and coal occurrences in Alaska with emphasis on the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. Compiled and modified from Merritt and Hawley (1986); Barnes (1967a, 1967b); Magoon and others (1976); Plafker (1987).

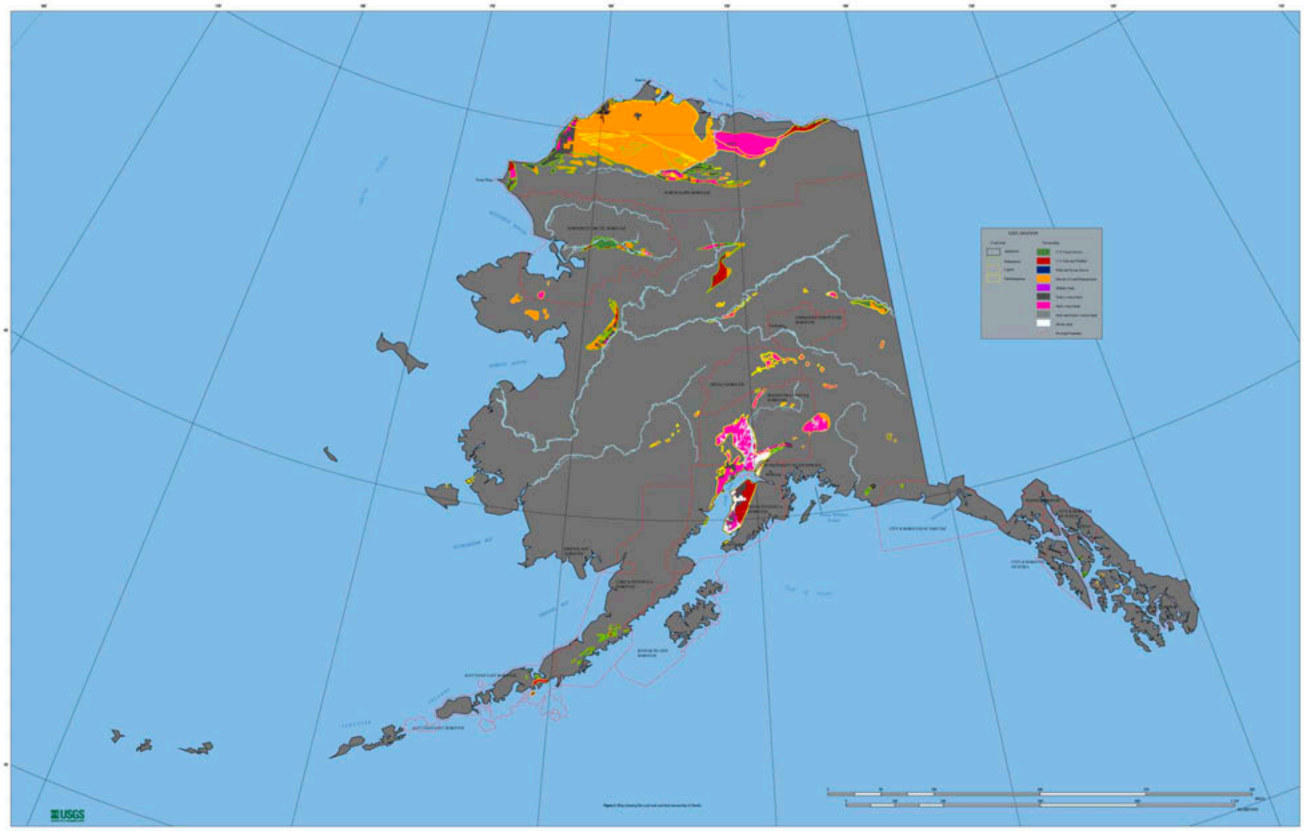


Figure 2. Map showing the coal rank and land ownership of Alaska

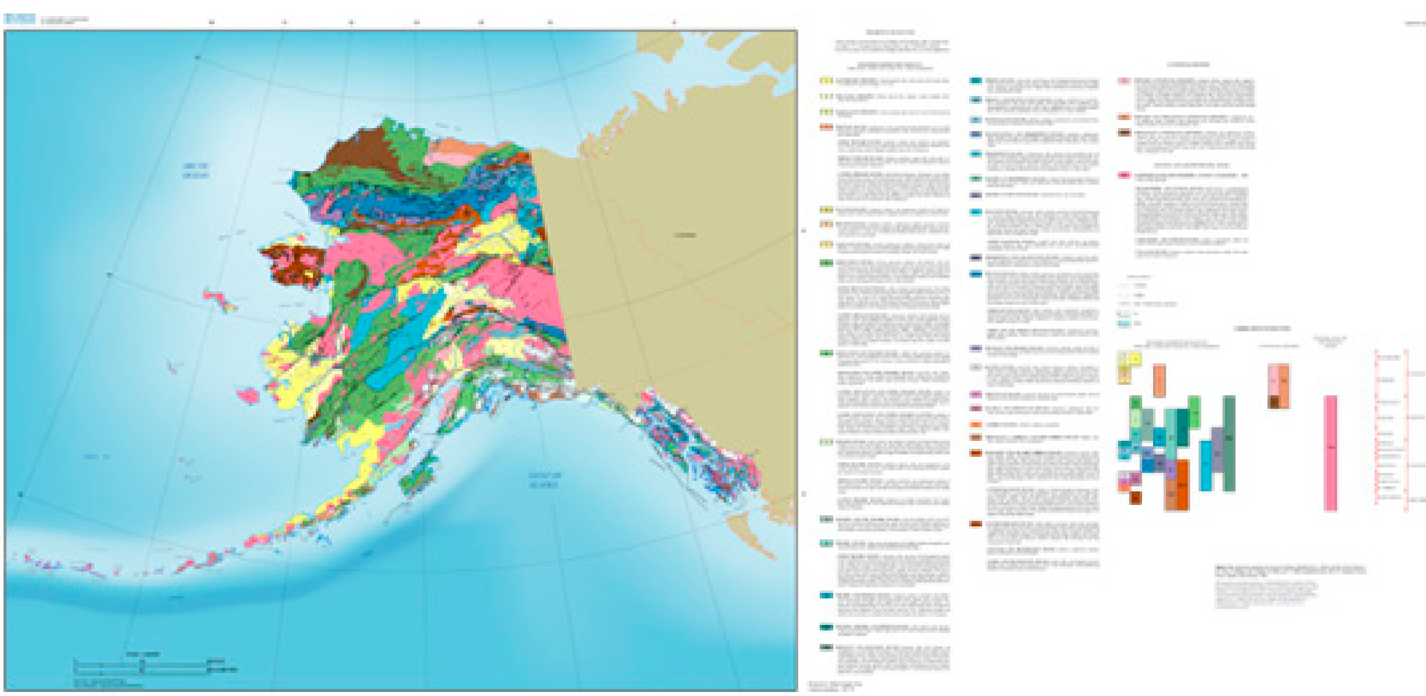


Figure 3. Map showing the geology and structure of Alaska. Modified from S.J. Moll, Scott Bie, Devon Peterson, D.C. Pray, F.H. Wilson, J.M. Schmidt, J.R. Riehle, T.P. Miller (unpublished data, 1997, U.S. Geological Survey, Reston, Virginia) after Beikman (1980).

Geological Setting

The geology of Alaska (fig. 3; Beikman, 1980) is best described by Plafker and Berg (1994) and by various authors in the 1994 Geology of Alaska volume of The Geological Society of America edited by George Plafker and H.C. Berg. These workers have discussed in detail the physiographic, geologic, tectonic, and volcanic evolution of Alaska from the Proterozoic to the present. Thus, this report describes only those physiographic and geologic settings of Alaska that are critical for understanding the coal-bearing rocks that were investigated in this study.

Physiographic Regions

Alaska is divided into four physiographic regions (fig. 4); from north to south, they are (1) arctic coastal plain, (2) northern Cordillera, (3) interior or intermountain plateau, and (4) southern Cordillera (Plafker and Berg, 1994; Wahrhaftig and others, 1994).

The arctic coastal plain region extends from the margin of the Arctic Ocean on the north to the northern margin of the Arctic Foothills Range on the south and consists mainly of Tertiary alluvial deposits. Paleozoic, Mesozoic, and Cenozoic rocks underlie the alluvial deposits. The major coal deposits are in the Cretaceous Nanushuk and Colville Groups and Tertiary Sagavanirktok Formation in this region (Wahrhaftig and others, 1994); minor coals occur in the Lower Mississippian Kekiktuk Conglomerate of the Endicott Group (see fig. 3; Tailleur, 1965; Conwell and Triplehorn, 1976; Sable and Stricker, 1987; Wahrhaftig and others, 1994).

The northern Cordillera region is dominated by the east-west-trending Brooks Range (see figs. 3 and 4; Plafker and Berg, 1994). During the Pleistocene, ice caps carved the glacial topography of these mountains. Mainly Cretaceous coal-bearing Nanushuk and Colville Groups underlie the Arctic Foothills Range (see fig. 4). The Paleozoic rocks are mainly exposed in the mountains.

The interior or intermountain plateau is between the Brooks Range on the north and the Alaska Range on the south (see figs. 3 and 4; Plafker and Berg, 1994). This region is part of the intermountain plateau that extends into Canada and the conterminous United States (Great Basin and Colorado Plateaus). Quaternary alluvial deposits sporadically cover the region from the Bering Sea to the Yukon Flats (fig. 3). Elsewhere the interior region is composed of plateaus, hills, and uplands, with numerous domes, ridges, and mountains at the higher elevations (Plafker and Berg, 1994). The interior region was generally free of ice during the Pleistocene glaciation. Beneath the loess and vegetation, the interior region contains pre-Cretaceous basement rocks that include displaced and rotated lithotectonic terranes of Proterozoic and Paleozoic age of miogeocline affinity (Plafker and Berg, 1994). The basement rocks also contain Devonian-Lower Jurassic terranes of oceanic affinity and Jurassic-Lower Cretaceous intraoceanic arc terranes. Mid-Cretaceous and younger plutonic and related rocks, flysch basins, and basalts conceal these rocks. Tertiary coal-bearing rocks are mainly present in several synclinal basins in the northern foothills of the Alaska Range (fig. 3) and are partly or wholly detached from each other by erosion of coal-bearing rocks from intervening structural highs (Wahrhaftig and others, 1994).

The southern Cordillera region is the northernmost extent of the Pacific Mountain system of North America that rims the Pacific Ocean margin (Plafker and Berg, 1994). The region extends from the Alaska Range on the north to the margin of the Gulf of Alaska on the south (fig. 3). It extends westward to the Aleutian Range and Aleutian Islands, which are a continuation of the Alaska Range (fig. 3). Widespread mountain glaciers and ice fields occur in the mountainous parts of the southern Cordillera region (fig. 3). Glaciers currently extend into tidewaters at numerous bays and fiords (Plafker and Berg, 1994). The southern Cordillera region is underlain by Proterozoic to Cenozoic accreted intraoceanic arc and plateau terranes, arc-related accretionary prisms, and flysch basins (Plafker and Berg, 1994). These terranes were intruded by mid-Cretaceous to Paleogene postaccretion plutons, which are, in turn, overlapped by Upper Cretaceous-Tertiary basinal and volcanic rocks. The Tertiary coal-bearing rocks in this region are mainly found in these basins as typified by the Cook Inlet Basin (fig. 3).

Regional Geology

Alaska is composed mainly of three crustal rock types: (1) continental crust of the Cordillera miogeocline; (2) amalgamated magmatic arcs, oceanic plateaus, melange, and flysch; and (3) oceanic (including ophiolite) rocks (Plafker and Berg, 1994). These crustal rocks were modified by magmatism and metamorphism, overlapped by Cretaceous and Cenozoic rocks, and affected by Cretaceous and Cenozoic faulting and rotation. These tectonic processes produced the structural trends as expressed by the physiographic features of Alaska (fig. 3).

The northern and eastern parts of Alaska were formed by intermittent rifting from the Proterozoic (850 Ma) to the early Paleozoic (Plafker and Berg, 1994). This event was followed by subsidence of the continental margin and deposition of the Proterozoic-Paleozoic rocks, which make up the Cordillera miogeocline (Dover, 1994; Grantz and others, 1994). The Cordillera miogeocline rocks were affected episodically by plate tectonism that formed the present Cordillera orogenic belt. Plate convergence during Jurassic-Cretaceous time along the continental margin resulted in a complex of intraoceanic arcs, arcs on rifted continental crust, arc-related accretionary prisms, flysch basins, oceanic plateaus, and oceanic crustal rocks. Structural deformation, metamorphism, magmatism, and erosion, in turn, modified these rock (Dusel-Bacon, 1994). The oceanic crustal rocks define suture zones of either autoch-

Figure 4. Map showing the physiographic regions of Alaska. Modified from Plafker and Berg (1994).

thonous or paratochthonous rocks along which the Alaskan continental margin rocks are adjacent to noncontinental rocks.

The Alaskan continental margin developed an Andean-type arc system during mid-Cretaceous to Tertiary time as imposed by the convergence of the Kula and North American plate (Plafker and Berg, 1994; Nokleberg and others, 1994). During this time period, accreted terranes were welded to the continental margin by numerous arc-related volcanic, plutonic, and metamorphic events (Brew, 1994). Arc-related volcanic rocks and terrigenous sediments built much of western Alaska, and the arc-related accretionary prisms formed seaward of the volcanic arc (fig. 5). The present structural trends of Alaska were formed by extensive rotations and translations from Early Cretaceous to early Tertiary time. For example, during the Early Cretaceous, the Arctic Ocean basin developed by counterclockwise rotation of northern Alaska away from the Arctic Canadian continental margin (Plafker and Berg, 1994; Grantz and others, 1994). During Late Cretaceous and early Tertiary time the interior physiographic region was translated west several hundred kilometers along the Tintina and Denali faults (fig. 3). These faults, in turn, were followed by counterclockwise rotation that displaced preexisting transcurrent faults.

Tectonic movements along the transcurrent faults controlled depositional environments of the Tertiary coal-bearing rocks in the interior and southern Cordillera regions (Flores and Stanley, 1995). Movements, particularly along the Denali fault, dammed flow-through fluvial systems that drained alluvial plains north and south of the Alaska Range, where peat precursors accumulated in associated mires. Damming of the fluvial systems created lakes, which in turn drowned peat-forming mires north of the Alaska Range. In addition, damming of fluvial systems shortened their headwaters, promoting erosion, high sediment dispersal, and consequently drowning of peat mires by detritus south of the Alaska Range.

Origin of Alaska Coal

Coal, containing more than 50 percent by weight and more than 70 percent by volume of organic matter, is composed of plant remains deposited as peat (Schopf, 1956). The vegetal remains accumulated under mainly reducing conditions beneath the ground-water table in mires or swamps. The high acidity of the water killed bacteria and fungi that would

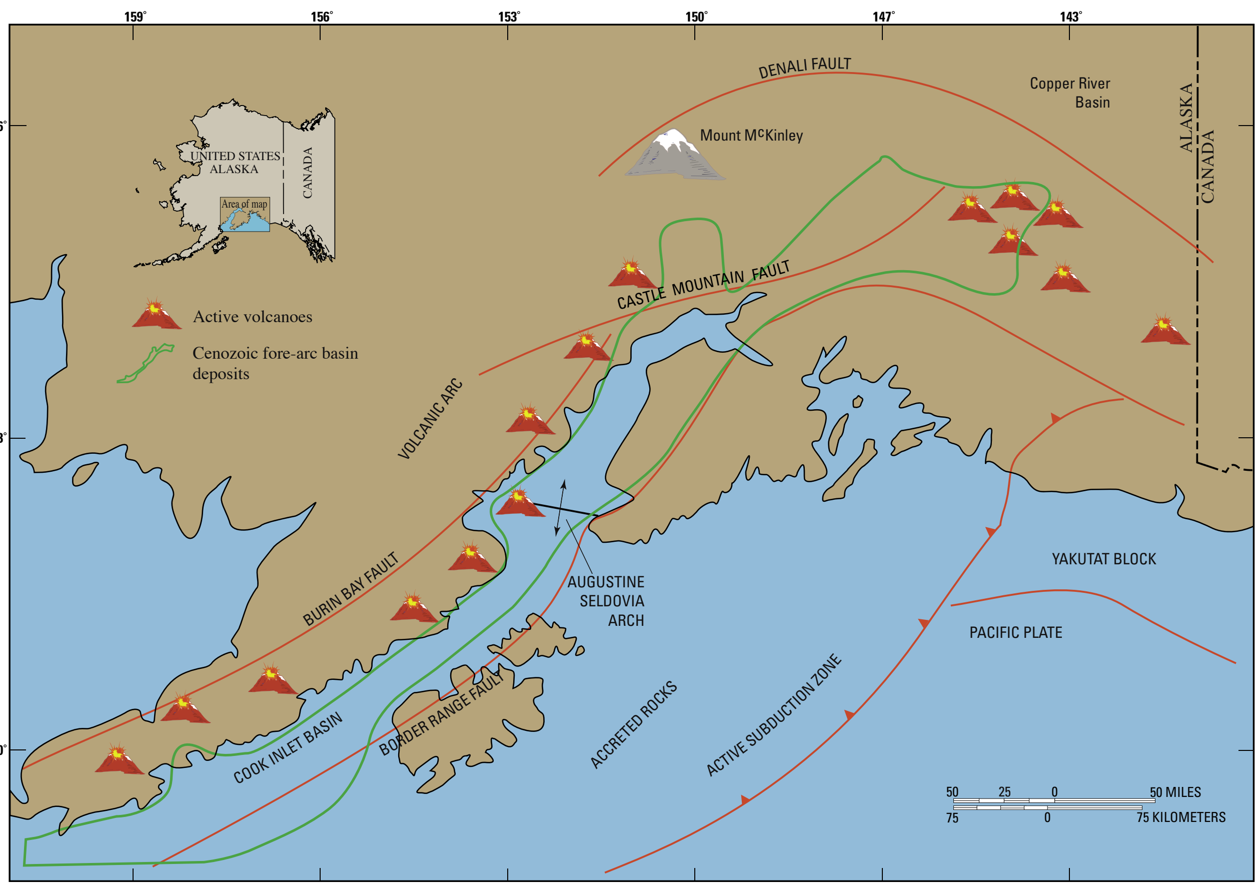


Figure 5. General tectonic framework of the Cook Inlet Basin, associated subduction zone, accreted terranes, and volcanic arc. Modified from Swenson (1997).

otherwise have digested and completely oxidized the peat (Schopf, 1956).

Peat-forming mires developed mainly in alluvial and coastal plains that were drained by fluvial and deltaic distributary channels (Flores and Stricker, 1993a and b). Commonly, the coastal plains were barred seaward by barrier-bar systems that protected back-barrier mires from active marine sedimentation, permitting accumulation of peat deposits (Flores, Stricker, and Stiles, 1997; Flores and others, 1999). Abandoned areas in the coastal plains, which were far removed from active sedimentation, also served as platforms for peat-mire development. In active sedimentation areas of the coastal plains, dense vegetation along margins of the mires juxtaposed with fluvial and distributary channels prevented flood water invasions and permitted peat accumulation. In regions where high rainfall rates existed, mires developed a raised topography that shielded them from sedimentation from adjoining rivers, particularly during floods. Preservation of these peat mires resulted from rapid subsidence, which promoted accommodation space and initiated burial of the peat deposits by overlying sediments, which led to subsequent compaction and metamorphism into coal.

The alluvial- and coastal-plain areas and associated mires in Alaska were formed from Paleozoic to late Tertiary time. The peat that accumulated in Alaska mires formed low-sulfur (average 0.3 percent) coal deposits, whereas in many other regions of the world, encroachment of the sea over peat-forming environments commonly brought sulfate-bearing sediments that transformed the peat into high-sulfur deposits. Additionally, when sediments flood portions of the peat mires, an increased pH typically enhances microbial activity within the top of the peat, which concentrates sulfur through degradation of plant material. Flooding of the mires also led to an increase of ash content of the peat due to settling of water-borne sediments.

Climate and (or) vegetation types may explain the accumulation of low-sulfur coal unique to Alaska, regardless of age. That is, the Alaskan coal contains low sulfur because of accumulation in mires developed in high paleolatitudes and in temperate paleoclimatic conditions (Affolter and Stricker, 1988, 1990). Alternatively, the vegetation may have evolved through time such that tropical or low paleolatitudinal plants became adapted to mires developed in high-paleolatitudinal regions.

The Alaskan peat-forming environments formed in depositional basins that were developed in the interior and margins of the State. Riverine plains, in which mires accumulated economic coal deposits, drained the interior basins (for example, Central Alaska-Nenana coal province; see fig. 1). Fluvial and deltaic coastal plains with associated mires accumulated economic coal deposits in margin basins (Northern Alaska-Slope and Southern Alaska-Cook Inlet coal provinces; see fig. 3). Coal that formed in these basins ranges from Mississippian to Miocene in age. The basins underwent detrital infilling after accumulation of the peat deposits followed by tectonic deformation that transformed these deposits into various ranks of coal.

The rank of a coal is a measure of the metamorphism that took place since deposition of the peat, due primarily to depth of burial, temperature, time, and pressure (Teichmüller and Teichmüller, 1968). The Earth's temperature increases with depth of burial (geothermal gradient), and the temperature necessary to metamorphose the peat to coal probably does not exceed 300˚–390˚F (150˚–200˚C). Time also plays an important role in coal rank because it controls coal composition. For example, peat coal buried for 50–65 Ma will contain higher volatile matter (subbituminous rank) than coal buried for 200 Ma, which contains low volatile matter (bituminous rank). Thus, Tertiary coals are generally subbituminous, and Cretaceous and Carboniferous coals are usually bituminous. This broad generalization, however, is not applicable in many geologic settings in Alaska. Along ancient plate margins and volcanic island arcs, where heat was produced either by igneous intrusions and volcanism or by increased pressure caused by tectonic compaction and compression, can increase coal rank, such as in the Matanuska coalfield.

Coal Metamorphism, Composition, Rank, and Occurrence

Metamorphism of peat results in transformation of plant parts (stems, leaves, and so forth) into macerals in coal. The plant vascular tissue parts such as cell walls (for example, cellulose and lignin of wood, leaves, roots, and humic cell contents) are transformed into a vitrinite (huminite) maceral, initially high in both oxygen and hydrogen. Plant waxes, secretions, resins, spores, and algae are converted into an exinite (liptinite) maceral that is high in hydrocarbons (fats and oils). Carbonized plant parts, the product of oxidation of organic matter, are changed into an inertinite maceral—for example, fossil charcoal or fusinite.

Varying degrees of metamorphism produce different maceral types. The vitrinite, exinite, and inertinite, which were formed by intense metamorphism, are unique to high-rank coal (for example, bituminous and anthracite). Low degree of coalification by less intense metamorphism yields a different physical category of macerals for low-rank coal such as in subbituminous coal and lignite. The vitrinite and exinite macerals may be correlated to huminite and liptinite macerals, respectively, in subbituminous coal and lignite (Stach, 1968; Neavel, 1981; Stach and others, 1982; Stanton and others, 1989). Economic properties of coals depend on the proportions of macerals, and the classification into various types is based on these proportions. Rao (1980), Rao and Wolff (1981), and Rao and Smith (1986) performed several petrographic studies of Alaskan coals, which show that coal rank and its suitability for various economic uses depends on moisture content, ash yield, and sulfur content.

Table 1. Coal resource estimates for Alaska using the classification of Wood and others (1983).
[Resource estimates are in millions of short tons (multiply by 0.9072 to convert to metric tonnes)]

Coal province, coalfield, and age		Resource Classifications			
		Identified			Undiscovered
		Demonstrated		Inferred	Hypothetical
		Measured	Indicated		
Northern Alaska-Slope	Tertiary				670,000[a]
	Cretaceous	120,000[c]			3,200,000[a]
Total for Northern Alaska-Slope		**120,000**			**3,900,000**
Central Alaska-Nenana	Healy Creek	1,000[b]–1,360[c]			2,000[b]
	Lignite Creek	4,100[c]–4,900[b]			7,000[b]
	Jarvis Creek	13[e]–77[c]			175[b]
	Wood River	15[c]	45[c]	241[c]	
	Wood River	275[b]			350[b]
	Rex Creek		9.5[c]	113[c]	
	Rex Creek	70[b]			130[b]
	Tatlanika Creek		117[c]	153[c]	
	Tatlanika Creek	290[b]			400[b]
Total for Central Alaska-Nenana		**6,400–7,700**			**10,000**
Southern Alaska-Cook Inlet	Matanuska	137[c]–200[g]			2,400[i]
	Susitna-Beluga	2,400[c]–11,100[b]			34,800[b]
	Broad Pass	0.3[f]–64[c]			13[f]–500[b]
	Kenai (onshore)	318[c]–400[h]			34,000[e]–35,000[b]
	Kenai (offshore)				900,000[d]–1,500,000[b]
Total for Southern Alaska-Cook Inlet		**2,900–12,000**			**970,000–1,600,000**
Total coal resources for Provinces		**129,000–140,000**			**4,900,000–5,500,000**

Source of estimate: (a) Stricker (1991); (b) Merritt and Hawley (1986); (c) Barnes (1967); (d) Affolter and Stricker (1987); (e) McGee and Emmel (unpublished report, 1979, Alaska Division of Geological and Geophysical Surveys, Fairbanks, Alaska); (f) Hopkins (1951); (g) Merritt and Belowich (1984); (h) Barnes and Cobb (1959); and (i) Renshaw (1983).

The occurrence of different ranks of coal in Alaska may be related to juxtaposition with deformed belts and igneous intrusions. For example, the bituminous coal in the North Slope coalfields, which are juxtaposed to the Brooks Range deformed belt (synclines, anticlines, and thrust and strike-slip faults), is higher rank than the subbituminous coal away from the deformed belt (see fig. 1). In the Southern Alaska-Cook Inlet coalfields, the coal changes from anthracite to bituminous to subbituminous from east to west in the northeast part of the inlet in the Matanuska coalfield (see fig. 1). There, the Matanuska coalfield is bounded by the Talkeetna Mountains and flanked by the Castle Mountain Fault on the north and by the Chugach Mountains on the south (see fig. 3). In addition, numerous volcanic rocks have intruded into the coal-bearing rocks.

Coal Resource Classification

Wood and others (1983) defined the terminology used in this report for coal resource classification and estimates. The categories of the coal resource classification, arranged in the degree of decreasing geologic assurance as to nearness to points of control and the relative quality and quantity of geologic data, are (1) measured, (2) indicated, (3) inferred, and (4) hypothetical. The sum of the measured and indicated resources is termed demonstrated resource. The sum of the measured, indicated, and inferred is termed identified resource. The state of certainty of the existence of a quantity of resource is also based mainly on correlations of coal beds and enclosed rocks in relation to the thickness, overburden, rank, quality, and areal extent of the coal.

1. Measured coal resources have the highest degree of geologic assurance. Resource estimates are based partly on measurements from outcrops, trenches, drill holes, and mine workings and partly on thickness projection of correlatable beds, coal rank, and geologic data (not more than a specified distance and depth). The area of measured coal resources is within 0.25-mi (0.4-km) radius.

2. Indicated coal resources have a moderate degree of geologic assurance. Estimates of resources are based on projection of coal thickness and other geologic data from outcrops, trenches, mine workings, and drill holes for specified distance and depth beyond those used for the measured resources. The area of indicated coal resources is between 0.25 and 0.75 mi (0.4 and 1.2 km) radii.

3. Inferred coal resources have a low degree of geologic assurance. Estimates of resource are calculated by projection of thickness, sample, and geologic data from distant outcrops, trenches, workings, and drill holes for a specified distance and depth beyond those used for indicated resources. The area of inferred coal resources is between 0.75 and 3 mi (1.2 and 4.8 km) radii. Estimates of coal thickness, extent, and quantity are based on inferred continuity, beyond measured and indicated resources, for which there is geologic evidence.

4. Hypothetical or undiscovered coal resources have the lowest degree of geologic assurance of these categories. Estimates of coal thickness, extent, and quantity are based on measurements and continuity of coal beyond parameters used in the inferred resources. The area of hypothetical coal resources is beyond a 3-mi (4.8-km) radius.

Table 1 shows the coal-resource classification system of Alaska using the concepts of Wood and others (1983). The estimates are determined from previous works (Wahrhaftig and Hickcox, 1955; Barnes and Cobb, 1959; Barnes, 1967a; McGee and Emmel, written commun., 1979; Merritt and Belowich, 1984; Merritt and Hawley, 1986; Sable and Stricker, 1987; Stricker, 1991; Wahrhaftig and others, 1994), which used different resource categories. For the present study, we analyzed and synthesized the various coal resource assessments of these workers and reconstructed them following the coal-resource classification system of the U.S. Geological Survey (Circular 891). The revision of the Alaska coal resource assessments here presented provides (1) a simplified and unified account of the coal resources; (2) a uniform application of the guidelines and principles outlined in Wood and others (1983); (3) standardized coal resource estimates comparable to those by different workers using the same data; and (4) some idea as to economic availability of the coal. Measurements are reported in English units followed by metric units given in parentheses.

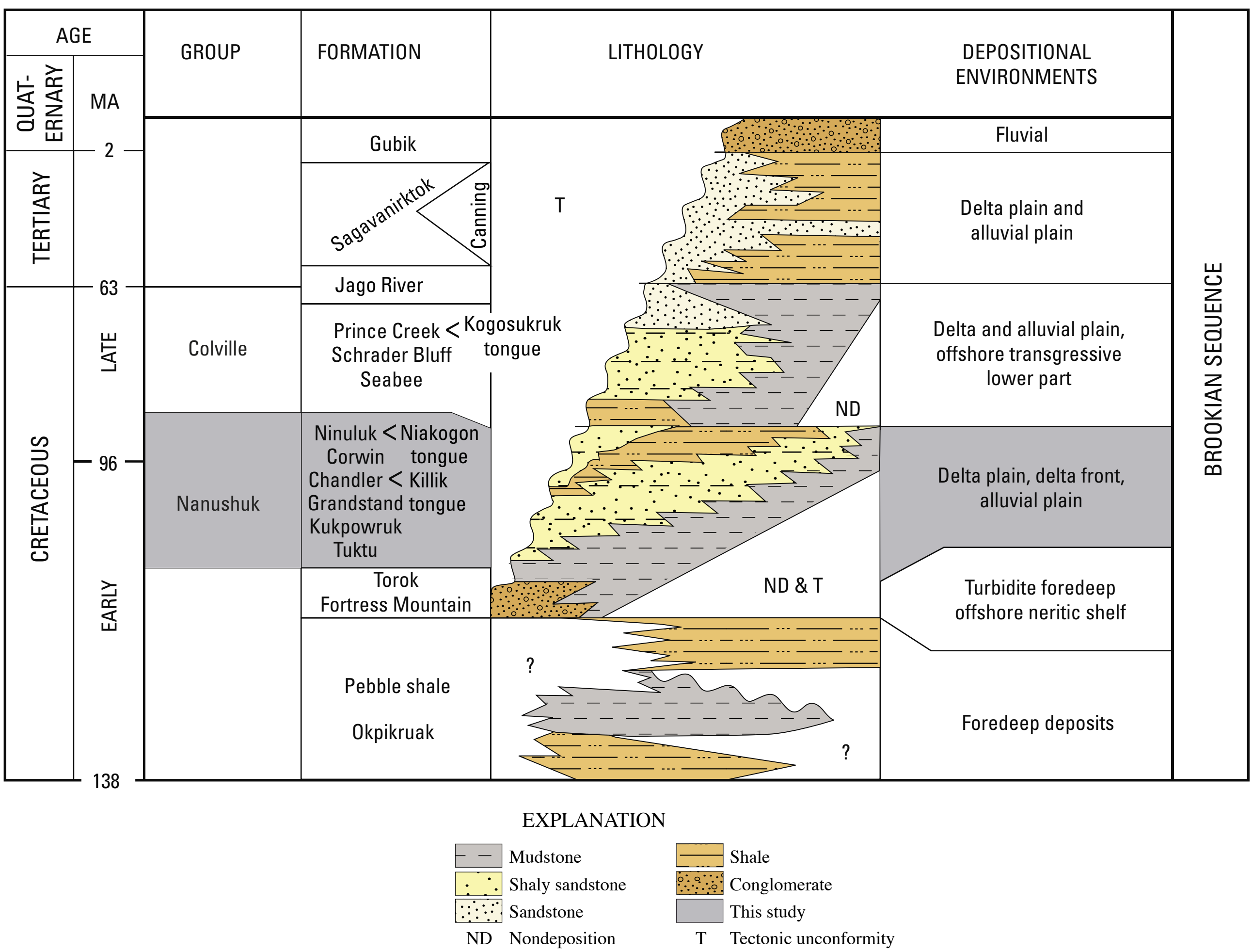


Figure 6. Stratigraphic column of the Mesozoic and Cenozoic rocks in the Northern Alaska-Slope coal province. Modified from Sable and Stricker (1987).

Distribution of Coal in Alaska

Wood and Bour (1988) identified 50 coalfields and occurrences in Alaska (fig. 1). A coalfield is a discrete area that contains coal-bearing strata with one or more coal beds. Coal occurrence is an outcrop that contains one or more coal beds that are isolated and cannot be correlated to other coal-bearing outcrops. The bulk (87 percent) of the known coal resources of Alaska are in the three previously mentioned coal provinces: (1) the Northern Alaska-Slope, (2) Central Alaska-Nenana, and (3) Southern Alaska-Cook Inlet coal provinces (modified from Wahrhaftig and others, 1994; fig. 1). The bulk of the resources in Northern Alaska-Slope coal province are contained in the Cretaceous and Tertiary coal-bearing rocks. The coal resources in the Central Alaska-Nenana and the Southern Alaska-Cook Inlet are contained in Tertiary rocks.

Northern Alaska-Slope Coal Province

The Northern Alaska-Slope coal province (fig. 1) is the largest in the State. It is situated at lat 69°N. and includes about 32,000 mi^2 (82,880 km^2) underlain by coal-bearing rocks, both near the surface and in the deep subsurface (see figs. 2 and 3). Rocks in this coal province range in age from Precambrian to Holocene; a representative columnar section is shown in figure 6.

The Northern Alaska-Slope coal province (fig. 1) consists of Cretaceous and Tertiary sedimentary wedges shed to the north-northeast from the Brooks Range during the Laramide orogeny. Sedimentary wedges were also shed eastward from now-collapsed highlands in the present Chukchi basin, into a deep trough that lay between the Brooks Range and the Barrow arch. The coal-bearing rocks were deposited in coastal plains drained by fluvial and deltaic distributary channels that flowed into the ancestral Beaufort Sea. Peat coal was deposited mainly in mires in highly constructive (river-dominated), progradational delta plains (for example, Corwin and Umiat deltas of Ahlbrandt and others, 1979; Roehler and Stricker, 1979; Huffman and others, 1985). Although these deltas were highly constructional systems, they were increasingly influenced by marine transgressions resulting in destructive deltas (Huffman and others, 1985, 1988). Sea-level rise reworked the deltaic sediments into barrier bars forming back-barrier mires. Deltaic sediments grade updip toward the Brooks Range uplift into coarse fluvial sediments (sandstones and conglomerates) that were deposited in alluvial fans and braided and meandering rivers. The Cretaceous and Tertiary coal deposits, combined in the Northern Alaska-Slope coal province, are the largest in Alaska. The remoteness of these coal deposits and the formidable logistic and environmental problems that come with their exploitation make them presently uneconomic. However, because of planned infrastructures (for example, gas pipeline), these coal deposits may be targeted for future coalbed methane development.

Cretaceous Rocks

The most important Cretaceous coal-bearing rocks in the Northern Alaska-Slope province are in the Nanushuk and Colville Groups (Collier, 1906; Tailleur, 1965; Barnes, 1967b; Conwell and Triplehorn, 1976; Bird and Andrews, 1979; Molenaar and others, 1984; Stricker, 1991). It should be noted that coal deposits also occur in Mississippian rocks, but they are of minor importance and are not discussed in this report.

Coal at Corwin Bluffs, on the Chukchi Sea north of Cape Lisburne, was mined as early as 1879 for use in whaling ships (Schrader, 1904). Various mining companies have carried out preliminary investigations since 1944. During a fuel shortage in Point Barrow from 1943 to 1944, at least one small mine was in operation on the Meade River (Clark, 1973). Although the Meade River coal mine demonstrated the feasibility of mining under permafrost conditions, active mining has yet to materialize in the Northern Alaska-Slope coal province.

Collier (1906) first described the Cretaceous coal deposits at Corwin Bluff. Later studies showed that coal occurs in outcrops in the foothills belt (Chapman and Sable, 1960) and beneath the Arctic coastal plain (Tailleur and Brosgé, 1976). Cretaceous coal-bearing rocks probably also exist beneath the Chukchi Sea (Grantz and others, 1975; Affolter and Stricker, 1987b) and the Beaufort Sea (Affolter and Stricker, 1987b).

Nanushuk Group

The Lower Cretaceous Nanushuk Group includes, from bottom to top, the Tuktu, Kukpowruk, Grandstand, Chandler, Corwin, and Ninuluk Formations (fig. 6); thickness is as much as 9,800 ft thick (3,000 m). It consists of a marine sequence that includes the Kukpowruk, Tuktu, and Grandstand Formations and a nonmarine sequence that includes the Corwin Formation and the Killik Tongue of the Chandler Formation (Sable and Stricker, 1987). Approximately 150 coal beds, with individual beds ranging from a few inches (a few centimeters) to 20.2 ft (6.1 m) thick, occur in the middle and upper parts of the Nanushuk Group (Callahan and Sloan, 1978). Rocks exposed at Corwin Bluffs include coal beds from 5.5 to 8.8 ft thick (1.7 to 2.7 m) (fig. 7), and those at Cape Beaufort contain coal beds 11 to 17 ft thick (3.4 to 5.2 m). Along the valley walls of the Kukpowruk River, a coal bed as much 20.2 ft thick (6.1 m) was described by Sanders (1981). Barnes (1967b) reported as many as 60 coal beds within a 4,600-ft-thick (1,400-m) sequence in the Koalak area. Many of these coal beds are of bituminous and subbituminous rank. A net coal thickness greater than 350 ft (106 m) in the Nanushuk Group in this area and surrounding western part of the National Petroleum Reserve-Alaska (NPRA) is shown in figure 8.

The Nanushuk Group consists of an offlap, postorogenic molasse sequence deposited on a passive continental margin.

Figure 7. Photograph of a coal bed (about 20 feet thick) in the Nanushuk Group.

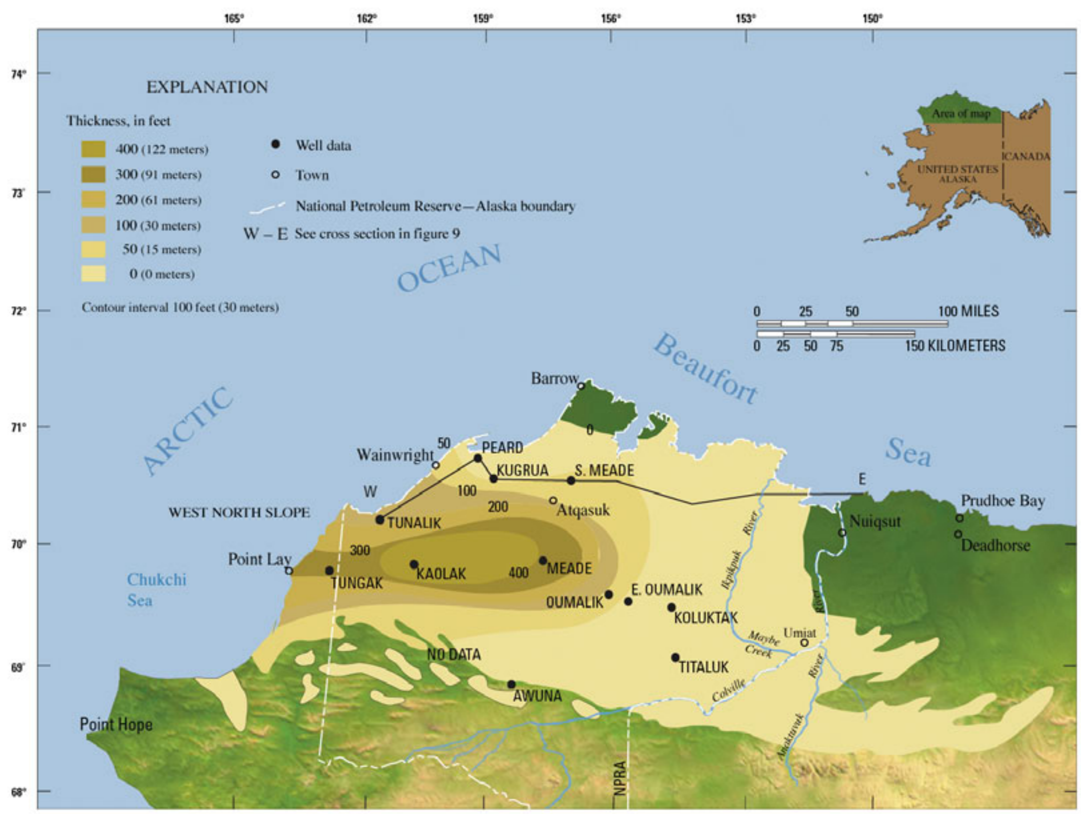


Figure 8. Net coal thickness map of the Nanushuk Group in the western part of the Northern Alaska-Slope coal province. See figure 9 for line of cross section. Modified from Sable and Stricker (1987).

The progressive progradational relation of the sedimentary units of the Nanushuk Group is depicted in figure 9. The strata were deposited by fluvial-dominated systems of the Corwin delta in the western part and the Umiat delta in the central part of the Northern Alaska-Slope coal province (Ahlbrandt and others, 1979; Huffman and others, 1985).

The Kukpowruk Formation in the western part of the Northern Alaska-Slope coal province consists of delta front-shoreline deposits that grade upward and intertongue with the nonmarine, coal-bearing Corwin and Chandler Formations (fig. 6). The Kukpowruk Formation, composed mainly of delta-front sandstones, ranges in thickness from 2,000 to 3,900 ft (610 to 1,200 m) in the outcrop belt in the northern foothills. The Corwin Formation consists of alluvial and delta-plain shale, sandstone, conglomerate, and coal (Roehler and Stricker, 1979). This formation, although more than 11,300 ft thick (3,450 m) at Corwin Bluffs along the Arctic coast, thins eastward to zero in the subsurface near the Colville River.

In the central Northern Alaska-Slope coal province, the rock succession consists of complexes of nonmarine and marginal marine rocks overlying and intertonguing with marine rocks. The marginal marine to marine (basin shelf-slope) Tuktu Formation, more than 8,000 ft thick (2,400 m), intertongues with the delta-front and lower delta-plain Grandstand Formation (fig. 6). The Grandstand Formation is overlain by, and intertongues with, the Killik Tongue of the Chandler Formation, which is an upper delta-plain rock unit. In the upper part of the stratigraphic section, a tongue of the Ninuluk Formation, which intertongues with the overlying Niakogon Tongue (fig. 6), overlies the Killik Tongue. Molenaar (1985) indicated that the Seabee Formation of the Colville Group interfingers with both the Ninuluk Formation and Niakogon Tongue of the Chandler Formation.

As depicted in figure 9, the vertical stacking of shoreline deposits of the Grandstand Formation marks a progradational sequence that may be correlated with the occurrence westward (landward) of numerous thick coal beds in the Corwin Formation. The progradational or regressive phase led to the stacking of shoreline deposits at the regressive maximum, which was described by Fassett and Hinds (1971), Ryer (1981), and Flores and Cross (1991). These studies have shown that most coal beds occur at the top, and landward, of shoreline deposits

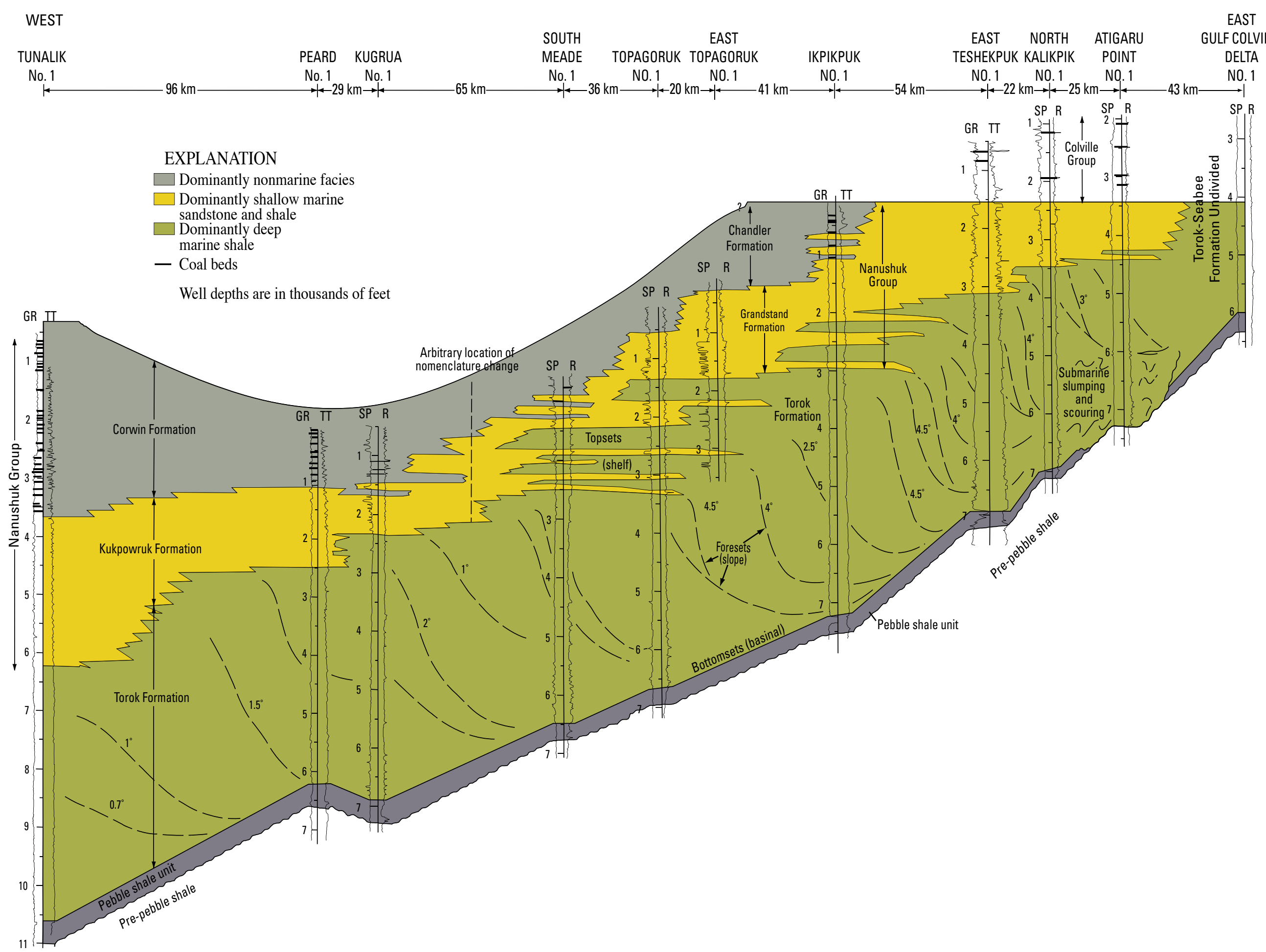


Figure 9. Cross section showing the Nanushuk progradation sequences. Modified from Molenaar, (1985). See figure 8 for location of the cross section.

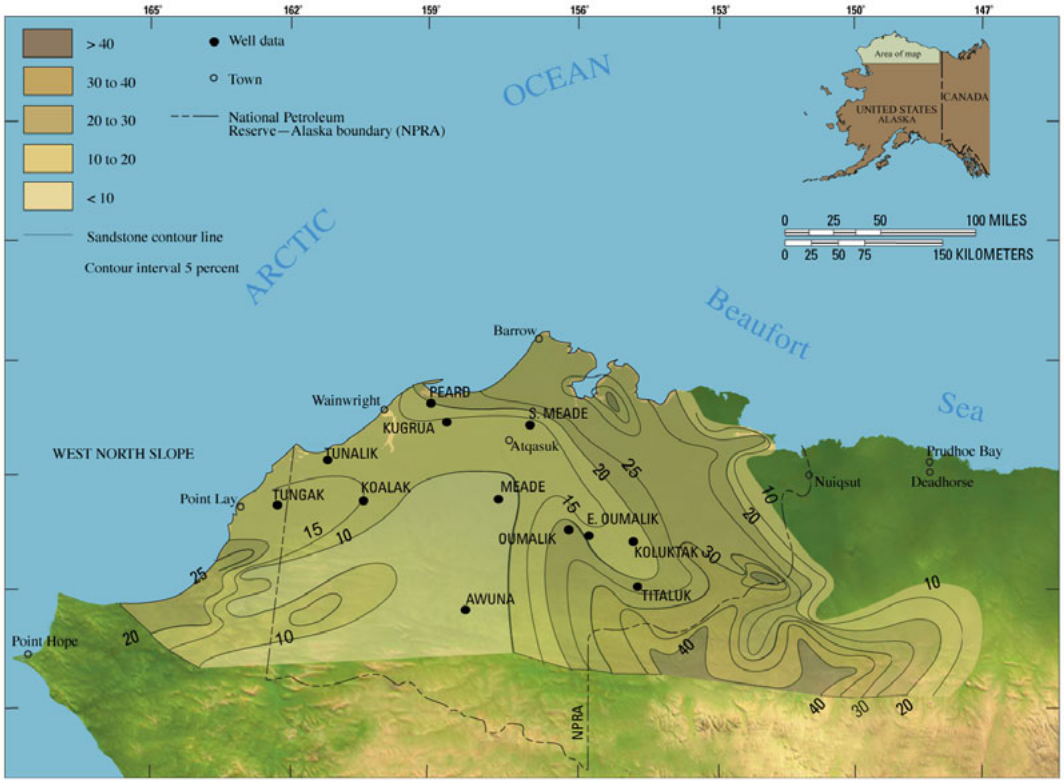


Figure 10. Sandstone percentage contour map in the Northern Alaska-Slope coal province. Modified from Huffman and others (1985).

from progradational events. However, the thickest coal, most extensive, and greatest volume of coal occur preferentially in stratigraphic positions where the shoreline deposits of successive progradational events are stacked vertically (Flores and Cross, 1991).

The Umiat deltaic sediments reflect a higher degree of reworking than the Colville deltaic sediments as indicated by a larger sandstone percentage (fig. 10; Ahlbrandt and others, 1979; Huffman and others, 1985). The Umiat delta (fig. 11A–D), probably being derived from a smaller source, also contains a smaller sediment volume than does the Corwin delta. Molenaar (1981, 1985) suggested that the Corwin delta formed earlier than the Umiat delta and that the two merged during Albian time without specific demarcation (fig. 11A–D). The Corwin delta continued to be the dominant depositional feature. The Meade arch, which extended southward from Point Barrow in Brookian time, probably did not play an active part in controlling the depocenters of the deltas. Paleogeographic interpretations of Nanushuk deposition by Molenaar (1981, 1985) and Huffman and others (1985) stressed the dominant east-northeast progradation of the Nanushuk prodelta slope sediments. These studies also showed a strong northwestward concentration of sandstone in the upper part of the Nanushuk Group, from Umiat toward Point Barrow and parallel to the paleoshoreline. This concentration also indicates that northwestward longshore currents probably transported sand from the Umiat delta along the active shelf of the Corwin delta front (Huffman and others, 1985). The sand accumulation represents offshore bars that shielded coastal plain-back barrier mires from detrital sedimentation, resulting in the most prolific coal-forming Nanushuk deltaic environments in the western Northern Alaska-Slope coal province.

Spicer (1987) reported that the paleoclimate of the North Slope during Albian to Cenomanian time was cool temperate with annual temperature varying 5°–50°F (3°–10°C). Rainfall was sufficient to sustain the vegetation of peat mires, resulting in thick accumulation of peat deposits. Tree growth rings on the North Slope indicate a rapid change from summer to winter conditions during the Albian to Cenomanian (Spicer, 1987). Precipitation was also distributed throughout the year in a manner to preclude oxidation and loss of organic material in the peat mires. However, Rao (1980) reported that there was a drying upward trend in the peat mires.

Colville Group

The Upper Cretaceous Colville Group, a Brookian sequence younger than the Nanushuk Group, contains, from bottom to top, the Seabee, Schrader Bluff, and Prince Creek Formations (see fig. 6). The group is as much as 5,000 ft (1,525 m) thick, consists of a marine interval (Seabee Formation), marine interval (Schrader Bluff Formation), and a coal-bearing, nonmarine interval (Prince Creek Formation).

The coal beds of the Colville Group in the vicinity of Umiat and Maybe Creek (see fig. 8) vary individually from 13

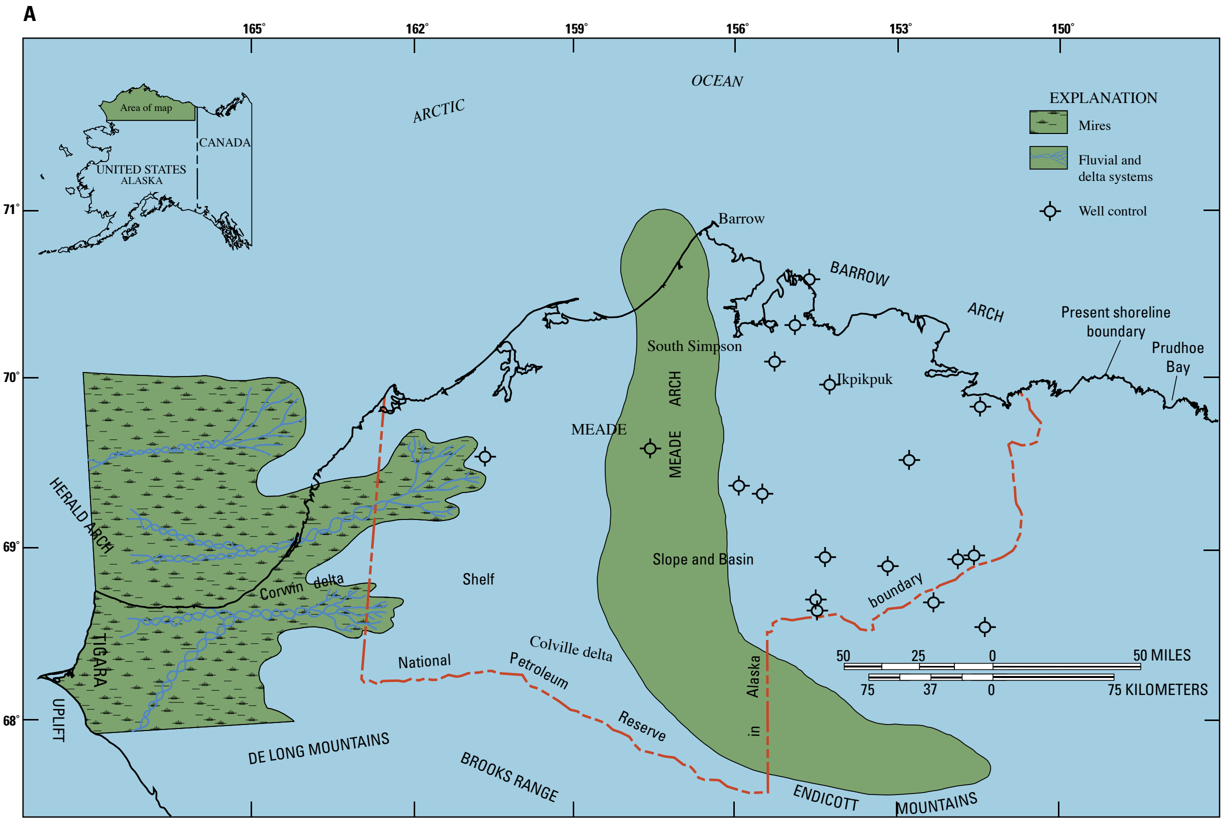


Figure 11. Paleogeographic maps showing the depositional environments of the Nanushuk Group in the central Northern Alaska-Slope coal province. A, Early to middle Albian time. Modified from Huffman and others (1985).

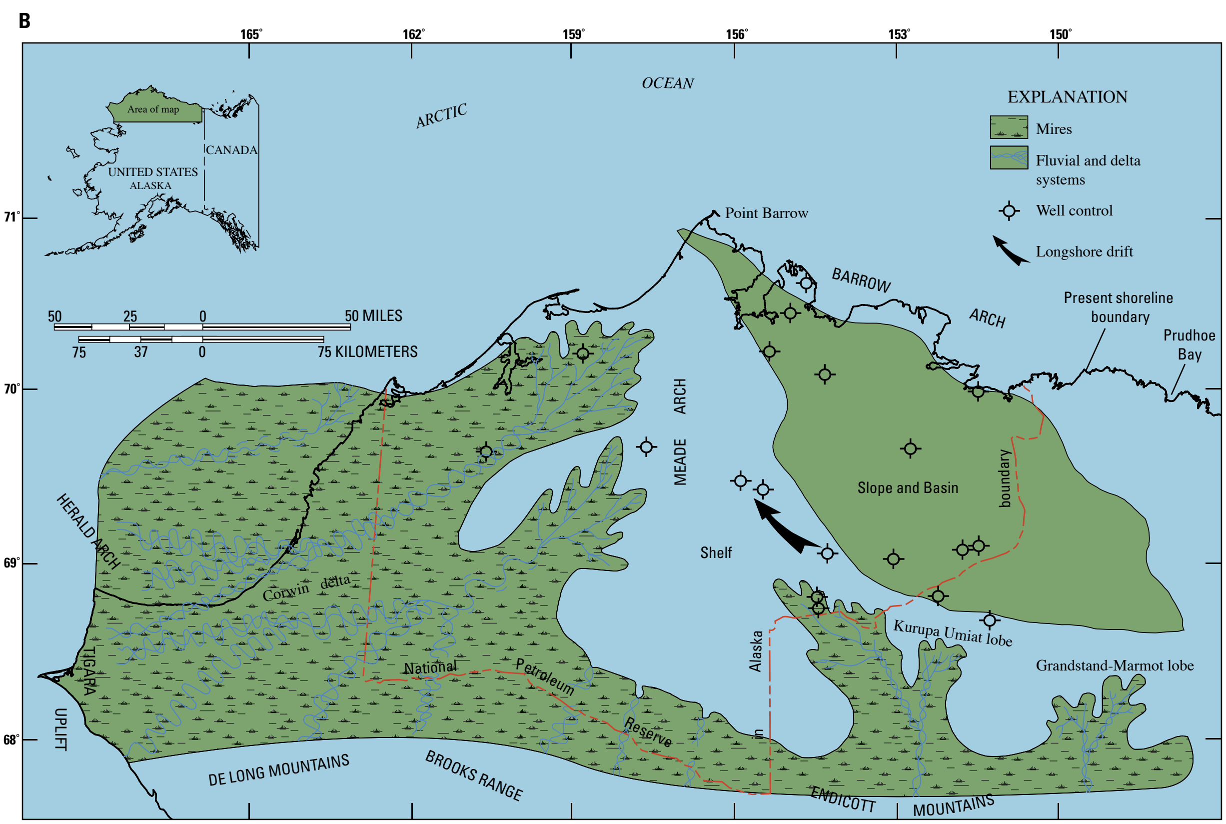


Figure 11. Paleogeographic maps showing the depositional environments of the Nanushuk Group in the central Northern Alaska-Slope coal province. B, Middle to late Albian time. Modified from Huffman and others (1985).

C

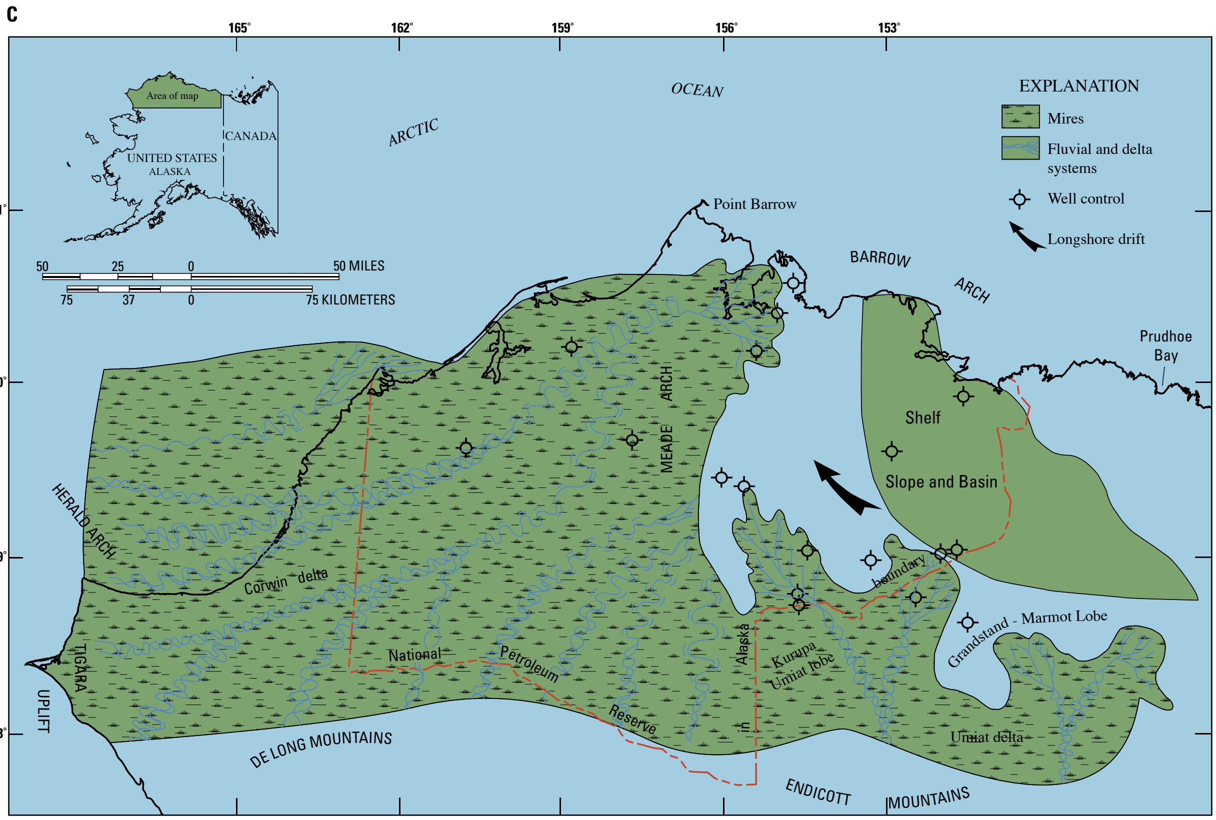


Figure 11. Paleogeographic maps showing the depositional environments of the Nanushuk Group in the central Northern Alaska-Slope coal province. C, Late Albian to Cenomanian (?) time. Modified from Huffman and others (1985).

D

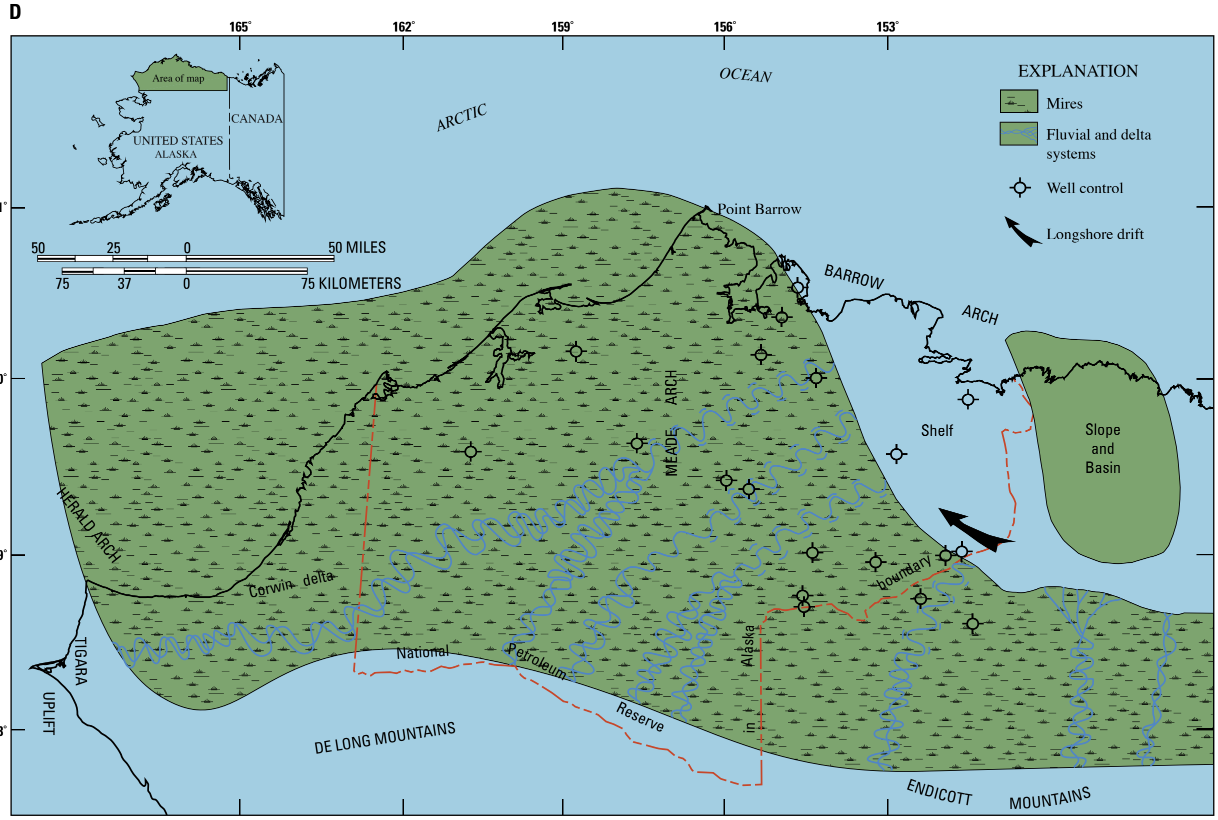


Figure 11. Paleogeographic maps showing the depositional environments of the Nanushuk Group in the central Northern Alaska-Slope coal province. D, Cenomanian time (maximum regression). Modified from Huffman and others (1985).

to 39 ft (4 to 12 m) thick (Brosgé and Whittington, 1966). On the lower Colville River, the coal beds of the Colville Group range from 13 to 39 ft (4 to 12 m) thick (Brosgé and Whittington, 1966). Coal beds in the subsurface are typically less than 39 ft (12 m) thick with a 19-ft-thick (6 m) zone of coal interbedded with black shale and bentonite described from the Square Lake Test Well No. 1 core as a bony coal (Collins, 1959).

Recent work by R.M. Flores and G.D. Stricker and other geologists from the USGS (Dave Houseknecht and Ken Takahashi) and Alaska Division of Oil and Gas Commission (Mark Myers, Don Brizzolara, and Tim Ryherd) in July, 2002 of outcrops of the Kogosukruk Tongue (see fig. 6) of the Prince Creek Formation at the bluffs along the Colville River below the mouth of the Anaktuvuk River (see fig. 8) shows coal beds ranging from a few inches (a few centimeters) to as much as 9 ft (2.7 m) thick (fig. 12). Upstream from this outcrop, the Kogosukruk Tongue is underlain by the upper part of the Sentinel Hill Member of the Schrader Bluff Formation, which is composed of coarsening-upward bentonitic mudstone, siltstone, and sandstone; the sandstone thickens and coarsens upward. The uppermost sandstone bed of the Sentinel Hill Member, which is rooted at the top, in turn, is overlain by a 3.5 ft-thick coal-carbonaceous mudstone bed of the Kogosukruk Tongue, with both beds separated by an erosional surface or probably a sequence boundary. The coarsening-upward Sentinel Hill Member was probably deposited in a delta front. The coal-carbonaceous mudstone bed and overlying interbedded coal, bentonitic mudstone and siltstone, and medium-grained to pebbly conglomeratic, stacked erosional-based sandstone of the Kogosukruk Tongue were probably deposited in fluvial environments.

Coal beds of the Colville Group have been studied less than those of the Nanushuk Group because they have shown less economic potential; most are thinner, have a high ash yield, and are of lower rank than those in the Nanushuk Group. Many of these coals are described as lignites.

Cretaceous-Tertiary Rocks

The contact between the Cretaceous and Tertiary rocks in the Northern Alaska-Slope coal province was determined to be gradational or conformable by Molenaar (1983) and Molenaar and others (1984). This led to difficulty in defining a specific contact and also contributed to inclusion of the Upper Cretaceous formations of the Colville Group with the overlying Tertiary Sagavanirktok Formation. Molenaar (1983) described this contact as diachronous resulting from a depositional continuum from the Cretaceous to Tertiary time. That is, the Cretaceous deltaic systems (for example, Corwin delta) that prograded northeastward also continued this advance seaward during Tertiary time. Thus, the nonmarine and marine deposits

Figure 12. Photograph of interbedded coal, sandstones, siltstone, and mudstone of the Kogosukruk Tongue of the Prince Creek Formation along the lower Colville River downstream from the mouth of the Anaktuvuk River.

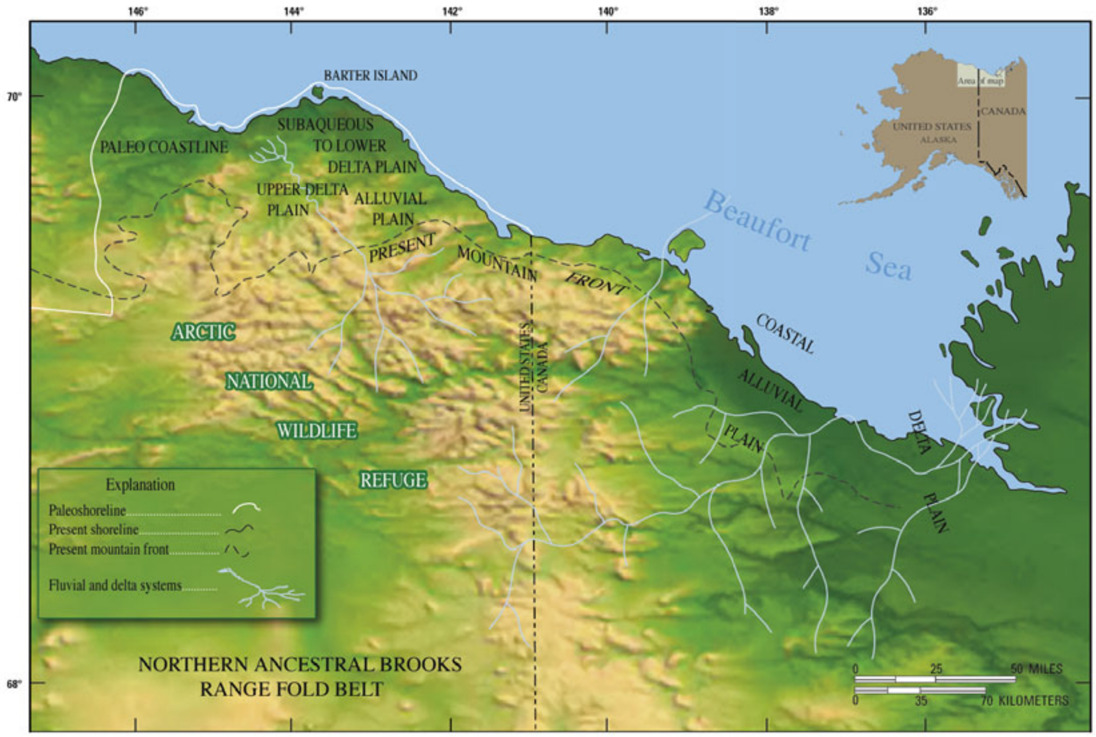


Figure 13. Paleogeographic map showing the depositional environments of the Jago River Formation in the Arctic National Wildlife Refuge area. Modified from Buckingham (1987).

of both deltaic systems blend imperceptibly into one another, and timelines are parallel to their depositional slopes. For example, the delta-front sands of these deltas deposited during the regression cross the sloping timelines and become younger toward the direction of progradation, which is northeastward.

The Cretaceous-Tertiary rocks in the Northern Alaska-Slope coal province include the Jago River and Sagavanirktok Formations (see fig. 6; Gryc and others, 1951; Detterman and others, 1975; Molenaar, 1983; Buckingham, 1987). The Jago River Formation was dated as Late Cretaceous to Paleocene based on pollen and plant fossils (Palmer and others, 1979; Detterman and Spicer, 1981; Buckingham, 1985). The Sagavanirktok Formation was dated as Paleocene to Pliocene (and may possibly be as young as Pleistocene) based on palynomorphs and microfossils (Molenaar and others, 1986). The Sagavanirktok Formation intertongues with the Canning Formation of the Colville Group (Molenaar and others, 1986).

Jago River Formation

The Jago River Formation, which was named and described by Buckingham (1987), is as much as 9,387 ft (2,861 m) thick. It consists of conglomerates, sandstones, siltstones, mudstones, carbonaceous shales, and coals. Buckingham (1987) divided the formation into four lithofacies units; from bottom to top these are (1) a delta-plain lithofacies—mainly sandstones and siltstones, as much as 928 ft (282 m) thick; (2) a meandering stream lithofacies (lower part)—mainly sandstones and subordinate conglomerates, siltstones, and coals, as much as 5,526 ft (1,685 m) thick; (3) a braided stream lithofacies—predominantly conglomerates and minor sandstones, as much as 2,228 ft (679 m) thick; and (4) a meandering stream lithofacies—mainly carbonaceous shales and minor sandstones conglomerates, as much as 702 ft (214 m) thick. The few coal beds that are in the Jago River Formation are associated with the meandering stream lithofacies and are thin and uneconomic.

The lithofacies of the Jago River Formation indicate that the rocks were deposited in a fluvial-dominated delta that was formed in close proximity to the ancestral Brooks Range (fig. 13). Through time the delta was prograded by a fan delta, which was subsequently replaced by a fluvial-dominated delta. This evolution of fluvio-deltaic systems may have been controlled by tectonism of the ancestral Brooks Range and (or) eustatic sea-level rise and fall. These fluvio-deltaic systems prograded to the north-northwest. Most coal-forming mires are related to these fluvial-dominated deltaic systems.

Sagavanirktok Formation

The Sagavanirktok Formation consists of a thick sequence of sandstones, siltstones, mudstones, conglomerates, carbonaceous shales, and coals (fig. 14). Thickness is as much as 7,500 ft (2,300 m) (Molenaar and others, 1986). Sandstones are the most abundant lithology (fig. 15). The formation is a generally coarsening-upward sequence with the lower part dominated by shaley tongues of the Canning Formation (Molenaar and others, 1986). There are at least three

Figure 14. Photograph of a coal bed underlain by a sandstone in the Sagavanirktok Formation. Photograph courtesy of S.B. Roberts. Hammer on the sandstone is 1 foot long for scale.

Figure 15. Photograph of fluvial-channel sandstone and associated rocks in the Sagavanirktok Formation. Photograph courtesy of S.B. Roberts.

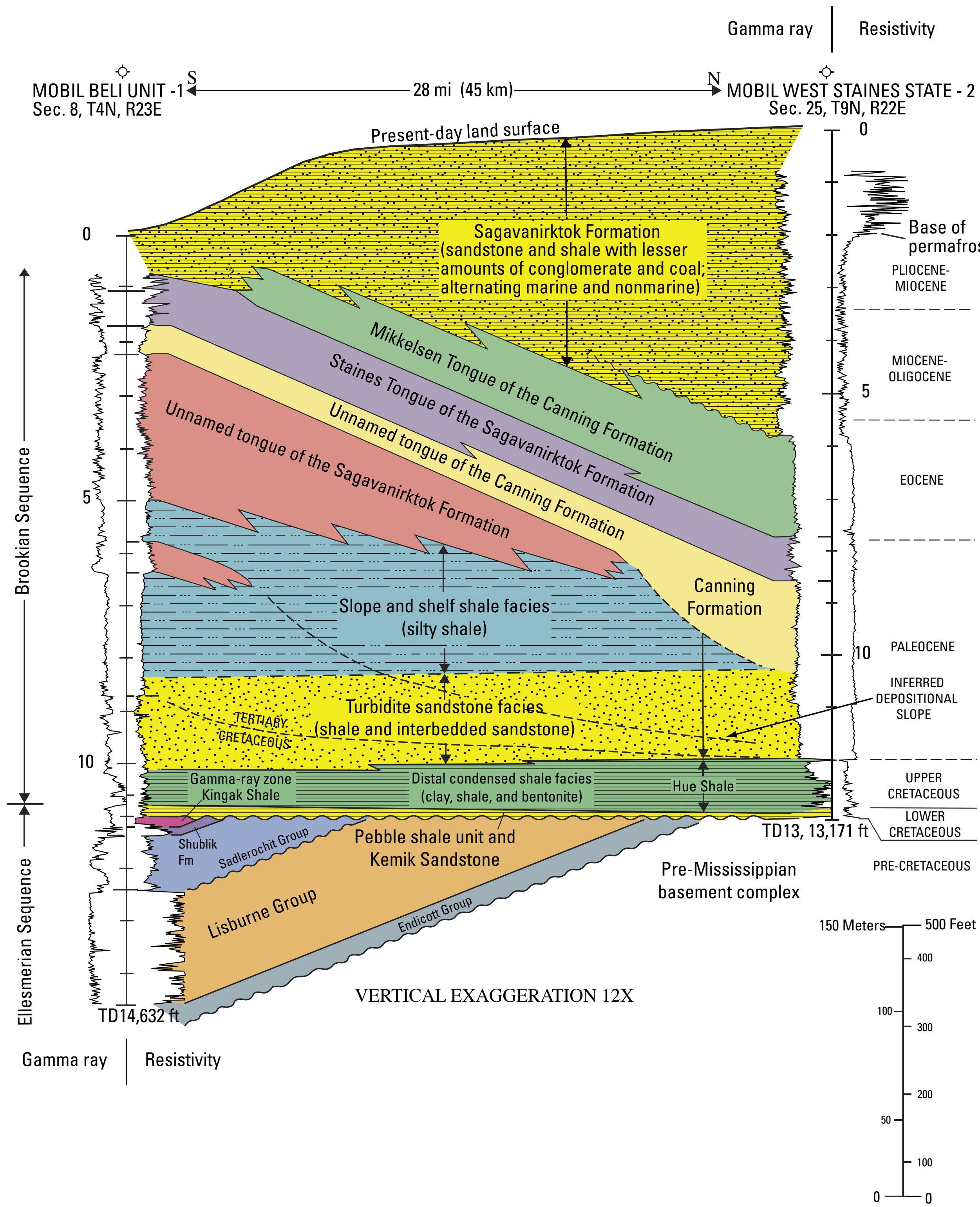


Figure 16. Stratigraphic cross section of the Tertiary Brookian sequence in the eastern part of the National Petroleum Reserve Alaska. Modified from Molenaar and others (1985).

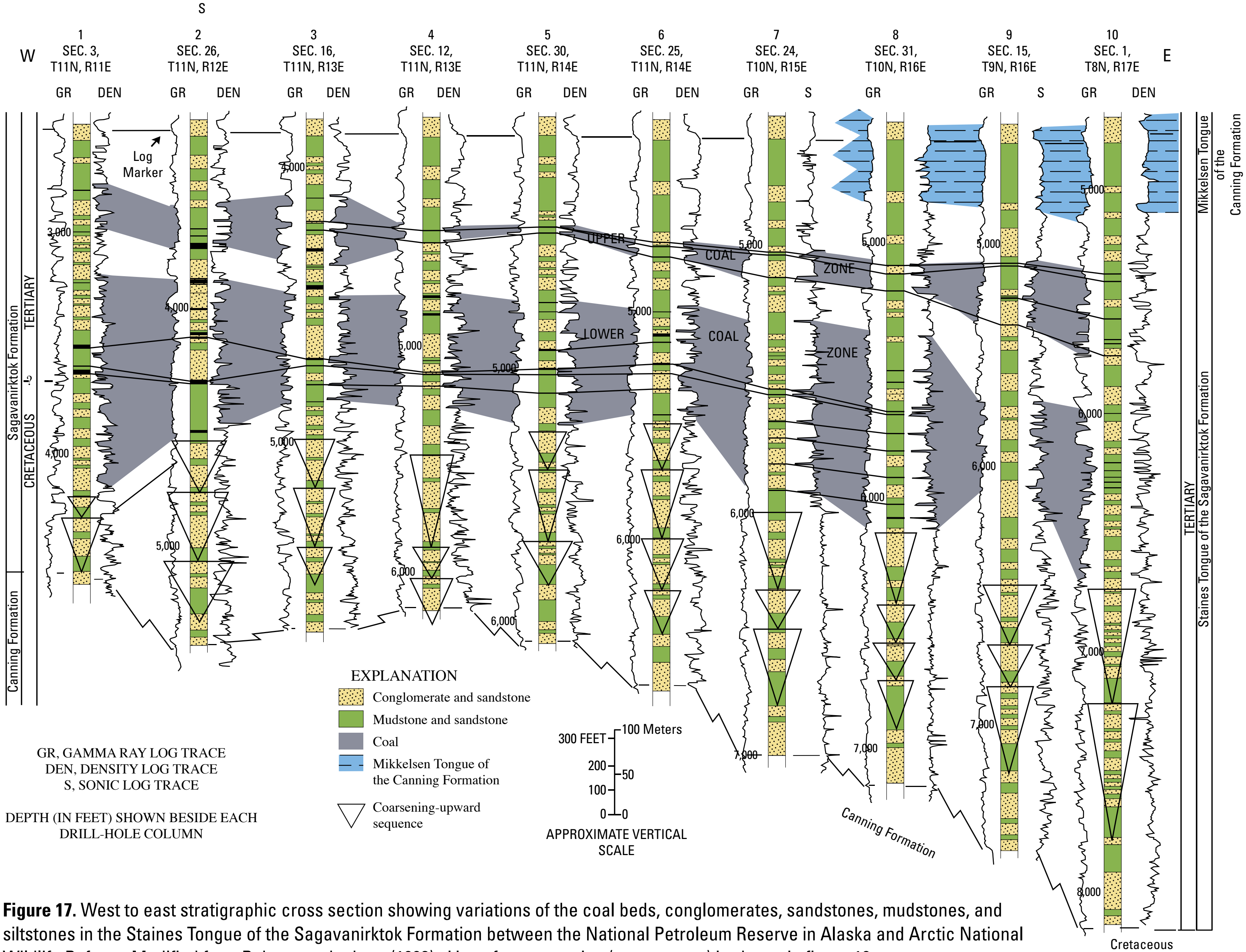
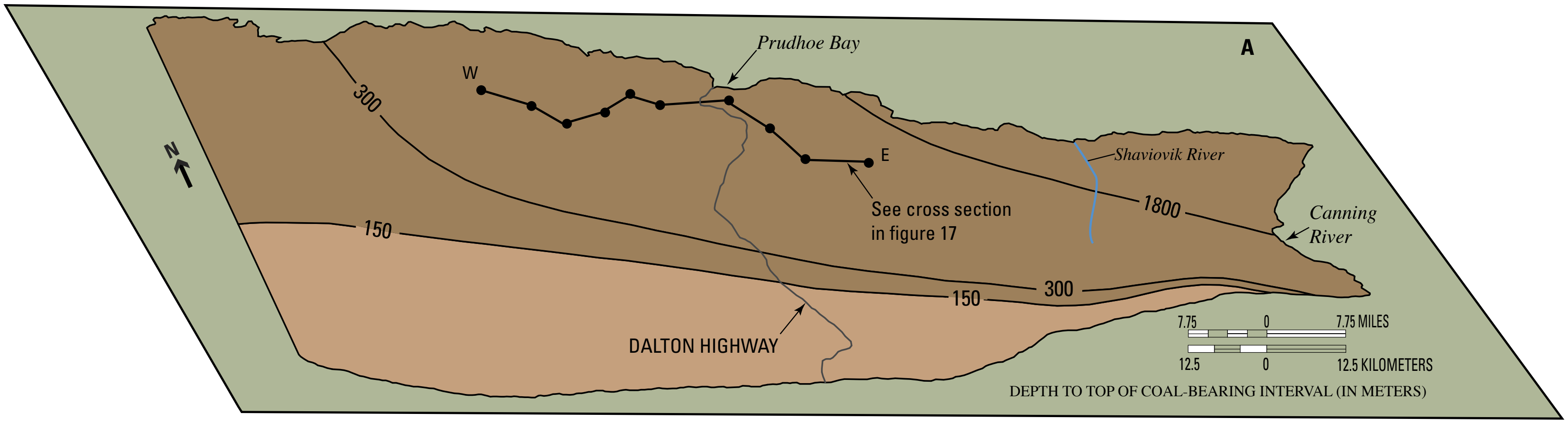


Figure 17. West to east stratigraphic cross section showing variations of the coal beds, conglomerates, sandstones, mudstones, and siltstones in the Staines Tongue of the Sagavanirktok Formation between the National Petroleum Reserve in Alaska and Arctic National Wildlife Refuge. Modified from Roberts and others (1992). Line of cross section (west to east) is shown in figure 18.



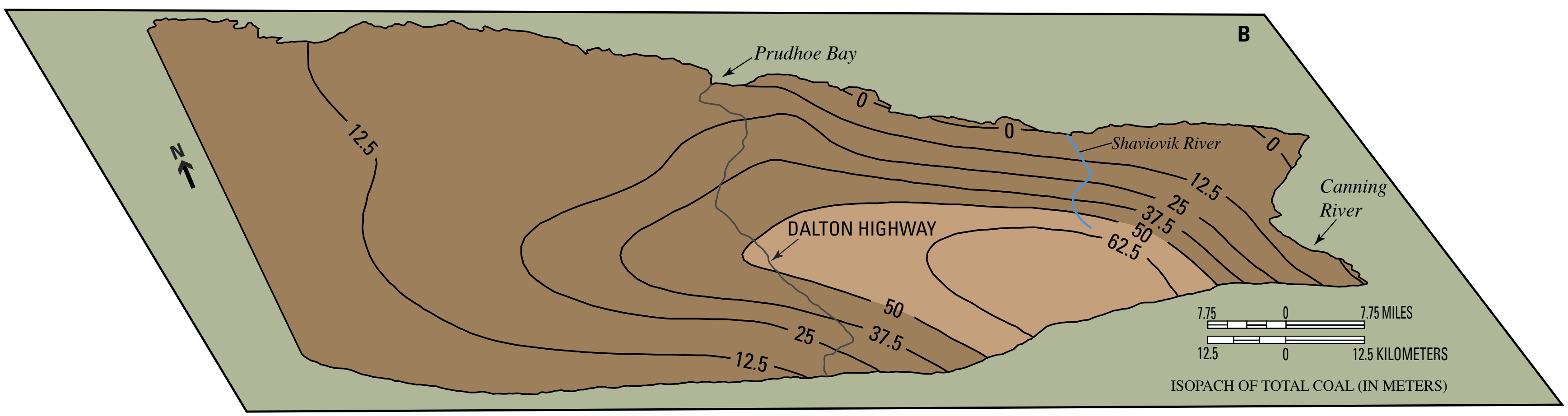


Figure 18. Maps showing the (A) depth to top of coal-bearing interval and (B) net coal thickness isopach of the Staines Tongue of the Sagavanirktok Formation. Modified from Roberts and others (1992).

Sagavanirktok tongues that intercalate with the Canning shales (fig. 16). The uppermost tongue identified by Molenaar and others (1986) as the Staines Tongue was studied by Roberts (1991) and Roberts and others (1992) and varies from 650 to 2,950 ft (200 to 900 m) in thickness (fig. 17). The lower 330 to 1,640 ft (100 to 500 m), of the Staines Tongue is dominated by coarsening-upward mudstone, siltstone, and sandstone representing parasequence sets. These parasequence sets are overlain by two coal-bearing intervals—the lower and upper coal zones in the middle part of the tongue (Roberts and others, 1992)—that are separated by interbedded sandstones and mudstones, which are as much as 295 ft (90 m) thick. The lower coal zone is as thick as 850 ft (260 m) and contains 12 coal beds. The upper coal zone is as thick as 360 ft (110 m) and contains seven coal beds. The individual coal beds are as much as 23 ft (7.1 m) thick. The uppermost part of the Staines Tongue is interbedded sandstone and mudstones and is as much as 260 ft (80 m) thick. This interval is, in turn, overlain by mudstones of the Mikkelsen Tongue of the Canning Formation. Coal beds are distributed over an area of 5,790 mi^2 (15,000 km^2). Near Prudhoe Bay, a coal-bearing interval as much as 1,310 ft (400 m) thick contains coal beds 1.9–22 ft (0.6–6.7 m) thick (Roberts, 1991); one 6.5-ft-thick (2 m) coal zone has been reported on the lower Shaviovik River (fig. 18; Roberts and others, 1992). Lignite and coaly shale as thick as 19 ft (6 m) occur in the lowermost part of the formation (Detterman and others, 1975; Molenaar and others, 1984).

The Sagavanirktok Formation represents the final infilling of the Colville Basin in the eastern part of the Northern Alaska-Slope coal province. The Staines Tongue represents an episode of this infilling by the deposition of fluvio-deltaic sediments. The lower part of the Staines Tongue is dominated by parasequence sets representing delta front-prodelta deposits, which grade into the shelf-slope mudstones of the Canning Formation (figs. 17 and 18). The lower coal zone was deposited in an alluvial-delta plain in which the coal beds accumulated in interfluvial and interdistributary mires. The noncoaly interval between the two coal zones reflects a landward advance of the paleoshoreline resulting from a minor transgression or sea-level rise. The coal beds of the upper coal zone were probably formed in lower delta-plain and back-barrier mires as the paleoshoreline then regressed. The thin nature of the upper coal zone (fig. 17) and the sandy character of the uppermost part of the Sagavanirktok, which is in turn overlain by the Mikkelsen mudstone tongue of the Canning Formation, indicate a back-stepping paleoshoreline. In this setting, rapid transgression over the peat-forming mires reworked older deposits, probably forming barrier-shoreface deposits prior to a marine flood.

The thick and laterally extensive coal beds of the lower coal zone of the Staines Tongue probably reflect a peat accumulation in mires formed during a time of paleoshoreline stability. This event may correspond to a regressive maximum that led to vertical stacking of paleoshoreline deposits, closely similar to that described for the Nanushuk Group. However, unlike the Nanushuk Group, the Staines Tongue of the Sagavanirktok Formation was affected by sea-level fluctuations prior to the maximum transgression that deposited the overlying Mikkelsen Tongue of the Canning Formation. Sea-level fluctuations and marine flooding interrupted coal-forming mires, which provided only a brief period of time for peat accumulation.

Coal Resource Assessment of the Northern Alaska-Slope Coal Province

The coal resource assessments of different workers in the Northern Alaska-Slope coal province vary greatly in magnitude and coal resource categories, resulting in confused reporting of estimates. As a result we reconstructed these different coal resource estimates following guidelines of the coal-resource classification system of Wood and others (1983). This new reporting system of the coal resources of Alaska in general, and of Northern Alaska-Slope coal province in particular, as modified from previous estimates, is summarized in table 1. Following is a historical account of the various coal resource assessments in the coal province.

Cretaceous Rocks

In an early resource assessment of Cretaceous rocks in the Northern Alaska-Slope coal province, Barnes (1967a) calculated a total of 2.4×10^9 short tons (2.2×10^9 metric tons) of demonstrated coal resources and 117×10^9 short tons (107×10^9 metric tons) of undiscovered (hypothetical) coal resources. Later Tailleur and Brosgé (1976) estimated the coal resources in the coal province by calculating the product of coal-bearing area and coal concentration. Using surface data and two oil and gas test wells, these workers estimated the coal resources in the Northern Alaska-Slope coal province at 120×10^9 short tons (109×10^9 metric tons) of identified coal resources plus 114×10^9 to 37×10^{12} short tons (104×10^9 to 34×10^{12} metric tons) of hypothetical coal resources (see table 1).

Later, Sable and Stricker (1987), using all available data for the Nanushuk Group, estimated coal resources for the National Petroleum Reserve in the Alaska portion of the North Slope. Using the methodology described by Wood and others (1983) and all available data for the area of the known Nanushuk Group coal-bearing rocks, Sable and Stricker (1987) estimated the hypothetical coal resources for the Nanushuk Group on the North Slope, which are shown in table 2. In summary, there are 1.3 trillion short tons (1.2 trillion metric tons) of subbituminous coal and 1.9 trillion short tons (1.7 trillion metric tons) of bituminous coal, for a total of 3.2 trillion short tons (2.9 trillion metric tons) of hypothetical coal resources for the Nanushuk Group on the North Slope of Alaska (table 2). Barnes (1967a) estimated about 101 billion short tons (92 billion metric tons) of identified coal resources in this group of rocks.

Stricker (1991) indicated that the Nanushuk Group contains an estimated 3.1 × 10^{12} short tons (2.9 × 10^{12} metric tons) of hypothetical coal resources for onshore northern Alaska (table 2); of this total, 1.3 × 10^{12} short tons (1.2 × 10^{12} metric tons) is subbituminous, and 1.9 × 10^{12} short tons (1.7 × 10^{12} metric tons) is bituminous (Stricker, 1983, 1991). In-situ speculative Cretaceous Nanushuk coal that lies under the Chukchi Sea has been estimated at 2.0 × 10^{12} short tons (1.8 × 10^{12} metric tons) of lignite A to high-volatile bituminous A coal (Affolter and Stricker, 1987b).

Coal Quality

The coal beds of the Nanushuk Group in the Northern Alaska-Slope coal province range in apparent rank from lignite A to high volatile A bituminous coal with a mean of high-

Table 2. Estimates of hypothetical coal resources for the Cretaceous Nanushuk Group (Stricker, 1991) and Tertiary Staines Tongue of the Sagavanirktok Formation (Roberts and others, 1992) in the Northern Alaska-Slope coal province.
[>, greater than]

Unit	Rank	Attitude	Overburden (feet)[1]	Coal resource estimate[2]
Staines Tongue	Subbituminous	Dips generally 15° or less	0–500	210
			500–1,000	94
			1,000–6,000	350
			>6,000	16
			Total	670
Nanushuk	Subbituminous	Dips generally 15° or less	0–500	1,149
			500–1,000	20
			1,000–2,000	10
			>2,000	1
			Total	1,180
		Dips generally 15° or more	0–500	101
			500–1,000	5
			1,000–2,000	5
			>2,000	1
			Total	112
		Subbituminous total (rounded)		1,290
	Bituminous	Dips generally 15° or less	0–500	1,340
			500–1,000	0
			Total	1,340
		Dips generally 15° or more	0–500	571
			500–1,000	0
			Total	571
		Bituminous total (rounded)		1,910
	Nanushuk Group total (rounded)			3,200
North Slope Total (rounded)				3,870

volatile C bituminous coal (table 3a). The heating values range from 9,100 to 12,700 Btu/lb (5,050 to 7,060 kilocalories/kilogram) with an average of 12,300 Btu/lb (6,830 kilocalories/kilogram) (State of Alaska, 1993). Total sulfur content ranges from 0.1 to 2.0 percent with a mean of 0.3 percent. The ash yield has a mean of 11.0 percent (Affolter and Stricker, 1987a). The coal is generally subbituminous A under the Arctic coastal plain and high-volatile bituminous in the folded foothills, is low in ash (less than 10 percent) and sulfur (1.4 percent) (Sanders, 1981; Affolter and Stricker, 1987a), and has low concentrations of elements of environmental concern (As, Be, Hg, Mo, Sb, and Se) (Affolter and Stricker, 1987a). The higher rank coal beds in the foothills are probably upgraded in apparent rank by tectonism.

Tertiary Rocks

Early resource assessment of the coal resources of the Sagavanirktok Formation by Sanders (1976) and Tailleur and Brosgé (1976) estimated 50–60 billion short tons (45–55 billion metric tons) of hypothetical resources. Evaluation of 48 geophysical logs penetrating coal beds of the formation led Roberts and others (1992) to estimate a hypothetical coal resource of 670 billion short tons (610 billion metric tons) (table 2), which is 10 times more than the original estimate. The coal included in the estimate by Roberts and others (1992) occurs mainly in the onshore Northern Alaska-Slope coal province, where the overburden varies from 150 to 1,800 ft (46 to 550 m). As shown in figure 17, the thickest coal is in the southeast part of the coal province. Affolter and Stricker (1987b) estimated the offshore (beneath the Beaufort Sea) hypothetical resources to be 300 billion short tons (270 billion metric tons).

Coal Quality

A summary of chemical analyses of 55 coal outcrop samples from the Sagavanirktok Formation, as reported by Roberts and others (1992), indicated that the apparent rank of the coal beds ranges from lignite A to subbituminous B coal (3,340–9,740 Btu/lb) (1,860–5,410 kilocalories/kilogram), with a mean of subbituminous C coal (7,780 Btu/lb) (4,320 kilocalories/kilogram) (table 3b). Total sulfur content is low, varying from 0.08 to 2.16 percent with a mean of 0.38 percent. The ash yield varies from 1.2 to 47.1 percent with mean of 11.1 percent. Moisture content ranges from 16.2 to 33 percent with mean of 23.6 percent.

Coal Petrology

The petrology of the coal beds in the Corwin Formation of the Nanushuk Group was studied by Rao (1980) in the Cape Beaufort region. Forty-eight samples from 14 coal beds showed that the coal is composed mainly of the macerals vitrinite (huminite), liptinite, and inertinite. The percentage of vitrinite varies from 47.1 to 89.5 (average of 74.4), that of liptinite from 0.4 to 10.4 (average of 2.3), and that of inertinite from 1.8 to 33.9 (average of 23.3). The macerals vary from coal bed to coal bed as well as within a coal bed. Many of the beds are high in inertinites (such as fusinite and semifusinite) (charcoals), the proportions of which are lowest at the bottom of the coal bed and increase toward the top. This pattern indicates that mires evolved into a drier setting during accumulation of peat deposits, which promoted forest fires that created the charcoals (fusinites). This interpretation is supported by Spicer (1987), whose investigation indicated seasonality of the generally humid climate during the development of the peat-forming mires. Platanoid-like leaves are closely associated with fluvial deposits, and gymnosperm and magnoliid-like

Table 3a. Coal quality of coal deposits in the Cretaceous Nanushuk Group in the Northern Alaska-Slope coal province.
[All analyses except Calorific value (Btu) and Ash-fusion-temperature (°F) are in percent. Values reported on an as-received basis. L after a value means less than the value shown and G after a value means greater than the value shown. Data from U.S. Geological Survey, 1997, USGS Coal Quality Database (USCHEM) [unpublished computer database: Reston, Virginia)]

Unit	Parameter	Number of samples	Range		Arithmetic mean	Standard deviation
			Minimum	Maximum		
Cretaceous Nanushuk Group	Proximate and ultimate analysis					
	Moisture	68	1.80	33.10	12.52	7.12
	Volatile matter	68	22.10	40.00	30.07	3.82
	Fixed carbon	68	24.50	60.20	47.13	7.87
	Ash yield	68	2.30	37.20	10.28	7.82
	Hydrogen	52	3.82	6.25	5.24	0.48
	Carbon	52	43.92	72.50	60.96	8.54
	Nitrogen	52	0.72	1.85	1.29	0.30
	Oxygen	52	11.30	39.33	23.73	6.58
	Sulfur	73	0.10	2.00	0.31	0.23
	Calorific value					
	Btu per pound	68	5,610	13,820	10,140	1,810
	Forms-of-sulfur					
	Sulfate	37	0.01L	0.04	0.01	0.01
	Pyritic	37	0.01L	0.06	0.01	0.01
	Organic	37	0.01L	0.55	0.28	0.12
	Ash-fusion-temperatures °F					
	Initial deformation	51	2,180	2,910G	5,540	200
	Softening temperature	51	2,130	2,910G	2,410	200
	Fluid temperature	51	2,030	2,910G	2,300	200

Table 3b. Coal quality of coal deposits in the Tertiary Staines Tongue of the Sagavanirktok Formation in the Northern Alaska-Slope coal province.
[All analyses except Calorific value (Btu) and Ash-fusion-temperature (°F) are in percent. Values reported on an as-received basis. L after a value means less than the value shown and G after a value means greater than the value shown. Data from U.S. Geological Survey, 1997, USGS Coal Quality Database (USCHEM) (unpublished computer database: Reston, Virginia)]

Unit	Parameter	Number of samples	Range		Arithmetic mean	Standard deviation
			Minimum	Maximum		
Tertiary Staines Tongue of the Sagavanirktok Formation	**Proximate and ultimate analysis**					
	Moisture	68	18.44	35.97	27.04	3.85
	Volatile matter	68	23.78	36.09	30.16	2.73
	Fixed carbon	68	25.05	42.35	34.65	4.35
	Ash yield	68	1.16	25.46	8.15	6.24
	Hydrogen	68	5.11	7.12	6.19	0.42
	Carbon	68	35.07	55.11	46.22	4.94
	Nitrogen	62	0.59	1.70	1.04	0.22
	Oxygen	68	30.09	49.21	38.16	3.86
	Sulfur	160	0.06	1.65	0.31	0.33
	Calorific value					
	Btu per pound	68	5,930	9,330	7,770	860
	Forms-of-sulfur					
	Sulfate	160	0.01L	0.23	0.03	0.03
	Pyritic	160	0.01L	0.24	0.03	0.03
	Organic	160	0.01L	1.54	0.26	0.31
	Ash-fusion-temperatures °F					
	Initial deformation	69	2,070	2,800G	2,460	240
	Softening temperature	69	1,930	2,800G	2,360	240
	Fluid temperature	69	1,890	2,800G	2,240	230

leaves are associated with lacustrine and mire deposits (Spicer, 1987). Vitrinite reflectance values of the 14 coal beds vary from 0.65 to 0.74 (average 0.70) percent.

Central Alaska-Nenana Coal Province

The Central Alaska-Nenana coal province (fig. 1) is the smallest, most centrally located, and most thoroughly studied of the coal provinces on the north side of the Alaska Range. It has accounted for more than one-half of the coal mined in Alaska and is the only province in Alaska being currently mined. This coal province is in the northern foothills of the Alaska Range, extending from about 50 mi (80 km) west to 50 mi (80 km) east of the Alaska Railroad (see fig 1). It consists of several synclinal basins partly or wholly detached from each other by erosion of coal-bearing rocks from intervening structural highs. These coal-bearing synclinal basins were recognized as coalfields and include the Jarvis Creek, East Delta, West Delta, Wood River, Mystic Creek, Tatlanika Creek, Lignite Creek, Healy Creek, Rex Creek, and Western Nenana. They extend as a discontinuous belt from 9 mi (14.5 km) wide to 56 mi (90 km) long (fig. 19).

The Healy Creek, Lignite, and Suntrana coalfields, where past mining occurred and most current mining occurs lie along the Alaska Railroad and the Anchorage to Fairbanks highway (see fig. 1; George Parks State Highway 1). The railroad provided the needed transportation for marketing the coal. In 1918, underground coal mining by the Healy River Coal Corporation began at Suntrana, 4 mi (6.4 km) east of the confluence of Healy Creek and the Nenana River (Usibelli, 1986). Horse-drawn sleds to the railroad camp in Healy originally transported coal until a railroad spur was built to the mine in 1922. The Healy River coal mine accounted for one-half of the State's production from 1920 to 1940. The rest of the production was from the Evan Jones mine in the Matanuska coalfield (see discussion of the Southern Alaska-Cook Inlet coal province).

The military buildup in Alaska in the 1940s and after World War II provided a new market for coal that resulted in opening more mines to meet the demand (Usibelli, 1986). Usibelli Coal Mine, Inc. (UCM), opened the first strip mine in the coal province east of Suntrana in 1943. In 1961, UCM purchased the Healy River Coal Corporation and continued mining underground. The Arctic Coal Company opened a small mine on Lignite Creek and operated it until 1963. The Vitro Mineral Mine was opened in 1963 east of Suntrana and

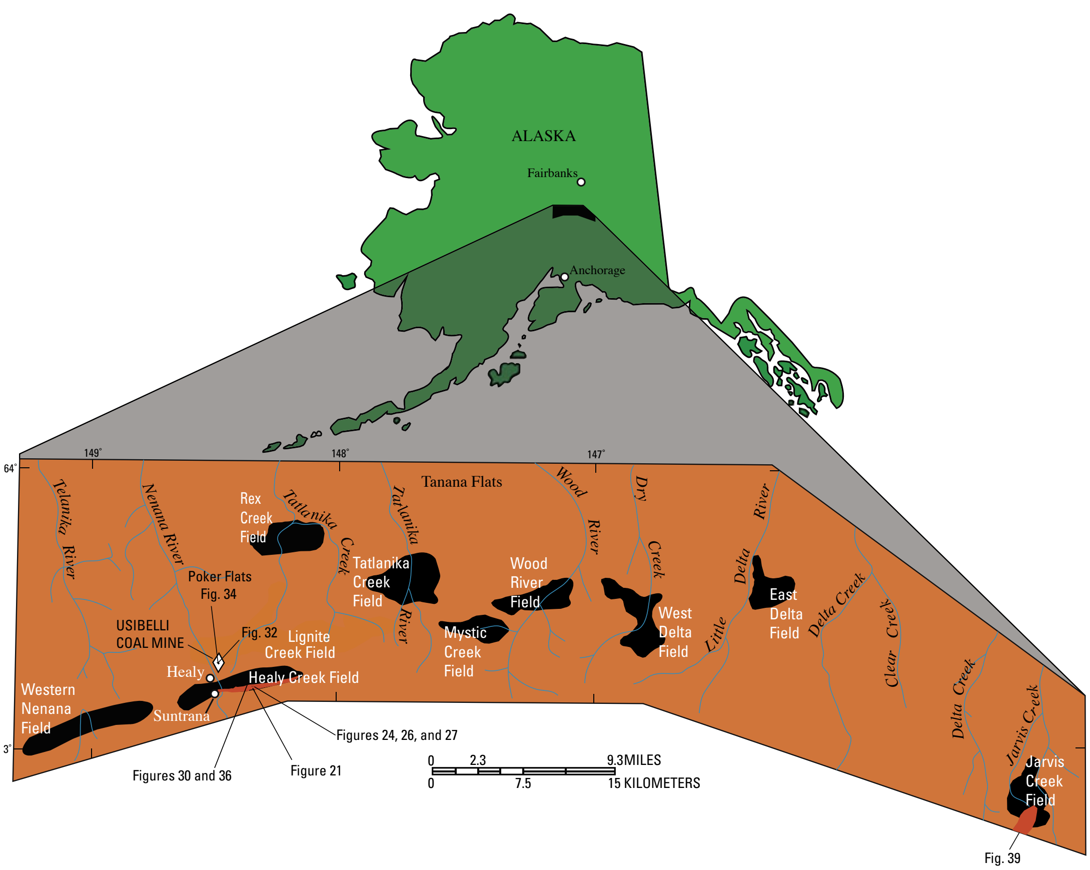


Figure 19. Map showing the coalfields in the Central Alaska-Nenana coal province.

in 1970 was purchased by UCM. Golden Valley Electric Association opened a mine-mouth powerplant at Healy in 1968. Since that time UCM has supplied coal to the powerplant and in 1985 entered the international market by supplying coal to South Korea. UCM is the only active coal mine in the State today.

Tertiary Usibelli Group

The Usibelli Group (Wahrhaftig, 1987), a nonmarine sedimentary sequence of Tertiary age, consists, from bottom to top, of the coal-bearing Healy Creek, noncoaly Sanctuary, coal-bearing Suntrana and Lignite Creek Formations and noncoaly Grubstake Formation (fig. 20). It is overlain unconformably by the Nenana Gravel. Detailed discussions of the group are summarized from Wahrhaftig and others (1969), Wahrhaftig (1987), Wahrhaftig and others (1994), and Stanley and others (1992). Sanders (1976) recognized as many as 30 coal beds in the Usibelli Group, which are mainly 2.5 ft (0.7 m) thick but can be as much as 30 ft (9.1 m) thick. The vertical and lateral stratigraphic variations of the Healy Creek, Sanctuary, and Suntrana Formations, which overlie the lower Paleozoic and Precambrian (?) pelitic and quartzose schist sequence (Csejety and others, 1992), are displayed in figure 21.

The depositional environments of the Usibelli Group have been interpreted as fluvial and lacustrine deposits (Buffler and Tripplehorn, 1976; Selleck and Panuska, 1983; Merritt, 1986; Stanley and others, 1992; Wahrhaftig and others, 1994). Flores and Stanley (1995) proposed that the Healy Creek Formation was deposited in an incised paleovalley infilled by sediments of transverse alluvial fans and longitudinal braided streams that flowed southward (fig. 22A–D). The paleocurrent directions from crossbeds in the sandstones of the Healy Creek, Suntrana, and Lignite Creek Formations (fig. 23) indicate southward flow of streams. Inactive braid-belt deposits formed platforms for raised mires on which thin to thick peat deposits accumulated. Lacustrine sediments of the Sanctuary Formation succeeded these alluvial environments being deposited in a lake that resulted from coalescing of flood-plain lakes and fluvial channels caused by damming of the downstream extent of the ancestral fluvial system, which flowed southward into the ancestral Cook Inlet Basin. Either uplift of the Alaskan Range or movement along the Denali fault may have caused damming. This tectonic movement caused base level to rise (Flores and Stanley (1995). The lake was filled by alluvial fan deltas, which gradually lowered base level and restored the fluvial systems that continued to flow southward. This led to formation of low-sinuosity streams

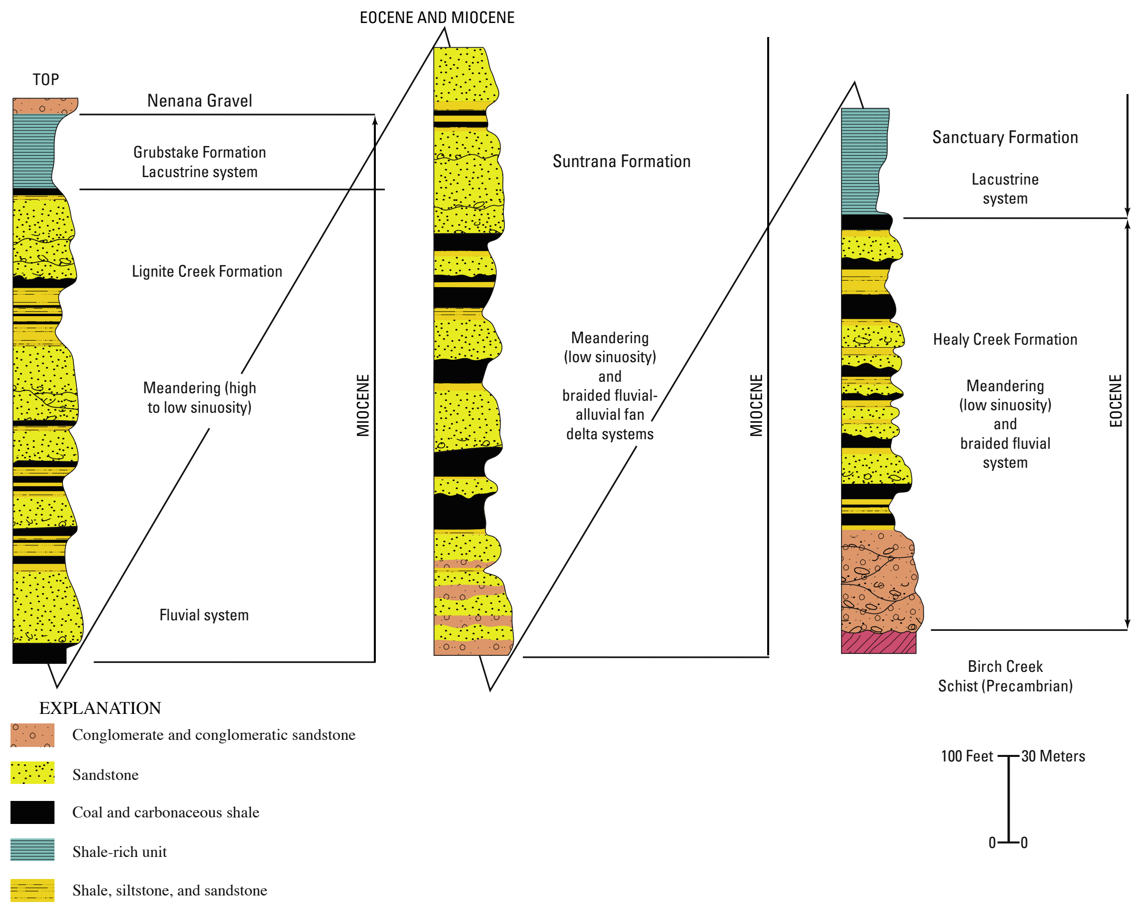


Figure 20. Generalized stratigraphic and lithofacies column of the Usibelli Group in the Central Alaska-Nenana coal province.

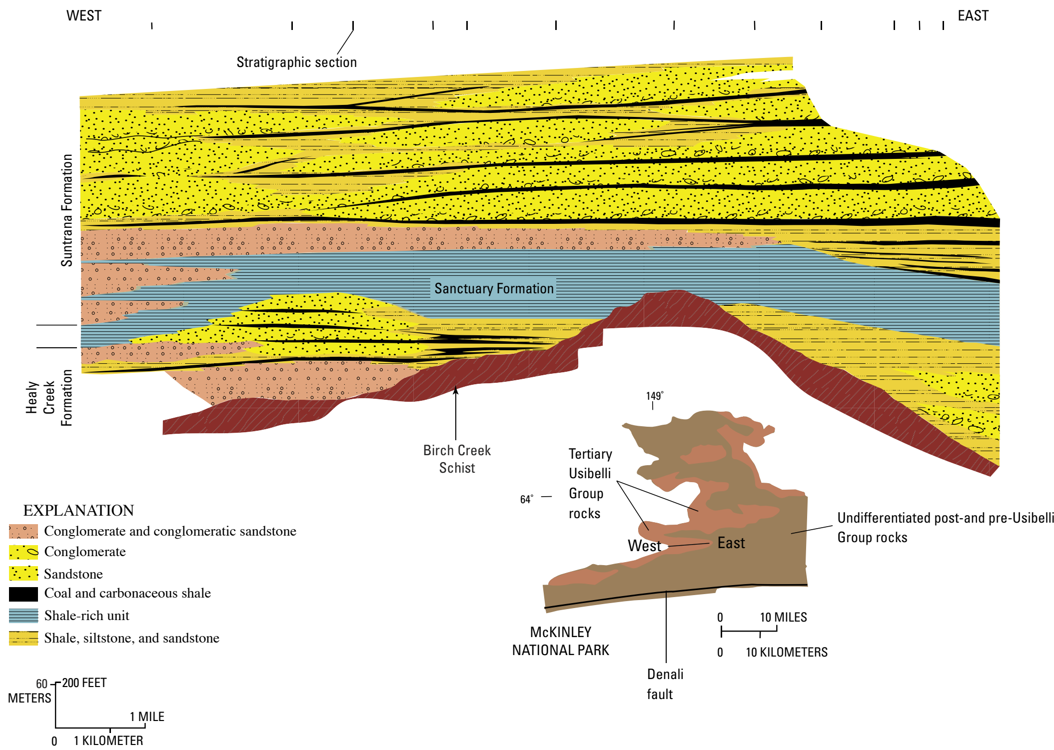


Figure 21. Stratigraphic cross section showing the variations of the conglomerates, sandstones, siltstones, mudstones, and coal beds in the lower part of the Usibelli Group in the Healy Creek coalfield on the southern part of the Central Alaska-Nenana coal province. See figure 19 for location of Healy Creek coalfield.

and related mires during deposition of the Suntrana Formation. These streams evolved into high-sinuosity (meandering) streams and accompanying mires during deposition of the Lignite Creek Formation. Raised mires were associated with these streams, forming on abandoned deposits of alluvial belts and flood basins. These mires were common during the deposition of the Suntrana Formation, and topogenous or low-lying mires, where thin peats accumulated, were common during the deposition of the Lignite Creek Formation. Another damming of the downstream extent of these streams by uplift of the Alaskan Range created a lake that was infilled by alluvial-fan delta sediments of the Grubstake Formation. Continued uplift and lowering of base level resulted in northward-flowing alluvial fans to be shed from the Alaskan Range, forming the Nenana Gravel.

Healy Creek Formation

The Healy Creek Formation is the oldest rock unit in the Usibelli Group (fig. 20). The formation, as much as 445 ft (136 m) thick, consists of interbedded sandstones, conglomerates, siltstones, and mudstones, including carbonaceous shale and coal beds. Sandstone is the most common rock type and coal is the least common. It unconformably overlies the pelitic and quartzose schist sequence (Csejety and others, 1992) with erosional relief of as much as a few hundred feet.

In most of the synclinal coalfields, the Healy Creek Formation is early to middle Miocene (Wolfe and Tanai, 1980; Wahrhaftig, 1987); but in the Rex Creek coalfield, where the formation was formerly thought to be as old as late Oligocene (Wolfe and Tanai, 1980), it is now regarded to be as old as late Eocene (Wolfe and Tanai, 1987).

The Healy Creek Formation consists mainly of fining-upward sequences of conglomerates, sandstones, and silty sandstones (fig. 24). The conglomerates are composed of sedimentary, igneous, and low- to medium-grade metamorphic rock types (Stevens, 1971). The sandstones are mainly quartz-feldspathic-rich rocks. The lower 130 ft (40 m) consists mainly of amalgamated, basally scoured, lenticular pebble-cobble conglomerates and sandstones (Stanley and others, 1992). The lowermost conglomerate beds rest with sharp, erosional contact on the pelitic and quartzose schist sequence. Conglomerates are normally graded, clast supported, and crudely imbricated (fig. 25). Sandstones exhibit abundant tabular and trough crossbeds in sets generally less than 2.3 ft (70 cm) in height. Ripple and small-scale cross laminations are common. Also present are scour surfaces at the bases of the conglomerates and sandstones with as much as 10 ft (3 m) of erosional relief.

Interbedded sandstones, siltstones, mudstones, coals, and carbonaceous shales (fig. 26) overlie the conglomeratic and sandy interval of the Healy Creek Formation. The sandstones exhibit erosional basal surfaces, fine upward, and are crossbedded (mainly trough and planar crossbeds). Rooted siltstones and mudstones overlie the sandstones and are interbedded with coal and carbonaceous shales. Coal beds have combined thickness of as much as 49–61 ft (15–20 m), and individual beds persist laterally for more than 0.6 mi (1 km). They commonly pinch out, split, and (or) merge. Also,

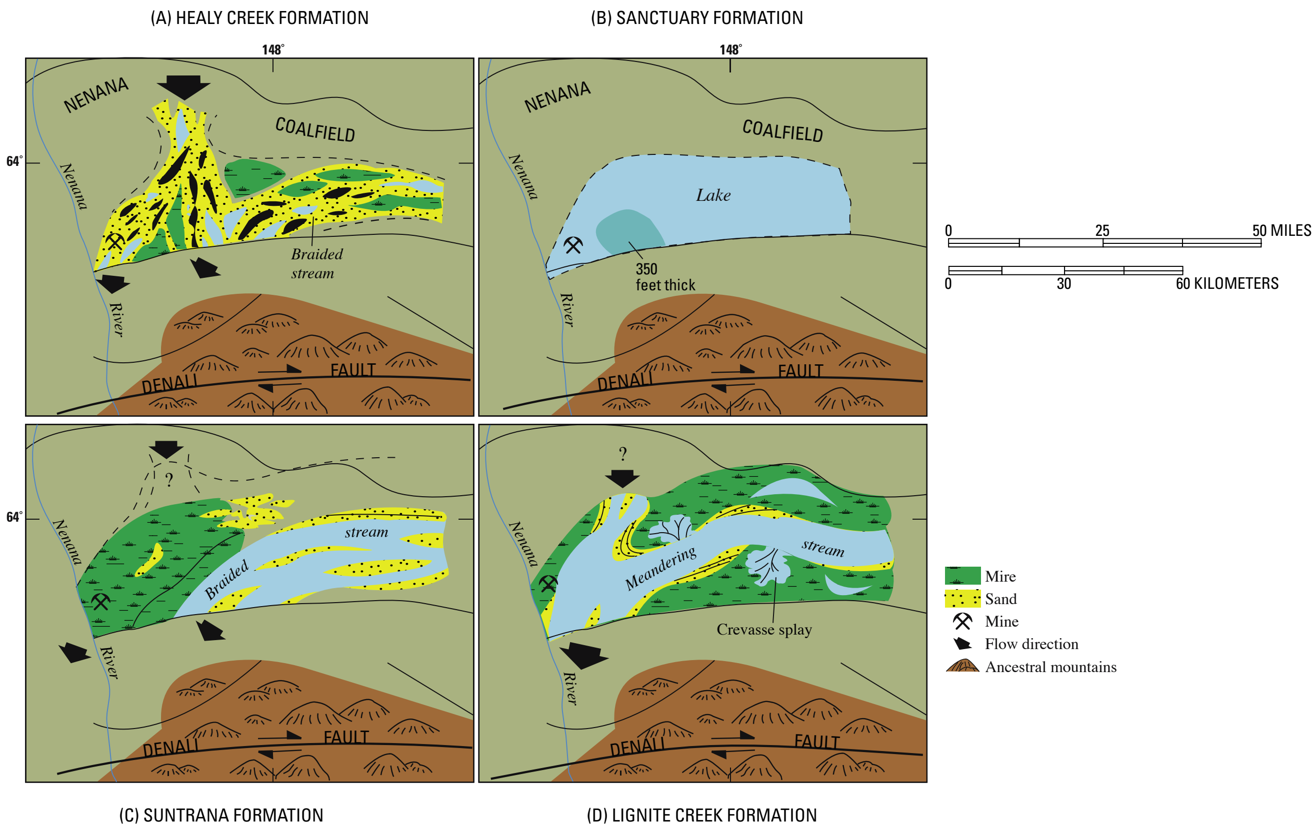


Figure 22. Paleogeographic maps showing depositional environments of: (A) Healy Creek Formation, (B) Sanctuary Formation, (C) Suntrana Formation, and (D) Lignite Creek Formation. Adopted from Flores and Stanley (1995).

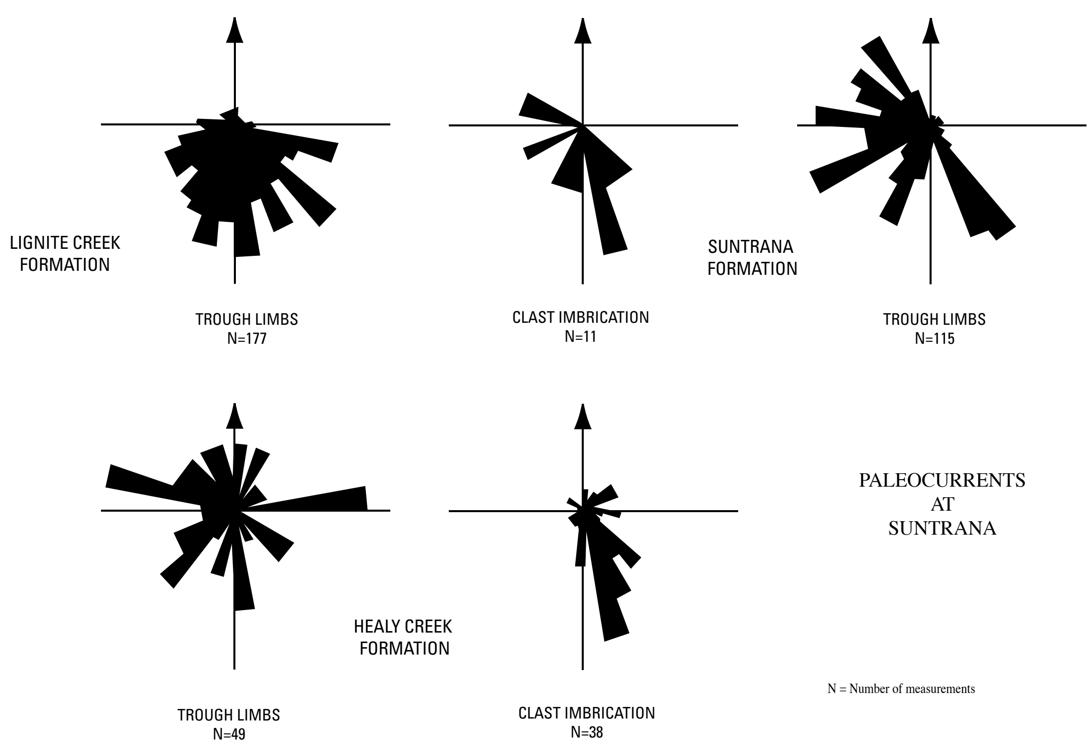


Figure 23. Crossbed-orientation measurements in fluvial-channel sandstones in the Healy Creek, Suntrana, and Lignite Creek Formations in Suntrana area. Modified from Flores and Stanley (1995).

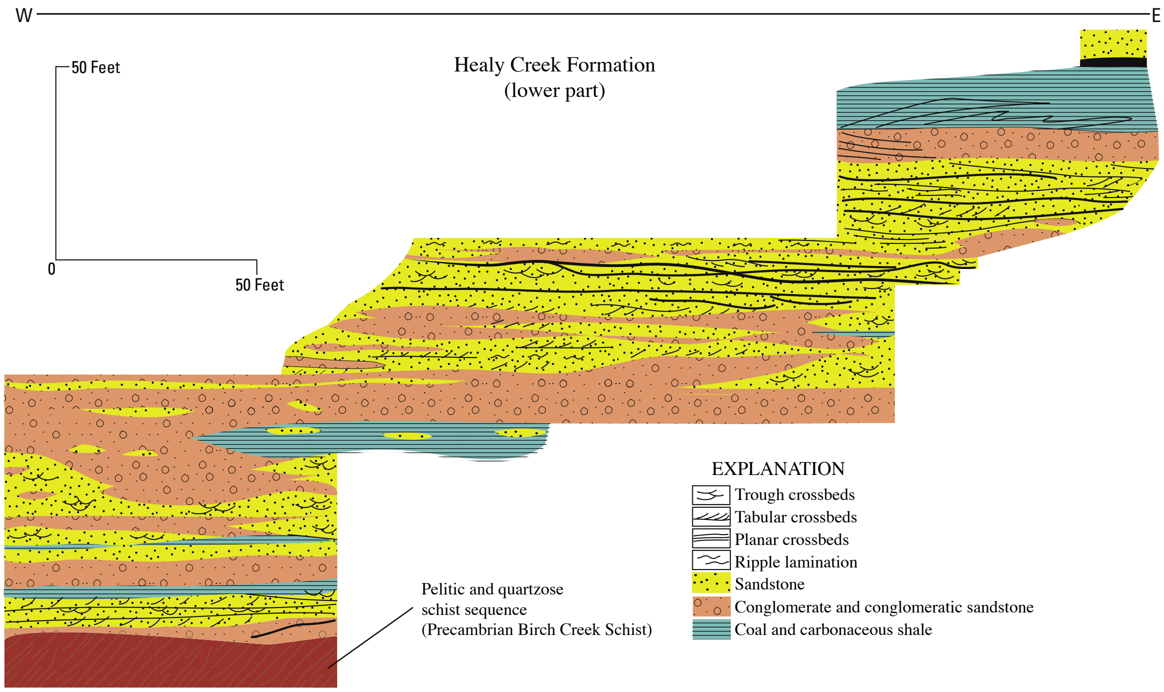


Figure 24. Stratigraphic cross section showing the basal conglomerates and sandstones in the lower part of the Healy Creek Formation east of Suntrana. Adopted from Flores and Stanley (1995). See figure 19 for location of cross section.

Figure 25. Photograph of conglomerates (a few inches to 5 feet thick or a few centimeters to 1.5 meters) and sandstones (6 inches to 8 feet thick or 15.2 centimeters to 2.4 meters) deposited by braided streams in the lower part of the Healy Creek Formation in east of Suntrana.

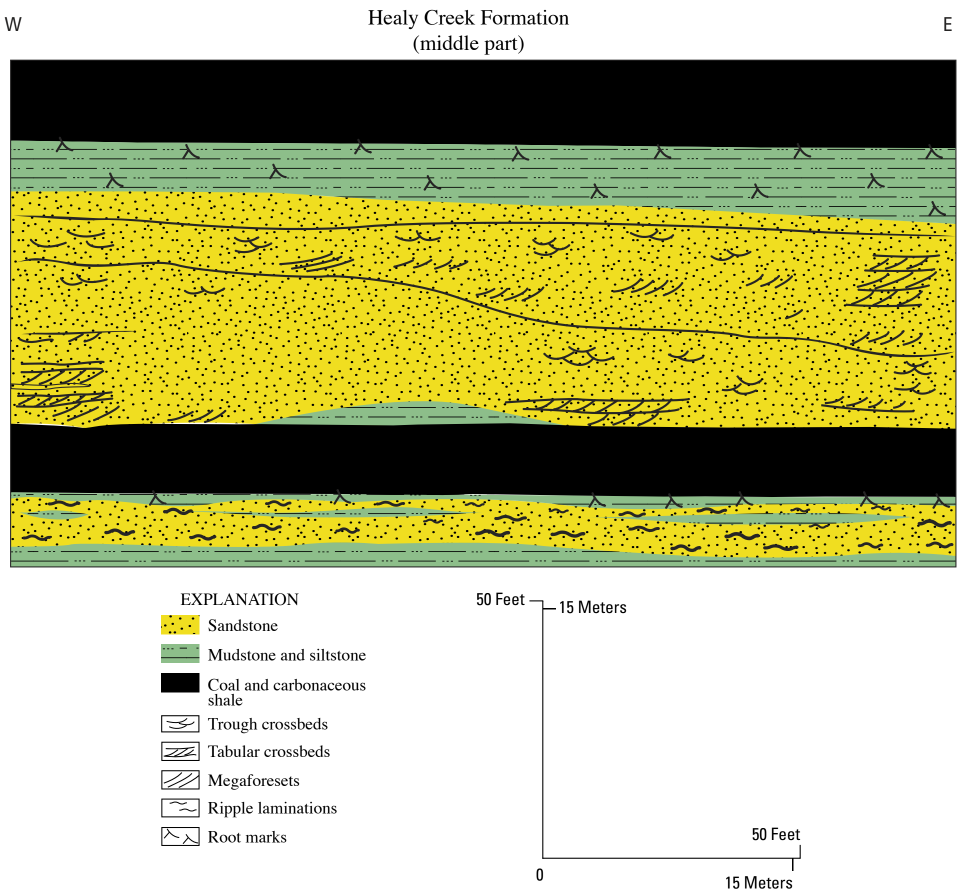


Figure 26. Stratigraphic cross section showing the middle, coal-bearing part of the Healy Creek Formation east of Suntrana. See figure 19 for location of cross section. Adopted from Flores and Stanley (1995).

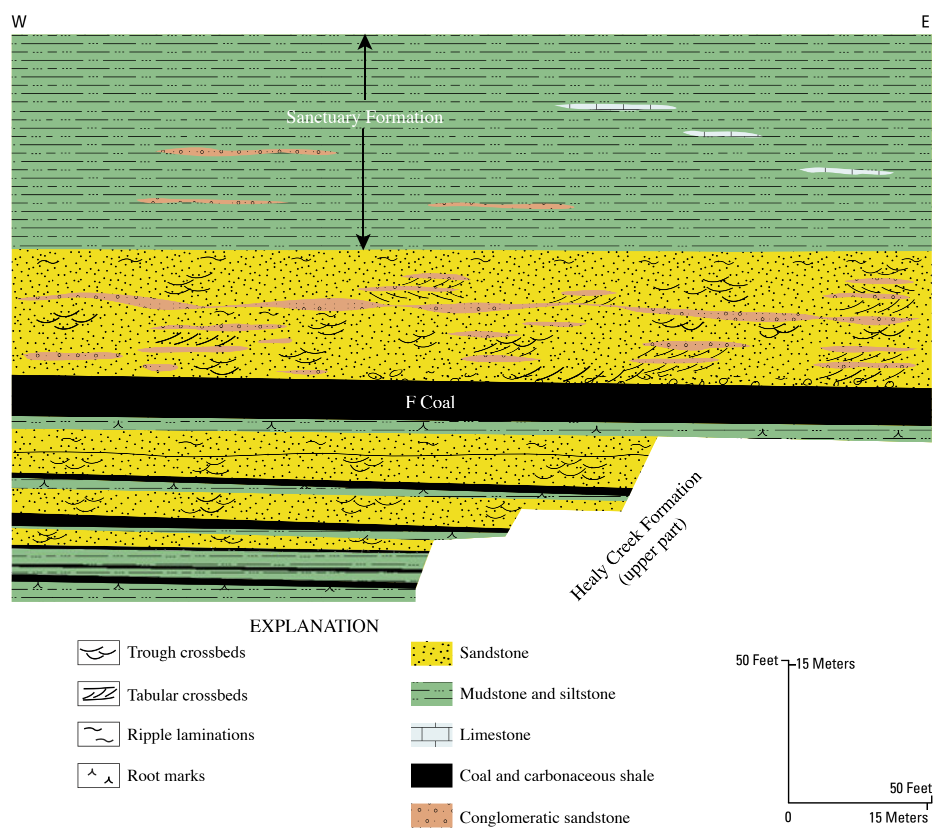


Figure 27. Stratigraphic cross section of the uppermost part of the Healy Creek Formation showing the fluvial-channel sandstones and F coal bed, and overlying Sanctuary Formation east of Suntrana. See figure 19 for location of cross section. Adopted from Flores and Stanley (1995).

they interfinger with carbonaceous shales, mudstones, and siltstones. The highest coal bed of the Healy Creek Formation, the F coal bed (figs. 27 and 28), which immediately underlies the Sanctuary Formation, is the only coal bed of sufficiently continuous lateral extent to be analyzed for reserve estimates (Wahrhaftig and others, 1994).

The Healy Creek Formation was interpreted to originate as braided to high-sinuosity stream deposits (Buffler and Tripplehorn, 1976; Selleck and Panuska, 1983; Stanley and others, 1992). The streams may have formed on a wet alluvial fan or on a proximal braid plain where the cobbles, pebbles, and sands were likely deposited by migrating longitudinal gravel bars and sandy transverse bars. The interbedded sandstones, siltstones, and mudstones probably were deposited in low-sinuosity fluvial channels and flood plains. Coal beds and carbonaceous shales may have accumulated in raised mires or abandoned mires built atop abandoned fluvial channels and flood-plain deposits.

Sanctuary Formation

The Sanctuary Formation is composed mainly of 130 ft (40 m) of gray, thinly laminated, varved mudstone and shale that weather chocolate brown (fig. 29). Mudstones commonly exhibit nondescript vertical animal burrows. The formation also contains minor sandstone, siltstone, and limestone. Sandstones are rippled and crossbedded and occur as a coarsening-upward sequence with the underlying siltstones. Limestones are found as gray, micritic, lenticular beds. This formation conformably overlies the Healy Creek Formation and was assigned by Wolfe and Tanai (1980) to the middle Miocene.

The Sanctuary Formation is interpreted to have accumulated in a large, shallow lake. The lake may have originated as a series of flood-plain lakes, which coalesced due to rise of base level either by damming of the streams and (or) by tectonic uplift along the path of the streams downstream. Coarsening upward sandstones and siltstones probably represent lacustrine deltas shed either from the nearby fluvial channels or from fan deltas.

Suntrana Formation

The Suntrana Formation unconformably overlies the Sanctuary Formation and is as thick as 1,310 ft (400 m) (see fig. 21). The formation, as a whole, thickens gradually southeastward and pinches out in the northwestern part of the coal province. It consists of interbedded sandstones, siltstones, mudstones, carbonaceous shales, and coal. Sandstones are abundant, erosional based, fining upward, mainly trough and planar crossbedded with crossbeds 3.2–6.5 ft (1–2 m) in height, and pebbly at the base (figs. 30 and 31). They grade either into rooted siltstone, mudstones and silty sandstones or are locally unconformably overlain by these deposits (fig. 32). Coal beds are interbedded with carbonaceous shales and have a combined thickness ranging from 1.6 to 65 ft (0.5 to 20 m). Most of the coal beds can be traced laterally over distances of as much as 15 mi (25 km) (Wahrhaftig, 1973). Two of the thicker beds (Nos. 3 and 4) are currently mined in the Usibelli coal mine at Poker Flats (figs. 33 and 34). Thickness of the No. 6 coal bed, the highest coal bed, is shown in figure 35. The Suntrana Formation was assigned by Wolfe and Tanai (1980) to middle Miocene.

The fining-upward, erosional-based sandstones of the Suntrana Formation probably were deposited in braided streams by migrating longitudinal bars and transverse side channel bars (Stanley and others, 1992; Flores and Stanley, 1995). An upward decrease in grain size reflects decreasing flow resulting from switching and lateral migration of the stream channels. The erosional-based siltstones, mudstones,

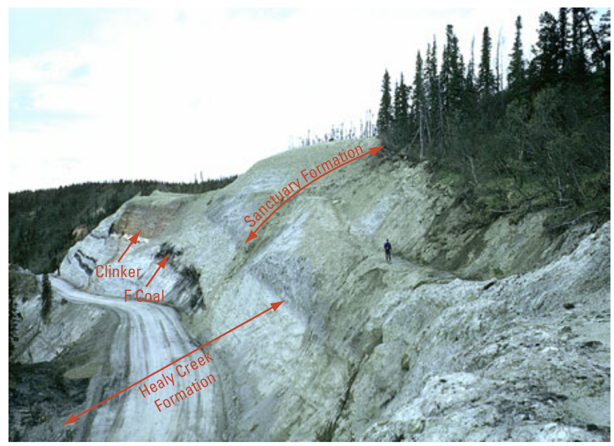


Figure 28. Photograph of the uppermost part of the Healy Creek Formation, F coal bed, and overlying mudstones of the Sanctuary Formation in the Lignite Creek coalfield. Man for scale is 6 feet (1.8 meters) tall.

Figure 29. Photograph of the lacustrine mudstone and lenticular limestone units in the Sanctuary Formation in the Lignite Creek coalfield. Hammer on left for scale is 1 foot (0.3 meter) long.

and silty sandstones that scoured into the fining-upward sandstones represent deposits in abandoned fluvial channels. A thick coal bed commonly overlies the fining-upward sandstones, which reflect accumulation of peat on raised mires. Abandoned fluvial channel deposits served as platforms on which raised mires could be sustained for a long period of time without drowning by detritus during floods from streams. However, when the mires were formed in low topography, detrital sediments flooded the mires and flood plains by crevasse splays and overbank splays, as indicated by interbedded mudstones, siltstones and silty sandstones. The thick crevasse-overbank sequence and associated thin coal beds indicate rapid sedimentation and local subsidence.

Lignite Creek Formation

The Lignite Creek Formation, which is from 490 to 790 ft (150 to 240 m) thick, overlies and is conformably gradational with the Suntrana Formation (see fig. 20). The Lignite Creek consists of interbedded sandstones, siltstones, mudstones, carbonaceous shales, and coals; sandstones and mudstones are the most dominant. The sandstones are fining-upward pebble to coarse grained in the lower part and fine grained in the upper part. They have an erosional, pebbly base and are trough and planar crossbedded. The fining-upward sandstone is commonly overlain by, and gradational to, interbedded siltstone, mudstone, and coal at the top (figs. 36 and 37). The coal beds are thin, generally less than 3 ft (1 m) thick, woody, and relatively lenticular and interbedded with coarsening-upward mudstones, siltstones, and silty sandstones (fig. 38); they pinch out northward. A noncoal-bearing conglomeratic deposit, as much as 37 ft (11 m) thick, occurs along the north and west margins of the Nenana coal field. Wolfe and Tanai (1980) have assigned the Lignite Creek Formation to the late middle to early late Miocene age.

The dominant mudstones and sandstones in the Lignite Creek Formation reflect its deposition in a high-sinuosity or meandering stream setting. Mudstones represent suspended load from these meandering streams, which overtopped the banks of the streams during floods. Continuous overtopping of the streambanks of muds resulted in accumulation of thin coals, mainly <3.2 ft (1 m) thick, in generally low-lying mires. Coal beds are platy and appear to contain mats of branches and twigs unlike the blocky appearance of the coal beds in the Healy Creek and Suntrana Formations. The difference in appearance is probably due to lower apparent rank of the Lignite Creek coal.

Grubstake Formation

The stratigraphically highest formation assigned to the Usibelli Group is the Grubstake Formation (see fig. 20; Wah-

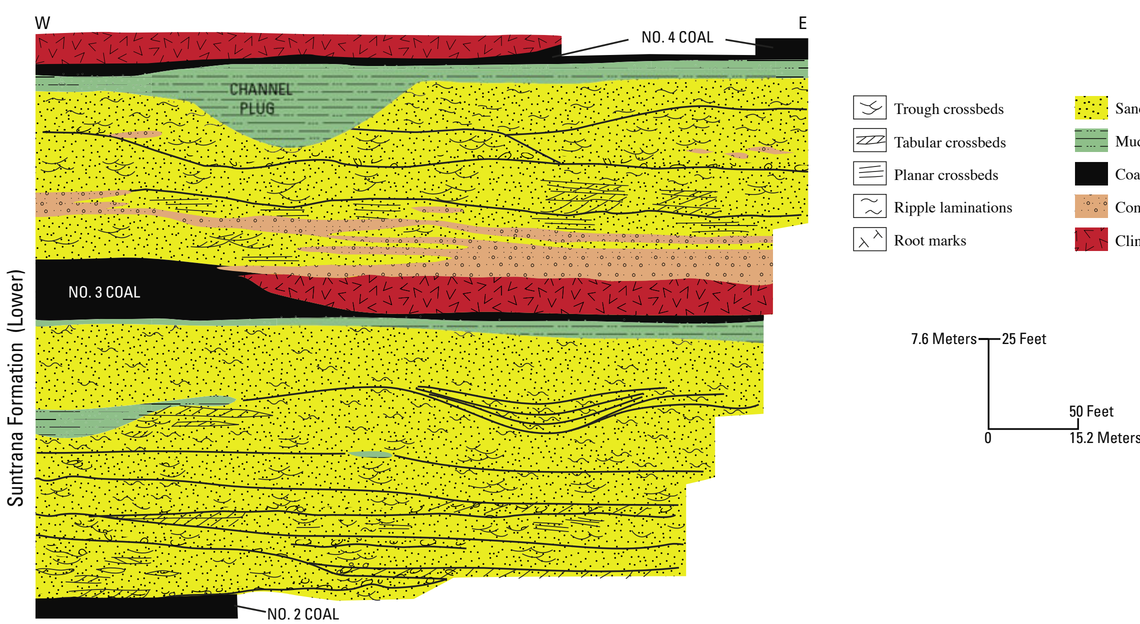


Figure 30. Stratigraphic cross section of the Suntrana Formation showing the Nos. 2, 3, and 4 coal beds and interbedded fluvial-channel sandstones west of Suntrana. See figure 19 for location of cross section. Adopted from Flores and Stanley (1995).

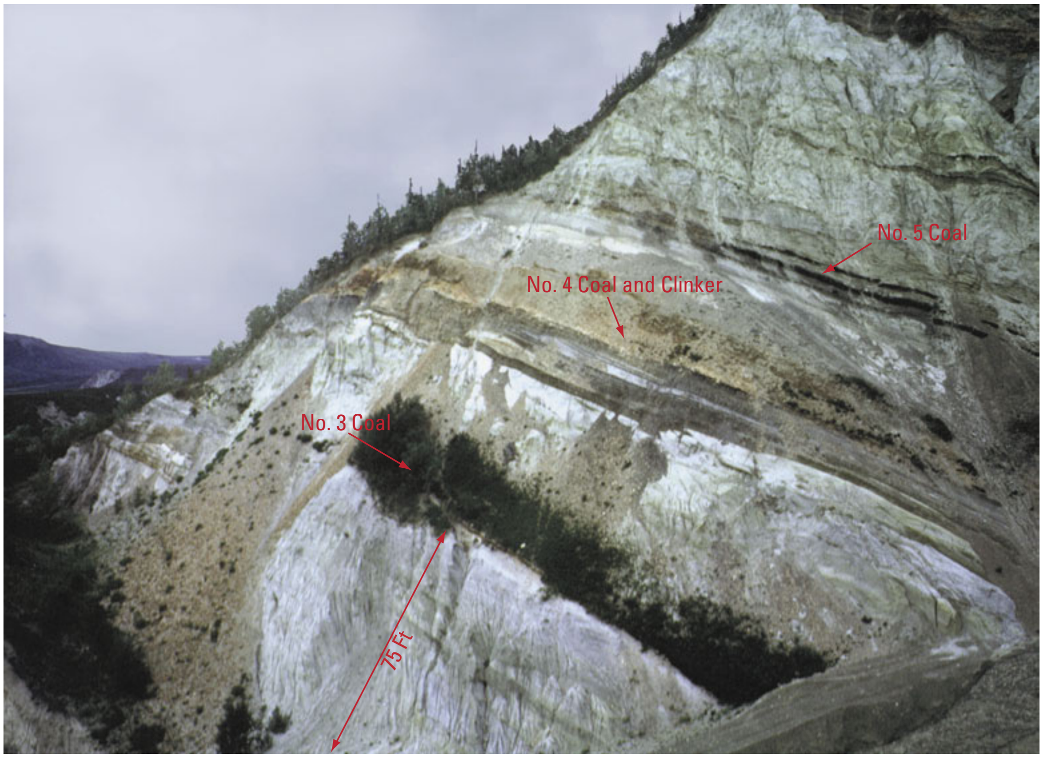


Figure 31. Photograph of the Suntrana showing the thick No. 3 coal bed, clinker bed of No. 4 coal bed, thin No. 5 coal bed, and interbedded fluvial-channel sandstones and clay plug-overbank deposits west of Suntrana. For scale, the sandstone below No. 3 coal bed is 75 feet (22.8 meters) thick.

Figure 32. Photograph of the abandoned fluvial-channel mudstone or clay plug deposit. Note erosional basal contact of the clay plug deposits west of Suntrana. Man is 6 feet (1.8 meter) tall for scale.

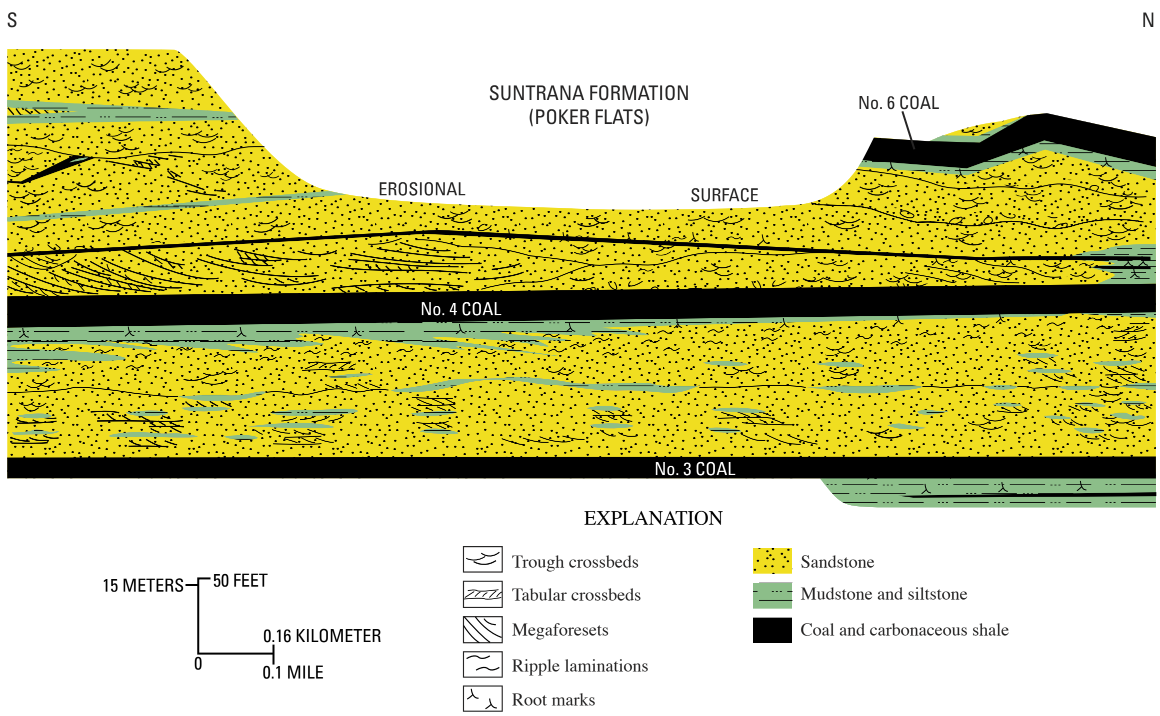


Figure 33. Stratigraphic cross section of the Nos. 3, 4, and 6 coal beds of the Suntrana Formation in the Poker Flats strip mine of Usibelli Coal Mine. Here the Nos. 3 and 4 coal beds are mined. See figure 19 for location of cross section. Adopted from Flores and Stanley (1995).

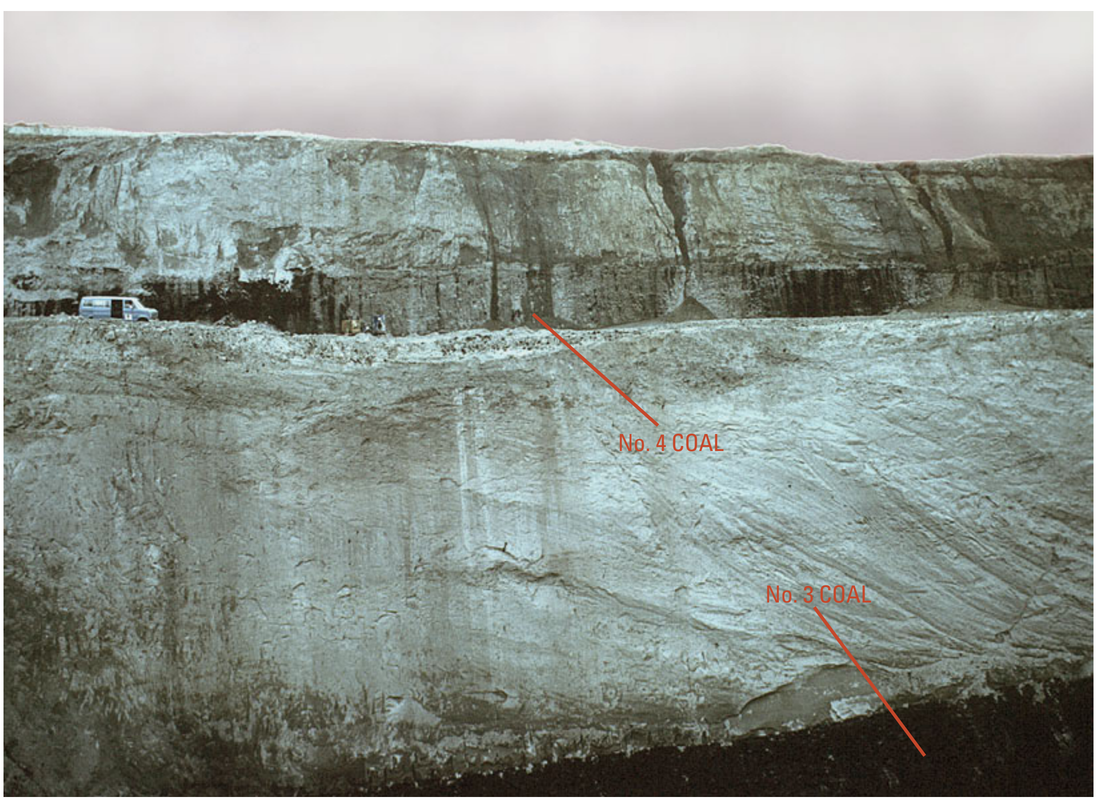


Figure 34. Photograph of the Poker Flats strip mine showing the highwall exposing fluvial-channel sandstones and No. 3 coal bed (lower bench) and No. 4 coal bed (upper bench). For scale, the sandstone between the Nos. 3 and 4 coal beds is 100 feet (30 meters) thick. White dashed line is the contact between the coal and fluvial-channel sandstone.

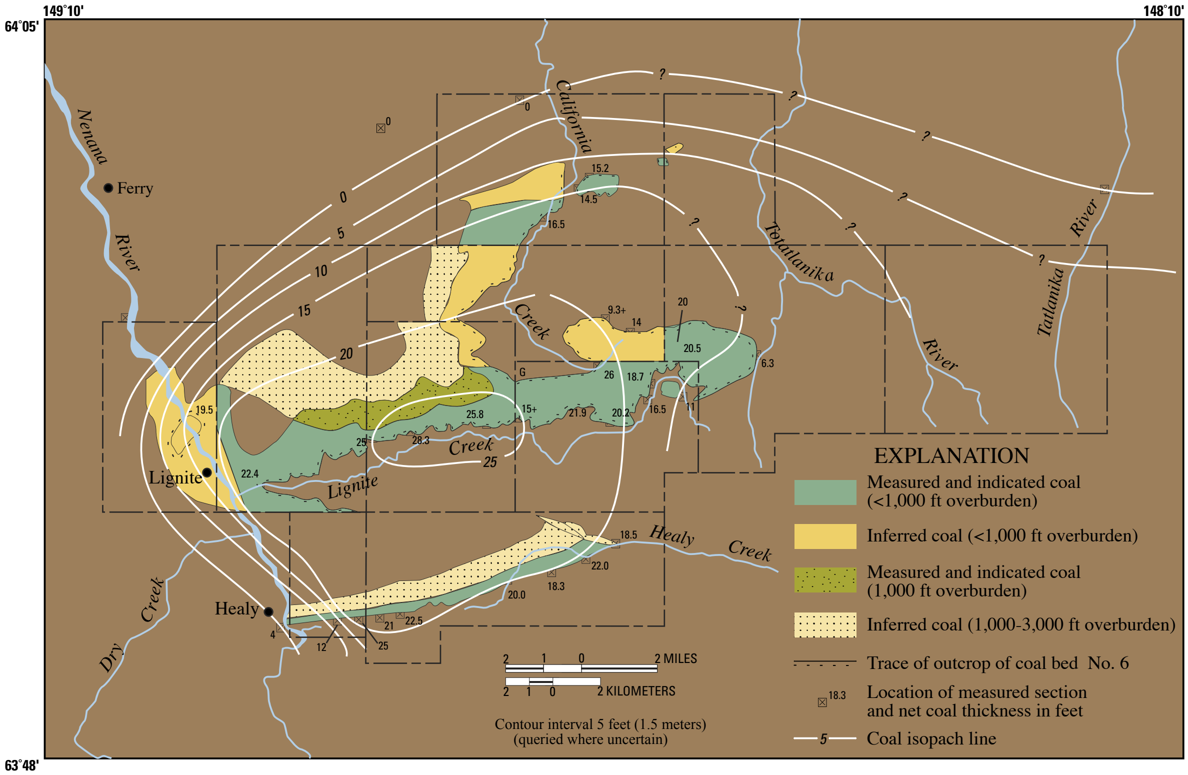


Figure 35. Thickness map of the No. 6 coal bed of the Suntrana Formation. Modified from Wahrhaftig and others (1994).

rhaftig and others, 1994). This formation consists of dark gray laminated shale and mudstone that is 590–980 ft (180–300 m) thick in the northeastern part of the Nenana coal province but only 2–6 ft (0.6–1.9 m) thick in the southwestern part. In the eastern part of the coal province, the Grubstake Formation interfingers southward with coarse-grained, dark, unconsolidated sandstones similar to those in the overlying Nenana Gravel. A K-Ar age on rhyolitic glass from an ash layer in the lower part of the Grubstake Formation is 8.3±0.4 Ma, which coincides with a late Miocene age based on plant megafossils (Wahrhaftig and others, 1969; Wolfe and Tanai, 1980; Wahrhaftig, 1987).

The Grubstake Formation probably accumulated in a lake closely similar to that of the Sanctuary lake. The lake was formed by the damming of southward-flowing Lignite Creek paleostreams by the rising Alaska Range and may be the result of coalesced flood-plain lakes and fluvial channels due to the rise of base level caused by tectonic damming.

Nenana Gravel

The Nenana Gravel consists of poorly consolidated, buff to red, pebble- to boulder-size conglomerates overlying the Usibelli Group. It ranges in thickness from 3,940 ft (1,200 m) at the south edge of the Nenana coal province to 980–1,310 ft (300–400 m) along the north edge of the Alaska Range foothills. Gravel detritus was shed northward from the rising Alaska Range that blocked the southward-flowing tributary to the Cook Inlet-Susitna Lowland (Wahrhaftig, 1970). Its age is bracketed between 8.3 and 2.75 Ma, so is contemporaneous with the Sterling Formation in the Cook Inlet area. The Nenana Gravel is much more widely distributed than the Usibelli Group, which is primarily confined to synclinal basins deformed early in the orogeny that later deposited the Nenana Gravel. Along much of its outcrop length, the formation rests on rocks older than the Usibelli Group, and detritus from the Usibelli Group can be recognized in the Nenana Gravel.

Coal Resource Assessment of the Central Alaska-Nenana Coal Province

The coal resource assessments of different workers in the Central Alaska-Nenana coal province differ in magnitude and coal resource categories, which result in varying estimates. We reconstructed these different coal resource estimates following guidelines of the coal-resource classification system of Wood and others (1983). This new reporting system of the coal resources of the Central Alaska-Nenana coal province, modified from previous estimates is summarized in table 1. Following is a historical account of the diverse coal resource assessments in the coal province.

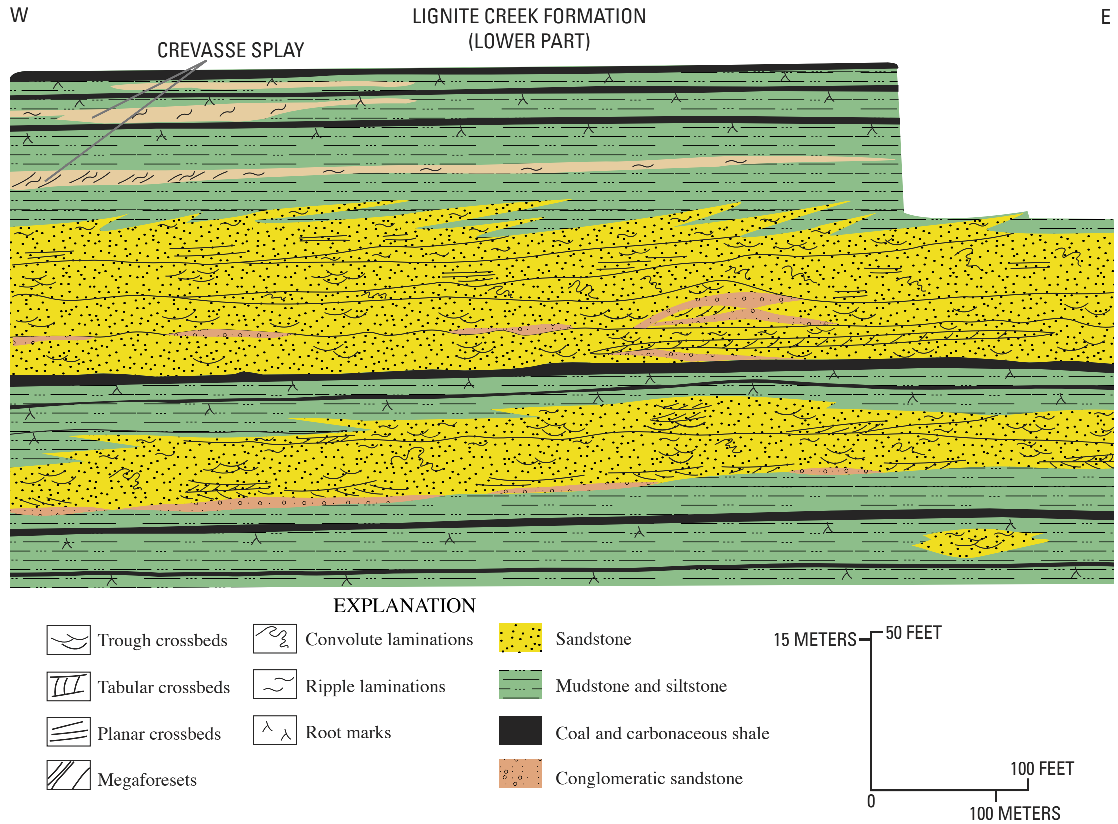


Figure 36. Stratigraphic cross section of the lower part of the Lignite Creek Formation showing interbedded fluvial-channel sandstones, crevasse splay flood-plain deposits, and thin coal beds west of Suntrana. See figure 19 for location of cross section. Adopted from Flores and Stanley (1995).

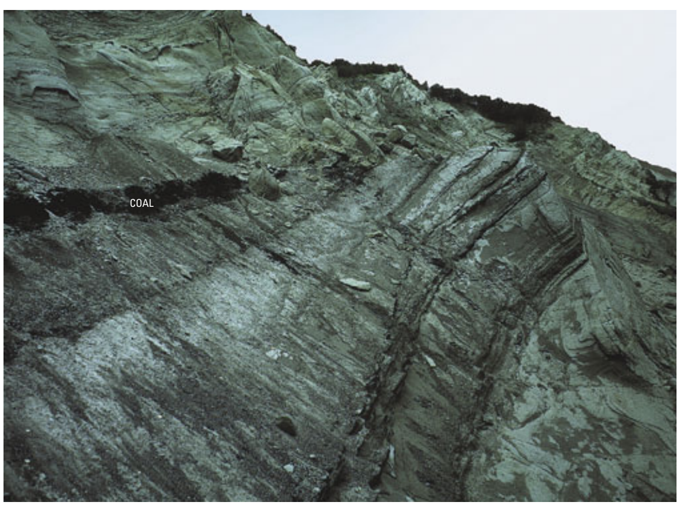


Figure 37. Photograph of the interbedded fluvial-channel sandstones, flood-plain deposits, and an interbedded thin coal bed of the Lignite Creek Formation west of Suntrana. For scale, the upper coal bed is 3 feet (0.9 meter) thick.

Figure 38. Photograph of the coarsening-upward mudstone, siltstone, and sandstone (tabular shape) sequence overlain by thin coal beds of the Lignite Creek Formation west of Suntrana. Hammer on lower left for scale is 1 foot (0. 3 meter) long.

Coal was first mined in the Nenana coal province in 1918 when the Alaska Railroad reached the town of Lignite near Lignite Creek. The Suntrana Mine was an underground operation in the Healy Creek coalfield from 1922 to the mid-1950's. Strip mining by Usibelli Coal Mine (UCM) in the Healy Creek coalfield began in 1944, eventually replacing the underground mining. Several 10- to 65-ft-thick (3–20 m) coal beds within the Suntrana Formation and Healy Creek Formation are separated by 32–195 ft (10–60 m) of poorly consolidated sandstone and are overlain at the surface by sand and gravel with an overburden: coal ratio of < 5:1. Present technologies and economics indicate that essentially all of the strippable coal in the Healy Creek coalfield has been mined. Production from the strip and underground mines in this coalfield since January 1, 1959, was 6.6 million short tons (5.9 million metric tons) (Barnes, 1967a). Approximately 18 million short tons (16 million metric tons) of coal has been produced from the Lignite Creek coalfield by the UCM from 1977 to 1992. In 1985, 48 percent of this production was consumed in Alaska; the rest was exported to South Korea (Green and Bundtzen, 1989). Coal production has come from proven reserves in the Healy Creek and Suntrana Formations. Lignite Creek Formation contains no currently minable reserves within the mine leases.

Healy Creek and Lignite Creek coalfields contain most of the coal resources in the Central Alaska-Nenana coal province (table 4), with more than 5.9×10^9 short tons (5.4×10^9 metric tons) of inferred, measured, and indicated resources (Wahrhaftig, 1973). Wahrhaftig and others (1994) revised this estimate to 6.2×10^9 short tons (5.6×10^9 metric tons). About 5.47 billion short tons (4.9 billion metric tons) are in beds more than 2.5 ft (0.76 m) thick (Barnes, 1967a). Coal resources are distributed as follows: 1 billion short tons (0.91 billion metric tons) identified and 2 billion short tons (1.8 billion metric tons) hypothetical for Healy Creek coalfield; 4.9 billion short tons (4.4 billion metric tons) identified and 7 billion short tons (6.4 metric tons) hypothetical for Lignite Creek coalfield (Stricker, 1991). Measured, indicated, and inferred coal resources in beds more than 2.5 ft (0.76 m) thick and from 0 to 3,000 ft (915 m) below the surface, are 4.9 billion short tons (4.4 billion metric tons) (Barnes, 1967a). About 1.36 billion short tons (1.2 billion metric tons) of total coal resources from 0 to 3,000 ft (915 m) below the surface was estimated by Barnes (1967a) in Healy Creek coalfield and 4.1 billions short tons (3.7 billion metric tons) for Lignite Creek coalfield.

Summaries of the estimates of coal resources of other coalfields such as Jarvis Creek, Wood River, Rex Creek,

Table 4. Estimates of coal resources for the Tertiary Usibelli Group in the Central Alaska-Nenana coal province.
[Resource estimates are in millions of short tons (multiply by 0.907 to obtain metric tons)]

Coalfield	Source	Classification	Resource estimate
Healy Creek	Barnes (1967a)	Identified[1]	1,360
	Merritt and Hawley (1986)	Identified	1,000
	Merritt and Hawley (1986)	Hypothetical	2,000
	Wahrhaftig and others (1994)	Identified[2]	1,300
Lignite Creek	Barnes (1967a)	Identified	4,100
	Merritt and Hawley (1986)	Identified	4,900
	Merritt and Hawley (1986)	Hypothetical	7,000
	Wahrhaftig and others (1994)	Identified[2]	4,900
Jarvis Creek	Wahrhaftig and Hickcox (1955)	Identified	13
	Wahrhaftig and Hickcox (1955)	Hypothetical	63
	Barnes (1967a)	Identified[3]	77
	Merritt (1985)	Measured	1
	Merritt (1985)	Identified	75
	Merritt (1985)	Hypothetical	175
Wood River	Barnes (1967a)	Measured[1]	15
	Barnes (1967a)	Indicated[1]	45
	Barnes (1967a)	Inferred Reported	241
	Merritt (1987)	High Assurance	65
	Merritt (1987)	Low Assurance	59
Rex Creek	Barnes (1967a)	Indicated[4]	9.5
	Barnes (1967a)	Inferred[4]	113
	Merritt and Hawley (1986)	Identified	70
	Merritt and Hawley (1986)	Hypothetical	130
Tatlanika Creek	Barnes (1967a)	Indicated[2]	117
	Barnes (1967a)	Inferred[2]	153
	Merritt and Hawley (1986)	Identified	290
	Merritt and Hawley (1986)	Hypothetical	400

[1] Reported resource estimates with overburden classifications of 0–1,000 feet, 1,000–2,000 feet, and 2,000–3,000 feet.

[2] Reported resource estimates with overburden classifications of less than 30 meters, 30–91 meters, less than 305 meters, 305–610 meters, and 610–915 meters.

[3] Reported resource estimates with overburden classifications of 0–1,000 feet and 1,000–2,000 feet.

[4] Reported resource estimates with overburden classifications of 0–1,000 feet.

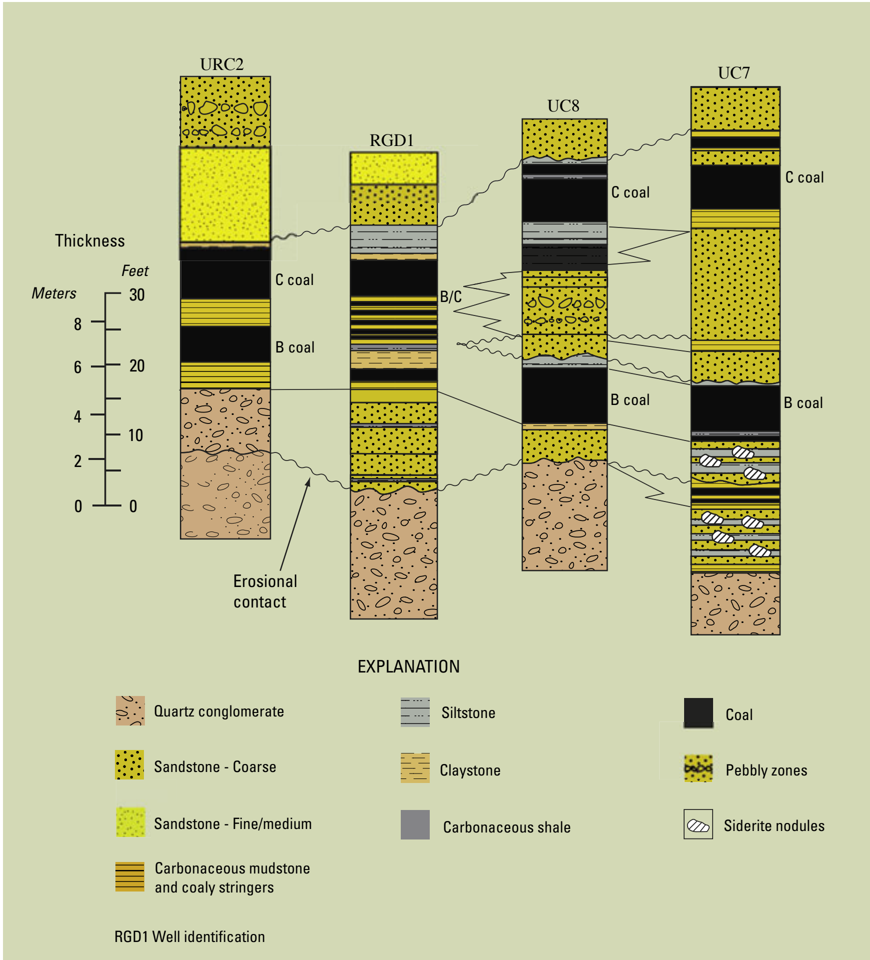


Figure 39. Stratigraphic cross section showing variation of minable Healy Creek coal beds and associated sandstones, mudstones, and siltstones in the Jarvis Creek coalfield. Modified from Belowich (1987). See figure 19 for location of cross section.

and Tatlanika Creek coalfields in the Central Alaska-Nenana coal province are in table 4. In the Jarvis Creek coalfield, the coal-bearing rocks are as much as 1,970 ft (600 m) thick and underlie an area of about 40 mi^2 (103 km^2). These coal-bearing rocks were correlated with the Healy Creek Formation of the Healy Creek coalfield by Wahrhaftig and Hickcox (1955). Thirty thin, discontinuous coal beds are present throughout the coal-bearing sequence, but most of these beds are less than 2.5 ft (0.75 m) thick. Wahrhaftig and Hickcox (1955) calculated 13×10^6 short tons (12×10^6 metric tons) of indicated and inferred resources of coal in seven beds exposed along the south and east sides of the Jarvis Creek coalfield. These workers suggested that the coalfield might contain as much as 62×10^6 short tons (57×10^6 metric tons) of additional coal resources for which no outcrop evidence is available. Metz (1981) reported that drilling had discovered about 1.1×10^6 short tons (1×10^6 metric tons) of stripping coal in part of the Jarvis Creek coalfield. Barnes (1967a) originally estimated indicated and inferred coal resources based on coal beds greater than 2.5 ft (0.75 m) thick in the Jarvis Creek coalfield to be about 51 million short tons (46 million metric tons) between 0 and 1,000 ft (0–305 m) of overburden and about 26 million short tons (24 million metric tons) between 1,000 and 2,000 ft (305–609 m) of overburden.

A small coal strip mine was opened in the center of the Jarvis Creek coalfield in 1958, and mining continued sporadically for many years; more than 1 million short tons (0.9 million metric tons) was estimated as strippable reserve in a 40-acre site (16 hectares) near the old mine by Metz (1981). At the mine, individual coal beds range from 1 to 10 ft (0.3 to 3 m) thick, and seven beds exceed 6 ft (1.8 m), four of which were mined at the surface (Belowich, 1987). The minable coal beds are plotted in figure 39, which shows an 11-ft-thick (3.4 m) coal separated by a 4-ft-thick (1.2 m) carbonaceous shale parting that, west and east of RGD1, splits this coal into two separate beds (B and C), each averaging 7–8 ft (2.1–2.4 m) thick (Belowich, 1987). The intervening strata are fluvial channel sandstones and flood plain overbank deposits.

In the Wood River coalfield (fig. 19), Merritt (1987) mapped the Usibelli Group from the Healy Creek Formation to the Grubstake Formation. However, he identified minable coal beds only within a 600-ft-thick (183 m) coal-bearing interval of the Suntrana Formation. The coal-bearing Usibelli Group underlies a >40-mi^2 (103-km^2) area that makes up the Wood River coalfield, where individual Suntrana coal beds are as much as 12 ft (3.7 m) thick. The coal beds considered as minable include an aggregate coal thickness of 50 ft (15 m) thick of which 30 ft (9.1 m) is recoverable, and overburden was limited to less than 500 ft (150 m). Utilizing all coal beds greater than or equal to 2.5 ft (0.75 m), Merritt (1987) estimated indicated coal resources (high assurance) to be 65 million short tons (59 million metric tons) and hypothetical coal resources (low assurance) to be as much as 200 million short tons (181 million metric tons). Barnes (1967a) originally estimated coal resources based on coal beds greater than 2.5 ft (0.75 m) thick in the Wood River coalfield as: 15 million short tons (13.6 million metric short tons) of measured with 0–1,000 ft (0–305 m) of overburden; 12 million short tons (11 million metric tons) of indicated with 0–1,000 ft (0–305 m) of overburden; and 241 million short tons (218 million metric short tons) of inferred with 0–1,000 ft (0–305 m) of overburden. Indicated coal resources under 1,000 to 3,000 ft (305–914 m) of overburden were estimated by Barnes (1967a) to be 33 million short tons (30 million metric tons).

Barnes (1967a) estimated the indicated and inferred coal resources in the Rex Creek coalfield (see fig. 19) based on coal beds greater than 2.5 ft (0.75 m) thick to be 9.5 and 113.5 million short tons (8.6 and 103 million metric tons) with 0–1,000 ft (0–305 m) of overburden, respectively. Total coal resources, based on coal beds greater than 2.5 ft (0.75 m) thick, are about 123 million short tons (111 million metric tons).

Indicated and inferred coal resources of the Tatlanika Creek coalfield (see fig. 19) were estimated by Barnes (1967a) to be about 117 and 77 million short tons (106 and 70 million metric tons) with 0–1,000 ft (0–305 m) of overburden, respectively. Inferred coal resources from 1,000 to 2,000 ft (305 to 610 m) of overburden are about 76 million short tons (69 million metric tons). Total coal resources based on coal beds greater than 2.5 ft (0.75 m) thick are about 270 million short tons (245 million metric tons) with 0–2,000 ft (0–610 m) of overburden.

Coal resources for the 10 coalfields of the Central Alaska-Nenana coal province were estimated by Merritt and Hawley (1986) to be 8 billion short tons (7.2 billion metric tons) identified and 15 billion short tons (14 billion metric tons) hypothetical. Barnes (1967a) estimated about 6.2 billion short tons (5.6 billion metric tons) of identified coal resources in this coal province (table 4).

Coal Quality

Coal in the Central Alaska-Nenana coal province ranges from lignite to subbituminous but is mainly subbituminous C (table 5). In the Usibelli Coal Mine the coal is subbituminous with 7,570–9,430 Btu/lb (4,210–5,240 kcal/kg) on an as-received basis, 17.8 percent moisture content, 3.5–13.2 percent ash yield, and 0.1–0.3 sulfur (Barnes, 1967a). The sulfur content of the Usibelli coal ranks among the lowest of any United States coal (Rao and Wolff, 1981; Affolter and others, 1981). Affolter and others (1994) reported that the Usibelli mine coal contains high concentrations of lead and selenium and low concentrations of beryllium and mercury, all of which are designated as hazardous air pollutants (HAPs) by the 1990 Clean Air Act Amendment.

In general, a typical coal in the Healy Creek and Lignite Creek coalfields ranges from 6,130 to 9,210 Btu/lb (3,410 to 5,120 kcal/kg) with a mean of 7,780 Btu/lb (4,320 kcal/kg); ash yield is from 5.2 to 34.5 percent (mean is 9.9 percent); sulfur is from 0.1 to 1.49 percent (mean is 0.27 percent); and moisture content ranges from 14.8 to 32.7 percent (mean is 24.7 percent) (Affolter and others, 1994).

Coal in the Jarvis Creek coalfield (see fig. 19) ranges mainly from 7,820 to 9,420 Btu/lb (4,340 to 5,230 kcal/kg); ash yield is from 5.2 to 13.1 percent; sulfur content is from 0.3 to 1.4 percent; and moisture content is from 20 to 23 percent (as-received basis; Barnes, 1967a). However, coal beds in the vicinity of the Jarvis Creek coal mine range, on an as-received basis, from 6,550 to 10,000 Btu/lb (3,640 to 5,560 kcal/kg); ash yield from 2.56 to 32.44 percent; sulfur content from 0.30 to 1.83 percent; and moisture content from 15.90 to 27.62 percent (Belowich, 1987). In addition, the coal beds contain low concentrations of trace elements (for example, chromium, beryllium, cadmiun, and cobalt) recognized as HAPs in the 1990 Clean Air Act Amendment.

In the Wood River coalfield (see fig. 19), coals range from 7,240 to 9,380 Btu/lb (4,020 to 5,210 kcal/kg) (as-received basis); ash yield from 1.81 to 16.31 percent (as-received basis); sulfur content from 0.19 to 0.73 percent (as-received basis); and moisture content from 18.03 to 27.57 percent (as received basis) (Merritt, 1987).

Coal Petrology

Petrology of the coal beds in the Jarvis Creek and Wood River coalfields exhibits three main maceral compositions: huminite (vitrinite), liptinite, and inertinite. At Jarvis Creek, the huminite varies from 62.0 to 88.8 percent, liptinite from 10 to 18.5 percent, and inertinite from 2.2 to 6.5 percent (Belowich, 1987). In contrast, in the Wood River coalfield the huminite varies from 77.7 to 93.9 percent, liptinite from 4.7 to 20.3 percent, and inertinite from 0.2 to 9.1 percent (Merritt, 1987). The abundant woody materials preserved as huminites in the coal beds of the Wood River coalfield suggest that the coal formed mainly from trees. The variable inertinite composition of the coal beds in the Wood River coalfield, indicates that the woody mires were not much affected by forest fires but more by fluctuating ground-water levels and fungal attack (Belowich, 1987). The higher huminite content of the coal beds in the upper part of the coal-bearing interval in the Wood

River suggests that the mire vegetation evolved through time with the increase of coniferous trees relative to deciduous trees (Merritt, 1987).

Southern Alaska-Cook Inlet Coal Province

The Southern Alaska-Cook Inlet coal province is a large coal-bearing region that is as much as 100 mi (161 km) wide and 225 mi (362 km) long and covers an area about 22,500 mi^2 (58,275 km^2), half of which is beneath the waters of Cook Inlet (fig. 1). Many of the Tertiary coal-bearing rocks in the Southern Alaska-Cook Inlet Basin lie beneath the Cook Inlet, Susitna Lowland, Broad Pass Depression, Matanuska Valley, and Kenai Peninsula. In this coal province, Barnes (1967a) identified four coalfields containing Tertiary coal deposits—the Broad Pass, Susitna-Beluga, Matanuska, and Kenai coalfields (fig. 40). Although these Tertiary coal-bearing coalfields occur in onshore areas bordering the Cook Inlet, this report will also describe equivalent Tertiary coal-bearing rocks offshore in the Cook Inlet.

The Southern Alaska-Cook Inlet coal province is centered on the deep trough in the arc-trench gap between the Aleutian volcanic arc and the Aleutian Trench (Fisher and Magoon, 1978). The Cook Inlet Basin, which includes the onshore coalfields and offshore Cook Inlet, lies in the northwesternmost part of this arc-trench gap. The basin, which contains the Southern Alaska-Cook Inlet coal province, is a subsiding, fore-arc basin that lies on the site of a middle Mesozoic open shelf between a volcanic arc and an ancient Pacific oceanic crust (fig. 41; Wahrhaftig and others, 1994). The Lower Jurassic Talkeetna Formation and the Middle Jurassic Talkeetna batholith on the north of the basin represent the volcanic arc (fig. 3). The Kenai and Chugach Mountains represent the ancient Pacific oceanic crust south and east of the basin. Thick Tertiary coal-bearing rocks (Paleocene to Pliocene) overlie

Table 5. Coal quality of coal deposits in the Tertiary Usibelli Group in the Central Alaska-Nenana coal province.
[All analyses except Calorific value (Btu) and Ash-fusion-temperature (°F) are in percent. Values reported on an as-received basis. L after a value means less than the value shown]. Data from U.S. Geological Survey, 1997, USGS Coal Quality Database (USCHEM) (unpublished computer database: Reston, Virginia)]

Unit	Parameter	Number of samples	Range		Arithmetic mean	Standard deviation
			Minimum	Maximum		
	Proximate and ultimate analysis					
Tertiary Usibelli Group	Moisture	30	14.80	32.70	24.70	4.97
	Volatile matter	30	27.30	40.10	35.89	2.82
	Fixed carbon	30	23.10	34.10	29.52	3.23
	Ash yield	30	5.20	34.50	9.89	5.49
	Hydrogen	30	4.60	6.90	6.11	0.58
	Carbon	30	35.60	52.40	45.58	4.63
	Nitrogen	30	0.50	1.00	0.67	0.12
	Oxygen	30	24.50	44.60	37.48	4.73
	Sulfur	206	0.01	1.49	0.27	0.24
	Calorific value					
	Btu per pound	30	6,130	9,210	7,780	910
	Forms-of-sulfur					
	Sulfate	206	0.01L	0.14	0.01	0.01
	Pyritic	160	0.01L	0.55	0.05	0.08
	Organic	160	0.01L	0.90	0.21	0.21
	Ash-fusion-temperatures °F					
	Initial deformation	22	1,970	2,320	2,170	100
	Softening temperature	22	2,050	2,420	2,250	120
	Fluid temperature	69	2,150	2,530	2,330	130

a thick, Middle Jurassic to Upper Cretaceous, terrigenous, epiclastic sequence, which accumulated on this shelf (Kirschner and Lyon, 1973; Fisher and Magoon, 1978). The McHugh Complex and the Valdez Group, which are oceanic crust and deep-sea turbidite sequences, were accreted to southern Alaska during Late Cretaceous time to form the Chugach and Kenai Mountains. This accreted terrane widened the arc-trench gap, which is now about 280 mi (450 km) wide. Irregular subsidence of the fore-arc basin began in latest Cretaceous time and continued sporadically throughout Cenozoic time. Basin subsidence, which was interrupted by mild uplift and erosion, was greatest during Neogene time in a 155-mi-long (250-km) segment of Cook Inlet in much of central and southern Alaska.

Swenson (1997) proposed, based on studies by Richard Curry, David Doherty, and Joseph McGowen (Atlantic-Richfield Company, oral commun., 1998), that the Hemlock, Tyonek, Beluga, and Sterling Formations of the Kenai Group and the West Foreland Formation are regionally time-transgressive units (fig. 42). In addition, these workers suggested that the rock units are laterally equivalent facies related to a dynamic nonmarine depositional basin. That is, the coarsest facies (conglomerates and sandstones) were deposited proximal to the source by an alluvial fan system, which transported sediments from the uplifted Aleutian volcanic arc and accretionary complex margins (Joseph McGowen, Atlantic-Richfield Company,

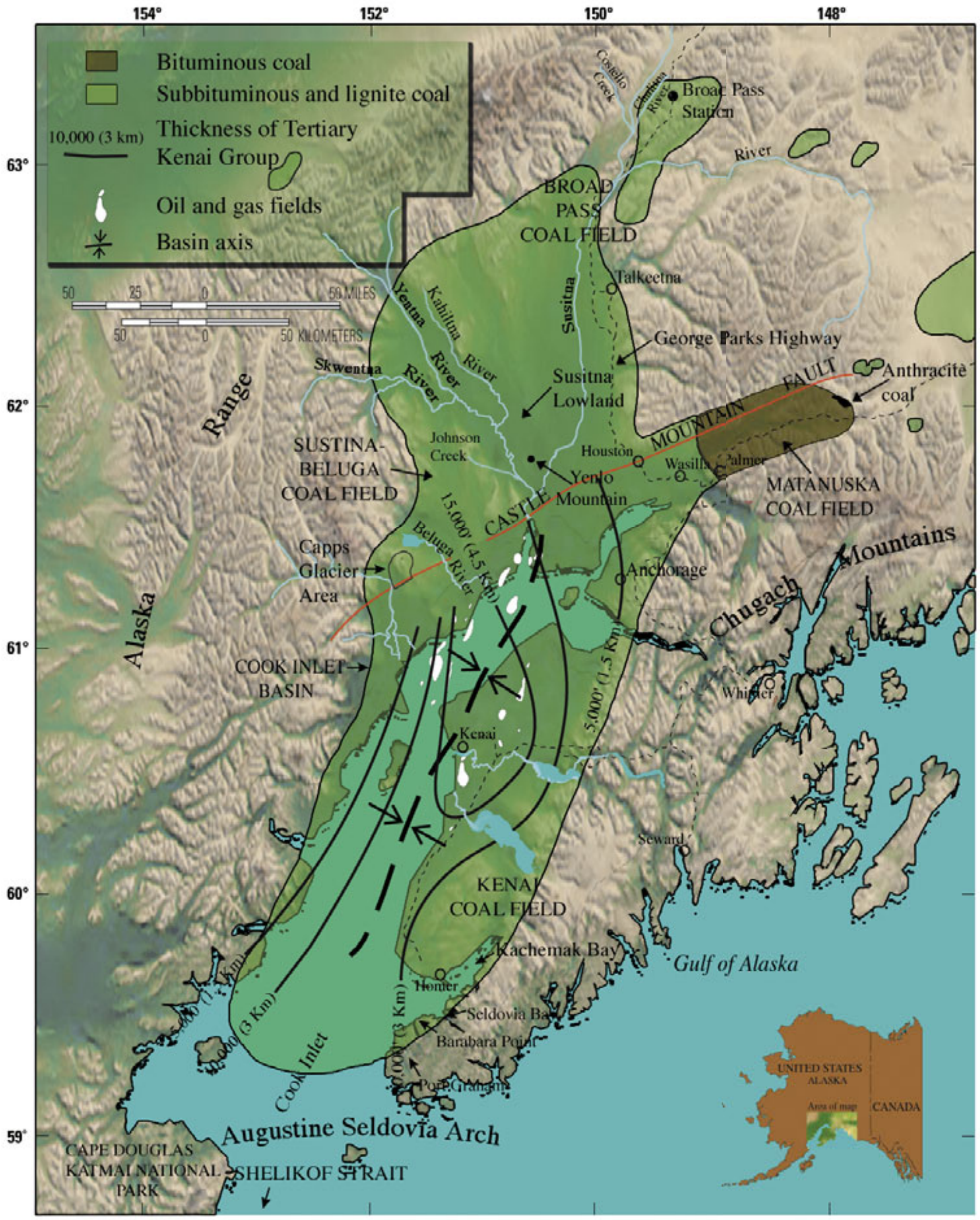


Figure 40. Map showing coalfields in the Southern Alaska-Cook Inlet coal province.

oral commun., 1998). The distal depositional system in the basin center consisted of an axial-fluvial system that reworked the alluvial fan deposits and migrated across the basin floor in relation to uplift and sediment input (fig. 43). Mires, where plant material accumulated, developed within the axial fluvial system.

The Tertiary coal-bearing rocks in the Southern Alaska-Cook Inlet coal province accumulated in the subsiding Cook Inlet Basin, which was probably drained by a large, fluvial, trunk-tributary and alluvial fan system that flowed into the Pacific (Kirschner, 1988). Alluvial fans drained the basin margins, and the trunk (axial) stream drained a broad alluvial plain now occupied by the Cook Inlet. Two major tributary streams of the trunk river extended northward through the present Susitna Lowland and Broad Pass Depression and eastward through the present Matanuska Valley. A Susitna-Broad Pass tributary stream probably extended along the north side of the Alaska Range and drained the Central Alaska-Nenana coal province (Flores and Stanley, 1995). The Yukon-Tanana Upland may have been in headwaters of this tributary stream. Thus, all the coal deposits in the Central Alaska-Nenana and Southern Alaska-Cook Inlet coal provinces are thought to have accumulated in mires related to this large, integrated fluvial drainage system.

Tertiary Rocks

The bulk of the coal in the Southern Alaska-Cook Inlet coal province is of Oligocene to early Pliocene age (fig. 44). These late Tertiary coals are distributed in the Susitna-Beluga, Broad Pass, and Kenai coalfields. However, early Tertiary (Paleocene and early Eocene) coal occurs in the Matanuska coalfield.

Lower Tertiary Rocks

The lower Tertiary rocks include the Paleocene-Eocene Chickaloon Formation and Eocene Wishbone Formation (fig. 45). The Chickaloon Formation is a 3,280- to 4,920-ft-thick (1,000–1,500 m) Paleocene to lower Eocene sequence of mudstones, siltstones, and sandstones, with minor conglomerates and coal beds (figs. 46, 47, and 48; Triplehorn and others, 1984; Flores and Stricker, 1993a). The formation rests unconformably on the Cretaceous Matanuska Formation, which is a sequence of marine sandstone and shale (Barnes and Payne, 1956; Grantz and Jones, 1960) and is overlain unconformably by the Eocene Wishbone Formation. The Wishbone consists of 2,950 ft (900 m) of thick, massive conglomerates and sandstones containing clasts derived from the Talkeetna Mountains to the north (figs. 49 and 50). The formation at the east end of the Matanuska coalfield is unconformably overlain by flat-lying Tertiary basalt. Gabbro sills and dikes and other Tertiary volcanic rocks also intrude the coal-bearing Chickaloon Formation and increase the coal rank along the intrusive contact. The Wishbone Formation is equivalent to the coal-bearing West Foreland Formation in the south-southwest part of the Cook Inlet Basin. The West Foreland Formation consists of abundant conglomerates and sandstones and minor siltstones,

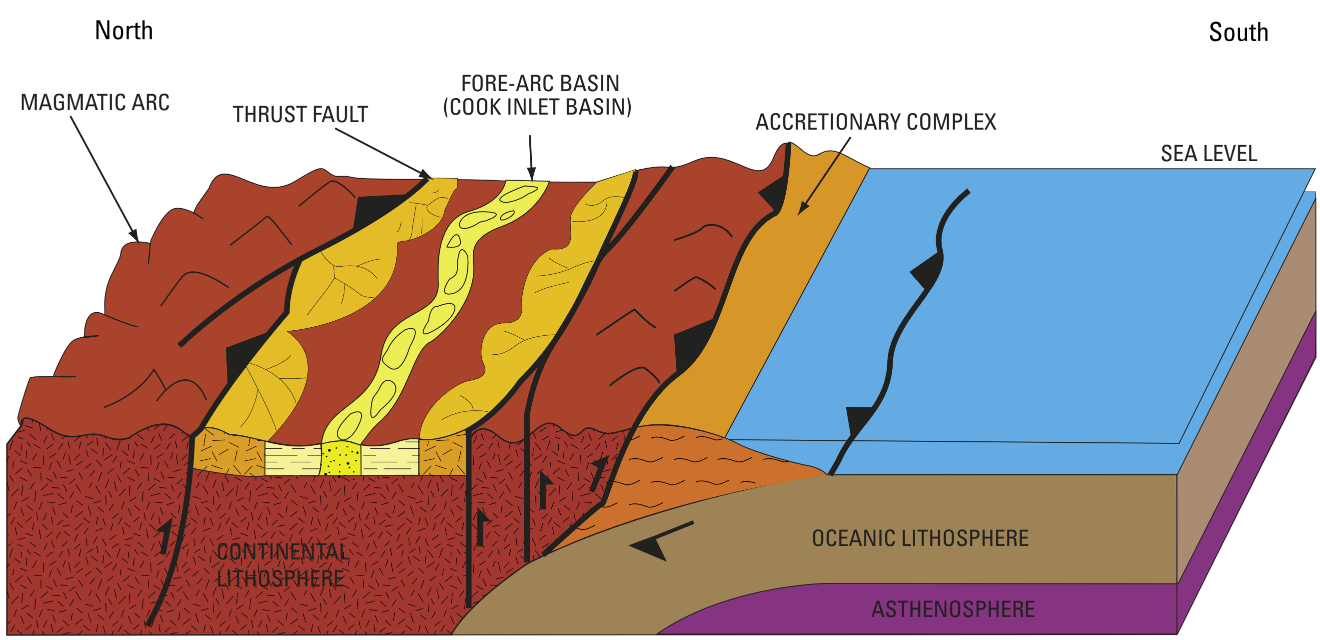


Figure 41. Tectonic and volcanic settings of the Cook Inlet Basin. Modified from McGowen and others in Swenson (1997).

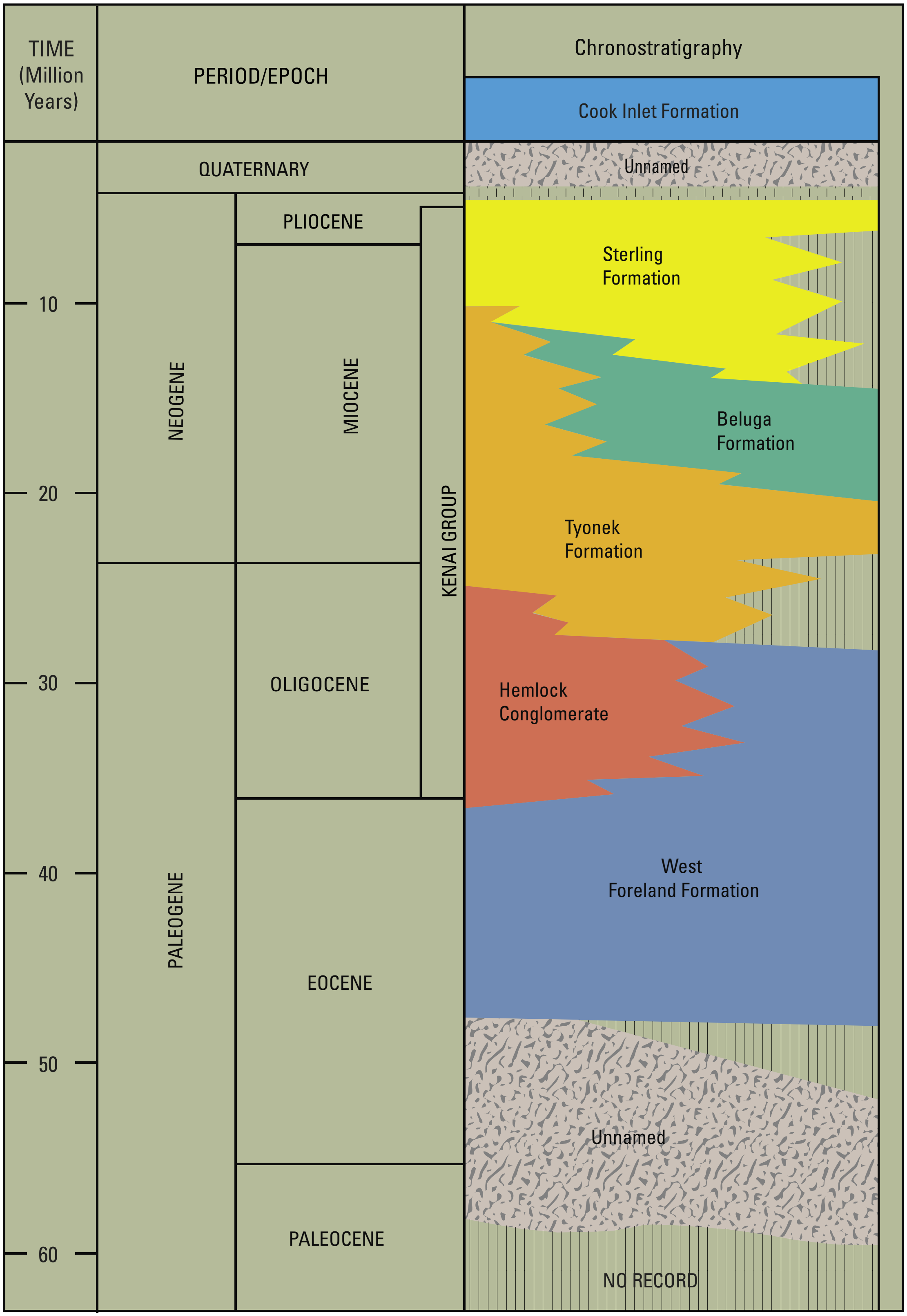


Figure 42. Generalized time-transgressive stratigraphy in the Cook Inlet Basin. Modified from McGowen and others in Swenson (1997).

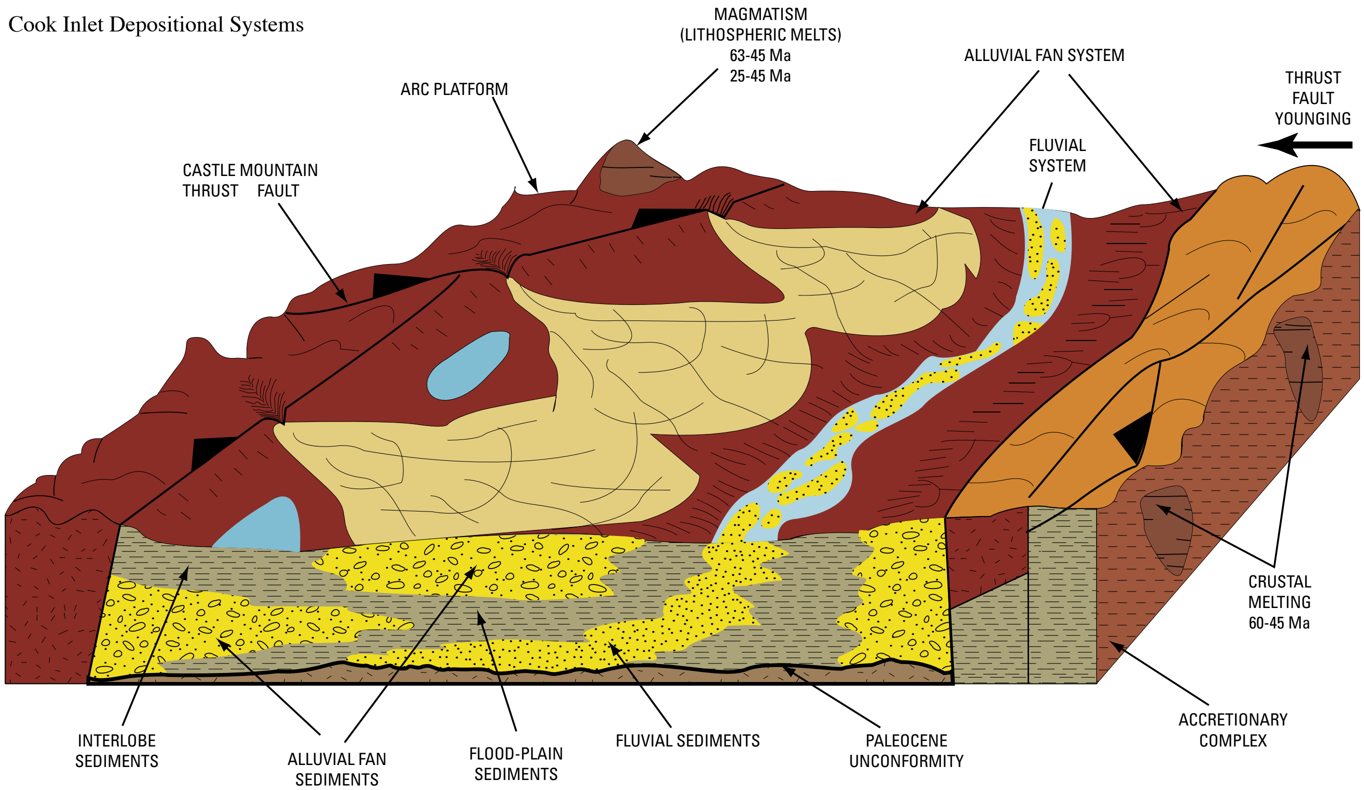


Figure 43. Depositional model of the Kenai Group in the Cook Inlet Basin. Modified from McGowen and others in Swenson (1997).

mudstones, and coal beds (Wahrhaftig and others, 1994). Houston (1994) reported a few coal beds as thick as 1 ft (30 cm) in the 4,100-ft-thick (1,259 m) West Foreland Formation in the Cape Douglas-Katmai National Park area west of the Shelikof Strait and southeast of the Cook Inlet (see fig. 40).

Flores and Stricker (1993a, 1993d) described and interpreted the depositional environments of the Chickaloon and Wishbone Formations. Stratigraphic variations of the Chickaloon sandstones, mudstones, and coal beds in the Wishbone Hill coal district are shown in figures 51, 52, 53, 54, 55, and 56. Sandstones are erosional based and range from lenticular (fig. 47) to tabular shape (fig. 48). Lenticular-shaped sandstones were deposited in fluvial channels and the tabular-shaped sandstones were deposited in crevasse splays. Coal beds (fig. 46, a photograph of the upper part of the Chickaloon Formation in the Wishbone Hill coal district) of the Chick-

ERA	PERIOD	EPOCH	GROUP	FORMATION THICKNESS IN METERS	DESCRIPTION	PROPOSED STAGE (Wolfe and others, 1966)
CENOZOIC	QUAT.				Alluvium and glacial deposits	
	TERTIARY	LATE MIOCENE TO PLIOCENE	Kenai Group	Sterling Formation 0 - 3,350 (10,991 feet)	Sandstone, siltstone, mudstone, carbonaceous shale, and lignites	CLAMGULCHIAN —?— —?— EARLY PLIOCENE HOMERIAN UPPER HALF OF MIOCENE —?— —?—
		LATE MIOCENE		Beluga Formation 1,500 (4,921 feet)	Sandstone, conglomeratic sandstone, siltstone, mudstone, carbonaceous shale, and subbituminous coal beds	LATE EARLY MIOCENE OR MIDDLE MIOCENE
		OLIGOCENE TO LATE MIOCENE		Tyonek Formation 1,200 - 2,350 (3,937 - 7,710 feet)	Sandstone, mudstone, siltstone, interbeds, and subbituminous coal beds	SELDOVIAN EARLY MIOCENE —?— —?— LATE OLIGOCENE
		OLIGOCENE		Hemlock Conglomerate 90 - 845 (295 - 2,772 feet)	Sandstone and conglomerate	
		OLDER TERTIARY ROCKS				

Figure 44. Generalized chronostratigraphic column of the coal-bearing Kenai Group and related rock units in the Southern Alaska-Cook Inlet coal province.

aloon Formation were deposited in topogenous or low-lying mires associated with low-gradient bedload meandering (fig. 57) and anastomosed (fig. 57) fluvial systems. The low-lying mires formed on abandoned belts of meandering streams during lateral aggradation influenced by autocyclic processes. In contrast, low-lying mires related to anastomosed streams developed during vertical aggradation controlled by basin subsidence. Growth faulting promoted prolonged peat accumulation in mires on upthrown blocks and caused stream capture on downthrown blocks. The Wishbone Formation was deposited in alluvial fans and braided stream deposits that were shed from the Talkeetna Mountains (see fig. 57; Flores and Stricker, 1993d). The West Foreland Formation, an equivalent of the Wishbone Formation, was interpreted by Houston (1994) as being deposited in braided streams and associated flood plains. The sediments were derived mainly from the Alaska-Aleutian volcanic arc terrane. The West Foreland coal beds were deposited in abandoned braid belts and flood plains.

Upper Tertiary Kenai Group

The upper Tertiary rocks in the Southern Alaska-Cook Inlet coal province include the Kenai Group consisting, from bottom to top, of the Oligocene Hemlock Conglomerate, Oligocene to middle Miocene Tyonek, upper Miocene Beluga, and upper Miocene to Pliocene Sterling Formations (Flores and Stricker, 1993b, 1993c; Flores, Stricker, and Bader, 1997; Flores, Stricker, and Stiles, 1997; Flores and others, 1999). The Kenai Group is more than 25,000 ft (7,620 m) thick. All these formations are coal bearing, with the Tyonek and Beluga Formations containing numerous thick, minable coal beds. In the offshore and onshore Cook Inlet Basin (fig. 58) the Hemlock, Tyonek, Beluga, and Sterling Formations vary in thickness and lithostratigraphy (figs. 59, 60, and 61). Generally, the formations, especially the Tyonek and Beluga, thicken toward the central part of the basin. The Tyonek Formation is generally sandstone dominated toward the western part of the basin, the Beluga Formation is generally sandstone dominated toward the eastern part, and the Sterling Formation appears to be sandy in the central and eastern parts.

Figure 45. A generalized stratigraphic column of the Chickaloon and Wishbone Formations in the Matanuska coalfield. Minable coal zones occur in the uppermost part of the Chickaloon Formation. Modified from Flores and Stricker (1993a).

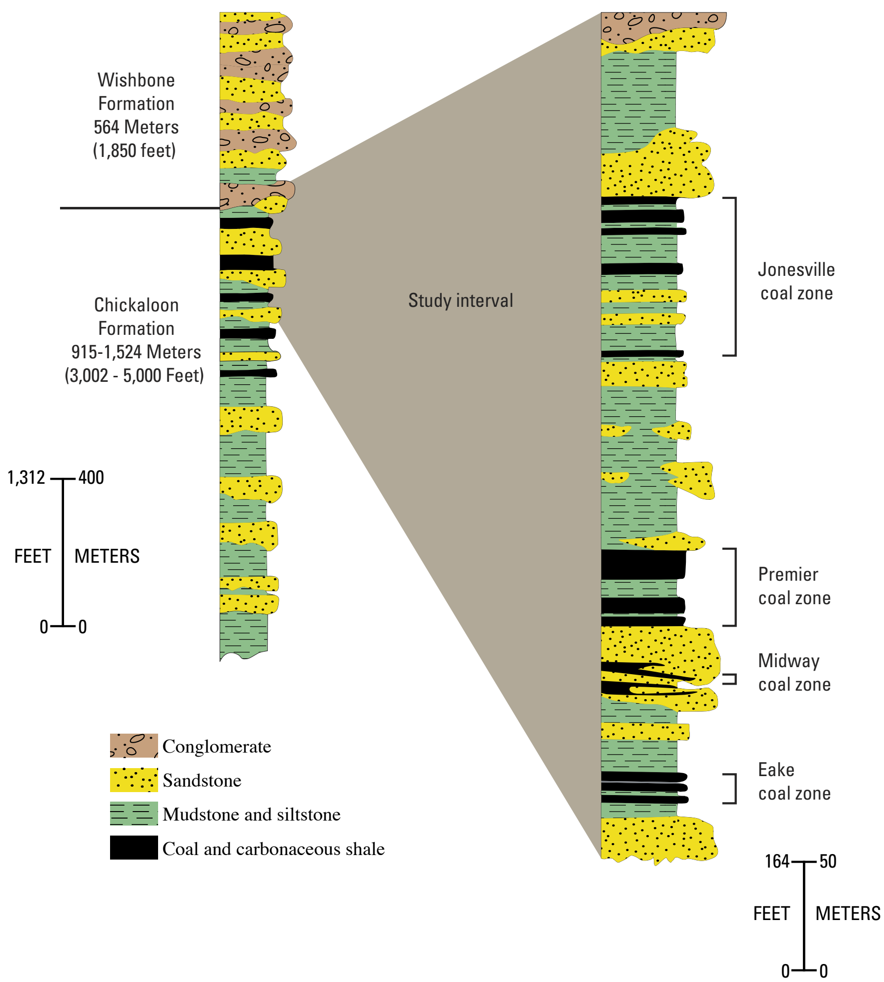


Figure 46. Photograph of coal beds of the Chickaloon Formation in the Wishbone Hill coal district. For scale, the Jonesville coal zone is 20 feet (6.1 meters) thick.

Figure 47. Photograph of the lenticular fluvial-channel sandstone (20 feet or 6.1 meters thick) and associated rocks of the Chickaloon Formation in the Wishbone Hill coal district.

Figure 48. Photograph of the tabular crevasse splay sandstone and associated flood-plain deposits of the Chickaloon Formation in the Wishbone Hill coal district. Hammer in lower left is 1 foot (0.3 meter) long for scale.

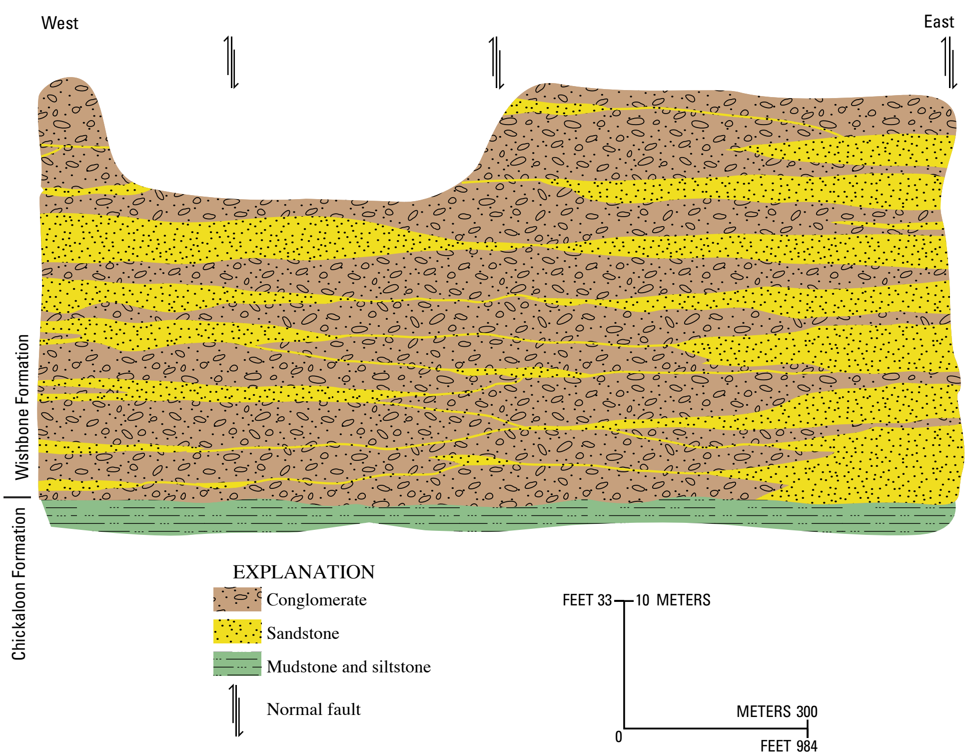


Figure 49. Vertical and lateral lithofacies variations of the Wishbone Formation in the Wishbone Hill coal district.

Figure 50. Photograph of the braided-stream-deposited conglomerates and sandstones in the Wishbone Formation in the Wishbone Hill coal district. Hammer is 1 foot (0.3 meter) long for scale.

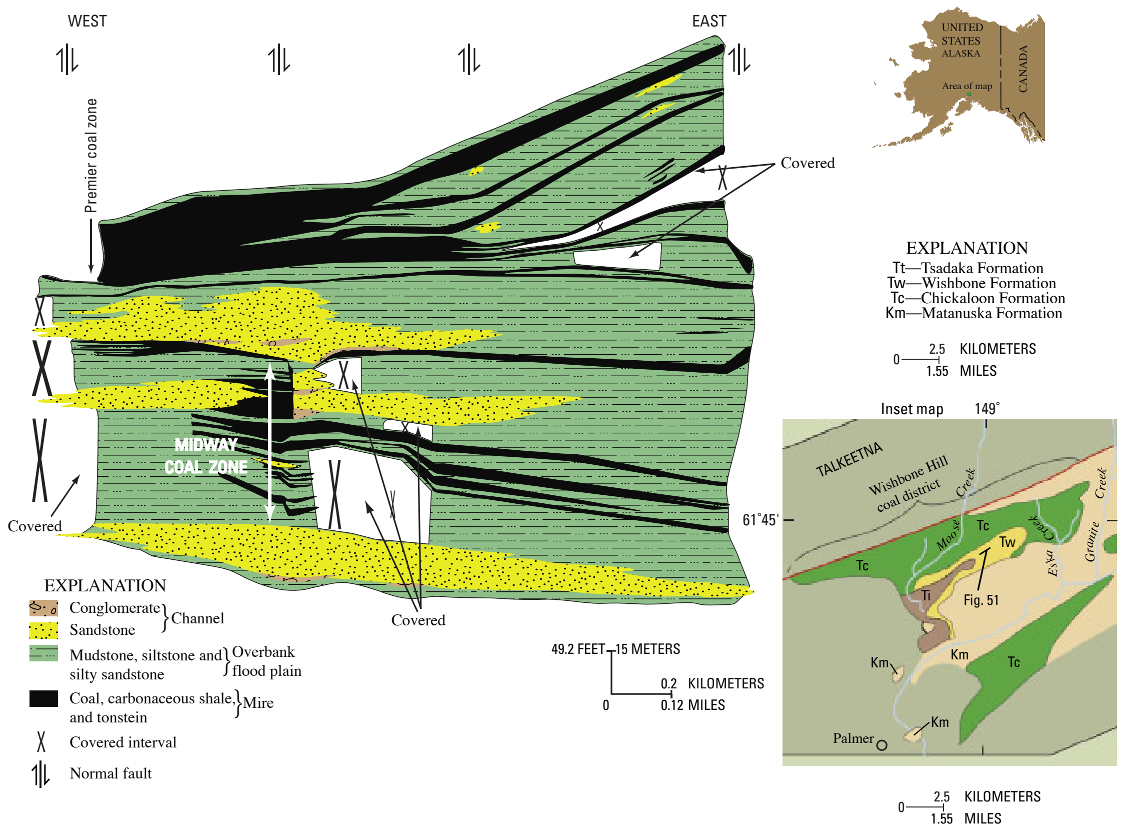


Figure 51. Stratigraphic cross section of the lower part of the Chickaloon Formation in the Wishbone Hill coal district. Adopted from Flores and Stricker (1993d). See inset map for location of cross section.

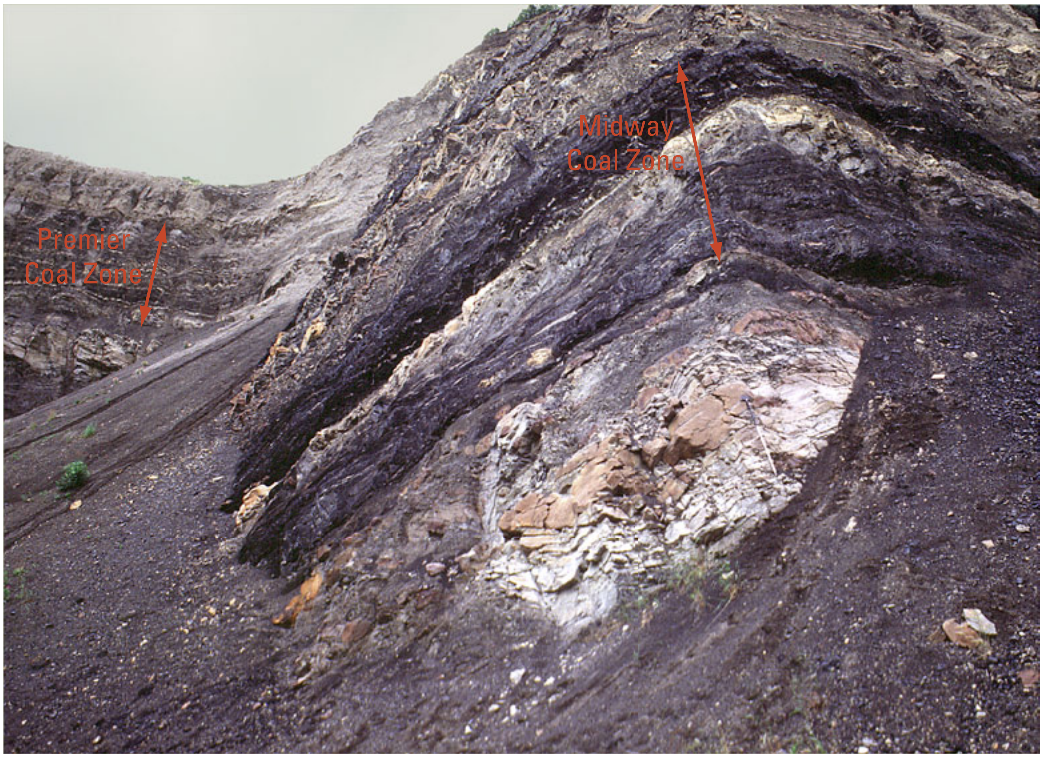


Figure 52. Photograph of the lower part of the Chickaloon Formation showing the Midway coal zone and adjoining fluvial-channel sandstones in the Wishbone Hill coal district. Jacob staff on the sandstone (see right side) is 5 feet (1.5 meters) for scale.

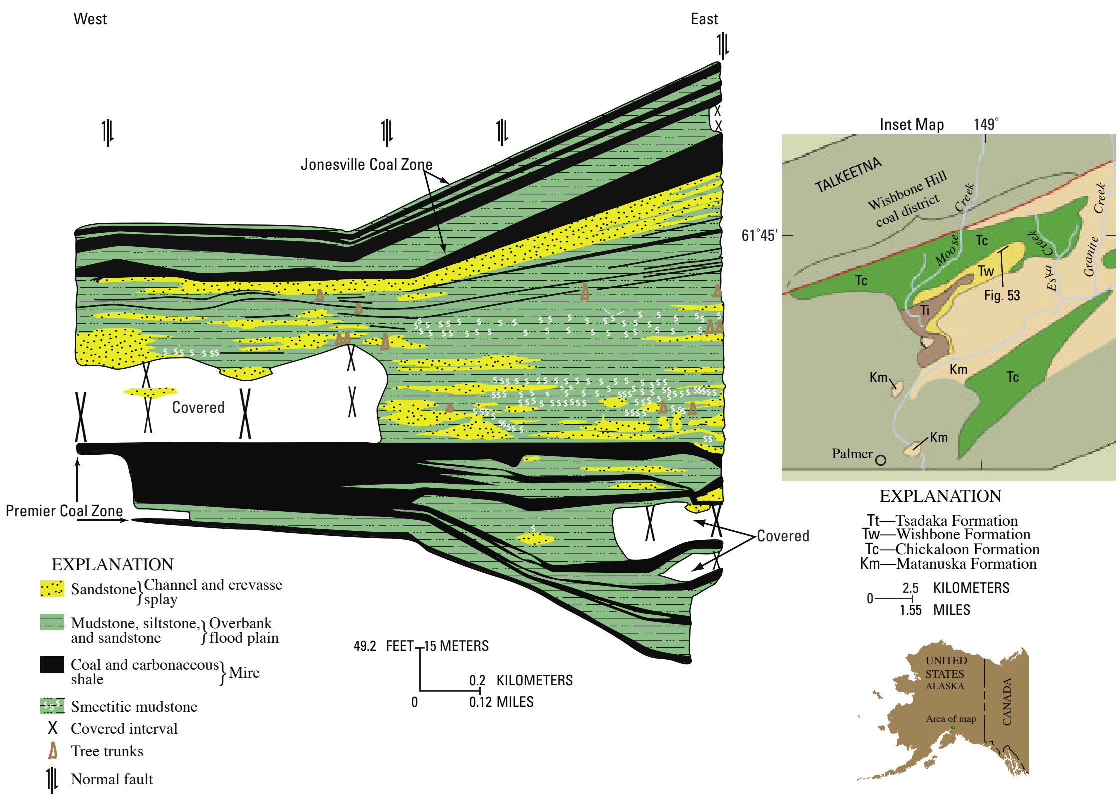


Figure 53. Stratigraphic cross section of the middle part of the Chickaloon Formation in the Wishbone Hill coal district. Adopted from Flores and Stricker (1993b). See inset map for location of cross section.

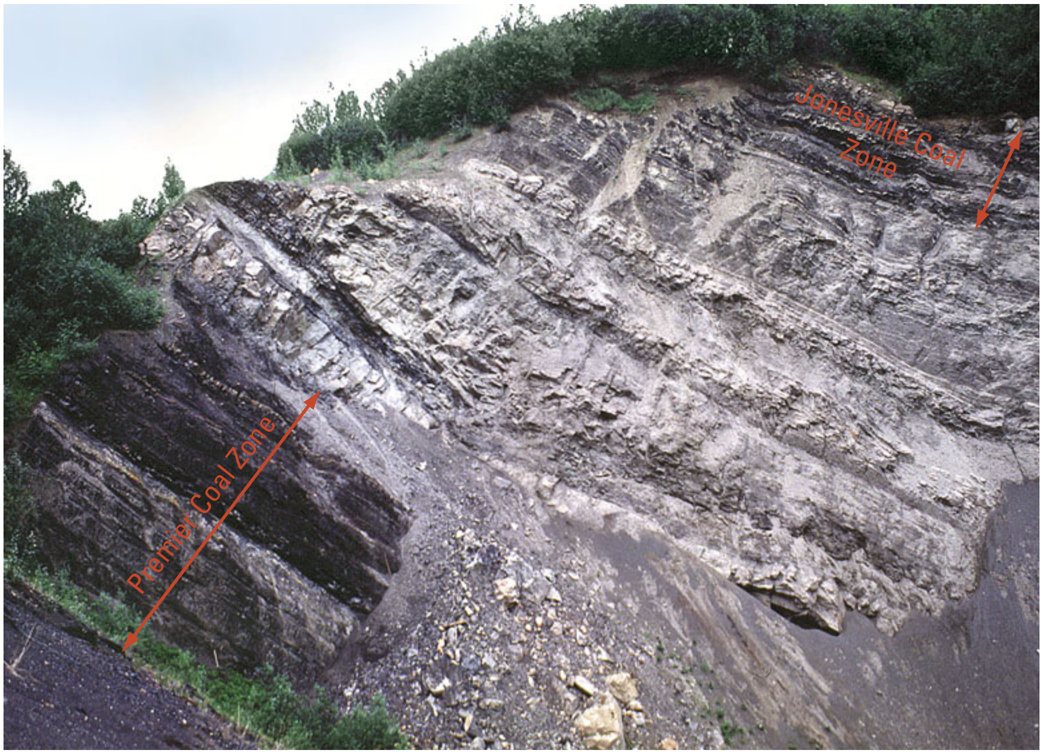


Figure 54. Photograph of the upper part of the Chickaloon Formation showing the Premier coal zone (50 feet or 15.2 meters thick), Jonesville coal zone (30 feet or 9.1 meters thick) and associated fine-grained sediments in the Wishbone Hill coal district.

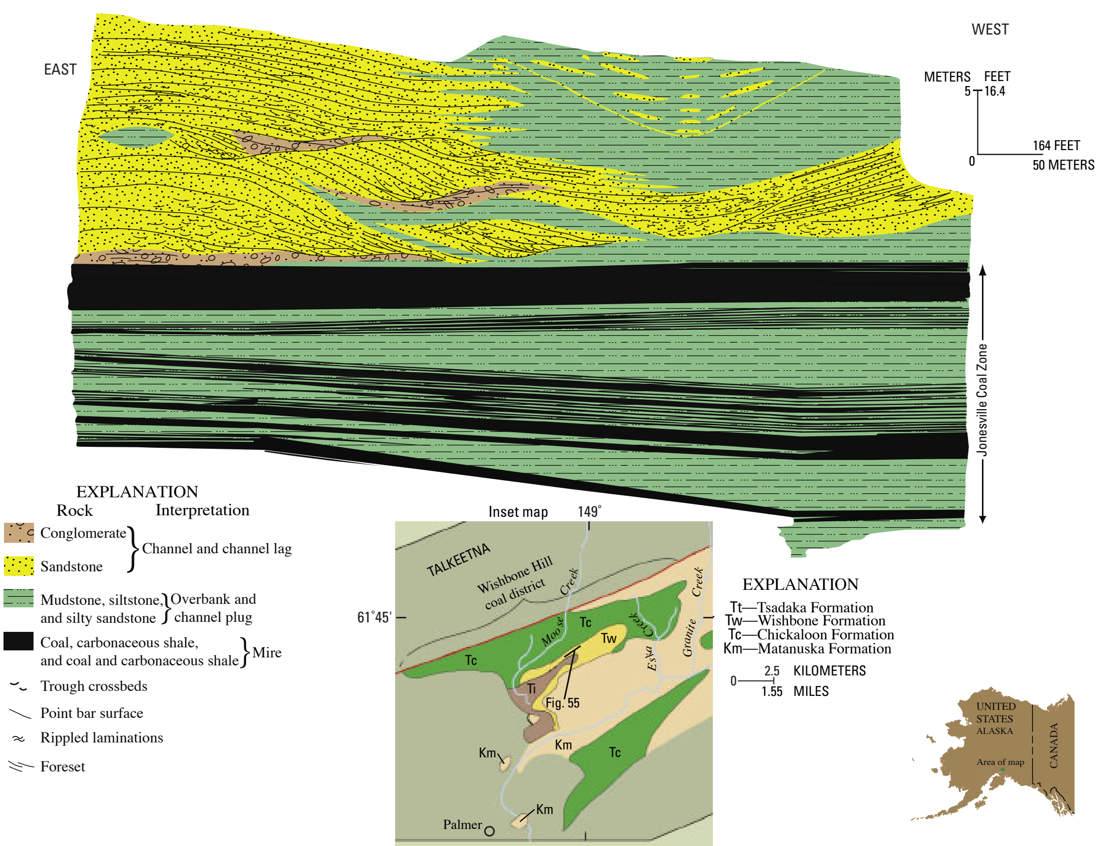


Figure 55. Stratigraphic cross section of the upper part of the Chickaloon Formation in the Wishbone Hill coal district. Adopted from Flores and Stricker (1993a). See inset map for location of cross section.

Figure 56. Photograph of the upper part of the Chickaloon Formation showing the Jonesville coal zone overlain by fluvial-channel sandstones (>50 feet or >15.2 meters thick) of the Wishbone Formation in the Wishbone Hill coal district.

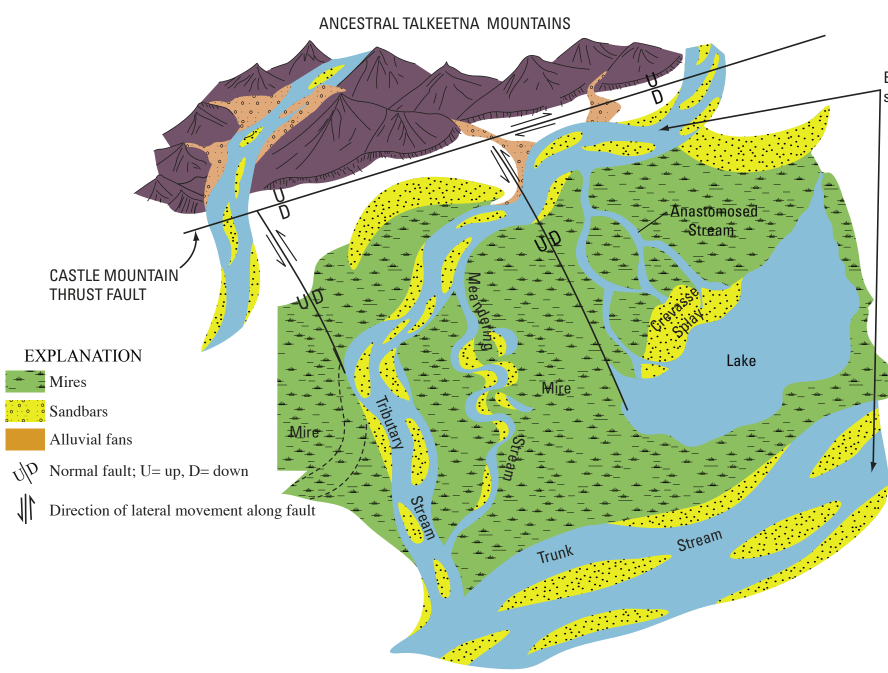


Figure 57. Paleogeographic map showing depositional environments of the Chickaloon Formation in the Matanuska coalfield. Modified from Flores and Stricker (1993a).

Hemlock Conglomerate

The Hemlock Conglomerate is unconformable, gradational, and interfingering with the West Foreland Formation (fig. 42). It consists mainly of pebble to boulder conglomerates containing quartz, chert, metamorphic, volcanic, and plutonic rock fragments. Minor conglomeratic sandstones are interbedded, which are arkosic in composition with sparse heavy minerals, predominantly epidote and garnet (Calderwood and Fackler, 1972; Magoon and Egbert, 1986). However, the formation contains a few thin coal beds and many siltstone beds and is the main producing horizon for oil in the offshore Cook Inlet (Magoon and Anders, 1990). Detrital rocks are interpreted as deltaic and lacustrine deposits, and apparently the sediments were derived from the north. Most coals formed in interdistributary low-lying mires. Together with the Bell Island Sandstone and the Tsadaka Formation, temporal equivalents at the east end of the Cook Inlet Basin, the Hemlock Conglomerate forms a variable sheet deposit 655 ft (200 m) thick, with a maximum thickness of about 2,772 ft (845 m). The formation is Oligocene in age (Wolfe and Tanai, 1980; Magoon and Egbert, 1986).

In the Cape Douglas-Katmai National Park area west of the Shelikof Strait (fig. 40) and southeast of the Cook Inlet, Houston (1994) described the 2,772-ft-thick (845 m) Hemlock Conglomerate as consisting of conglomerates and sandstones

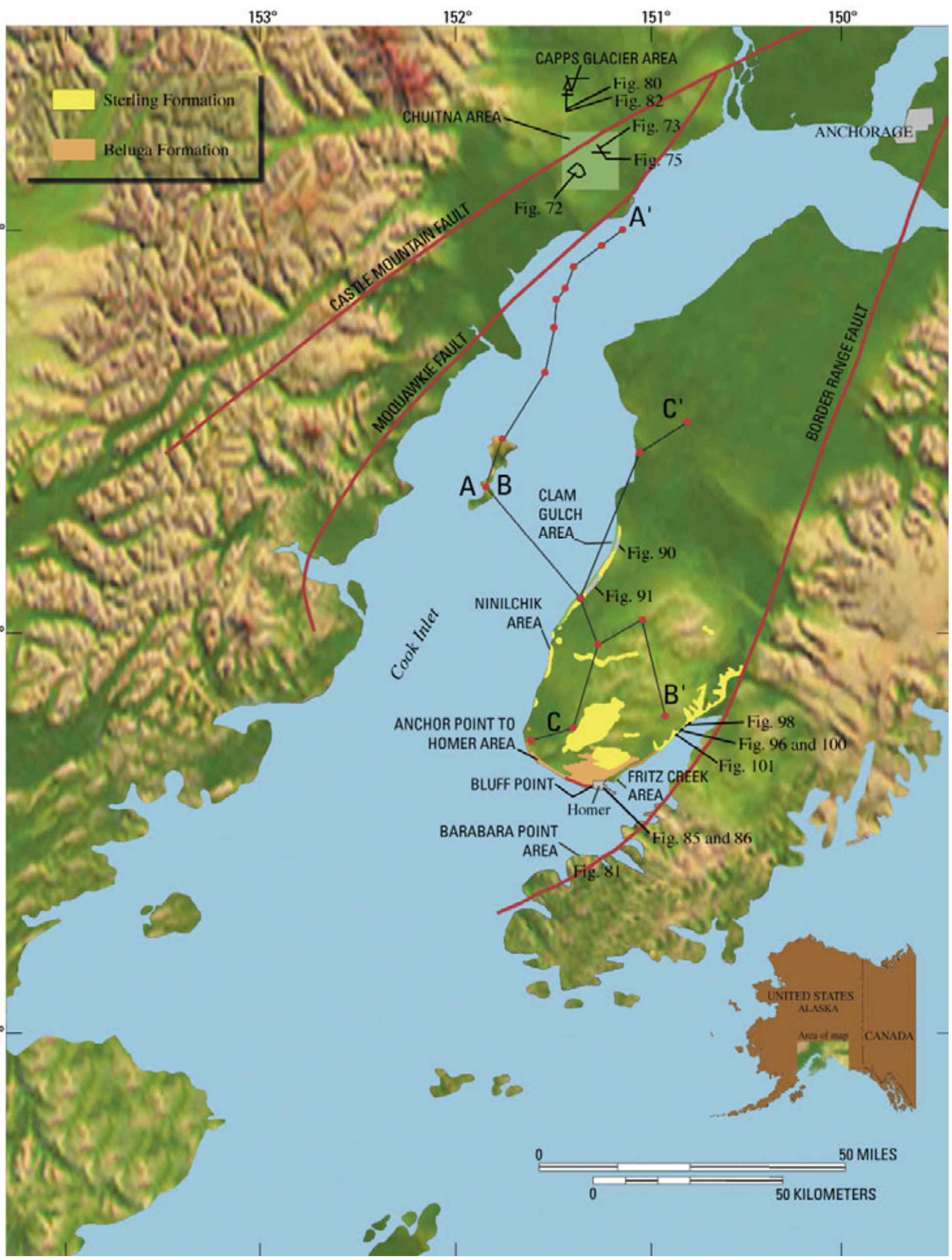


Figure 58. Map showing lines of stratigraphic cross sections (see figs. 59–61) of the Kenai Group in the offshore and onshore Cook Inlet Basin. Map also shows areas of cross sections (see figs. 72–73, 75, 85–86, 90–91) of the Kenai Group in the Chuitna area, Capps Glacier area, along the west coast of Kenai Peninsula, and along the north coast of Kachemak Bay.

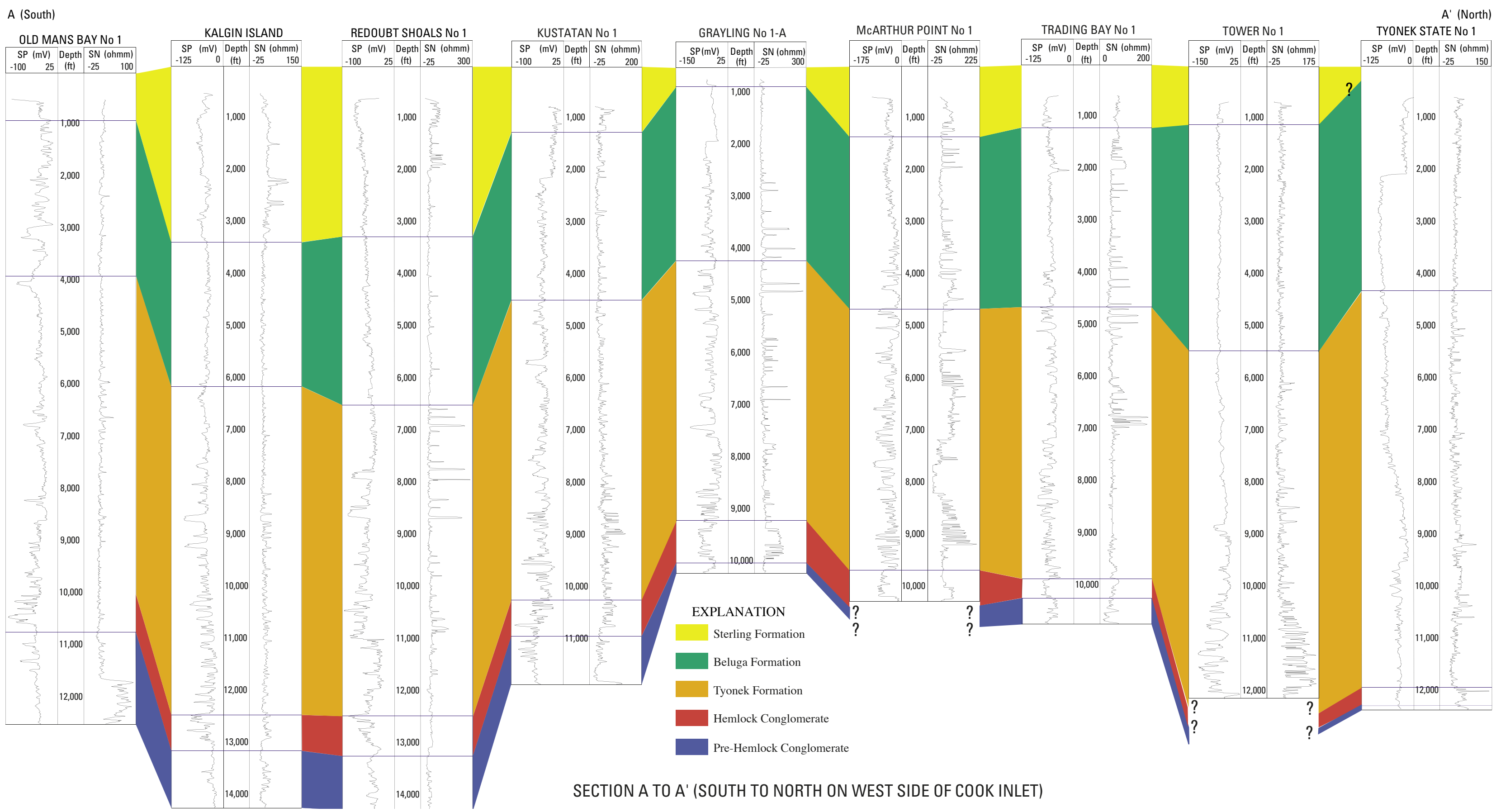


Figure 59. Offshore north-south cross section (A–A') of the Kenai Group along the axis of the Cook Inlet Basin. Modified from Alaska Geological Society (1969a). See figure 58 for location of cross section.

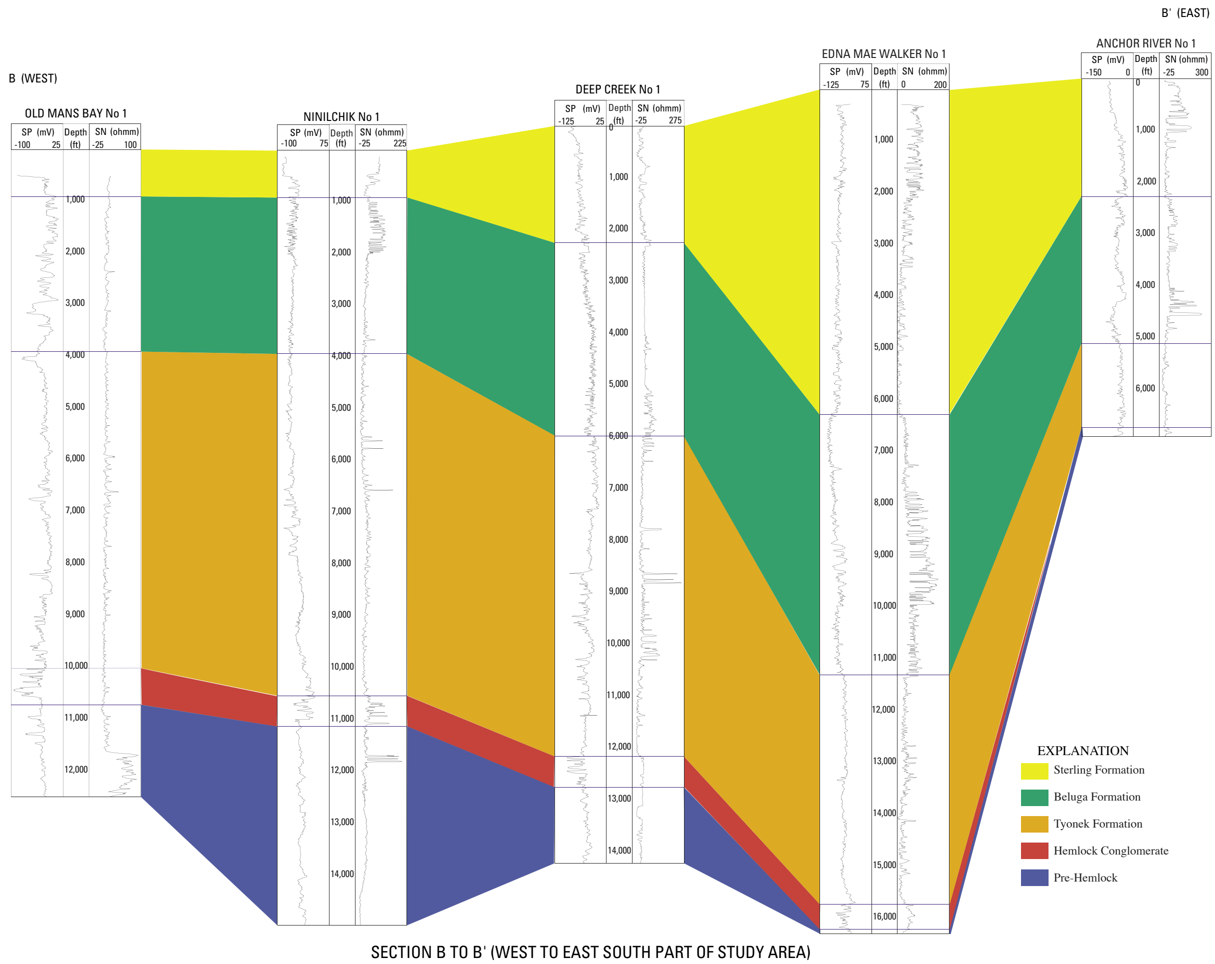


Figure 60. Offshore (west) to onshore (east) cross section (B–B′) of the Kenai Group across the Cook Inlet Basin. Modified from Alaska Geological Society (1969b). See figure 58 for location of cross section.

deposited in meandering streams (figs. 62 and 63). Minor siltstones and mudstones were interpreted to be deposited in overbank and flood-plain environments (figs. 64 and 65). Sparse coal and carbonaceous shale beds, which vary from 2 inches to 2.5 ft (5 cm to 0.75 m) thick, were interpreted to have accumulated in mires developed on abandoned flood plains and meander belts. These streams derived sediments from the Alaska-Aleutian volcanic arc terrane.

Hite (1976) interpreted the sandstones of the Hemlock Conglomerate distributed along the central part of the Cook Inlet Basin (figs. 59 and 60) as being deposited in a marine-influenced environment. Based on size analysis and vertical variability mapping, 18 percent of the analyzed samples showed evidence of tidal transport by bidirectional currents. Twenty-five percent of the analyzed samples indicate transport by turbidity or density suspension currents. Hite (1976) interpreted the coal beds to have accumulated in coastal mires and mapped them as two bands (fig. 66) parallel to the basin margins. Also, Hite (1976) suggested that the paleogeographic setting of the basin during deposition of the Hemlock Conglomerate was very similar to the modern Cook Inlet, which is composed of coastal plains influenced by tidal estuaries, flats, and marshes. Although the present report agrees with this scenario, the elongate shape and coastal-parallel (northeast-southwest orientation) nature of the Hemlock sandstones in the central part of the Cook Inlet Basin, which were interpreted by Hite (1976) as tidal channel and turbidity deposits, are here reinterpreted as tidal sand-flat deposits. These tidal sand flats were probably derived by reworking of deltaic sediments of the streams that deposited the Hemlock Formation in the Cape Douglas-Katmai National Park area southeast of the basin.

Tyonek Formation

The Tyonek Formation (Wolfe and Tanai, 1980) consists of a sequence of sandstones, siltstones, mudstones, carbonaceous shales, and coal beds as much as 7,640 ft (2,330 m) thick (fig. 67; Calderwood and Fackler, 1972). Sandstones, the most common rock type, are basally erosional, crossbedded, thick, and vertically stacked (fig. 68). Individual coal beds are as much as 33 ft (10 m) thick. A sandstone:mudstone ratio map of the formation by Hartman and others (1971) shows more than 50 percent sandstone in an area along the west side

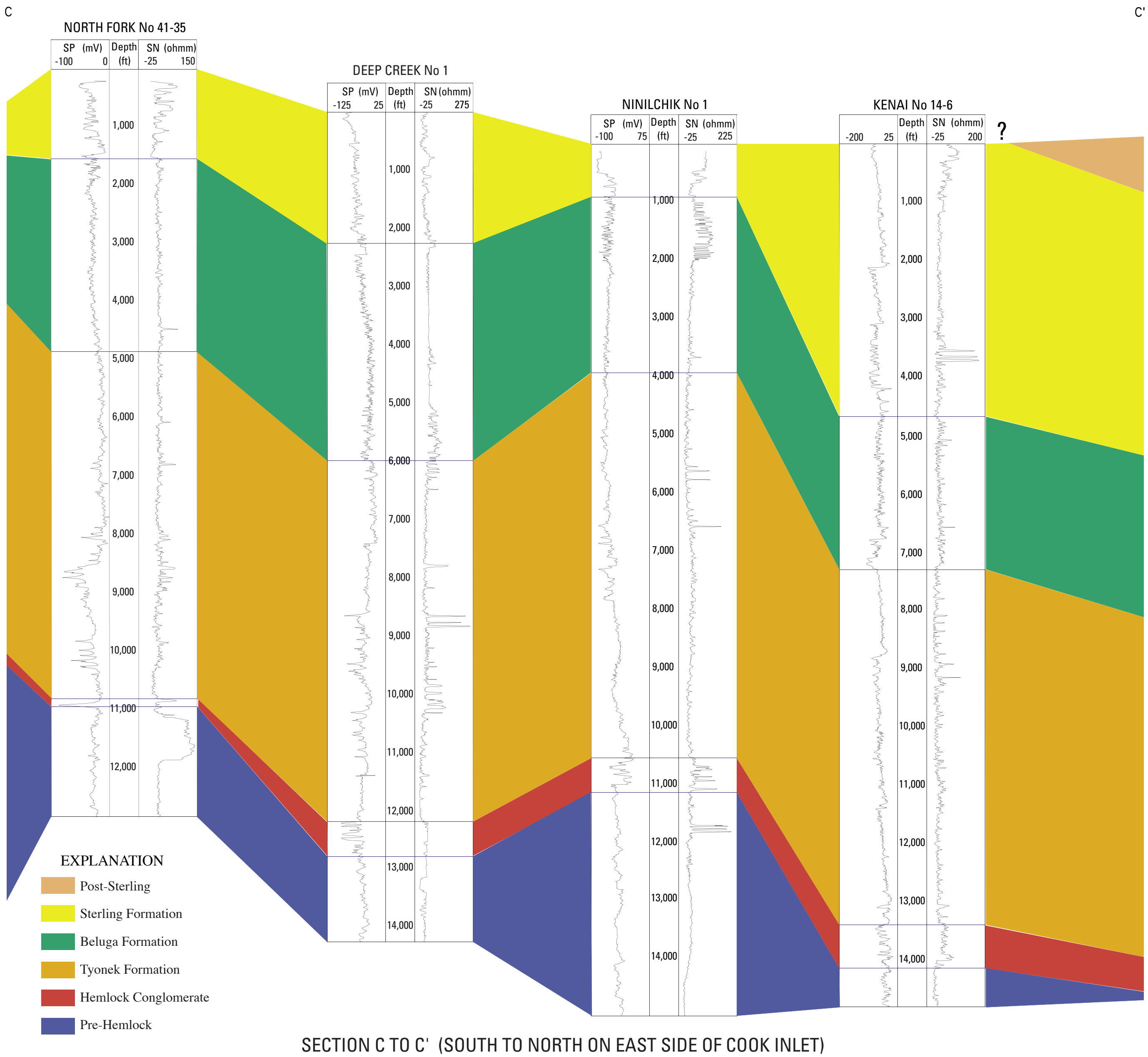


Figure 61. Onshore north-south cross section (C–C′) of the Kenai Group along the western part of the Kenai Peninsula or eastern margin of the Cook Inlet Basin. Modified from Alaska Geological Society (1969c). See figure 58 for location of cross section.

Figure 62. Photograph of conglomerates in the Hemlock Conglomerate in the Katmai National Park. Jacob's Staff is 5 feet (1.5 meters) long for scale. Photograph courtesy of Frank Ethridge.

Figure 63. Photograph of sandstones in the Hemlock Conglomerate in the Katmai National Park. Man is 5.5 feet (1.7 meters) tall for scale. Photograph courtesy of Frank Ethridge.

Figure 64. Photograph of thin coal and carbonaceous shale beds in the Hemlock Conglomerate in the Katmai National Park. Man is 6 feet (1.8 meters) tall for scale. Photograph courtesy of Frank Ethridge.

Figure 65. Photograph of braided stream deposits (conglomeratic lower part) in the Hemlock Conglomerate. The upper part contains fluvial-channel sandstones and carbonaceous siltstones. Jacob's staff in the lower part of the photograph is 5 feet (1.5 meters) long for scale. Photograph courtesy of Frank Ethridge.

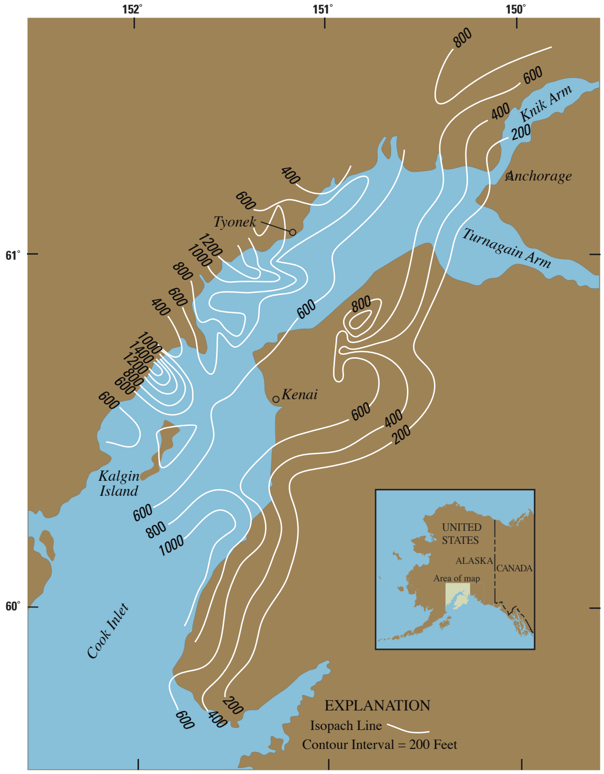


Figure 66. Net coal thickness isopach map of the Tyonek Formation in the Cook Inlet Basin. Modified from Hite (1976) and Wahrhaftig and others (1994).

of the Cook Inlet Basin and in the extreme northeastern part of the basin. The sites with higher sandstone content were interpreted as loci of sediment input. An extensive mudstone band containing as little as 10 percent sandstone extends south-southwestward along the western part of the Kenai Peninsula. Sandstone content increases southeastward of this band of maximum mudstone content. This site of extensive belt of mud represents the distal point of sandstone input.

Hite (1976) presented an isolith sand map (net sandstone thickness isopach map) of the Tyonek in the Cook Inlet Basin (see fig. 69) that shows the high concentration of sandstone along the western part of the basin and decreasing toward the eastern part. In addition, on the west side, the contour lines define a lobate concentration of sandstone, which flares as elongate bodies to the northeast and southeast of the basin. We interpret these sandstone concentrations as alluvial-fan delta and tidal-flat deposits (fig. 70).

The alluvial-fan delta and tidal-flat lithofacies of the Tyonek Formation were studied by Flores and others (1994) and Flores, Stricker, and Stiles (1997) whose descriptions of the vertical and lateral variations of these facies in the Chuitna River drainage basin, about 10 miles (16 km) northeast of Tyonek, are depicted graphically in figures 71, 72, and 73. The tidal sand flat and intertidal lithofacies as described by Flores and others (1999) 2.6 mi (4.2 km) northwest of Wasilla are shown in figure 74. Sediments of the tidal sand flats may have been sourced from the alluvial-fan delta sediments and reworked by tidal currents. Streams from adjacent areas to the north and east of the Cook Inlet Basin may also have contributed minor amounts of sediment.

The net total thickness of coal beds penetrated in wells in the Tyonek Formation increases toward the northwestern part of Cook Inlet Basin (see fig. 66; Hite, 1976; Wahrhaftig and others, 1994). The beds are concentrated along the northwest margin of the basin, from Kalgin Island northeastward along the west shore of the inlet to the Susitna River. In that area, the coal isopach map displays lobe shape with fingerlike extensions oriented to the east and southeast (see fig. 66). Lobe-shaped coal concentrations, which also correspond to the sites of lobate concentrations of sandstones, are interpreted as having been deposited in mires associated with alluvial-fan deltas. At those sites, abandoned alluvial-ridge braid belts of the fan deltas served as raised platforms where mires devel-

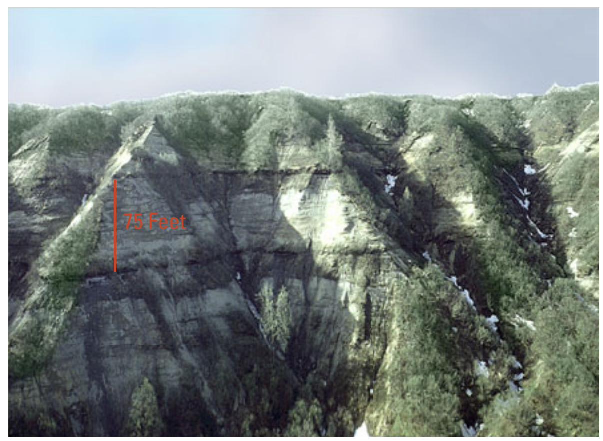


Figure 67. Photograph of coal beds and interbedded fluvial-channel sandstones and mudstones in the Tyonek Formation in the Chuitna River drainage basin. The sandstone in the upper part of the outcrop is 75 feet (22.8 meters) thick for scale.

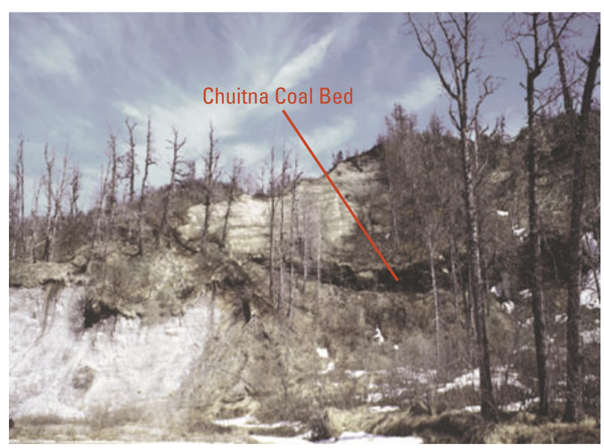


Figure 68. Photograph of fluvial-channel sandstones and Chuitna coal bed in the Tyonek Formation in the Chuitna River drainage basin. The sandstone in the lower part of the outcrop is 50 feet (15.2 meters) thick for scale.

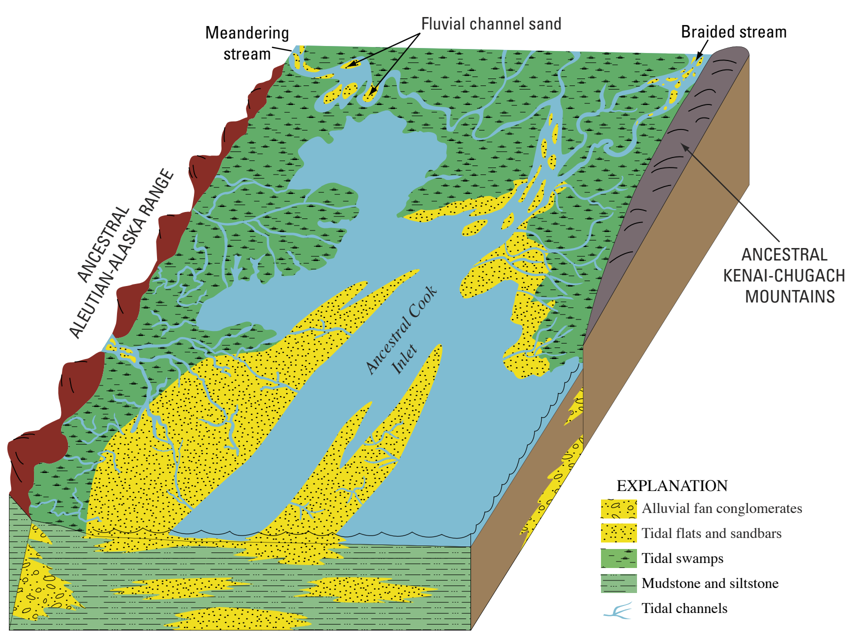
Figure 69. Net sandstone thickness isopach map of the Tyonek Formation in the Cook Inlet Basin. Modified from Hite (1976).

oped as much as 28 ft (8.5 m) of minable coal (see figs. 72 and 73) as described at the Diamond Chuitna coal-mine lease area by Flores and others (1994) and Flores, Stricker, and Stiles (1997). However, the coal beds are associated with intertidal sediments indicating development in supratidal mires (figs. 75, 76, and 77). The fingerlike pattern of the net coal thickness isopach map (see fig. 66) indicates tidal influence much like the mires along the coast in west-central Sumatra, Indonesia (Flores and Moore, in press).

The total coal isopach map (fig. 66) shows thinning to the northeast, southeast, and southwest toward the zone of minimum sandstone content (Hartman and others, 1971; Hite, 1976). The southwest-northeast orientation of the net coal thickness isopach, a trend that is perpendicular to the southeast-oriented deltaic wedges, indicates accumulation of coal in low-lying tidal sand flat and supratidal mires. Tidal influence in the Tyonek Formation in the Barabara Point, southwest of Kachemak Bay (see fig. 40) in the eastern Cook Inlet was described by Stricker and Flores (1996). However, the tidal deposits overlie a sequence of conglomerate, sandstone, siltstone, and mudstone, with coals a few inches to 2 ft (few centimeters to 0.6 m) thick (fig. 77). Mudstones and siltstones are the most abundant lithologies, which are interpreted to be derived from the Chugach metamorphic rock complex. Stricker and Flores (1996) and Myers and others (1998) interpreted this sequence as an alluvial fan drained mainly by anastomosed streams.

The thick Capps Glacier coal bed (figs. 78, 79, and 80) and coal beds along the Beluga and Chuitna Rivers (Barnes, 1966; Adkison and others, 1975; Myers and others, 1998) are in the Tyonek Formation (Magoon and others, 1976). Within a single coalfield, correlation of the coal beds from well to well has proved difficult for distances of more than a mile (few kilometers), which indicates considerable lenticularity of the coal seams and the intervening sedimentary rocks. The rapid changes in the lateral and vertical stratigraphy of the coal beds and intervening rocks are shown in figures 81 and 82. In both cross sections, the Capps Glacier coal bed is traceable for a mile or two; however, the coal bed splits and merges laterally as influenced by the thinning, pinching out, and thickening of the intervening fluvial channel sandstones. The pattern of the

Figure 70. Paleogeographic map (block diagram) showing depositional environments of the Tyonek Formation in the Cook Inlet Basin. Modified from Hite (1976).



coal bed wrapping around the sandstones is enhanced by differential compaction. That is, the sandstones are less compactible than adjacent mudstones. In outcrop, however, individual coal beds have been traced for as much as 6.2 mi (10 km) (Barnes, 1966; Ramsey, 1981).

Nearly flat-lying outliers of the Tyonek Formation along the southeast shore of Kachemak Bay near Seldovia Bay and at Port Graham (see fig. 40) rest unconformably on metamorphic rocks of Triassic and Jurassic age and appear in part to fill steep-sided valleys and in part to be downfaulted (Stone, 1906; Martin and others, 1915; Magoon and others, 1976). The occurrence on the northeast side of the entrance to Port Graham was the site of the plant fossils on which Oswald Heer in 1869 (Wahrhaftig and others, 1994) established the "Arctic Miocene" flora of Alaska (see Stone, 1906), and the locality on which the name "Kenai Formation" (now Kenai Group) was established by Dall (1896). Portlock first reported coal there in 1786 (see Stone, 1906, p. 54). Coal (chiefly lignite)

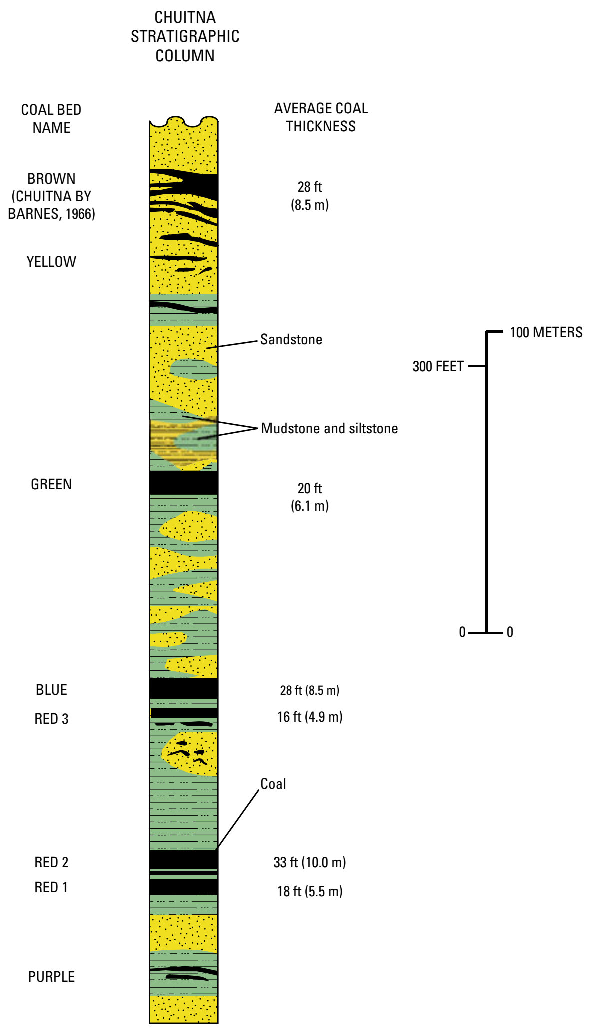


Figure 71. Generalized stratigraphic column of minable coal beds in the Tyonek Formation in the Chuitna River drainage basin and adjoining areas. Modified from Flores and others (1994) and Flores, Stricker, and Bader (1997).

was mined at this site by the Russians from 1855 to 1867, but it could not be produced at a profit, and operations ceased when Alaska was sold to the United States in 1867 (Stone, 1906).

Beluga Formation

The Beluga Formation (fig. 42) is as much as 4,900 ft (1,500 m) thick, is composed of interbedded conglomerates, sandstones, siltstones, mudstones, carbonaceous shales, and coal beds (see fig. 44). The sandstones are the most abundant rock type and coal beds are the least common. The sandstones are erosional based, as much as 50 ft (15 m) thick, cross-bedded, and vertically stacked (figs. 83 and 84; Flores and Stricker, 1993b). Stratigraphic variations of the sandstones and coal beds are shown in figures 85 and 86. These lithic units are drab-gray in color. In the outcrop, the color of the formation is used to distinguish it from the overlying buff to light-brown Sterling Formation (Barnes and Cobb, 1959; Wolfe and others, 1966; Merritt and others, 1987). Abundant heavy minerals (Kirschner and Lyon, 1973) and metamorphic rock fragments in the locally pebbly sandstones led Hayes and others (1976) to interpret the Beluga Formation to be derived mainly from the Kenai and Chugach Mountains. Paleocurrent analysis of crossbeds of the sandstones by Rawlinson (1984) and Kremer and Stadnicky (1985) indicate a westerly transport direction of its sediments. The Beluga Formation is well exposed in beach bluffs along the northwest side of Kachemak Bay and the south-southwest end of the Kenai Peninsula between Homer and Anchor River (Magoon and others, 1976; Merritt and others, 1987). There it contains numerous coal beds with individual beds as thick as 6.6 ft (2 m) (Barnes and Cobb, 1959). The formation was dated as middle and late Miocene (Wolfe and Tanai, 1980).

Environments of deposition of the Beluga Formation are interpreted to be braided and meandering streams and alluvial fans (fig. 87; Hayes and others, 1976; Hite, 1976; Rawlinson, 1984; Merritt, 1986). Recent studies by Flores and Stricker (1992, 1993b) indicate deposition in an alluvial plain drained by alternating braided streams and crevasse splay-anastomosed streams. Through time the braided streams evolved into the crevasse splay-anastomosed streams, which, in turn, evolved into the braided streams. Regional and basin subsidence and autocyclic avulsion processes caused these alternations through time. Flores and Stricker (1993b) suggested that the coal beds accumulated in mires on abandoned braid belts and anastomosed stream belts. However, the coal beds formed in mires on braid-belt deposits were thicker and more extensive than coal formed in mires developed on crevasse-splay-anastomosed deposits.

Hayes and others (1976) suggested that the Beluga Formation was deposited by meandering streams along the length of the western part of the Cook Inlet Basin. These stream deposits, which are the chronostratigraphically equivalent of the Lignite Creek Formation (Central Alaska-Nenana coal

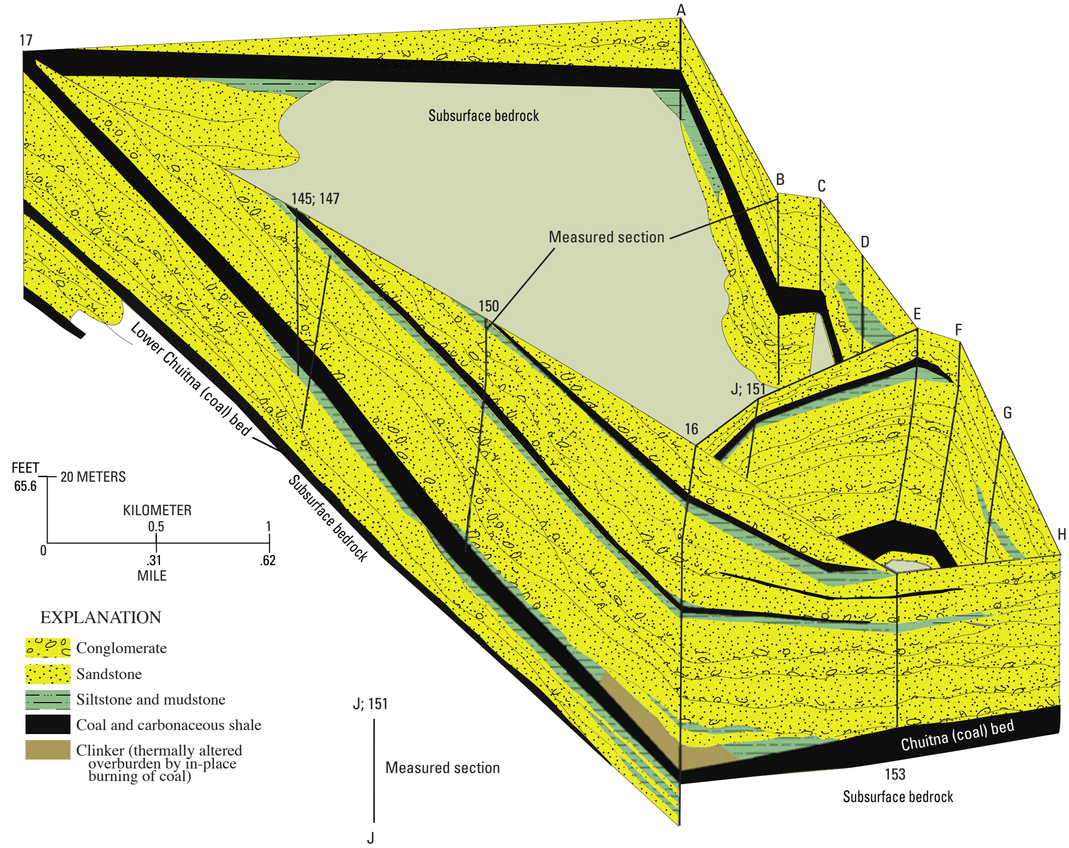


Figure 72. Three-dimensional cross sections (fence diagram) of the Chuitna coal bed and interbedded erosional-based sandstones deposited by braided streams of the Tyonek Formation in the Chuitna River drainage basin. Adopted from Flores and others (1994). See figure 58 for location of the cross section.

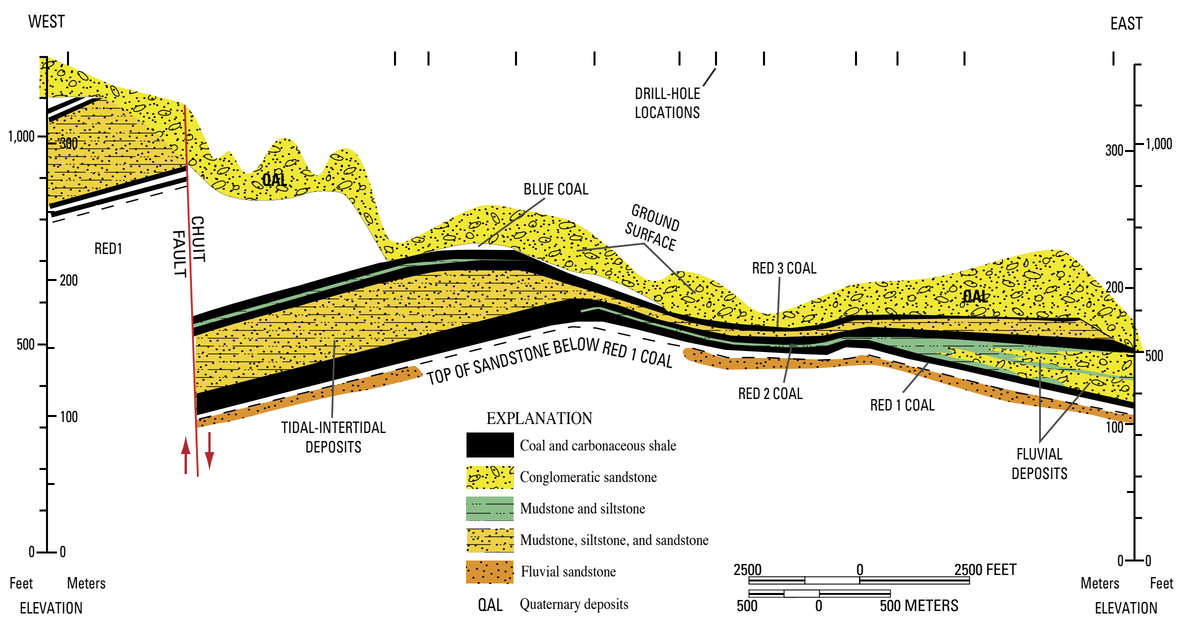


Figure 73. Stratigraphic cross section of the coal beds, fluvial-channel sandstones and intertidal deposits in the Diamond Chuitna lease area east of the Chuitna River drainage basin. See figure 58 for location of the cross section. Adopted by Flores, Stricker, and Stiles (1997).

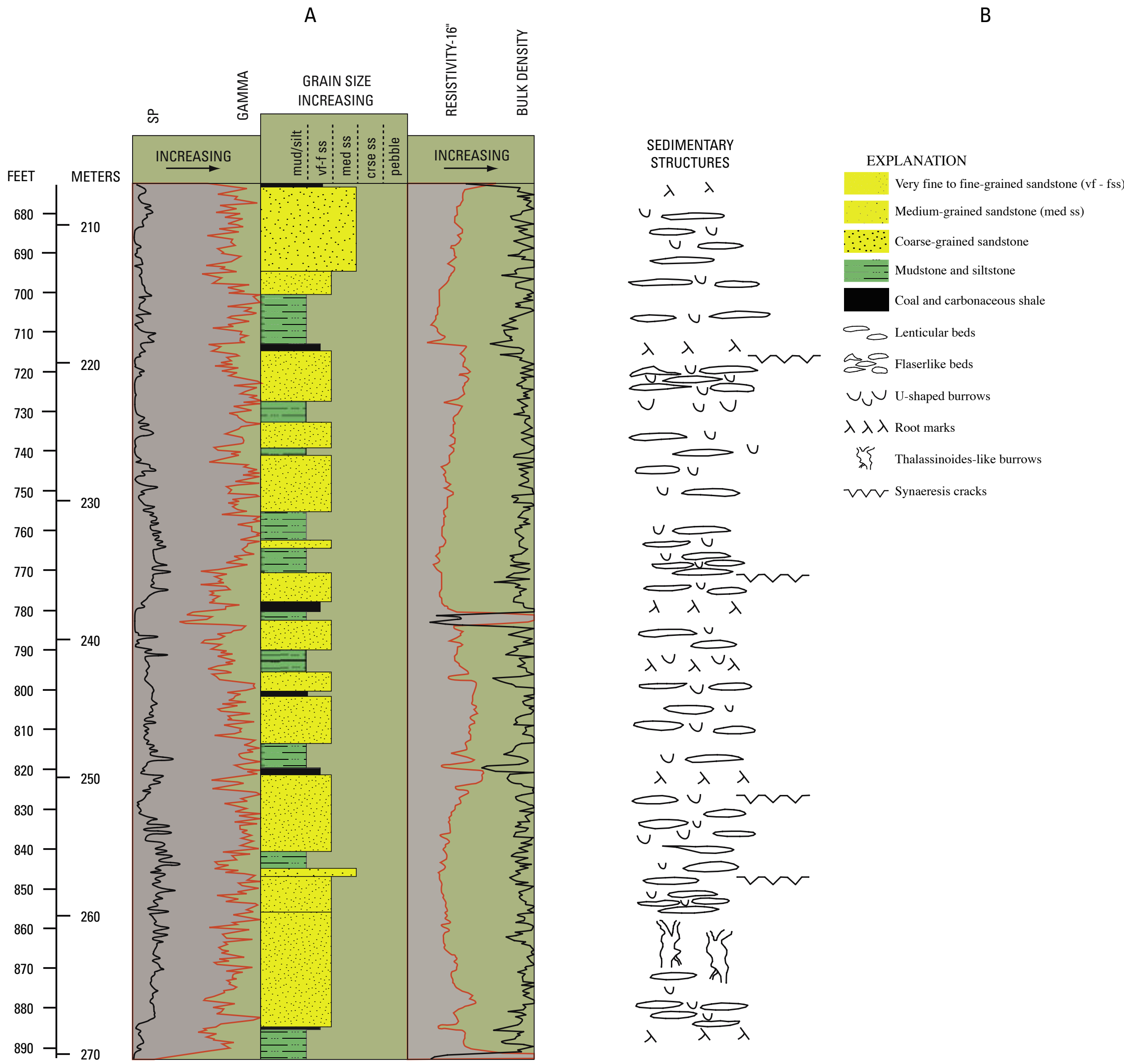


Figure 74. A, Stratigraphic lithofacies sequence in the Tyonek Formation showing tidal sandstone flats facies near Wasilla. Adopted from Flores and others (1999). B, Explanations of sedimentary structures for figures 74A and 77.

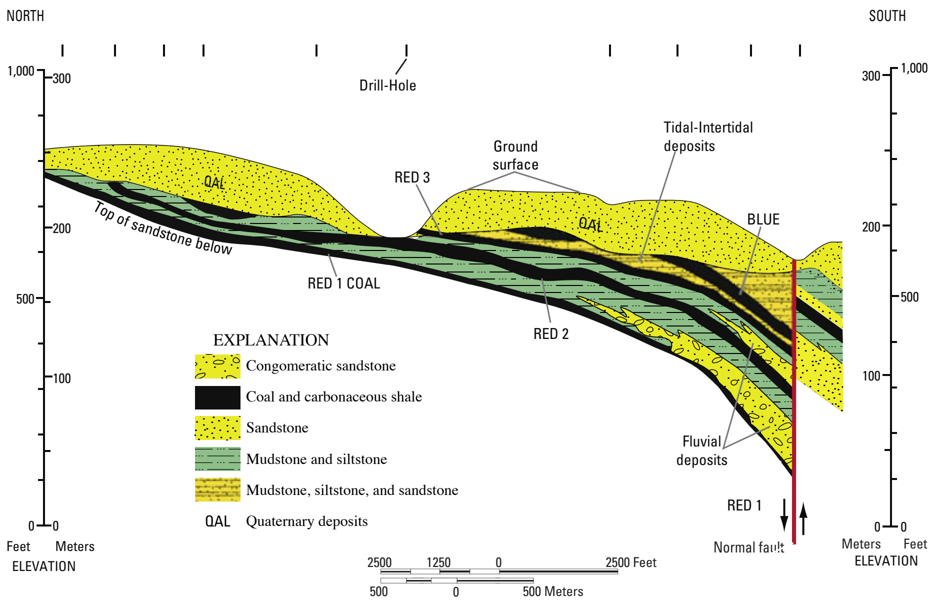


Figure 75. Stratigraphic cross section of the coal beds and fluvial-channel sandstones in the Diamond Chuitna lease area east of the Chuitna River drainage area. Adopted from Flores, Stricker, and Bader (1997). See figure 58 for location of the cross section.

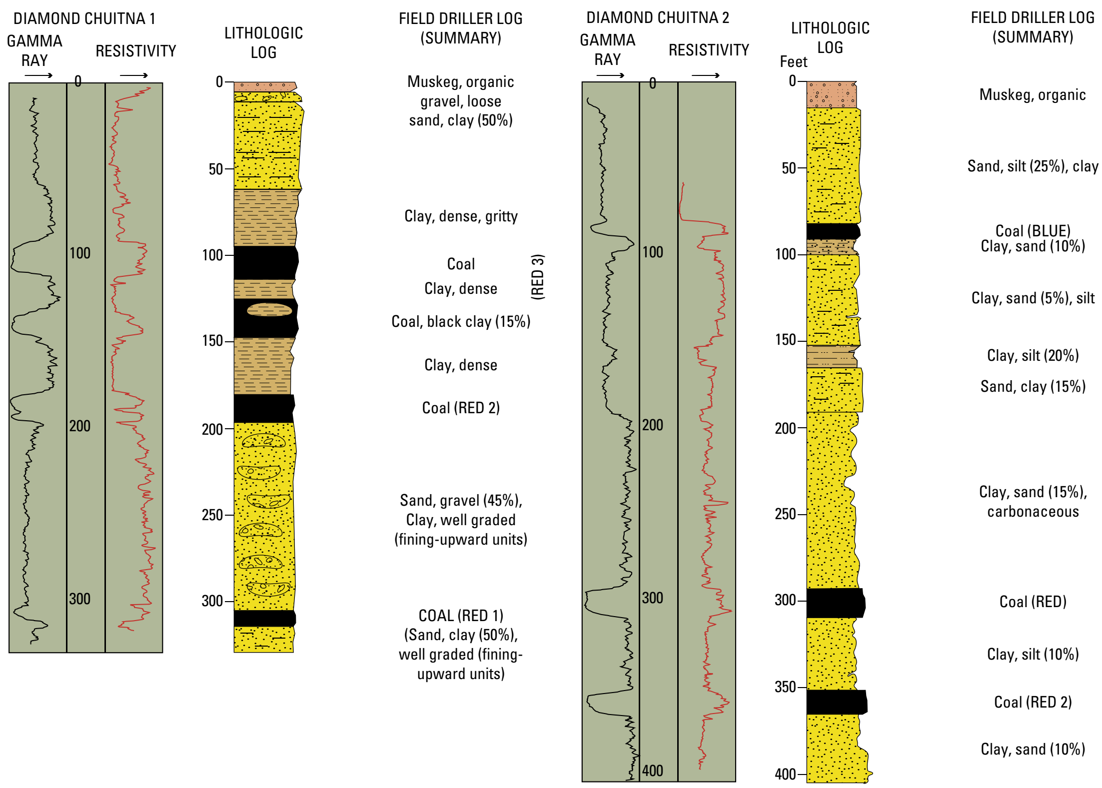


Figure 76. Vertical lithofacies and associated geophysical logs of minable coal beds (Reds 1, 2, and 3, and Blue) and interbedded fluvial-channel sandstones, and flood plain claystones and siltstones in the Diamond Chuitna lease area east of the Chuitna River drainage area. Adopted from Flores, Stricker, and Stiles (1997).

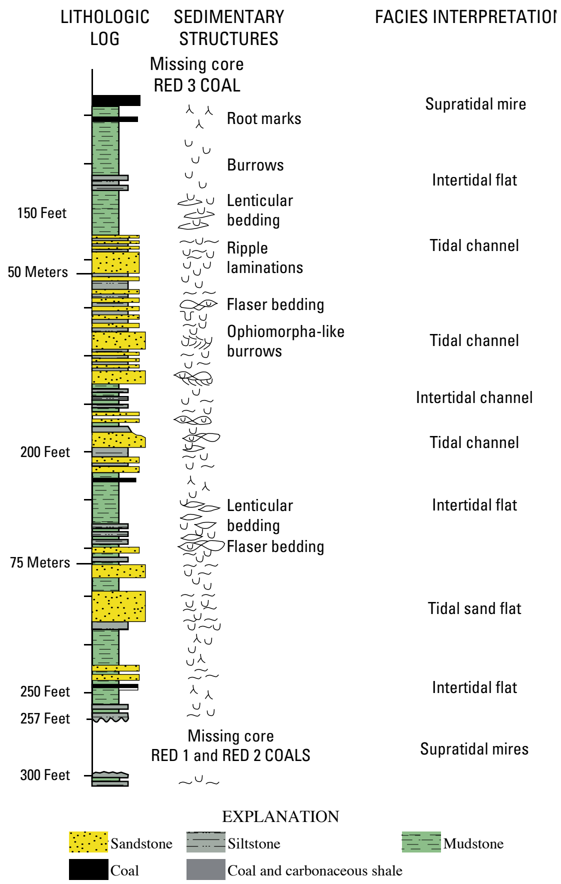


Figure 77. Vertical lithofacies of coal beds (Reds 1, 2, and 3) and interbedded tidal and intertidal sandstones, siltstones, and mudstones in the Diamond Chuitna lease area east of the Chuitna River drainage area. Adopted from Flores, Stricker, and Stiles (1997). See figure 74B for explanation of symbols for sedimentary structures.

Figure 78. Photograph of the Capps Glacier coal bed (50 feet or 15.2 meters thick) and overlying fluvial-channel sandstones in the Capps Glacier area.

Figure 79. Photograph of the coal beds and interbedded flood-plain/crevasse splay deposits in the Capps Glacier area. Man for scale is about 5.9 feet (1.8 meters) tall.

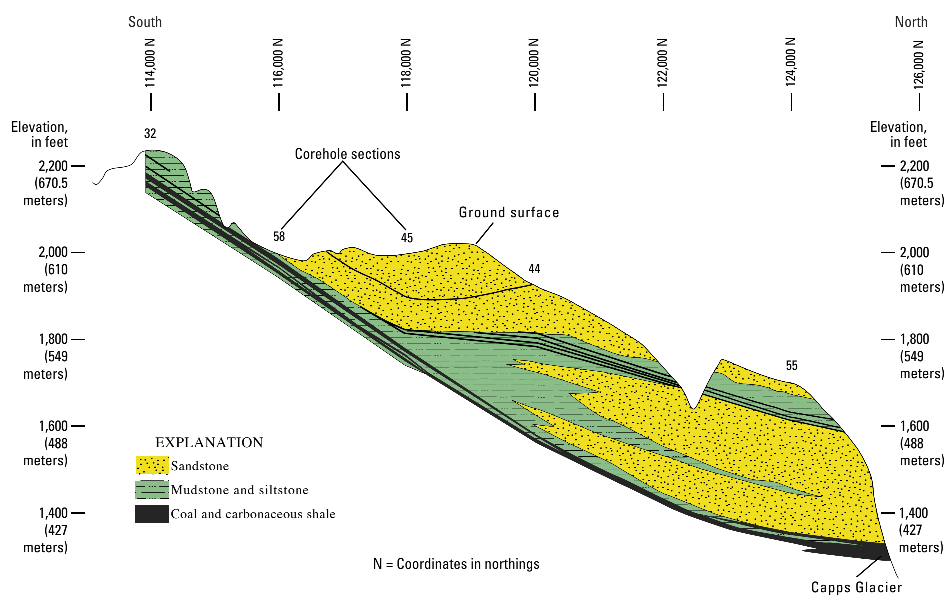


Figure 80. Structural cross section (north-south) of the Capps Glacier coal bed and associated rocks of the Tyonek Formation in the Capps Glacier area. See figure 58 for location of the cross section.

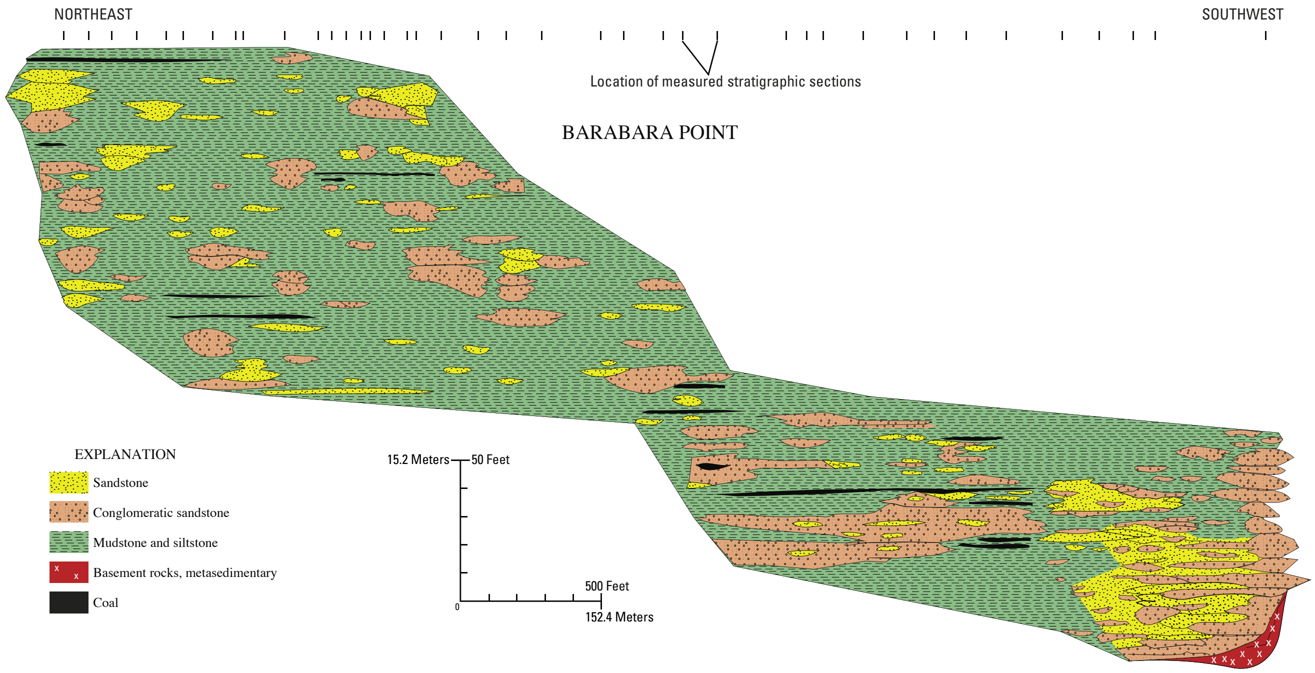


Figure 81. Stratigraphic cross section (northeast-southwest) of the rocks of the Tyonek Formation at Barabara Point showing lenticular conglomerates, sandstone, and coal beds. The sandstone and conglomerate in the southwestern part of the cross section represent paleovalley deposits incised into basement rocks. See figure 58 for location of the cross section.

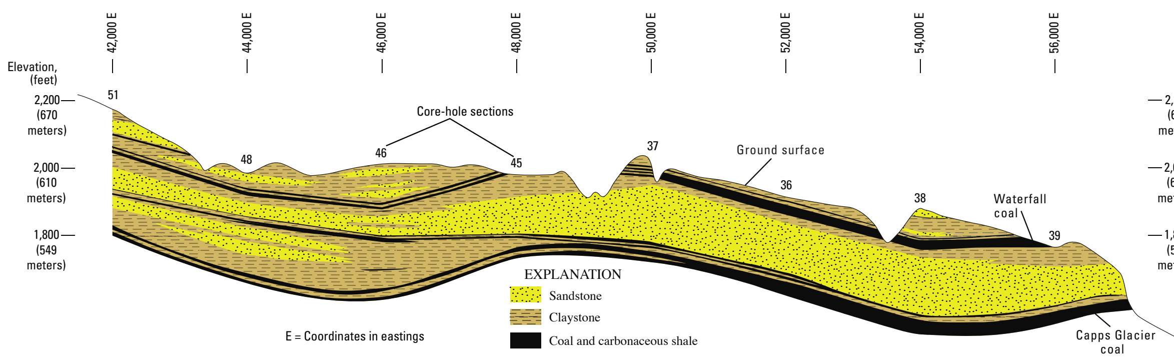


Figure 82. Stratigraphic (structural) cross section of the Capps Glacier coal bed and associated rocks of the Tyonek Formation in the Capps Glacier area. See figure 58 for location of the cross section.

province; Wolfe and Tanai, 1980), have their watershed in the central Alaska interior. The meandering streams were fed by transverse alluvial fans that were better developed along the eastern part of the basin than along the western part. The ancestral Chugach-Kenai uplift was uplifted more than the ancestral Aleutian-Alaska Arc Range (see fig. 87).

Sterling Formation

The Sterling Formation is as much as 10,990 ft (3,350 m) thick and consists of sandstones, conglomeratic sandstones, siltstones, mudstones, carbonaceous shales, and coal beds (see fig. 43; Kirschner and Lyon, 1973; Hayes and others, 1976; Hite, 1976); Hartman and others, 1971; Calderwood and Fackler, 1972). The sandstones are as much as 200 ft (61 m) thick, fining upward, basally scoured, and multistory (figs. 88 and 89); their vertical and lateral variations are exhibited in figures 90 and 91. Tonsteins or volcanic ash units are commonly interbedded with the coal beds. Hornblende and volcanogenic hypersthene are abundant in the sandstones. These heavy minerals indicate that the Sterling Formation was probably derived from the ancestral Aleutian-Alaska Arc Range to the west (see fig. 58). Coal beds are generally no more than 3 ft (1 m) thick, but a few are as thick as 8 ft (2.5 m) (fig. 92; Barnes and Cobb, 1959; Calderwood and Fackler, 1972). Coal is lignitic throughout much of the formation but is high-volatile subbi-

Figure 83. Photograph of the fluvial-channel sandstones (average 60 feet or 18.3 meters thick), flood plain mudstone and siltstones, and coal beds of the Beluga Formation along the coastal bluffs in west Homer, Kenai Peninsula.

Figure 84. Photograph of a coal bed (3.5 feet or 1.1 meters thick) and crevasse splay deposits of the Beluga Formation along the coastal bluffs west of Homer, Kenai Peninsula.

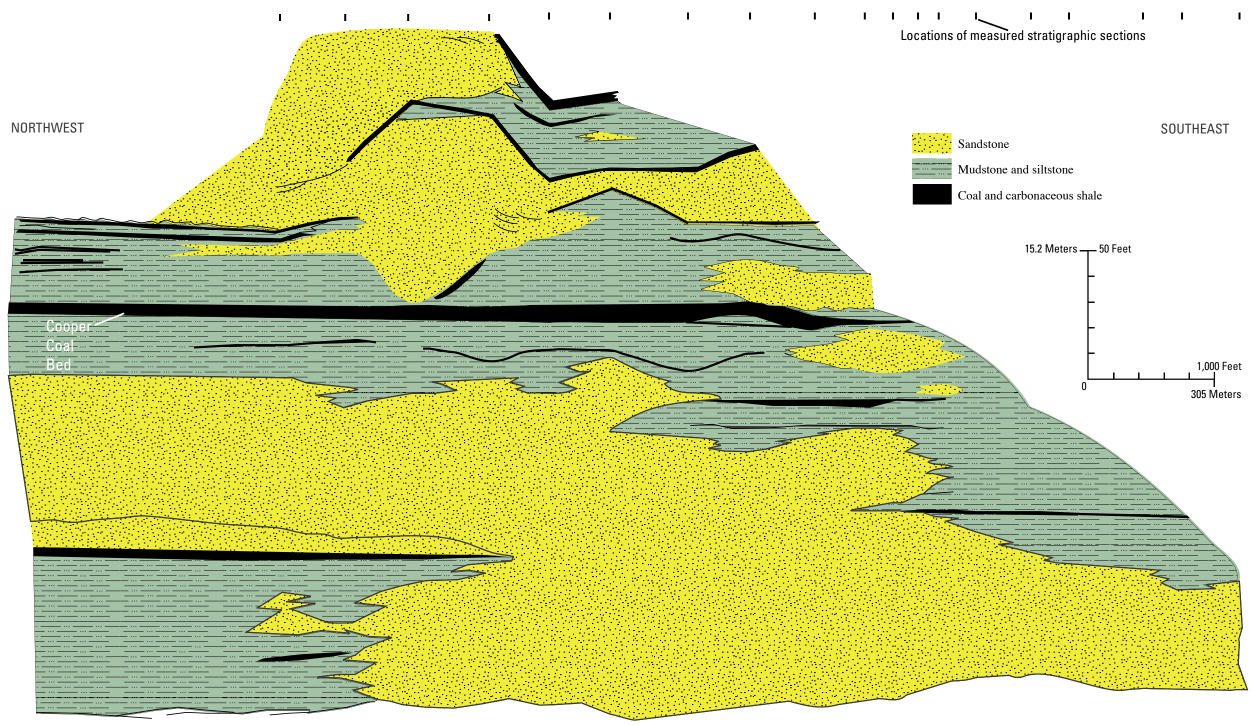


Figure 85. Stratigraphic cross section of the Beluga Formation showing thick coal beds (for example, Cooper coal bed), fluvial-channel sandstones, and flood-plain mudstone and siltstone along the coastal bluffs west of Homer, Kenai Peninsula. Adopted from Flores and Stricker (1993b). See figure 58 for location of the cross section.

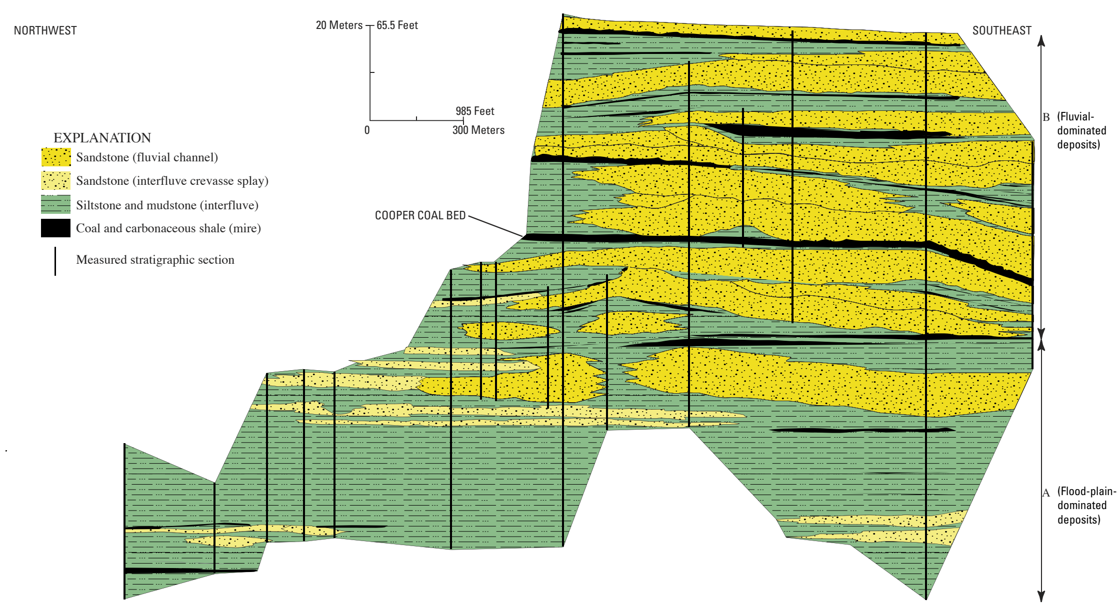


Figure 86. Stratigraphic cross section of the Beluga Formation showing interbedded thin to thick coal beds (for example, Cooper coal bed), fluvial-channel sandstones, and flood-plain deposits along the coastal bluffs west of Homer, Kenai Peninsula. Adopted from Flores and Stricker (1993b). See figure 58 for location of the cross section.

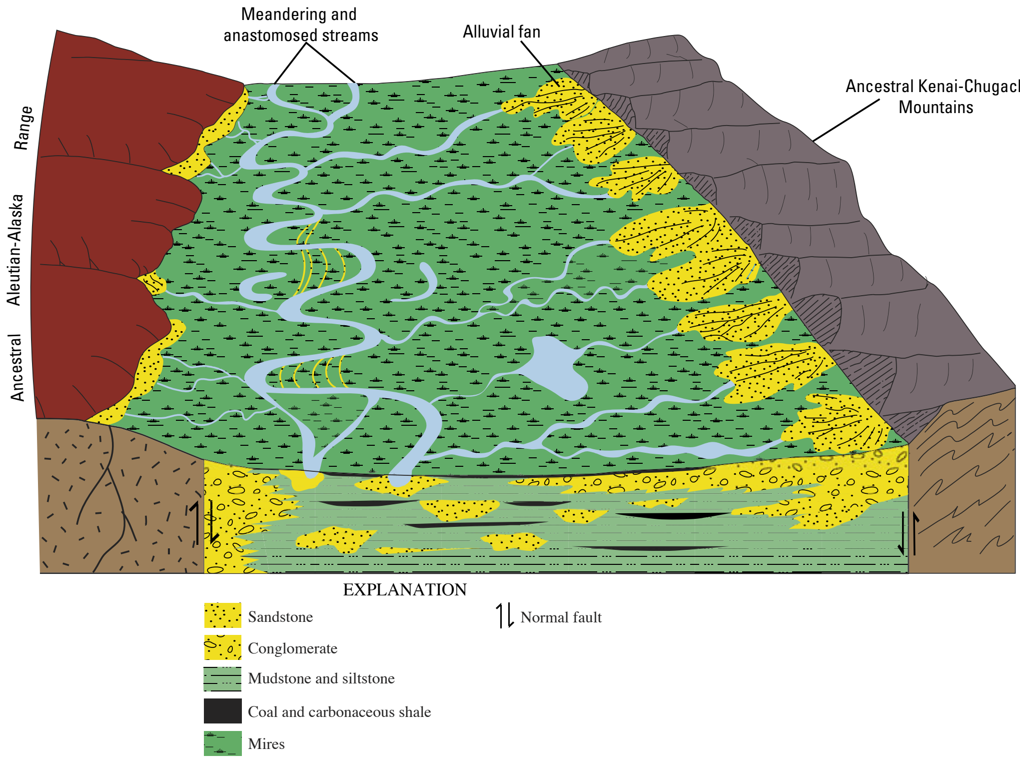


Figure 87. Paleogeographic map (block diagram) showing depositional environments of the Beluga Formation in the Cook Inlet Basin. Modified from Hayes and others (1976).

tuminous near the base. The Sterling Formation was dated as latest Miocene and Pliocene age by Wolfe and Tanai (1980).

Hite (1976) and Hayes and others (1976) interpreted the Sterling Formation as being deposited by meandering and braided streams (fig. 93), with the former mainly draining the basin axis and the latter draining the margins of the basin. The braided streams built alluvial fans that were better developed along the western part of the basin than along the eastern part. Flores and Stricker (1993c) interpreted the Sterling Formation as being deposited in low-sinuosity (braided) streams that evolved into high-sinuosity (meandering) streams. A close facies association exists between thick coal beds and deposits of the low-sinuosity streams. Mires in high-sinuosity streams were commonly choked by overbank and flood-plain sediments.

Coalfields:

Matanuska Coalfield

The Matanuska coalfield is the most important Paleocene coalfield in Alaska because it contains high-rank minable coal beds. This coalfield occupies a graben along the extent of the Matanuska Valley, between the Talkeetna Mountains on the north and the Chugach Mountains on the south (fig. 94). Coal beds of the Chickaloon Formation are distributed in an area about 62 mi (100 km) long, from Moose Creek on the west to Anthracite Ridge on the east (Capps, 1927).

Coal districts in the Matanuska coalfield were divided into leases under the Federal Coal Leasing Act of 1915. The Wishbone Hill coal district (about 15 mi^2 or 38 km^2 in area) is on the north side of the coalfield between Moose and Granite Creeks. More than 20 coal beds, with thicknesses exceeding 3 ft (0.9 m), are known in the Wishbone Hill coal district (Belowich, 1994). There, individual coal beds are as much as 23 ft (7 m) thick, but average 8 ft (2.4 m) thick. Mining began in 1917 at the west end of the district. The Federal Government operated the Eska mine in 1917 and started a second coal mine, the Chickaloon, on the Chickaloon River. At one time or another nine mines operated in the Wishbone Hill coal district between 1917 and 1970, and three or four coal mines operated in the Chickaloon-Castle Mountain coal district during the same period of time. The latter district was about 12 mi^2 (31 km^2) in the area around the old mining camps in the Chickaloon River Valley. Annual coal production in both districts averaged about 50,000 short tons (45,360 metric tons) from 1917 to 1940, 160,000 short tons (145,000 metric tons) from 1940 to 1951, and about 240,000 short tons (217,700 metric tons) from 1952 to 1970. A total of 3×10^6 short tons (2.7 million metric tons) was produced from open pit mines and the rest from underground mines. Total coal production was about 7.7×10^6 short tons (7×10^6 metric tons) between 1915 and 1970, after which production of oil in the State eliminated the market for coal (Merritt and Belowich, 1984).

Coal beds within the Chickaloon Formation vary in thickness considerably or pinch out altogether within short distances as shown in figures 51, 53, and 55. Correlation of exposure of the Premier coal zone and associated coal beds

Figure 88. Photograph of fluvial-channel sandstones and thin coal of the Sterling Formation along the coastal bluffs in the Clam Gulch area, Kenai Peninsula. Men are 6 feet (1.8 meters) tall for scale. See figure 58 for location of the cross section.

Figure 89. Photograph of fluvial-channel sandstones overlying thin (3 feet [0.9 meter]) to thick (12 feet [3.6 meters]) coal beds of the Sterling Formation along the coastal bluffs between the Clam Gulch and Ninilchik, Kenai Peninsula.

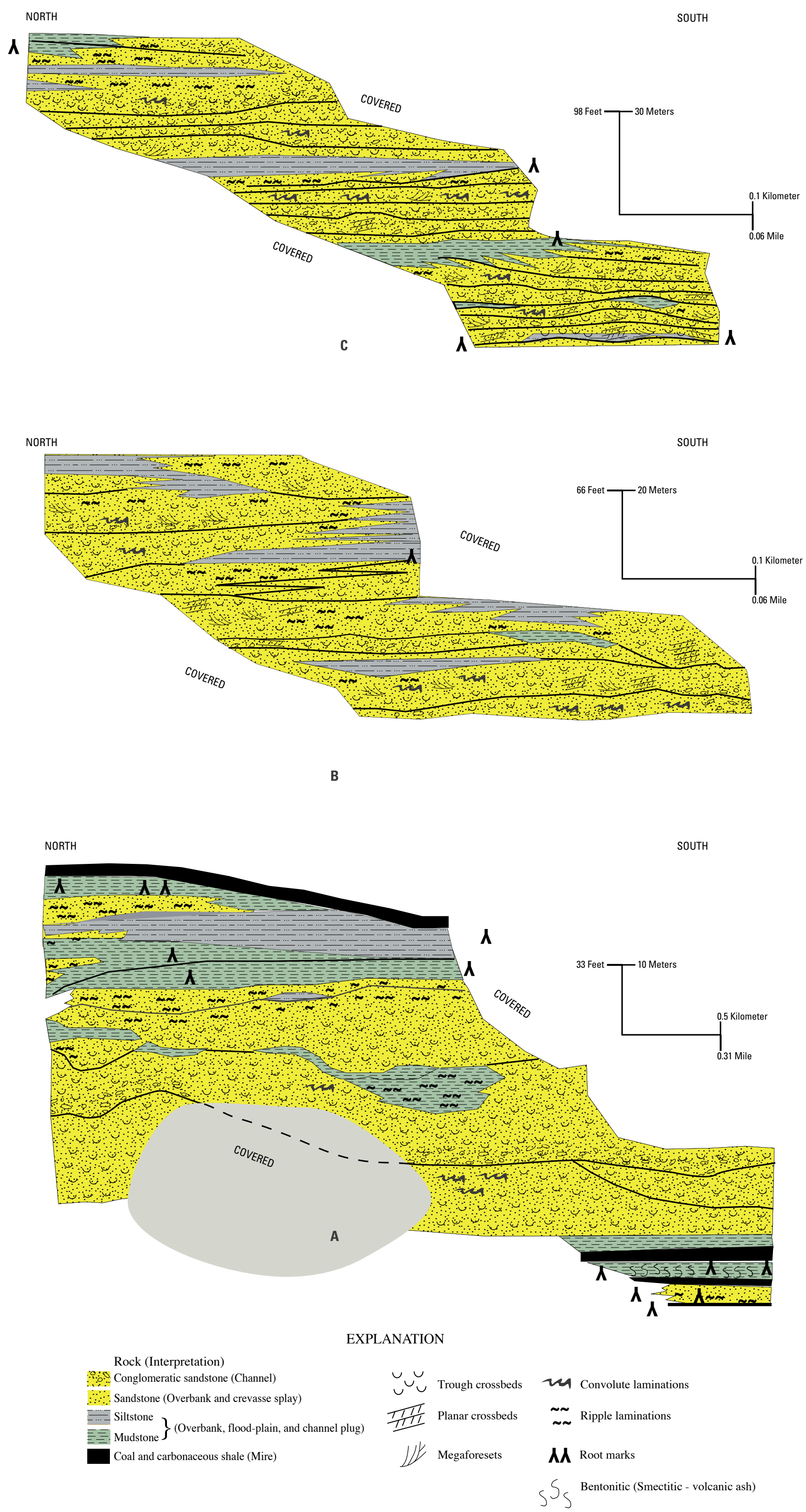


Figure 90. Stratigraphic cross sections showing variations in fluvial-channel architecture in the upper part of the Sterling Formation in the Clam Gulch area, Kenai Peninsula: A, Lower part of Clamgulchian type section; B, Middle part of Clamgulchian type section; C, Upper part of Clamgulchian type section. See figure 58 for location of the cross section.

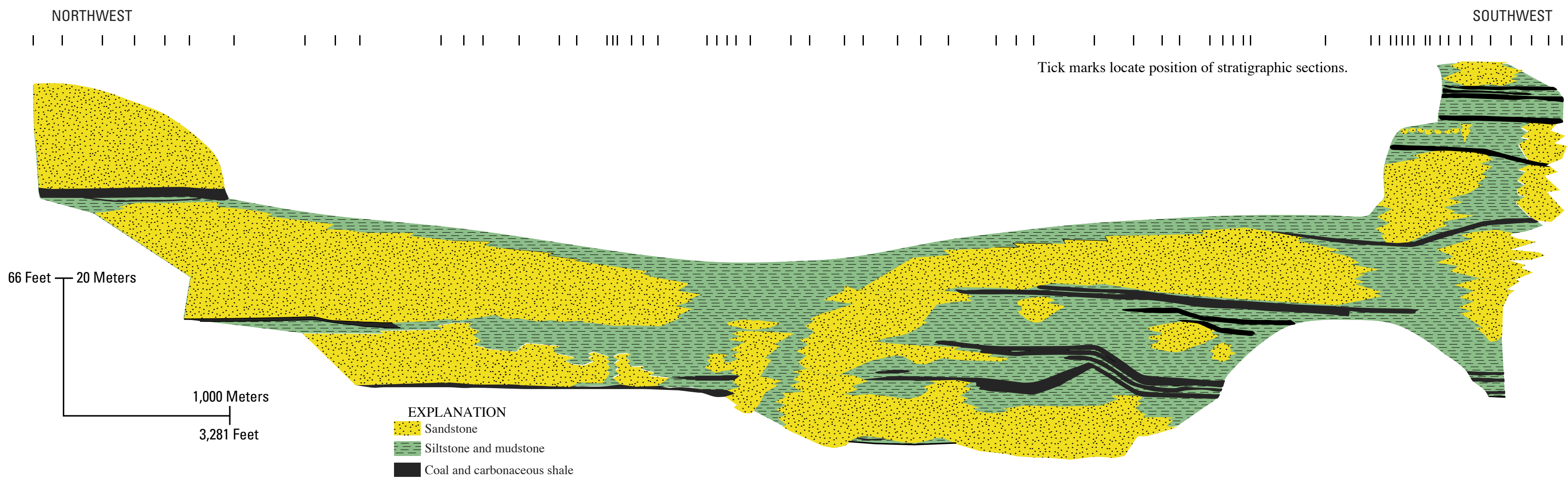


Figure 91. Stratigraphic cross section showing coal beds, fluvial-channel sandstones, and interbedded flood-plain mudstones and siltstones in the lower part of the Sterling Formation between the Clam Gulch area and Ninilchik, Kenai Peninsula. See figure 58 for location of the cross section.

Figure 92. Photograph of thin to thick coal beds in the lower part of the Sterling Formation. Hammer on left of photograph between lower and middle coal beds is 1 foot (0.3 meter) long for scale.

was performed by Flores and Stricker (1993a) in the Wishbone Hill district where minable coal beds split and merge over short distances laterally as shown in figure 95. In this coal district, four groups of minable coal beds, one to six beds in each group, are separated by 49–295 ft (15–90 m) of interburden rock in a section 1,180–1,510 ft (360–460 m) thick. Combined, 12 minable beds totaled about 49 ft (15 m) in thickness. The thickest coal bed is about 10 ft (3.3 m) thick (Barnes and Payne, 1956; Barnes and Sokol, 1959).

Six to 10 coal beds were penetrated by drilling in the Chickaloon coal district, most less than 3 ft (1 m) thick, but one bed is more than 14 ft (4.3 m) thick. The beds are lenticular and vary in thickness within 197–295 ft (60–90 m) laterally, making correlations, reserve calculations, and prospecting across transverse faults difficult.

The Anthracite Ridge coal district covers about 30 mi^2 (77 km^2) at the eastern end of the coalfield (fig. 94). The number of coal beds in this district is uncertain owing to poor exposures and complex structure. A few beds in the coal district are as thick as 3.9–6.5 ft (1.2–2.0 m) and one reaches 39 ft (12 m); the coal beds are exceptionally lenticular.

The intensity of deformation and abundance of igneous dikes and sills in the Chickaloon Formation increase eastward along the Matanuska coalfield. A few small dikes occur in the Wishbone Hill coal district, and thick sills are abundant in the Anthracite Ridge coal district. Heating induced by the igneous intrusions may be the main reason for the increase in coal rank

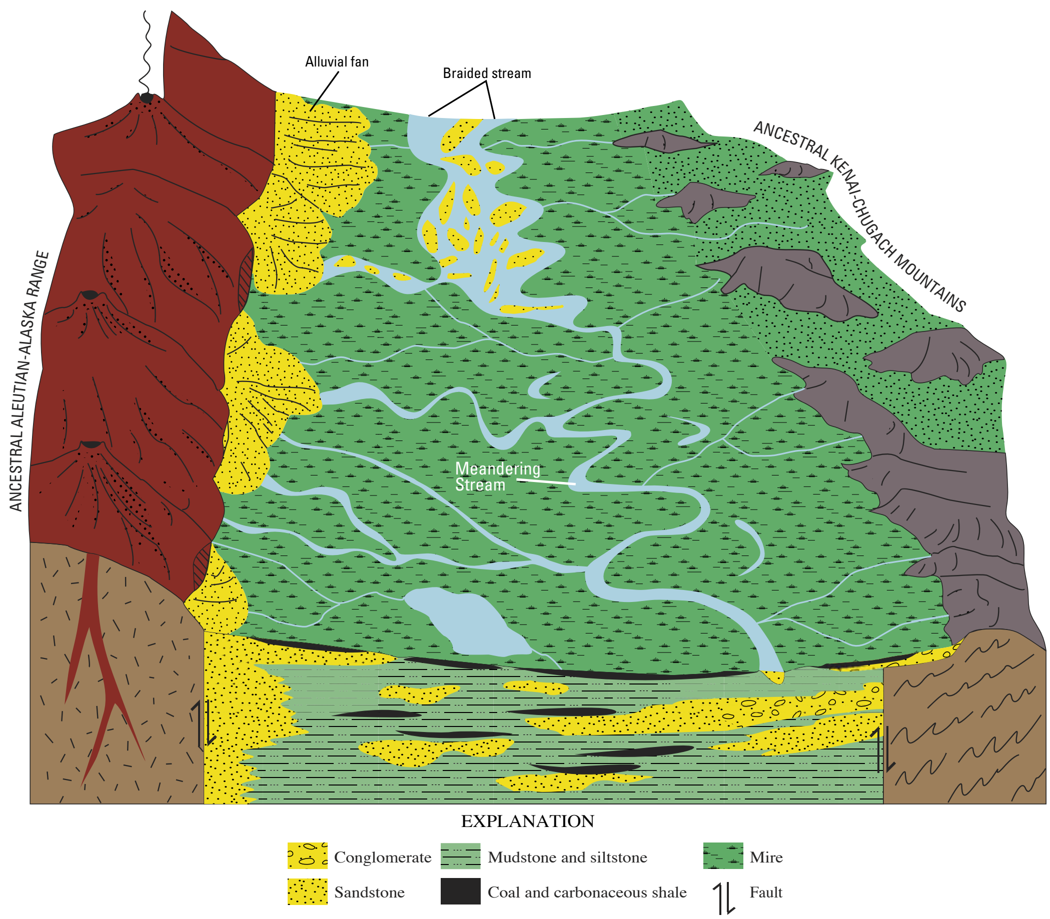


Figure 93. Block diagram showing depositional environments of the Sterling Formation in the Cook Inlet Basin. Modified from Hayes and others (1976).

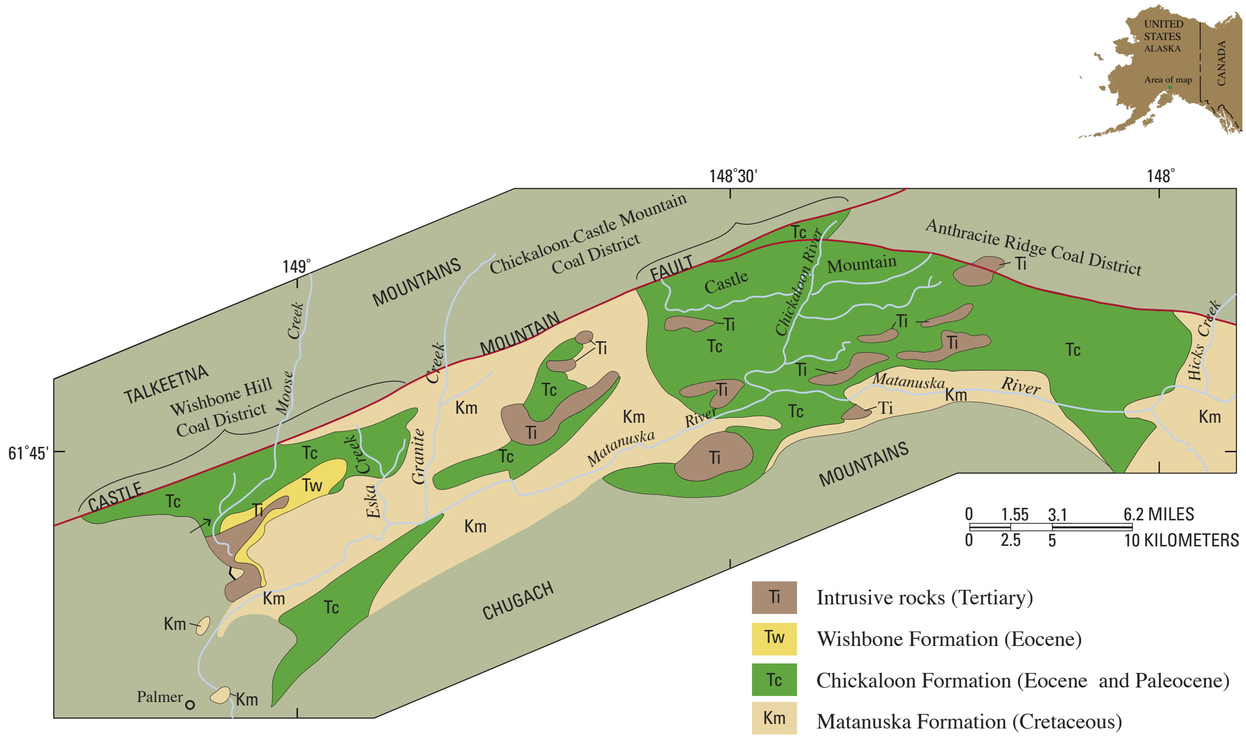


Figure 94. Map showing the geology and coal districts in the Matanuska coalfield.

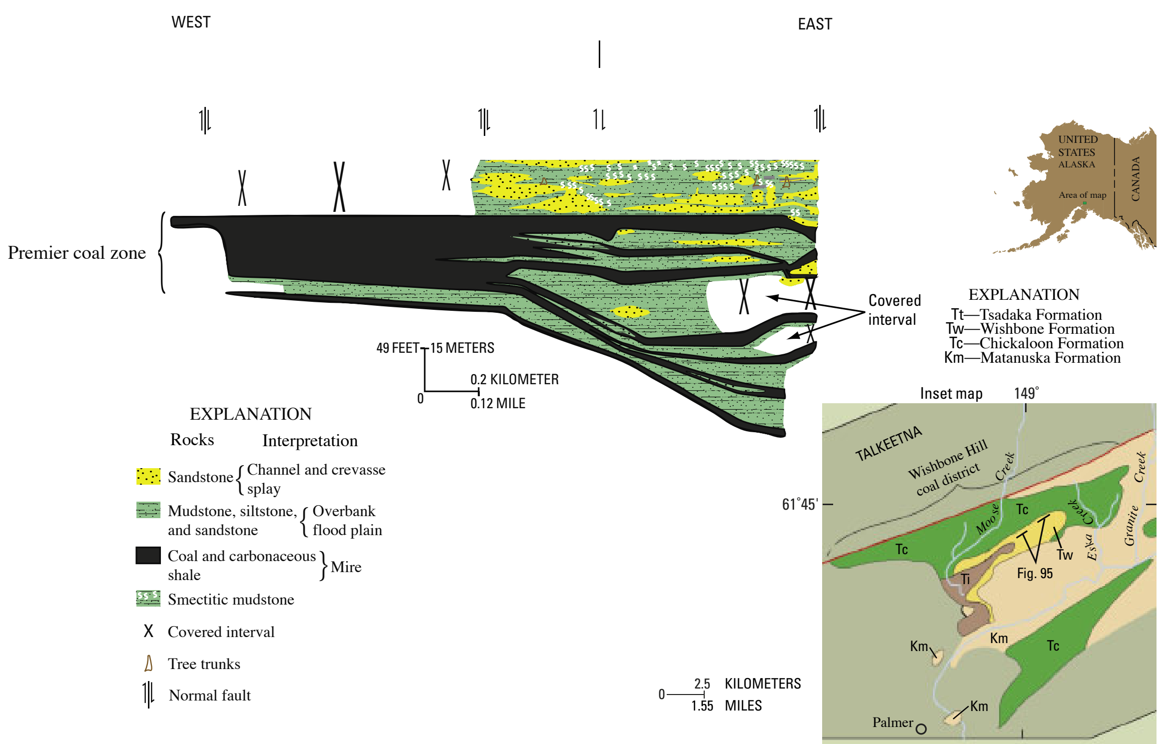


Figure 95. Cross section of the Premier coal zone of the Chickaloon Formation in the Wishbone Hill coal district. Modified from Flores and Stricker (1993d). See figure 96 for location of cross section.

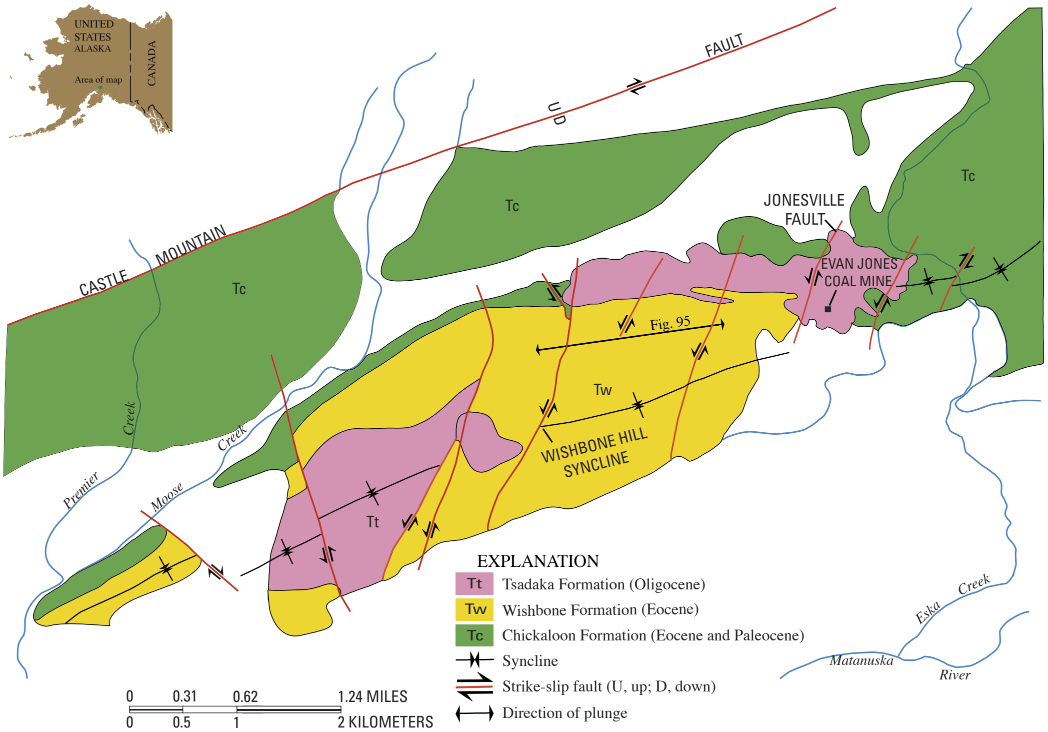


Figure 96. Geologic map of the Wishbone Hill coal district showing doubly plunging syncline disrupted by normal faults. Modified from Flores and Stricker (1993a).

from subbituminous to anthracite eastward in the coalfield. However, Barnes (1962) suggested that heat generated by tectonic activity was more important than that from igneous intrusions. Merritt (1985) described the natural coking of coal adjacent to an intrusive diabase sill in which the contact temperature reached 1,020˚F (550˚C). The coal bed along the contact was locally coked and raised to semianthracite, but about 165 ft (50 m) away from the contact, the coal was ranked high-volatile bituminous A. The coal rank in the Anthracite Ridge coal district also changes abruptly from low-volatile bituminous to semianthracite or anthracite within about 196 ft (60 m) toward an intrusion (see fig. 40; Waring, 1936).

Structures in the Matanuska coalfield are typically complex. The doubly plunging Wishbone Hill syncline, a relatively simple structure, has beds that dip 20˚–40˚ on either flank; the structure is cut by two sets of transverse faults (fig. 96). Structural complications on its northwest flank make the coal beds in some structural blocks difficult to mine and preclude meaningful estimation of reserves (Barnes and Payne, 1956). With the possible exception of the Castle Mountain district, structural complexities increase eastward. In the Chickaloon district, beds dip as much as 90˚; in the Chickaloon mine, coal beds are overturned (Chapin, 1920) and faulted. Large areas of the Chickaloon Formation are covered by a thick mantle of glacial till and crop out only along stream bluffs (Capps, 1927). Anthracite occurrences on the south flank of Anthracite Ridge are bordered on the north by a high-angle fault of large displacement and are in tightly folded and locally overturned synclines cut by many faults.

Susitna-Beluga Coalfield

The Susitna-Beluga coalfield is situated in the Susitna Lowland (see fig. 40) north of the Cook Inlet between the Talkeetna Mountains on the east and the Alaska Range on the north and west. Glacial and alluvial deposits mainly cover the Susitna Lowland. Coal beds are in the Kenai Group. The rocks are exposed in isolated areas but mainly along the banks and tributaries of the Susitna, Yentna, Beluga, and Chuitna Rivers. These coal-bearing rocks underlie an area of at least 3,440 mi^2 (8,910 km^2). Barnes (1967a) studied these exposures and concluded that the potentially minable coal beds are located in a 400-mi^2 (1,036-km^2) area at the southwestern end of the coalfield in the drainage basins of the Chuitna and Beluga Rivers. There, the coal beds range from lignite to subbituminous and range from a few inches (few centimeters) to more than 50 ft (15 m) thick. Barnes (1967a) has traced a few of the thick (30–50 ft or 9.1–15 m) coal beds for distances of more than 7 mi (11 km) along the course of the Chuitna River. Flores and others (1994) and Flores, Stricker, and Stiles (1997) have described the lateral variations of these coal beds, which are shown in figures 73, 74, and 75. Myers and others (1998) traced one 50-ft (15-m) coal for 4 mi (6.4 km) in the Capps Glacier area (see fig. 40). Other thick (10–25 ft or 3–7.6 m) coal beds are exposed along the Beluga, Skwentna, and Yentna Rivers (see fig. 40). Along the southeast margin of the Alaska Range, the Kenai Group rocks lie in downfaulted or downwarped basins (Barnes, 1966; Magoon and others, 1976; Reed and Nelson, 1980).

Reed and Nelson (1980) divided the Tyonek Formation in the Susitna-Beluga coalfield into two members. The basal member consists of 40 percent conglomerate, 20 percent sandstone, and 40 percent siltstone, claystone, and coal; the latter are in beds as much as 56 ft (17 m) thick. The overlying member consists predominantly of sandstones about 558 ft (170 m) thick, composed of repetitive cycles 23–75 ft (7–23 m) thick and grading from coarse-grained, pebbly sandstone at the base to silt and clay with coal or bony coal at the top. The Tyonek is overlain by the Sterling Formation, consisting of an orange to light gray, massive pebble to boulder conglomerate, as much as 2,525 ft (770 m) thick.

Barnes (1966) reported two negative gravity anomalies beneath the Susitna Lowland—one between Johnson Creek and Yenlo Mountain and north of the Skwentna River, and the other between Yenlo Mountain and the Susitna River, centered at the confluence of the Kahiltna and Yentna Rivers (see fig. 40). Barnes interpreted both anomalies as thick fill of the Kenai Group that may contain potential for large deposits of coal.

Broad Pass Coalfield

The Broad Pass coalfield underlies a narrow trough extending northeastward from south of the divide of the Alaska Range, on the headwaters of the Chulitna River (see fig. 40), to the north end of the Cook Inlet-Susitna Lowland (Wahrhaftig, 1965; Barnes, 1967a). The coalfield is about 5 mi (8 km) wide and is bordered by mountains that rise abruptly to elevations of about 3,300–8,200 ft (1,000–2,500 m). Although Mesozoic and older metamorphic and igneous rocks are mainly exposed in the coalfield, several small areas of coal-bearing rocks of the Kenai Group occur. Only two of these areas are known to contain coal resources: Costello Creek and Broad Pass Station on the Alaska Railroad (see figs. 1 and 40). Only a 7-mi^2 (18-km^2) area was mapped with coal-bearing rocks in the Costello Creek and a 1.5-mi^2 (3.8-km^2) area near the Broad Pass Station. A detailed U.S. Bureau of Mines-U.S. Geological Survey investigation in the Costello Creek area disclosed a lower unit of interbedded sandstone, mudstone, and coal beds, 0–85 ft (0–26 m) thick, overlain by an upper, predominantly sandstone unit, as much as 490 ft (150 m) thick, lacking coal beds (Wahrhaftig, 1944).

The coal beds at the Broad Pass Station, 8–10 mi (13–16 km) east of the Costello Creek area, are interbedded with white to orange sandstones and gravelly conglomerates (Hopkins, 1951). These coal beds are correlated to the Sterling Formation of the Susitna-Beluga coalfield. Coal has been reported south of these areas along the Chulitna River. The coalfield contains orange to yellow gravels exposed in railroad cuts and streambanks, which resemble the Nenana Gravel in the Central Alaska-Nenana coal province and the Sterling Formation of the Susitna Lowland.

Kenai Coalfield

The Kenai coalfield lies on the lowland between the Kenai Mountains on the east and the Cook Inlet on the west, in the western part of Kenai Peninsula (see fig. 40). The coalfield contains the thick, coal-bearing Beluga and Sterling Formations of the Kenai Group and is divided into two coal districts: the northern Kenai and southern Homer coal districts (Barnes, 1967a). The northern Kenai coal district includes mainly outcrops of the Sterling Formation, and the coal beds are exposed mainly along the coastal bluff from north of Clam Gulch to south of Ninilchik (see figs. 58 and 97; Merritt and others, 1987). The coal beds are mainly thin in the upper part and thicker in the lower part of the formation. The Homer coal district contains outcrops of both the Beluga and Sterling Formations, which are mainly exposed along the coastal bluffs from north of Anchor Point to Homer and along the north shore of Kachemak Bay (see figs. 58 and 98) on the southern end of the Kenai Peninsula. The coal-bearing rocks are completely concealed by as much as several hundred feet of glacial and alluvial deposits, particularly in the northern Kenai coal district. However, where the Sterling coal beds are exposed along the coastal bluffs, they are as thick as 12 ft (3.8 m) and are laterally continuous for more than 1.75 mi (3 km) (Flores and Stricker, 1992).

The Homer coal district (Barnes and Cobb, 1959) is about 1,200 mi^2 (3,110 km^2) in area and includes as much as 5,000 ft (1,525 m) of the Beluga and Sterling Formations. These formations contain at least 30 coal beds ranging individually from 3 to 7 ft (0.9 to 2.1 m) in thickness (Barnes, 1967a). Flores and Stricker (1993b) reported that Beluga coal beds range from a few inches (few centimeters) to 8.2 ft (2.5 m) thick and average 3.2 ft (1 m) (fig. 99). Thin coal beds, a few inches to 1 ft (a few centimeters to 30 cm) are traceable laterally from a few tens to hundreds of feet. Thicker coal beds, greater than 2 ft (>0.6 m), are traceable laterally as much as a few miles. The thickness-to-length ratio of coal beds indicates they vary from lenticular (1:9) to elongate (1:1,000–3,000). Stratigraphic variations of the coal beds in the Homer coal district are shown in figures 100 and 101. Coal beds of the Beluga Formation are thick and laterally continuous where they are interbedded with thick and extensive sandstones, which were deposited by meandering streams (see fig. 100). Beluga Formation coal beds are thin and discontinuous where interbedded with thin and lenticular sandstones, in which case anastomosed streams (see fig. 101) deposited the sandstones.

Coal was mined intermittently since 1888 along the north shore of Kachemak Bay by the Alaska Coal Company at Miller's Landing northwest of Homer (Barnes, 1967a). In 1891, the U.S. Navy mined 50 short tons (45 metric tons) from four localities on Kachemak Bay. In 1894, the North Pacific Mining and Transportation Company began development in Eastland Canyon (about 1 mi northeast of Kachemak Bay). At least 650 short tons (590 metric tons) of coal was produced from this underground mine and shipped to San Francisco.

Figure 97. Photograph of a 4-foot-thick (1.2 meters) coal bed interbedded with fluvial-channel sandstones and flood plain mudstones and siltstones in the Sterling Formation in the Clam Gulch area.

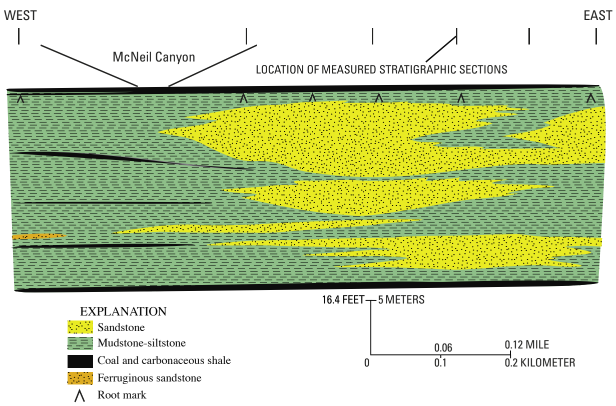


Figure 98. Stratigraphic cross section showing interbedded coal beds, fluvial-channel sandstones, and flood-plain mudstones and siltstones in the lowermost part of the Sterling Formation along the north shore of Kachemak Bay east and west of McNeil Canyon. See figure 58 for location of the cross section.

Underground mines were also opened from 1894 to 1897 west of McNeil Canyon.

Coal mining shifted to the west of Homer along the beach bluffs of the Cook Inlet from 1899 to 1951. The Cook Inlet Coal Fields Company developed the Cooper coal bed from five mine shafts in the beach bluff on Bidarki Creek, about a mile (1.6 km) west of Homer. The 1899–1902 total coal production from these mines was only a few hundred short tons. In 1915, Bluff Point (see fig. 58) underground mine was opened near Bidarki Creek and produced about 1,400 short tons (1,270 metric tons). Barnes (1967a) reported production from this mine to be about 1,200 short tons (1,090 metric tons) in 1921, 2,700 short tons (2,450 metric tons) in 1922, and 700 short tons (635 metric tons) in 1923. No production records were found for 1924 to 1945. In 1946, the Bluff Point mine was taken over by Homer Coal Corporation, which blocked out reserves of stripping coal. No reported production was recorded from this operation, which operated until 1951. Total production in the Homer coalfield is at least a few thousand tons.

Coal Resource Assessment in the Southern Alaska-Cook Inlet Coal Province

The coal resource assessments of various workers in the Southern Alaska-Cook Inlet coal province vary in magnitude and coal resource categories, which resulted in different estimates. We reconstructed these diverse coal resource estimates following guidelines of the coal-resource classification system of Wood and others (1983). This new reporting system of the coal resources of the Southern Alaska-Cook Inlet coal province modified from previous estimates is summarized in table 1. Following is a historical account of the variable coal resource assessments in the coal province.

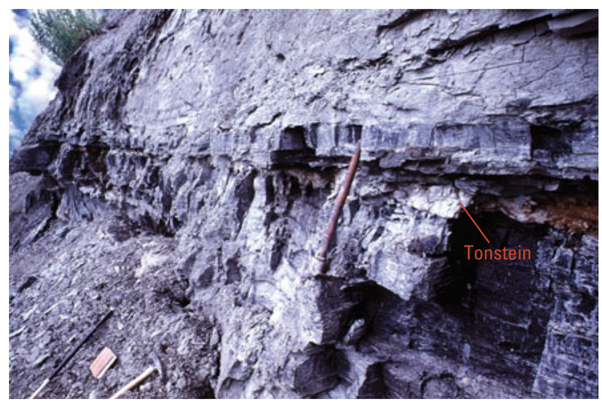


Figure 99. Photograph of a coal bed with tonstein partings and related rocks of the Beluga Formation along the beach bluffs on the northern shore of the Kachemak Bay. Mattock is 2 feet (0.6 meter) long for scale.

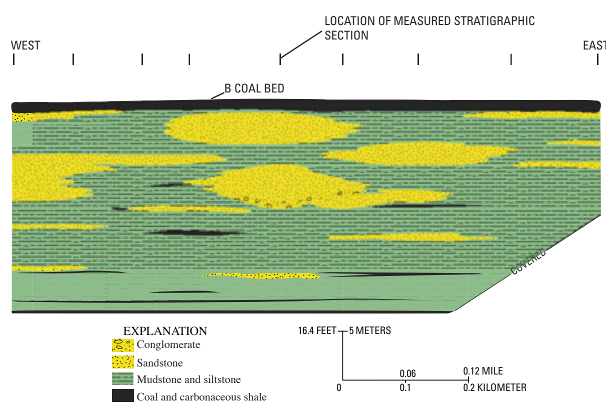


Figure 100. Stratigraphic cross section showing interbedded coal beds, fluvial-channel sandstones, and flood-plain mudstones and siltstones in the uppermost part of the Beluga Formation west of McNeil Canyon. See figure 58 for location of the cross section.

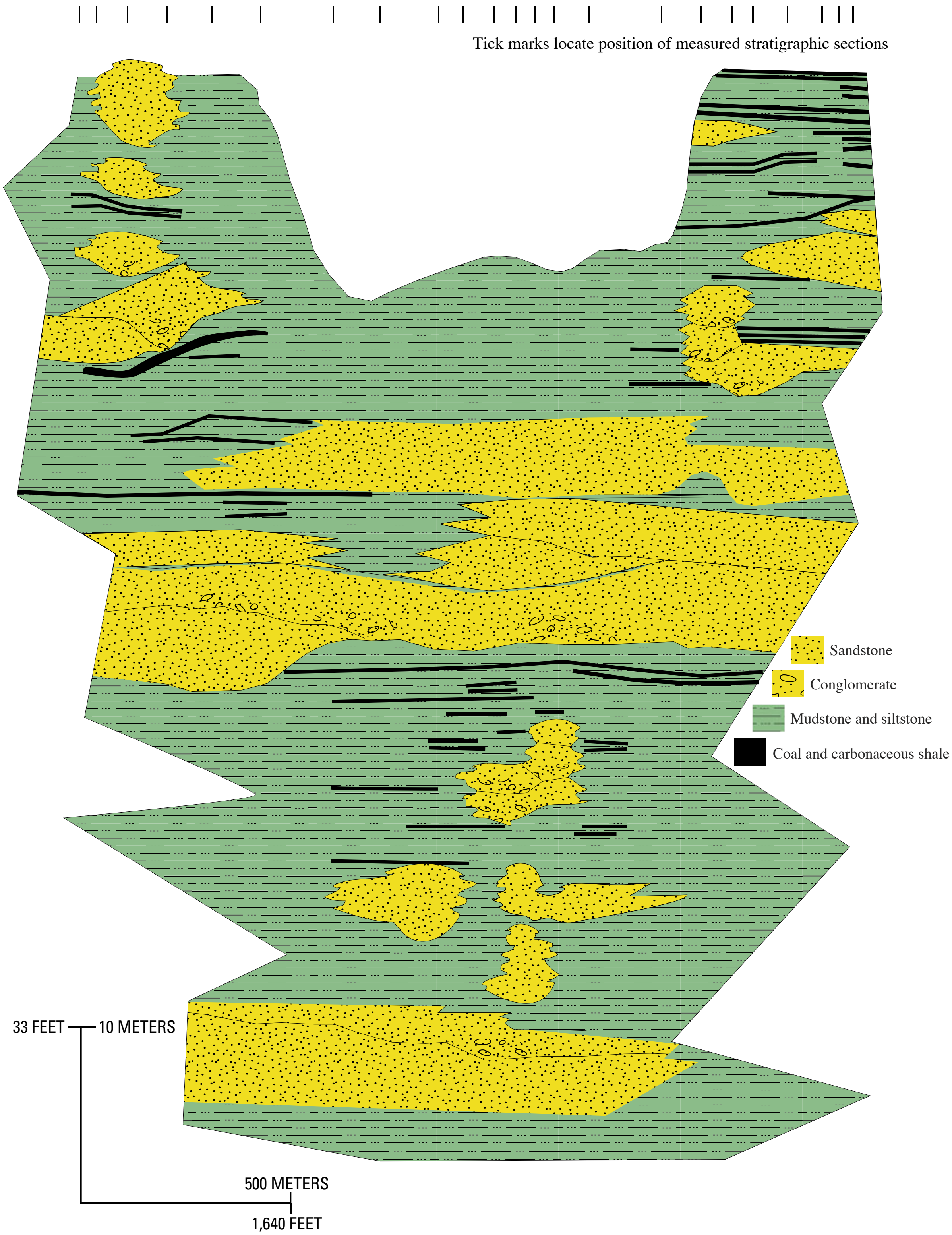


Figure 101. Stratigraphic cross section showing interbedded coal beds, fluvial-channel sandstones, and flood plain mudstones and siltstones in the uppermost part of the Beluga Formation at the mouth of Fritz Creek. See figure 58 for location of the cross section.

Barnes (1967a) estimated identified coal resources in the Southern Alaska-Cook Inlet coal province to be about 2,910 million short tons (2,640 million metric tons). Later, McGee and Emmel (written commun., 1979) estimated the identified coal resources to be about 34,320 million short tons (31,130 million metric tons).

Matanuska Coalfield

Estimates of coal resources produced by various workers for the Matanuska coalfield were reported by Merritt and Belowich (1984) as being as high as 200×10^6 short tons (181×106 metric tons) for measured to inferred coal resources and as high as 2.4×10^9 short tons (2.2×10^9 metric tons) for hypothetical coal resources. The most reliable coal-resource estimates are from Barnes (1967a), who reported 137×10^6 short tons (125×10^6 metric tons) of combined measured, indicated, and inferred coal resources, and from Merritt and Belowich (1984) who reported 24×10^9 short tons (22×10^9 metric tons) of hypothetical coal resources (table 6).

In the Wishbone Hill coal district, Barnes (1967a) reported total coal resources of 112 million short tons (101 million metric tons), based on apparent rank of bituminous coal with thicknesses greater than 14 inches (35 cm), and between 0 and 2,000 ft (0–610 m) of overburden. Total resources were divided into 6.6 million short tons (6.0 million metric tons) measured coal resources, 51.7 million short tons (47 million metric tons) indicated coal resources, and 53.7 million short tons (49 million metric tons) inferred coal resources.

In the Chickaloon-Castle Mountain coal district, Barnes (1967a), reported total coal resources of 25 million short tons (23 million metric tons), based on apparent rank of bituminous coal, with thicknesses greater than 14 inches (35 cm), and between 0 and 2,000 ft (0–610 m) of overburden. Total resources were divided into 0.0 measured coal resources, 0.7 million short tons (0.6 million metric tons) indicated coal resources, and 24.3 million short tons (22 million metric tons) inferred coal resources.

In the Anthracite Ridge coal district, the only identified minable bed of anthracite, 4.2–6.6 ft (1.3–2.0 m) thick, underlies an area of no more than 2.5 acres (1 hectare) and totals no more than 22,000 short tons (20,000 metric tons) (Waring, 1936; Merritt and Belowich, 1984). One other reported anthracite occurrence (Merritt and Belowich, 1984), too thin to be mined, is on a large active landslide (Detterman and others, 1976).

Susitna-Beluga Coalfield

Barnes (1967a) reported identified coal resources of the Susitna-Beluga coalfield as 2.4 billion short tons (2.2 billion metric tons) (table 6). Total resources were estimated for subbituminous coal beds greater than 2.5 ft (0.76 m), with overburden to 1,000 ft (0–305 m) in the drainage basins of the Yentna, Skwentna, Beluga, and Chuitna Rivers, the Capps Glacier coal district, and an area southwest of Tyonek. Indicated coal resources are 56 million short tons (51 million metric tons) in the Yentna River Basin, 123 million short tons (116 million metric tons) in the Skwentna River Basin, 260 million short tons (236 million metric tons) in the Beluga River Basin, 1.54 billion short tons (1.4 billion metric tons) in the Chuitna River Basin, 406 million short tons (368 billion metric tons) in the Capps Glacier district, and 9.4 million short tons (8.5 million metric tons) southwest of Tyonek.

Wahrhaftig and others (1994), based on Barnes' 1966 report, calculated indicated coal resources of (1) 4.5×10^6 short tons (4.1×10^6 metric tons) in beds less than 6.5 ft (2 m) thick in the Peters Hills; (2) about 44×10^6 short tons (40×10^6 metric tons) of coal mainly in beds more than 10 ft (3 m) thick in the Fairview Mountain area; (3) 20×10^6 short tons (18×10^6 metric tons) of coal mainly in beds more than 6.5 ft (2 m) thick in the Johnson Creek area; and (4) 110×10^6 short tons (100×10^6 metric tons) of coal in the downfaulted half graben along Canyon Creek area. A drilling program by Mobil Oil Corporation resulted in estimates of 500×10^6 short tons (450×10^6 metric tons) of coal within 250 ft (76 m) of the surface in beds 10 to 50 ft (3 to 15 m) thick, in two leased areas totaling 23,000 acres (9,300 hectares). One area includes the Canyon Creek drainage basin and the other extends from the Skwentna River northward across Johnson Creek (Blumer, 1981).

Table 6. Estimates of coal resources for the Tertiary Kenai Group in the Matanuska, Susitna, Broad Pass, and Kenai coalfields in the Southern Alaska-Cook Inlet coal province.
[Resource estimates are in millions of short tons (multiply by 0.907 to obtain metric tons)]

Coal field	Source	Classification	Coal Resource estimate
All Southern Alaska-Cook Inlet	Barnes (1967a)	Identified[1]	2,910
	McGee, D.L., and Emmel, K.S[2]	Identified	34,320
	Merritt and Hawley (1986)	Identified	11,600
	Merritt and Hawley (1986)	Hypothetical	1,570,000
Matanuska	Barnes (1967a)	Identified[3]	137
	Barnes (1967a)	Hypothetical	274
	Merritt and Belowich (1984)	Identified	200
	Merritt and Belowich (1984)	Hypothetical	24,000
Susitna-Beluga	Barnes (1967a)	Identified[4]	2,400
	Merritt and Hawley (1986)	Identified	11,100
	Merritt and Hawley (1986)	Hypothetical	34,800
Broad Pass	Hopkins (1951)	Identified	13
	Barnes (1967a)	Identified[3]	64
	Merritt and Hawley (1986)	Identified	50
	Merritt and Hawley (1986)	Hypothetical	500
	Wahrhaftig and others (1994)	Identified	0.3
	Wahrhaftig and others (1994)	Hypothetical	13
Kenai	Barnes and Cobb (1959)	Indicated[4]	400
	Barnes (1967a)	Identified[4]	318
Kenai (onshore)	McGee, D.L., and Emmel, K.S[2]	Identified	318
	Merritt and Hawley (1986)	Identified	320
	Merritt and Hawley (1986)	Hypothetical	35,000
	McGee, D.L., and Emmel, K.S[2]	Hypothetical	34,000
Kenai (offshore)	McGee, D.L., and Emmel, K.S[2]	Hypothetical	100,000
	Merritt and Hawley (1986)	Hypothetical	1,500,000

[1] Reported resource estimates with overburden classifications of 0–1,000 feet, 1,000–2,000 feet, and 2,000–3,000 feet.

[2] McGee, D.L., and Emmel, K.S., 1979, unpublished report, Alaska Division of Geological and Geophysical Surveys, Fairbanks, Alaska.

[3] Reported resource estimates with overburden classifications of 0–2,000 feet.

[4] Reported resource estimates with overburden classifications of 0–1,000 feet.

Broad Pass Coalfield

The hypothetical and identified coal resources of the Broad Pass coalfield reported by Wahrhaftig and others (1994) were 13.3 × 10^6 short tons (12 × 10^3 metric tons) of coal combined for two beds with a maximum thickness of 10 ft (3 m). According to Barnes (1967a), 64 × 10^3short tons (58 × 10^3 metric tons) of coal was mined from 1940 to 1954, and the rest was unminable (table 6).

Hopkins (1951) estimated that at least 13 x 10^6 short tons (12.2 × 10^6 metric tons) of coal exist beneath the area of known exposures of Tertiary rocks at Broad Pass Station, but only 300 × 10^3 short tons (270 × 10^3 metric tons) of lignite with an ash yield of 8–25 percent was actually measured.

Barnes (1967a) reported total coal resources of the Broad Pass coalfield as 64 million short tons (58 million metric tons). Based on coal-bed thickness of 2.5 ft (0.75 m) for subbituminous rank and overburden of 0–1,000 ft (0–305 m), Broad Pass Station area contains as much as 0.3 million short tons (0.27 million metric tons) indicated coal resources, 63.3 million short tons (57 million metric tons) inferred coal resources, or a total coal resource of 63.6 million short tons (57.4 million metric tons). Costello Creek area contains 0.3 million short tons (0.27 million metric tons) indicated coal resources.

Kenai Coalfield

Coal resources of the Kenai coalfield are mainly concentrated in the Homer coal district. Barnes and Cobb (1959) calculated indicated coal resources of 400 × 10^6 short tons (360 × 10^6 metric tons) for coal beds greater than 2 ft (0.6 m) thick, of which 50 × 10^6 short tons (45 × 10^6 metric tons) are in beds more than 5 ft (1.5 m) thick. These coal beds are covered by <990 ft (300 m) of overburden. Barnes and Cobb’s investigation indicated that all except the extreme northern and northeastern parts of the Homer coal district, about 750-mi^2 (1,940-km^2) area, is underlain by coal beds greater than 2 ft (0.6 m) thick. Thus, the potential coal resources of the Homer coal district may be several billion short tons. Barnes (1967a) reported the total coal resources of the Homer coal district to be more than 318 million short tons (290 million metric tons). McGee and Emmel (written commun., 1979) reported Kenai coalfield onshore resources as 0.2 million short tons (0.18 million metric tons) measured coal resources, 318 million short tons (290 million metric tons) identified coal resources, and 34 billion short tons (31 billion metric tons) hypothetical resources (table 6).

Based on geophysical logs from drill holes throughout the Cook Inlet Basin, McGee and O’Connor (1975) calculated a hypothetical resource of 1.2 × 10^{12} short tons (1.1 × 10^{12} metric tons) of coal of apparent lignite rank to a depth of 10,000 ft (3,048 m) and 110 × 10^9 short tons (100 × 10^9 metric tons) to a depth of 2,000 ft (610 m). McGee and Emmel (written commun., 1979) reported about 34.32 billion short tons (31 billion metric tons) of hypothetical coal resources in the offshore Cook Inlet Basin. Affolter and Stricker (1987b) estimated a hypothetical resource of 0.8 × 10^{12} short tons (0.7 × 10^{12} metric tons) of the Kenai Group coal to lie beneath the waters of Cook Inlet.

Coal Quality

Coal in the Southern Alaska-Cook Inlet coal province ranges from lignite to anthracite (table 7). The lignite with heat values of 5,410–8,020 Btu/lb (3,010–4,460 kcal/kg) and subbituminous coal with heat values of 8,060–9,520 Btu/lb (4,480–5,290 kcal/kg) are mainly in the Broad Pass, Susitna-Beluga, and Kenai coalfields (Barnes, 1967a). Bituminous coal with heat values of 10,390–14,380 Btu/lb (5,770–7,990 kcal/kg) and semianthracite with heat values of 10,720–13,420 Btu/lb (5,960–7,460 kcal/kg) coal are mainly in the Matanuska coalfield (Barnes, 1967a).

In the Matanuska coalfield, the ash yield varies from 2.4 to 21.7 percent, sulfur from 0.2 to 1.0 percent, and moisture content from 1.1 to 20.3 percent (as-received basis; Barnes, 1967a). Run-of-the-mine coal quality in the Wishbone Hill coal district varies from 9 to 29 percent ash, 0.3 to 0.4 percent sulfur, and 4.0 to 6.0 percent moisture content (as-received basis; Germer, 1986; Belowich, 1994).

In the Susitna-Beluga coalfield, coal varies from 2.1 to 30.5 percent ash yield, 0.1 to 0.3 percent sulfur, and 11.3 to 33.1 percent moisture contents (as-received basis; Barnes, 1967a). In the Chuitna River drainage basin, Affolter and Stricker (1994) reported ash yield that varies from 4.83 to 38.67 percent, sulfur content from 0.08 to 0.18 percent, and moisture content from 19.19 to 26.15 percent. In the Beluga River drainage basin, the ash yield varies from 3.59 to 29.87, sulfur content from 0.08 to 0.32, and moisture content from 16.78 to 7.49 percent. In the Capps Glacier district the coal beds contain ash yield of 9.3–40.3 percent, sulfur 0.12–0.33, and moisture 4.8–26.0 percent (as-received basis; Affolter and Stricker, 1986). Flores and others (1994) suggested that the higher sulfur content in coal beds in the Chuitna River drainage basin was influenced by tidal incursions into mires.

In the Broad Pass coalfield, the ash yield varies from 6.0 to 21.2 percent, sulfur from 0.2 to 0.6 percent, and moisture content from 8.7 to 35.8 percent (as-received basis; Barnes, 1967a).

In the Kenai coalfield, with emphasis on the coal beds in the Homer coal district, ash yield varies from 3.8 to 22.0 percent, sulfur content from 0.1 to 0.4 percent, and moisture content from 16.5 to 30.4 percent (Barnes and Cobb, 1959; Barnes, 1967a). Affolter and Stricker (1994) reported ash yield ranging from 4.80 to 26.90 percent, sulfur content from 0.20 to

1.30 percent, and 11.0 to 26.50 percent moisture content from the Kenai coalfield.

Coal Petrology

The coal petrology of the Tyonek coal beds in the Chuitna River drainage area was investigated by Rao and Smith (1986). Vitrinite (or huminite) is the most abundant maceral and varies from about 66 to 92 percent. Minor liptinite varies from 4 to 18 percent and inertinite from 0 to 9 percent. The woody or huminite maceral is composed mainly of cypress trees (Rao and Smith, 1986). However, oak, beech, hickory, elm, walnut, alder, and birch trees are represented in the peat-forming mires. The huminite maceral is either unevenly distributed vertically throughout the coal beds or it increases in the upper and lower parts of the coal beds. Liptinite macerals in some coal beds increases in the upper part of the coal beds. Inertinite appears to be less preferentially distributed vertically in the coal beds than the huminite and liptinite macerals. However, local peak occurrences of inertinite indicate generation of fusinite or charcoal that is formed by forest fires during dry periods. High occurrence of liptinite suggests differential decomposition of the more resistant exinite from vegetal matter. The high concentration of huminite in the lower part of coal beds indicates that the mires were initially vegetated by abundant trees, which evolved into less woody vegetation through time. The high concentration of huminite in the upper part indicates that the mire supported more woody vegetation through time.

Coalbed Methane Potential

The coal resources of Alaska (about 5,526 billion short tons; see table 1) contain significant potential economic coalbed methane resources. Methane derived from coal, which has migrated and is stored in interbedded sandstone reservoirs in the Cook Inlet Basin, is presently being developed. Coalbed gas or methane-rich gas is stored (adsorbed) in the coal along fractures, cleats, and pores and (or) within (absorbed) the molecular structure of the coal. Gas is stored in the coal by molecular attraction on the surfaces of the structures of the coal. Methane is a by-product of fermentation during deposition and coalification during burial of peat. The ability of the coal to store gas is a function of rank or grade of coalification (for example, lignite, subbituminous, bituminous) and temperature and pressure. Generally, more methane is stored in higher rank coal and at high pressure whereas higher temperature decreases storage capacity. Methane generated in higher rank coal (for example, bituminous) is thermogenic in origin, and methane produced in lower rank coal (lignite and subbituminous) is biogenic in origin. Biogenic gas is generated during bacterial activity by methanogens or anaerobes that produced methane as a by-product of their metabolism. In most cases methanogens do this by reducing carbon dioxide with hydrogen to produce methane. Biogenic gas generated from lignites in Alaska was determined from a 1994 U.S. Geological Survey test well in the Yukon Basin (Flats), where the coal beds are more than 21 ft (6.4 m) thick.

A major by-product of development of coalbed methane, especially for subbituminous coal, is coproduced water. Volumes of water produced in major methane-producing

Table 7. Range (minimum and maximum values) of quality parameters for Tertiary coal deposits in the Matanuska, Broad Pass, Susitna, and Kenai coalfields in the Southern Alaska-Cook Inlet coal province.
[All analyses except Calorific value (Btu) are in percent. Values reported on an as-received basis. Modified from Merritt, 1984]

Area	Moisture	Volatile matter	Fixed carbon	Ash yield	Total sulfur	Calorific value Btu per pound
Broad Pass	20–35	27–35	20–28	10–20	0.2–0.4	5,500–7,100
Kenai	20–27	30–38	25–35	3–25	0.2–0.4	6,500–8,500
Matanuska Valley						
Wishbone Hill	3–9	32–45	38–51	4–22	0.2–1.0	10,400–13,200
Chickaloon	1–5	14–24	60–72	5–20	0.4–0.7	11,960–14,400
Anthracite Ridge	3–9	7–11	65–81	7–20	0.2–0.7	10,720–14,000
Susitna Lowland	10–30	28–40	25–45	3–30	0.1–0.7	6,200–9,500

basins in the conterminous United States vary significantly between bituminous and subbituminous coal. The volume of coproduced water from bituminous coal ranges in average from 48 to 240 barrels (7,632 to 38,160 liters) of water per day per well and from the subbituminous coal the average is about 440 barrels (91,600 liters) (Flores, 2000). Hence, the water: gas ratio for the bituminous coal ranges from 0.029 to 0.51 barrel per thousand cubic feet (16.3 to 286 liters per 100 m^3) and from the subbituminous coal is 2.88 barrels per thousand cubic feet (21,360 liters per 100 m^3) (Flores, 2000). In order to produce the methane from the coal, the reservoir needs to be dewatered, which results in the depressurization of the reservoir. This water can be disposed of either on the surface, into ponds or existing drainages, or reinjected below the surface. Regulations, quality, and amount of the coproduced water influence the choice of a disposal system. Coproduced water from subbituminous coal of the Tertiary Fort Union Formation being developed in the Powder River Basin of Wyoming is freshwater. It contains concentrations of dissolved solids mainly of bicarbonate, and trace elements and pH values that are generally below and within recommended drinking-water standards (Flores, 2000). Thus gas operators in that basin are permitted to dispose of the coproduced water on the surface; however, the large volume of water being disposed of is affecting the environment (for example, biota, ephemeral drainages, ground-water supply). Water-disposal problems may influence potential development in Alaska where the permafrost (for example, Northern Alaska-Slope coal province) is thick (Ferrians, 1965), and freezing temperatures at the surface for much of the year may curtail surficial disposal by ponding or along preexisting drainages. The quality of water such as concentration of total dissolved solids and location of coalbed gas production where recharge areas are juxtaposed to brackish-marine bodies of water (sea, ocean, bay) may prevent surface disposal or reinjection, which may contaminate ground-water supply.

Smith (1995) reported that Alaska's in-place coalbed methane resources might be as much as 1,000 trillion cubic feet (tcf) (28 trillion cubic meters [tcm]) based on estimates of the gas content of as much as 245 standard cubic feet per ton (scf/t) for the coals. The high coalbed-methane resource estimate of Smith (1995) utilized 200 scf/t for both the subbituminous and bituminous coals in the Northern Alaska-North Slope coal province and 152 scf/t for the subbituminous coal in the offshore area in the Southern Alaska-Cook Inlet coal province. Our investigations of the subbituminous coals in the Powder River coals indicate gas content ranging from 0 to 99 scf/t, averaging 25 scf/t (Stricker and others, 2001). If the Powder River Basin coalbed-methane content is applied for the Alaska subbituminous coal, Smith's estimate will be reduced to about one-half the volume.

Northern Alaska-Slope Coal Province

The voluminous lignite, subbituminous, and bituminous coal of the Northern Alaska-Slope coal province indicates a high potential for large biogenic and thermogenic gas resources. The abundance of bituminous coal with 1,910 billion short tons (1,732 billion metric tons) and subbituminous coal with 1,960 billion short tons (1,778 trillion metric tons) in the Northern Alaska-Slope coal province (fig. 102) indicates a high potential for thermogenic and biogenic methane resources. Outcrop and surface-projected mean vitrinite reflectance values in the Northern Alaska-Slope coal province range from 0.31 to 1.71 percent, which corresponds to lignite to low volatile bituminous coal ranks (figs. 103 and 104; table 8a and 8b). Coal rank generally increases southward toward the Brooks Range where the vitrinite reflectance values exceed 1.71 percent (see table 8a and 8b). Thus, the vitrinite reflectance values suggest a range of coal maturation in which coalbed methane, both biogenic and thermogenic, may be generated from subbituminous and bituminous coals, respectively.

Tyler and others (2000) and Clough and others (2000) evaluated the potential coalbed methane for the rural communities in the Northern Alaska-Slope coal province. They suggested that based on depth, coal thickness, and depositional systems, primary coalbed methane targets and potential exploration fairways occur mainly in the Cretaceous Nanushuk Group. These workers identified the area between the eastern boundary of the National Petroleum Reserve of Alaska (NPRA) to Chukchi Sea (see figs. 8 and 10) as containing the highest coalbed methane potential because of the thickest net coal, which is >300 ft (91 m) (see fig. 8). Potential methane development in this area may be from most of the coal beds that lie at an average depth of 2,000 ft (610 m).

Drilling depths for coalbed methane are recommended below the permafrost zone, which is as much as 2,000 ft deep (610 m) (Ferrians, 1965), to 6,000 ft (1,830 m). McKee and others (1986) suggested that permeability is very low below the 6,000-ft (1,825-m) threshold. The Meade Test Well No. 1 and Kaolak Test Well No. 1 have related gas shows with coal beds as much as 30 ft (9.1 m) thick as well as interbedded sandstones at depths between 1,240 and 2,200 ft (378 and 670 m) (Collins, 1959). Here, Barnes (1967a) reported that there are as many as 60 coal beds with a net coal thickness of 350 ft (107 m) within a 4,600-ft (1,400-m) interval. Methane gas shows associated with coal beds in the Nanushuk Group and Corwin Formation were recorded at depths between the surface to about 1,420 ft (430 m) by Husky Oil NPR, Operations, Inc. (1982–83). The presence of high gas content in subbituminous coal beds in the Nanushuk and Colville Groups in the NPRA was also reported by Claypool and Magoon (1988). These investigators also noted that the shallow, immature nature of the coal beds make for an unfavorable thermogenic gas source. However, similar subbituminous coal beds of the Fort Union Formation in the Powder River Basin of Wyoming are currently producing coalbed gas from depths of 250–1,500 ft (76–460 m).

The vitrinite reflectance values of the Cretaceous coal-bearing rocks (Corwin-Chandler, Grandstand, Torok Formations, the Pebble shale unit, and underlying Jurassic-Devonian rocks) in the Northern Alaska-Slope coal province are shown in figures 105 and 106. The vitrinite reflectance values down to 6,000 ft (1,830 m) range from about 0.30 to 0.66 percent, which corresponds mainly to lignite to subbituminous coal through subordinate high-volatile bituminous C coal (Stach and others, 1982). Vitrinite reflectance values are superimposed on the cross section of the Nanushuk Group and underlying rocks (fig. 107). Here, the vitrinite reflectance values of the coal-bearing Corwin-Chandler Formations range from <0.5 to >0.7 percent in the western part (updip) of the Northern Alaska-Slope coal province and from <0.5 to <0.6 percent in the eastern part (downdip). This indicates that the coal beds may have generated mixed biogenic and thermogenic methane in the western part of the coal province and mainly biogenic methane in the eastern part. The extent of Nanushuk coal beds and the high-potential coalbed methane resources in the western part of the Northern Alaska-Slope coal province is shown in figures 108 and 109. In figure 108, the depths to the vitrinite reflectance value of 0.6 percent are superimposed on the base of Nanushuk Group and the net coal thickness of the Nanushuk Group. When the vitrinite reflectance contours are merged with the extent of the Nanushuk coal and where the Nanushuk coal beds have a net thickness of >400 ft (192 m), the area of highest coalbed methane potential is in the southwestern part of the Northern Alaska-Slope coal province.

Callahan (1979) suggested that the North Slope gas is biogenic and generated by a microbial activity. Carbon isotopic analyses of near-surface (0–4,920 ft, 0–1,500 m) gas-hydrate- and coal-bearing units by Collett (1993) yielded carbon isotopic values averaging about –49 permil. This indicates that the methane in near-surface strata is from mixed biogenic and thermogenic origin. However, based on vitrinite reflectance values (0.30–0.66), the gas-hydrate and coal-bearing rocks probably were not subjected to high temperatures; thus, the thermogenic gas may have migrated from greater depths.

Tyler and others (2000) suggested that in addition to targeting coal beds for conventional methane exploration, stratigraphic and structural traps should be explored for coalbed methane potential. Conventional play for thermogenic gas in the coal that migrated updip and was trapped below the permafrost was also recommended for exploration. The permafrost zone serves as a seal for trapping migrating gas. Stratigraphic traps were suggested by Tyler and others (2000) where coal beds pinch out updip behind progradational shoreline sequences (for example, delta-front, barrier-shoreface sandstones) in the Nanushuk Group. Structural traps may be found in fault-cored anticlines (for example, Meade and Wainwright arches) (see fig. 8; Tyler and others, 2000).

Central Alaska-Nenana Coal Province

The coalbed methane potential for the Central Alaska-Nenana coal province is not as high as the Northern Alaska-Slope coal province. The coal beds in this coal province are mainly subbituminous, range from 50 to 66 ft (15 to 20 m) in thickness, and occur to depths of 3,000 ft (910 m). In addition, the Healy Creek Formation is sealed by thick mudstones of the overlying Sanctuary Formation. Exploration targets for potential coalbed methane are along the axes of large synclinal basins such as the Healy Creek and Lignite Creek Basins. In these basins, most of the coal resources in the Healy Creek and Suntrana Formations are thick (as much as 65 ft or 20 m thick) and found from 1,000-to 3,000-ft (305 to 914 m) depths (Wahrhaftig and others, 1994).

Although the rank of the Healy Creek, Suntrana, and Lignite Creek coals is mainly subbituminous, Affolter and Stricker (1994) reported heating (calorific) values ranging from 6,130 to 9,210 Btu/lb (3,410 to 5,120 kcal/kg), which correspond to lignite to subbituminous coal. Outcrop and surface-projected vitrinite values of the coal-bearing Usibelli Group in the Central Alaska-Nenana coal province range from 0.21 to 0.48 percent, which corresponds to lignite to subbituminous C coal ranks (fig. 104). Coal ranks generally increase south-southeast toward the Alaska Range, indicating that methane generated in these mainly subbituminous coal deposits is biogenic. The rank and quality (low ash and sulfur) of the Healy Creek, Suntrana, and Lignite Creek coals beds are very similar to the subbituminous coal beds of the Fort Union Formation in the Powder River Basin of Wyoming, which are producing economic biogenic methane at an average of 25 scf/t. In that basin, coalbed methane is produced as close as 1–2 miles (1.6–3.2 km) from coal strip mines (Stricker and others, 2001). However, the strip mining has liberated gas by pressure reduction. Because the Fort Union coal beds have high water saturation, depressurization from dewatering during strip mining releases and subsequently causes migration of gas by desorption and diffusion through the microstructures in the coal. Thus, success in developing the coalbed methane for the Healy Creek and Suntrana coal beds should probably be focused on areas removed from old underground coal mines and current strip mines.

Southern Alaska-Cook Inlet Coal Province

The coalbed methane potential for the Southern Alaska-Cook Inlet coal province is high. This resource potential varies from the Kenai, Broad Pass, and Beluga coalfields, which contain lignite and subbituminous coal, to the Matanuska coalfield, which contains bituminous and semianthracite coals.

Magoon and Anders (1990) reported that the gas produced from the Kenai Group in the Cook Inlet is biogenic. Gas is mainly derived from the Tyonek and Beluga Formations. This gas is produced primarily from gas-driven–sandstone reservoirs (table 9) in the Tyonek, Beluga, and Sterling

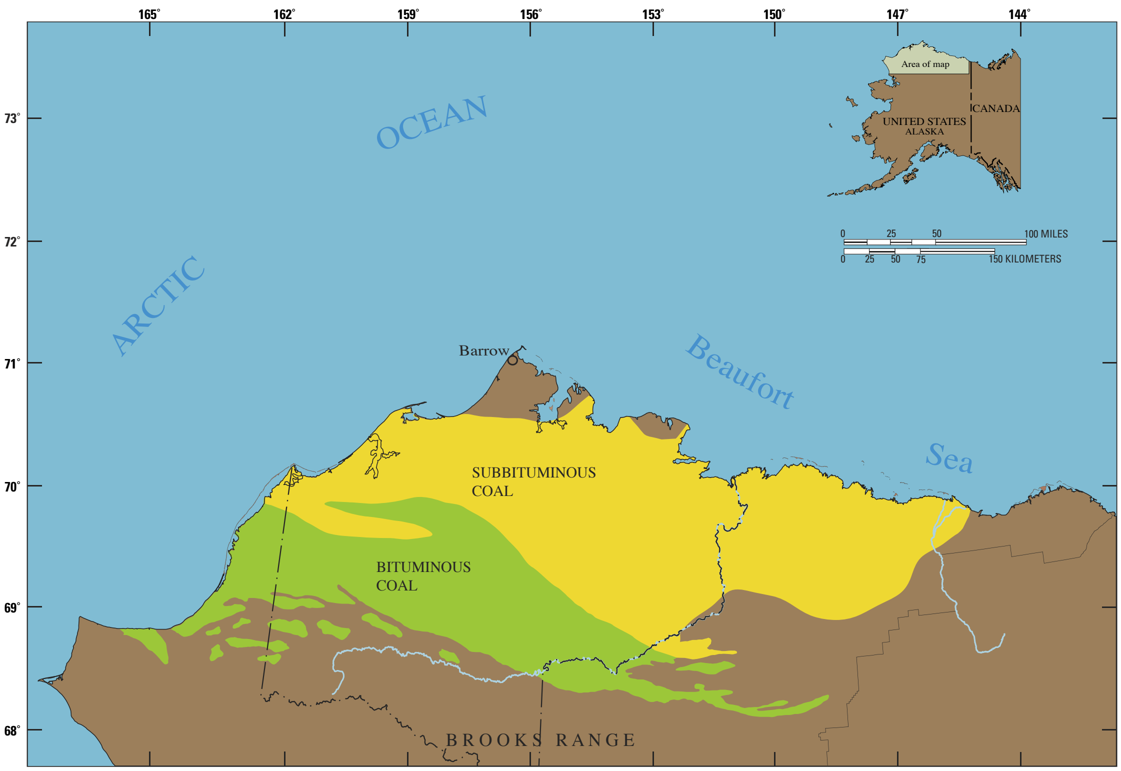


Figure 102. Map of the Northern Alaska-Slope coal province showing distribution of bituminous and sub-bituminous coals. Modified from Sable and Stricker (1987).

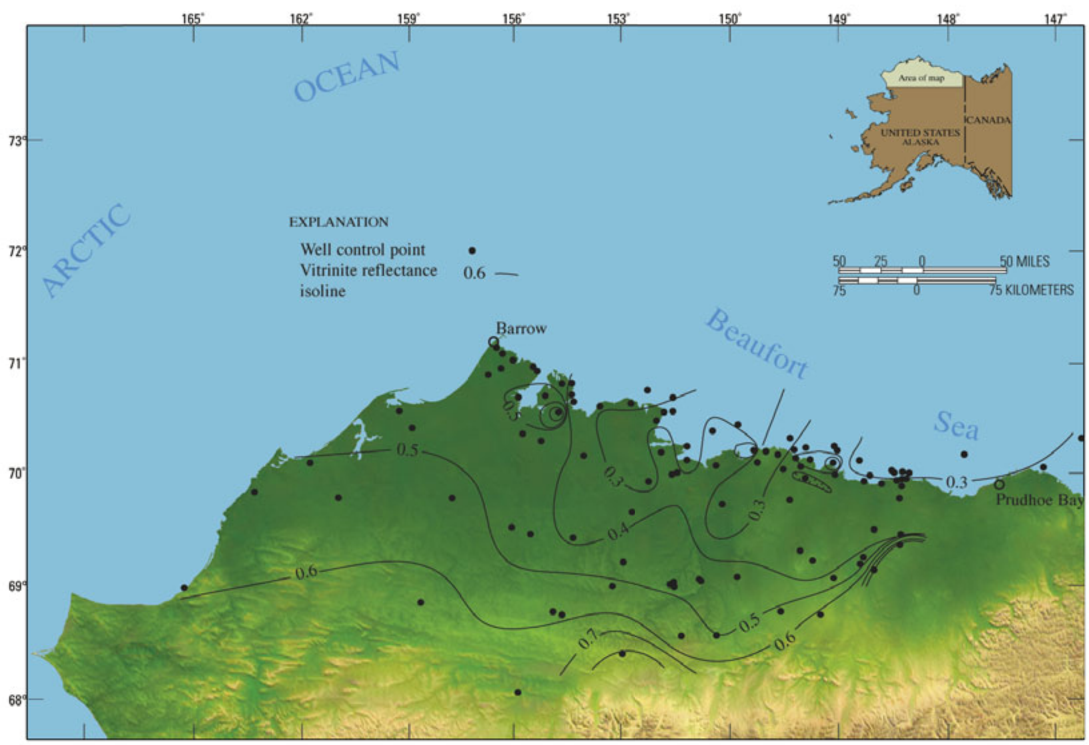


Figure 103. Distribution of surface vitrinite reflectance values at sea level in the Northern Alaska-Slope coal province.

Formations (Brimberry and others, 1997; Flores and others, 1998). Figure 110 shows the distribution of gas and oil fields in the Cook Inlet Basin producing mainly from the Tyonek, Beluga, and Sterling sandstones. Figures 111 and 112 show the vertical distribution and occurrence of gas in the Sterling and Beluga sandstone reservoirs; gas accumulations in associated coal beds in the Kenai field are shown in figure 113 (Brimberry and others, 1997; Flores and others, 1998). Since 1958, when gas production from the Cook Inlet was first recorded by the Alaska Department of Natural Resources, Division of Oil and Gas (1997), the total (gross) production from these sandstone reservoirs was about 7,993 billion cubic feet. This gas is thought to be derived from the Tyonek, Beluga, and Sterling coal beds (Kelly, 1968). Coal mines in the Matanuska coalfield have emitted methane from the Chikaloon coal beds, which has caused several mine explosions in 1937 and 1957 (Barnes and Payne, 1956; Smith, 1995).

Thirteen out of 18 coal beds in the Tyonek Formation in the upper Cook Inlet Basin (northwest of Wasilla) were determined to contain coalbed methane by Smith (1995). Gas content ranges from 63 ft^3 per short ton (1.97 scm^3/gm) at standard temperature and pressure (STP) for coal beds at a shallow depth of 500 ft (152 m) to 245 ft^3 per short ton (7.6 scm^3/gm) at STP for coal beds at a depth of 1,200 ft (366 m). Vitrinite reflectance values range from 0.47 to 0.58 percent and generally increase with depth. The carbon isotope composition of the coalbed gases range from –49.3 to –43.3 permil $\delta^{13}C$ with slightly heavier isotope values at depth (Smith, 1995). In general, biogenic methane is isotopically light with methane $\delta^{13}C$ values ranging from –55 to –90 permil (Rice and Claypool, 1981; Rice, 1993). However, biogenic methane can be as heavy as –40 permil, which can be produced by reduction of isotopically heavy carbon dioxide (Jenden and Kaplan, 1986). Thus, the gas from the Tyonek coal beds may be slightly biogenic but mostly thermogenic. Chemical composition is 98–99 percent methane with minor amounts of carbon dioxide and nitrogen (see table 9; Flores and others, 1998).

Attempts to develop Tyonek coal beds by energy companies (Union and Ocean Energy) in the Wasilla area were affected by coproduced water problems. Large amounts of ground water were encountered, which posed production problems in separating the coalbed methane from the coproduced water as well as water-disposal problems by reinjection. Similar problems were met by gas operators in developing the coal beds of the Fort Union Formation in the Powder River Basin of Wyoming. However, the gas operators in that area are permitted to dispose of coproduced water at the surface. Other targets for coalbed methane development in the Upper

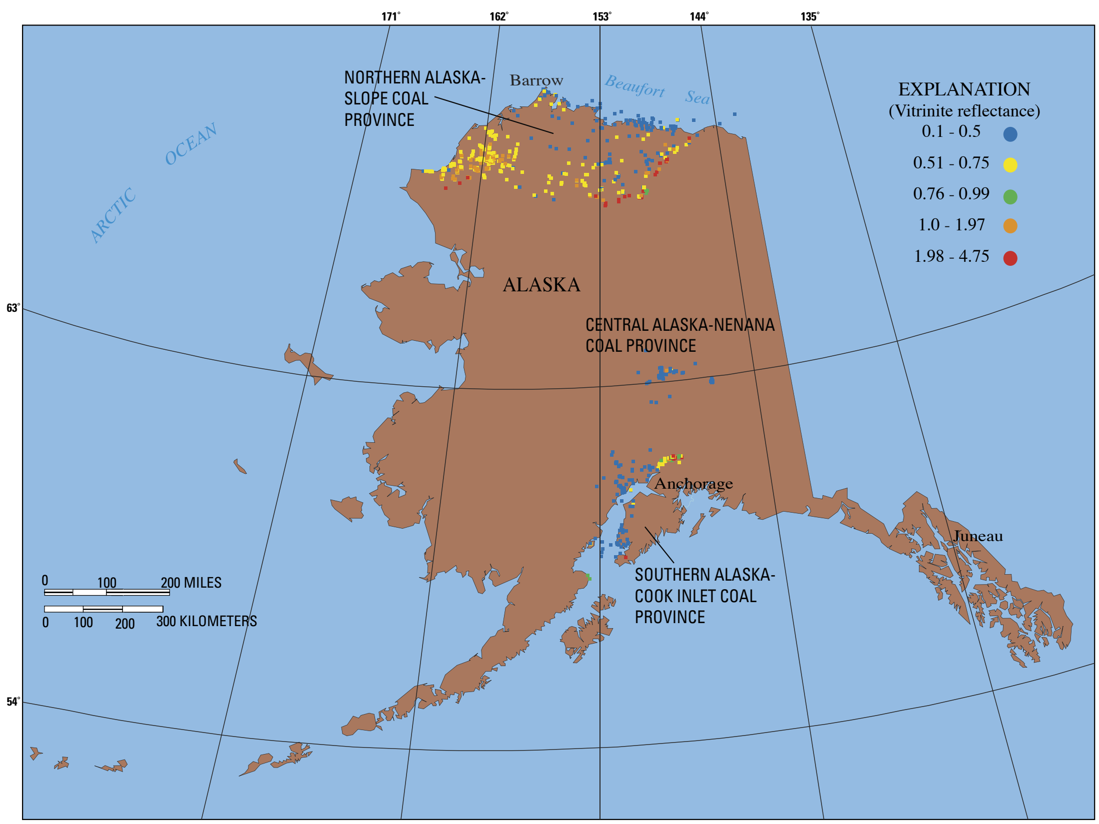


Figure 104. Map showing surface vitrinite reflectance values in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces.

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. [Modified from Johnsson and others, 1992]

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-0063	Afognak	58.8580	153.2860	West Forelands	3.36
VO-0068	Afognak	58.9460	153.4070	West Forelands	3.76
VO-0070	Anchorage	61.6500	149.8530	Kenai	0.47
VO-0071	Anchorage	61.6650	149.0730	Chickaloon	0.75
VO-0075	Anchorage	61.6800	148.1330	Kenai	0.66
VO-0081	Anchorage	61.6950	149.2520	Kenai	0.58
VO-0082	Anchorage	61.7080	149.0690	Chickaloon	0.65
VO-0084	Anchorage	61.7080	149.1020	Chickaloon	0.65
VO-0085	Anchorage	61.7380	148.9500	Chickaloon	0.61
VO-0091	Anchorage	61.7478	148.5364	Chickaloon	2.85
VO-0092	Anchorage	61.7489	148.5403	Chickaloon	3.42
VO-0093	Anchorage	61.7536	148.9081	Chickaloon	0.55
VO-0094	Anchorage	61.7581	148.8819	Chickaloon	0.54
VO-0096	Anchorage	61.7661	148.7311	Chickaloon	3.69
VO-0097	Anchorage	61.7670	149.1330	Arkose Ridge	2.10
VO-0099	Anchorage	61.7797	148.4147	Chickaloon	1.06
VO-0105	Anchorage	61.7833	148.7006	Chickaloon	0.82
VO-0106	Anchorage	61.7861	148.4306	Chickaloon	1.08
VO-0107	Anchorage	61.7883	148.4325	Chickaloon	1.30
VO-0109	Anchorage	61.7886	148.6883	Chickaloon	0.92
VO-0110	Anchorage	61.8033	148.3228	Chickaloon	1.55
VO-0111	Anchorage	61.8056	147.9753	Chickaloon	1.73
VO-0118	Anchorage	61.8078	148.4456	Chickaloon	1.42
VO-0121	Anchorage	61.8100	148.5570	Chickaloon	1.07
VO-0122	Anchorage	61.8131	148.6989	Chickaloon	0.74
VO-0124	Anchorage	61.8153	148.9464	Chickaloon	0.55
VO-0127	Anchorage	61.8169	148.5881	Chickaloon	1.26
VO-0130	Anchorage	61.8228	148.1406	Chickaloon	2.00
VO-0132	Anchorage	61.8228	148.4278	Chickaloon	1.12
VO-0135	Anchorage	61.8250	148.5469	Chickaloon	2.04
VO-0138	Anchorage	61.8289	148.5375	Chickaloon	2.07
VO-0139	Anchorage	61.8375	148.3922	Chickaloon	0.94
VO-0141	Anchorage	61.8378	148.0131	Chickaloon	0.84
VO-0143	Anchorage	61.8392	147.9908	Chickaloon	2.92
VO-0146	Anchorage	61.8392	148.0028	Chickaloon	0.81
VO-0147	Anchorage	61.8408	148.0131	Chickaloon	0.76
VO-0152	Anchorage	61.8408	148.5131	Chickaloon	0.64
VO-0153	Anchorage	61.8414	147.9908	Chickaloon	0.81
VO-0155	Anchorage	61.8417	148.0019	Chickaloon	0.76
VO-0156	Anchorage	61.8417	148.0039	Chickaloon	0.71
VO-0158	Anchorage	61.8461	148.0947	Chickaloon	3.27

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-0160	Anchorage	61.8472	148.1006	Chickaloon	4.08
VO-0161	Anchorage	61.8472	148.1050	Chickaloon	3.88
VO-0164	Anchorage	61.8497	148.1033	Chickaloon	3.74
VO-0165	Anchorage	61.8511	148.1022	Chickaloon	4.75
VO-0168	Anchorage	61.8550	148.4380	Chickaloon	1.15
VO-0647	Chandler Lake	68.3236	151.8950	Okpikruak	1.32
VO-0648	Chandler Lake	68.3458	151.8708	Okpikruak	1.60
VO-0649	Chandler Lake	68.3569	151.8750	Okpikruak	1.18
VO-0656	Chandler Lake	68.3867	151.8708	Torok	1.31
VO-0666	Chandler Lake	68.4131	150.9178	Okpikruak	1.58
VO-0673	Chandler Lake	68.4575	150.9247	Okpikruak	1.23
VO-0679	Chandler Lake	68.4625	152.0250	Torok	0.94
VO-0694	Chandler Lake	68.5250	150.4733	Torok	0.99
VO-0696	Chandler Lake	68.5272	150.4775	Torok	1.01
VO-0700	Chandler Lake	68.5450	152.4783	Fortress Mountain	0.96
VO-0701	Chandler Lake	68.5458	152.5000	Fortress Mountain	0.93
VO-0702	Chandler Lake	68.5536	150.1472	Torok	1.38
VO-0703	Chandler Lake	68.5661	152.5822	Fortress Mountain	0.64
VO-0704	Chandler Lake	68.5700	152.9797	Fortress Mountain	0.71
VO-0707	Chandler Lake	68.5700	152.9822	Fortress Mountain	0.74
VO-0708	Chandler Lake	68.5706	152.5639	Fortress Mountain	0.65
VO-0709	Chandler Lake	68.5708	152.9767	Fortress Mountain	0.76
VO-0710	Chandler Lake	68.5711	152.5869	Fortress Mountain	1.08
VO-0715	Chandler Lake	68.6294	150.5692	Killik Tongue	0.56
VO-0716	Chandler Lake	68.6314	150.5703	Killik Tongue	0.72
VO-0717	Chandler Lake	68.6403	150.5783	Killik Tongue	0.49
VO-0718	Chandler Lake	68.6464	150.5883	Killik Tongue	0.52
VO-0719	Chandler Lake	68.6508	150.5936	Killik Tongue	0.56
VO-0720	Chandler Lake	68.6578	150.5950	Killik Tongue	0.59
VO-0722	Chandler Lake	68.6447	150.9036	Nanushuk Gp	0.74
VO-0724	Chandler Lake	68.6692	150.6086	Tuktu	0.55
VO-0727	Chandler Lake	68.7694	152.1150	Killik Tongue	0.68
VO-0731	Chandler Lake	68.7581	152.1403	Killik Tongue	0.47
VO-0732	Chandler Lake	68.7375	152.1472	Killik Tongue	0.59
VO-0733	Chandler Lake	68.7344	152.2569	Killik Tongue	0.50
VO-0734	Chandler Lake	68.7250	152.2639	Killik Tongue	0.62
VO-0735	Chandler Lake	68.8431	150.5611	Tuktu	0.51
VO-0736	Chandler Lake	68.8436	150.5586	Tuktu	0.56
VO-0737	Chandler Lake	68.8417	150.5803	Shale Wall Mbr	0.46
VO-0738	Chandler Lake	68.8417	150.5792	Shale Wall Mbr	0.47
VO-0739	Chandler Lake	68.9294	151.2175	Killik Tongue	0.55
VO-1177	De Long Mountains	68.5325	163.5330	Fortress Mountain	1.10
VO-1179	De Long Mountains	68.7408	163.8864	Corwin	0.59
VO-1180	De Long Mountains	68.7400	163.8844	Unnamed	0.63

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-1181	De Long Mountains	68.7564	163.9106	Torok	0.69
VO-1182	De Long Mountains	68.7814	162.9556	Torok	0.71
VO-1183	De Long Mountains	68.7869	162.9419	Kukpowruk	0.88
VO-1184	De Long Mountains	68.7850	162.9492	Unnamed	0.87
VO-1185	De Long Mountains	68.8078	163.9614	Torok	0.85
VO-1186	De Long Mountains	68.8150	163.9358	Unnamed	0.66
VO-1187	De Long Mountains	68.8106	163.9453	Unnamed	0.78
VO-1188	De Long Mountains	68.7764	163.9511	Unnamed	0.79
VO-1189	De Long Mountains	68.8086	163.9594	Unnamed	0.89
VO-1190	De Long Mountains	68.8489	163.8611	Unnamed	0.80
VO-1192	De Long Mountains	68.8636	163.8611	Kukpowruk	0.74
VO-1193	De Long Mountains	68.8600	163.1111	Unnamed	0.93
VO-1194	De Long Mountains	68.8542	163.1022	Unnamed	0.90
VO-1195	De Long Mountains	68.8494	163.0950	Unnamed	0.86
VO-1196	De Long Mountains	68.8397	163.0767	Unnamed	0.90
VO-1197	De Long Mountains	68.7972	163.1208	Unnamed	0.85
VO-1198	De Long Mountains	68.8925	164.6994	Nanushuk Gp	0.72
VO-1199	De Long Mountains	68.8925	164.8364	Nanushuk Gp	0.68
VO-1205	De Long Mountains	68.8925	164.8489	Nanushuk Gp	0.58
VO-1210	De Long Mountains	68.8936	164.8147	Nanushuk Gp	0.60
VO-1212	De Long Mountains	68.8947	164.7992	Nanushuk Gp	0.49
VO-1213	De Long Mountains	68.8958	164.7772	Nanushuk Gp	0.67
VO-1214	De Long Mountains	68.8969	164.7742	Nanushuk Gp	0.72
VO-1215	De Long Mountains	68.8981	164.7556	Nanushuk Gp	0.69
VO-1216	De Long Mountains	68.9631	162.8450	Unnamed	0.69
VO-1217	De Long Mountains	68.9647	162.8442	Unnamed	0.69
VO-1218	De Long Mountains	68.9714	162.8050	Unnamed	0.71
VO-1219	De Long Mountains	68.9822	162.8000	Unnamed	0.80
VO-1220	De Long Mountains	68.9950	162.8161	Unnamed	0.80
VO-1221	Point Lay	69.0019	162.8144	Unnamed	0.76
VO-1222	Point Lay	69.0056	162.8439	Unnamed	0.81
VO-1223	Point Lay	69.0108	162.8469	Unnamed	0.68
VO-1224	Point Lay	69.0161	162.9081	Unnamed	0.68
VO-1225	De Long Mountains	68.9653	163.8408	Nanushuk Gp	0.86
VO-1226	De Long Mountains	68.9722	163.9314	Nanushuk Gp	0.73
VO-1228	De Long Mountains	68.9725	163.8442	Corwin	0.74
VO-1229	De Long Mountains	68.9772	163.8561	Corwin	0.74
VO-1231	De Long Mountains	68.9878	163.8692	Nanushuk Gp	0.70
VO-1232	De Long Mountains	68.9925	163.8625	Corwin	0.73
VO-1235	De Long Mountains	68.9931	163.8650	Corwin	0.71
VO-1238	De Long Mountains	68.9939	163.8903	Corwin	0.72
VO-1241	De Long Mountains	68.9953	163.7619	Corwin	0.72
VO-1242	De Long Mountains	68.9989	163.7714	Corwin	0.73
VO-1243	De Long Mountains	68.9997	163.8722	Corwin	0.66

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-1345	Fairbanks	64.0050	148.2470	Suntrana	0.30
VO-1347	Fairbanks	64.0067	148.7842	Grubstake/Lignite Ck	0.21
VO-1348	Fairbanks	64.0111	148.2842	Suntrana	0.35
VO-1351	Fairbanks	64.0167	148.1400	Unnamed	0.63
VO-1355	Fairbanks	64.0180	148.2050	Lignite Creek	0.29
VO-1356	Fairbanks	64.0181	148.7433	Suntrana	0.27
VO-1357	Fairbanks	64.0350	148.4100	Grubstake	0.82
VO-1358	Fairbanks	64.0772	148.2072	Grubstake	0.50
VO-1362	Fairbanks	64.1017	148.7333	Sanctuary	0.33
VO-1366	Fairbanks	64.1050	148.8350	Healy Creek	0.31
VO-1367	Fairbanks	64.1220	148.7380	Healy Creek	0.33
VO-1369	Fairbanks	64.1283	146.6261	Healy Creek	0.29
VO-1372	Healy	63.2500	149.1870	Unnamed	0.23
VO-1373	Healy	63.2700	149.5050	Unnamed	0.41
VO-1482	Healy	63.7394	149.7033	Healy Creek	0.24
VO-1487	Healy	63.7661	149.6017	Sanctuary	0.31
VO-1489	Healy	63.7681	149.5811	Unnamed	0.28
VO-1490	Healy	63.7903	149.5056	Healy Creek	0.27
VO-1492	Healy	63.7928	149.5067	Sanctuary	0.29
VO-1495	Healy	63.8300	148.6670	Suntrana	0.30
VO-1497	Healy	63.8550	148.8400	Healy Creek	0.38
VO-1513	Healy	63.8567	148.8400	Suntrama	0.39
VO-1516	Healy	63.8567	148.8433	Unnamed	0.39
VO-1517	Healy	63.8567	148.8533	Sanctuary	0.40
VO-1519	Healy	63.8567	148.9200	Lignite Creek	0.33
VO-1521	Healy	63.8570	148.8330	Healy Creek	0.29
VO-1529	Healy	63.8580	148.7380	Suntrana	0.26
VO-1530	Healy	63.8583	148.8533	Suntrama	0.34
VO-1576	Healy	63.8617	148.8533	Unnamed	0.22
VO-1581	Healy	63.9000	148.9000	Suntrana	0.25
VO-1582	Healy	63.9006	148.9139	Suntrama	0.28
VO-1584	Healy	63.9020	148.9330	Suntrana	0.24
VO-1588	Healy	63.9025	148.9317	Suntrama	0.32
VO-1595	Healy	63.9028	148.9150	Suntrama	0.37
VO-1596	Healy	63.9150	148.9000	Suntrana	0.27
VO-1597	Healy	63.9167	148.6956	Sanctuary	0.28
VO-1600	Healy	63.9180	148.8567	Healy Creek	0.32
VO-1602	Healy	63.9217	148.6850	Sanctuary	0.40
VO-1621	Healy	63.9267	148.4700	Healy Creek	0.43
VO-1622	Healy	63.9294	147.4872	Healy Creek	0.41
VO-1627	Healy	63.9350	147.4311	Unnamed	0.50
VO-1630	Healy	63.9375	148.5894	Suntrana	0.34
VO-1631	Healy	63.9430	148.6350	Suntrana	0.26
VO-1632	Healy	63.9431	148.6381	Suntrana	0.30

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-1634	Healy	63.9453	147.4106	Unnamed	0.44
VO-1635	Healy	63.9453	148.6814	Suntrana	0.29
VO-1638	Healy	63.9667	147.9986	Unnamed	0.43
VO-1640	Healy	63.9711	147.9972	Unnamed	0.36
VO-1641	Healy	63.9733	148.7456	Suntrana	0.30
VO-1643	Healy	63.9750	148.7680	Suntrana	0.22
VO-1644	Healy	63.9833	147.9119	Healy Creek	0.42
VO-1647	Healy	63.9867	147.8397	Healy Creek	0.42
VO-1650	Healy	63.9933	147.8425	Suntrana	0.27
VO-1653	Healy	63.9933	147.9272	Suntrana	0.27
VO-1657	Howard Pass	68.5467	156.9608	Fortress Mountain	0.46
VO-1660	Howard Pass	68.5800	157.0814	Fortress Mountain	0.52
VO-1661	Howard Pass	68.6917	156.2356	Fortress Mountain	0.54
VO-1663	Howard Pass	68.7550	158.4439	Fortress Mountain	0.60
VO-1664	Howard Pass	68.7556	158.4439	Fortress Mountain	0.65
VO-1665	Howard Pass	68.7564	158.4439	Fortress Mountain	0.61
VO-1666	Howard Pass	68.7569	158.4369	Fortress Mountain	0.64
VO-1667	Howard Pass	68.7614	158.1589	Fortress Mountain	0.44
VO-1670	Howard Pass	68.9156	156.0253	Fortress Mountain	0.57
VO-1714	Ikpikpuk River	69.0256	155.8794	Killik Tongue	0.58
VO-1715	Ikpikpuk River	69.0294	155.8733	Killik Tongue	0.58
VO-1716	Ikpikpuk River	69.0267	155.8781	Killik Tongue	0.59
VO-1717	Ikpikpuk River	69.0792	156.0217	Unnamed	0.57
VO-1718	Ikpikpuk River	69.0758	156.0044	Tuktu	0.57
VO-1719	Ikpikpuk River	69.1208	153.2917	Seabee	0.55
VO-1721	Ikpikpuk River	69.1208	153.2903	Seabee	0.49
VO-1722	Ikpikpuk River	69.1250	153.2889	Seabee	0.52
VO-1723	Ikpikpuk River	69.1292	153.1819	Seabee	0.52
VO-1724	Ikpikpuk River	69.1292	153.2819	Ninuluk	0.55
VO-1725	Ikpikpuk River	69.1692	155.0064	Nanushuk Gp	0.44
VO-1759	Kantishna River	64.0350	150.1967	Unnamed	0.21
VO-1771	Kenai	60.0570	151.6550	Beluga	0.23
VO-1773	Kenai	60.0780	151.4930	Sterling	0.31
VO-1780	Kenai	60.1130	151.5700	Sterling	0.28
VO-1788	Kenai	60.9750	151.7170	Kenai	0.29
VO-1818	Killik River	68.6189	153.0280	Fortress Mountain	0.63
VO-1819	Killik River	68.6383	155.7569	Fortress Mountain	0.58
VO-1820	Killik River	68.6383	155.7614	Fortress Mountain	0.73
VO-1821	Killik River	68.8675	153.3917	Killik Tongue	0.57
VO-1822	Killik River	68.8656	153.3889	Unnamed	0.71
VO-1823	Killik River	68.8633	153.3828	Unnamed	0.66
VO-1824	Killik River	68.9111	153.3792	Unnamed	0.62
VO-1825	Killik River	68.8533	153.3683	Unnamed	0.60
VO-1826	Killik River	68.8789	155.1058	Tuktu	0.61

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-1827	Killik River	68.9178	155.0756	Unnamed	0.62
VO-1828	Killik River	68.9081	155.0922	Unnamed	0.63
VO-1829	Killik River	68.8994	155.1053	Unnamed	0.57
VO-1830	Killik River	68.8939	155.1056	Unnamed	0.60
VO-1831	Killik River	68.8911	155.1056	Unnamed	0.64
VO-1832	Killik River	68.8831	155.1056	Unnamed	0.61
VO-1833	Killik River	68.8814	155.1056	Unnamed	0.62
VO-1835	Killik River	68.8806	155.1058	Unnamed	0.53
VO-1836	Killik River	68.8794	155.1058	Unnamed	0.60
VO-1837	Killik River	68.9597	153.5472	Niakogon Tongue	0.58
VO-1838	Killik River	68.9706	153.5519	Niakogon Tongue	0.56
VO-1839	Killik River	68.9750	153.9611	Killik Tongue	0.80
VO-1840	Killik River	68.9778	153.9625	Killik Tongue	0.76
VO-1841	Killik River	68.9786	153.9625	Killik Tongue	0.63
VO-1842	Killik River	68.9800	153.9639	Killik Tongue	0.60
VO-1843	Killik River	68.8472	153.9639	Killik Tongue	0.83
VO-1844	Killik River	68.9819	153.9653	Killik Tongue	0.84
VO-1916	Lookout Ridge	69.2239	158.7597	Torok	0.61
VO-1917	Lookout Ridge	69.2428	158.7419	Corwin	0.50
VO-1918	Lookout Ridge	69.2272	158.7553	Corwin	0.57
VO-1919	Lookout Ridge	69.2250	158.7567	Corwin	0.59
VO-1920	Lookout Ridge	69.4575	158.7206	Nanushuk Gp	0.71
VO-1921	Lookout Ridge	69.4900	158.7114	Nanushuk Gp	0.76
VO-1922	Lookout Ridge	69.5336	158.6861	Nanushuk Gp	0.73
VO-1923	Lookout Ridge	69.6078	158.6222	Nanushuk Gp	0.60
VO-1924	Lookout Ridge	69.6189	158.6161	Nanushuk Gp	0.75
VO-1925	Lookout Ridge	69.6256	158.6128	Nanushuk Gp	0.68
VO-1926	Lookout Ridge	69.6369	158.6097	Nanushuk Gp	0.56
VO-1927	Lookout Ridge	69.7039	158.5872	Nanushuk Gp	0.60
VO-1928	Lookout Ridge	69.7297	158.5778	Nanushuk Gp	0.58
VO-1929	Lookout Ridge	69.8622	158.5194	Nanushuk Gp	0.58
VO-2071	Misheguk Mountain	68.8819	161.8667	Corwin	0.68
VO-2072	Misheguk Mountain	68.8822	161.8667	Corwin	0.77
VO-2073	Misheguk Mountain	68.8792	161.8722	Corwin	0.80
VO-2074	Misheguk Mountain	68.8681	161.9042	Corwin	0.83
VO-2075	Misheguk Mountain	68.8667	161.9056	Corwin	0.74
VO-2076	Misheguk Mountain	68.8653	161.9208	Corwin	0.80
VO-2077	Misheguk Mountain	68.8639	161.9278	Corwin	0.82
VO-2078	Misheguk Mountain	68.8583	161.9597	Corwin	0.90
VO-2079	Misheguk Mountain	68.8833	162.0250	Corwin	0.79
VO-2080	Misheguk Mountain	68.8686	162.0250	Corwin	0.80
VO-2081	Misheguk Mountain	68.8672	162.0333	Corwin	0.87
VO-2082	Misheguk Mountain	68.8667	162.0417	Corwin	1.02
VO-2083	Misheguk Mountain	68.9225	159.1455	Fortress Mountain	0.73

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-2085	Misheguk Mountain	68.9278	160.7917	Kukpowruk	0.53
VO-2086	Misheguk Mountain	68.9289	160.7944	Kukpowruk	0.52
VO-2087	Misheguk Mountain	68.9333	160.8000	Kukpowruk	0.51
VO-2088	Misheguk Mountain	68.9472	160.8069	Kukpowruk	0.63
VO-2089	Misheguk Mountain	68.9500	160.8111	Kukpowruk	0.59
VO-2090	Misheguk Mountain	68.9533	160.8125	Kukpowruk	0.66
VO-2091	Misheguk Mountain	68.9819	160.8569	Torok	0.60
VO-2092	Mount Hayes	63.3733	148.3800	Healy Creek	0.33
VO-2093	Mount Hayes	63.6028	145.7383	Unnamed	0.43
VO-2094	Mount Hayes	63.6039	145.7472	Unnamed	0.42
VO-2095	Mount Hayes	63.6131	145.7306	Unnamed	0.41
VO-2097	Mount Hayes	63.6181	145.7611	Unnamed	0.40
VO-2099	Mount Hayes	63.6183	145.7103	Unnamed	0.42
VO-2100	Mount Hayes	63.6211	145.7436	Unnamed	0.39
VO-2102	Mount Hayes	63.6222	145.7083	Unnamed	0.37
VO-2103	Mount Hayes	63.6231	145.7533	Unnamed	0.38
VO-2105	Mount Hayes	63.6250	145.7658	Unnamed	0.37
VO-2106	Mount Hayes	63.6253	145.7142	Unnamed	0.41
VO-2108	Mount Hayes	63.6253	145.7603	Unnamed	0.38
VO-2113	Mount Hayes	63.6258	145.7725	Unnamed	0.39
VO-2118	Mount Hayes	63.6269	145.7808	Unnamed	0.37
VO-2120	Mount Hayes	63.6281	145.7075	Unnamed	0.40
VO-2122	Mount Hayes	63.6283	145.6814	Unnamed	0.39
VO-2124	Mount Hayes	63.6303	145.7294	Unnamed	0.35
VO-2127	Mount Hayes	63.6311	145.7842	Unnamed	0.40
VO-2129	Mount Hayes	63.6317	145.7158	Unnamed	0.44
VO-2130	Mount Hayes	63.6325	145.8033	Unnamed	0.42
VO-2133	Mount Hayes	63.6328	145.6808	Unnamed	0.42
VO-2134	Mount Hayes	63.6344	145.7281	Unnamed	0.36
VO-2137	Mount Hayes	63.6389	145.7153	Unnamed	0.36
VO-2138	Mount Hayes	63.6439	145.7108	Unnamed	0.35
VO-2140	Mount Hayes	63.6447	145.7153	Unnamed	0.35
VO-2144	Mount Hayes	63.6469	145.7142	Unnamed	0.36
VO-2146	Mount Hayes	63.6558	145.7828	Unnamed	0.37
VO-2152	Mount Hayes	63.6570	145.7800	Healy Creek	0.30
VO-2153	Mount Hayes	63.6586	145.7133	Unnamed	0.35
VO-2156	Mount Hayes	63.6600	145.7172	Unnamed	0.34
VO-2157	Mount Hayes	63.6842	145.7417	Unnamed	0.39
VO-2158	Mount Hayes	63.6842	145.7475	Unnamed	0.34
VO-2159	Mount Hayes	63.6944	145.7469	Unnamed	0.38
VO-2160	Mount Hayes	63.7008	145.7314	Unnamed	0.38
VO-2285	Mount Michelson	69.6530	146.8569	Sagavanirktok	0.74
VO-2334	Mount Michelson	69.7133	145.5864	Sagavanirktok	0.75
VO-2341	Mount Michelson	69.7500	145.3375	Sagavanirktok	0.50

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces.—Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-2342	Mount Michelson	69.7875	145.3125	Sagavanirktok	0.32
VO-2343	Mount Michelson	69.7944	145.3194	Sagavanirktok	0.77
VO-2344	Mount Michelson	69.8333	145.3500	Sagavanirktok	0.90
VO-2345	Mount Michelson	69.8611	145.2750	Sagavanirktok	1.91
VO-2347	Mount Michelson	69.9083	144.6500	Sagavanirktok	0.25
VO-2630	Philip Smith Mountains	68.4764	149.2725	Torok	1.70
VO-2631	Philip Smith Mountains	68.4775	149.2767	Torok	1.09
VO-2635	Philip Smith Mountains	68.4800	149.4100	Fortress Mountain	1.86
VO-2638	Philip Smith Mountains	68.4817	149.2822	Torok	1.01
VO-2640	Philip Smith Mountains	68.4831	149.2842	Torok	0.87
VO-2643	Philip Smith Mountains	68.4836	149.2853	Torok	0.91
VO-2645	Philip Smith Mountains	68.4858	149.2272	Fortress Mountain	1.27
VO-2646	Philip Smith Mountains	68.4872	149.4189	Fortress Mountain	0.63
VO-2647	Philip Smith Mountains	68.4903	149.4086	Fortress Mountain	0.67
VO-2648	Philip Smith Mountains	68.4925	149.3856	Fortress Mountain	0.50
VO-2649	Philip Smith Mountains	68.4933	149.4342	Fortress Mountain	0.71
VO-2652	Philip Smith Mountains	68.5203	149.4550	Fortress Mountain	0.58
VO-2654	Philip Smith Mountains	68.5325	149.2819	Fortress Mountain	0.86
VO-2661	Philip Smith Mountains	68.5864	148.9056	Torok	2.13
VO-2667	Philip Smith Mountains	68.6378	148.7928	Torok	2.96
VO-2670	Philip Smith Mountains	68.6408	148.7911	Torok	2.89
VO-2671	Philip Smith Mountains	68.6417	149.0833	Fortress Mountain	1.02
VO-2676	Philip Smith Mountains	68.6458	148.7872	Torok	2.91
VO-2677	Philip Smith Mountains	68.6475	148.7911	Torok	2.91
VO-2681	Philip Smith Mountains	68.6628	148.8933	Torok	2.65
VO-2687	Philip Smith Mountains	68.7267	149.0269	Chandler	0.70
VO-2688	Philip Smith Mountains	68.7278	149.0297	Chandler	0.72
VO-2689	Philip Smith Mountains	68.7278	149.0219	Chandler	0.74
VO-2690	Philip Smith Mountains	68.7375	149.0083	Torok	0.66
VO-2691	Philip Smith Mountains	68.7428	149.0639	Unnamed	0.47
VO-2692	Philip Smith Mountains	68.7417	149.0489	Unnamed	0.55
VO-2693	Philip Smith Mountains	68.7344	149.0256	Unnamed	0.52
VO-2694	Philip Smith Mountains	68.7339	149.0217	Unnamed	0.66
VO-2695	Philip Smith Mountains	68.7328	149.0206	Unnamed	0.71
VO-2696	Philip Smith Mountains	68.7275	149.0211	Unnamed	0.74
VO-2721	Point Hope	68.8719	165.1300	Corwin	0.58
VO-2722	Point Hope	68.8656	165.2306	Corwin	0.54
VO-2723	Point Hope	68.8644	165.2439	Corwin	0.57
VO-2724	Point Hope	68.8594	165.3281	Corwin	0.50
VO-2725	Point Hope	68.8769	165.0744	Corwin	0.60
VO-2726	Point Hope	68.8783	165.0508	Corwin	0.56
VO-2727	Point Hope	68.8794	165.0358	Corwin	0.60
VO-2728	Point Hope	68.8800	165.0278	Corwin	0.66
VO-2729	Point Hope	68.8808	165.0175	Corwin	0.62

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-2730	Point Hope	68.8817	165.0033	Corwin	0.64
VO-2731	Point Hope	68.8819	164.9956	Corwin	0.67
VO-2732	Point Hope	68.8822	164.9889	Corwin	0.67
VO-2733	Point Hope	68.8839	164.8425	Corwin	0.67
VO-2734	Point Hope	68.8761	165.0942	Corwin	0.72
VO-2735	Point Hope	68.8756	165.1025	Corwin	0.58
VO-2736	Point Hope	68.8853	164.9578	Corwin	0.74
VO-2737	Point Hope	68.8872	164.9397	Corwin	0.71
VO-2738	Point Hope	68.8667	165.1681	Nanushuk Gp	0.57
VO-2739	Point Hope	68.8678	165.1369	Nanushuk Gp	0.64
VO-2740	Point Hope	68.8678	165.1619	Nanushuk Gp	0.55
VO-2741	Point Hope	68.8711	165.1275	Nanushuk Gp	0.61
VO-2742	Point Hope	68.8739	165.0686	Nanushuk Gp	0.70
VO-2743	Point Hope	68.8744	165.1153	Nanushuk Gp	0.69
VO-2744	Point Hope	68.8889	164.9222	Kukpowruk	0.68
VO-2745	Point Lay	69.0033	163.7531	Corwin	0.74
VO-2747	Point Lay	69.0050	163.8397	Corwin	0.74
VO-2748	Point Lay	69.0050	163.8436	Corwin	0.73
VO-2750	Point Lay	69.0083	163.7944	Corwin	0.74
VO-2751	Point Lay	69.0086	163.7833	Corwin	0.74
VO-2753	Point Lay	69.0119	163.8414	Corwin	0.70
VO-2762	Point Lay	69.0181	163.8383	Nanushuk Gp	0.65
VO-2763	Point Lay	69.0192	163.8792	Nanushuk Gp	0.73
VO-2764	Point Lay	69.0211	163.8414	Corwin	0.72
VO-2767	Point Lay	69.0217	163.8397	Corwin	0.74
VO-2769	Point Lay	69.0236	163.8792	Nanushuk Gp	0.74
VO-2770	Point Lay	69.0242	162.9167	Torok	0.86
VO-2771	Point Lay	69.0797	162.5567	Nanushuk Gp	0.80
VO-2774	Point Lay	69.0831	162.5503	Nanushuk Gp	0.75
VO-2775	Point Lay	69.0831	162.5692	Nanushuk Gp	0.79
VO-2777	Point Lay	69.1056	163.3931	Nanushuk Gp	0.70
VO-2782	Point Lay	69.1067	162.5597	Nanushuk Gp	0.79
VO-2783	Point Lay	69.1072	162.7700	Kukpowruk	0.87
VO-2784	Point Lay	69.1036	162.7689	Kukpowruk	0.87
VO-2785	Point Lay	69.1167	162.5725	Nanushuk Gp	0.74
VO-2786	Point Lay	69.1233	162.5819	Nanushuk Gp	0.70
VO-2787	Point Lay	69.1256	162.6258	Nanushuk Gp	0.69
VO-2788	Point Lay	69.1303	163.3836	Nanushuk Gp	0.71
VO-2789	Point Lay	69.1336	162.6356	Nanushuk Gp	0.70
VO-2790	Point Lay	69.1381	163.3833	Nanushuk Gp	0.64
VO-2791	Point Lay	69.1481	163.1231	Nanushuk Gp	0.68
VO-2793	Point Lay	69.1581	163.1544	Nanushuk Gp	0.62
VO-2794	Point Lay	69.1619	163.1831	Nanushuk Gp	0.67
VO-2797	Point Lay	69.1672	163.1642	Nanushuk Gp	0.72

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-2798	Point Lay	69.1683	163.1989	Nanushuk Gp	0.71
VO-2799	Point Lay	69.1706	163.2272	Nanushuk Gp	0.68
VO-2800	Point Lay	69.1750	163.2842	Nanushuk Gp	0.73
VO-2801	Point Lay	69.1761	163.1294	Nanushuk Gp	0.73
VO-2804	Point Lay	69.1761	163.1956	Nanushuk Gp	0.61
VO-2805	Point Lay	69.2397	162.6661	Corwin	0.80
VO-2806	Point Lay	69.2419	162.6700	Unnamed	0.78
VO-2807	Point Lay	69.2428	162.6739	Unnamed	0.81
VO-2808	Point Lay	69.2456	162.6800	Unnamed	0.86
VO-2809	Point Lay	69.2464	162.6811	Unnamed	0.89
VO-2810	Point Lay	69.2478	162.6861	Unnamed	0.94
VO-2811	Point Lay	69.2486	162.6861	Kukpowruk	0.92
VO-2812	Point Lay	69.2517	162.7086	Torok	0.67
VO-2813	Point Lay	69.2611	162.7836	Unnamed	0.76
VO-2814	Point Lay	69.2594	162.7761	Unnamed	0.73
VO-2815	Point Lay	69.2594	162.7733	Unnamed	0.69
VO-2816	Point Lay	69.2581	162.7647	Unnamed	0.84
VO-2817	Point Lay	69.2533	162.7564	Unnamed	0.76
VO-2818	Point Lay	69.2517	162.7522	Unnamed	0.72
VO-2819	Point Lay	69.2578	162.7278	Unnamed	0.75
VO-2820	Point Lay	69.2525	162.7128	Unnamed	0.68
VO-2821	Point Lay	69.2519	162.7097	Unnamed	0.67
VO-2822	Point Lay	69.3611	162.0889	Nanushuk Gp	0.71
VO-2823	Point Lay	69.3914	162.6514	Corwin	0.63
VO-2824	Point Lay	69.3956	162.6589	Corwin	0.64
VO-2825	Point Lay	69.3933	162.6558	Corwin	0.64
VO-2826	Point Lay	69.3922	162.6542	Corwin	0.63
VO-2827	Point Lay	69.4128	162.6828	Kukpowruk	0.79
VO-2828	Point Lay	69.4183	162.6939	Unnamed	0.70
VO-2829	Point Lay	69.4169	162.6928	Unnamed	0.72
VO-2830	Point Lay	69.4161	162.6919	Unnamed	0.72
VO-2831	Point Lay	69.4150	162.6903	Unnamed	0.75
VO-2832	Point Lay	69.4144	162.6889	Unnamed	0.70
VO-2833	Point Lay	69.4136	162.6867	Unnamed	0.63
VO-2834	Point Lay	69.4133	162.6844	Unnamed	0.77
VO-2835	Point Lay	69.5156	162.7692	Corwin	0.53
VO-3011	Sagavanirktok	69.0125	148.8094	Nanushuk Gp	0.86
VO-3012	Sagavanirktok	69.0217	148.8364	Nanushuk Gp	0.60
VO-3013	Sagavanirktok	69.0389	148.1131	Nanushuk Gp.	1.34
VO-3015	Sagavanirktok	69.0925	148.7683	Unnamed	0.64
VO-3016	Sagavanirktok	69.0928	148.7703	Unnamed	0.74
VO-3017	Sagavanirktok	69.0936	148.7739	Unnamed	0.70
VO-3018	Sagavanirktok	69.0928	148.7719	Nanushuk Gp	0.68
VO-3019	Sagavanirktok	69.0942	148.7792	Nanushuk Gp	0.84

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-3020	Sagavanirktok	69.0983	148.0058	Nanushuk Gp	1.87
VO-3023	Sagavanirktok	69.1617	147.7833	Unnamed	0.76
VO-3028	Sagavanirktok	69.1850	148.5386	Unnamed	0.41
VO-3032	Sagavanirktok	69.3119	147.6728	Unnamed	1.35
VO-3035	Sagavanirktok	69.3161	147.7036	Torok	1.69
VO-3036	Sagavanirktok	69.3217	148.6719	Unnamed	0.34
VO-3038	Sagavanirktok	69.3430	147.2039	Unnamed	1.50
VO-3040	Sagavanirktok	69.3642	147.1233	Unnamed	1.16
VO-3041	Sagavanirktok	69.3647	147.1233	Unnamed	0.95
VO-3042	Sagavanirktok	69.3653	147.1233	Unnamed	0.95
VO-3043	Sagavanirktok	69.3828	148.7147	Sagavanirktok	0.37
VO-3046	Sagavanirktok	69.3906	147.1430	Unnamed	1.15
VO-3047	Sagavanirktok	69.3925	147.1453	Unnamed	1.24
VO-3048	Sagavanirktok	69.4033	148.6758	Sagavanirktok	0.39
VO-3058	Sagavanirktok	69.4336	148.5233	Sagavanirktok	0.46
VO-3060	Sagavanirktok	69.5583	147.0833	Unnamed	0.34
VO-3062	Sagavanirktok	69.5592	146.5250	Unnamed	0.62
VO-3064	Sagavanirktok	69.5833	147.7933	Sagavanirktok	0.32
VO-3075	Sagavanirktok	69.9667	148.8017	Unnamed	0.60
VO-3086	Seldovia	59.3700	151.3650	Unnamed	1.97
VO-3089	Seldovia	59.3980	151.8980	Kenai	0.44
VO-3092	Seldovia	59.4750	151.6700	Kenai	0.32
VO-3094	Seldovia	59.6430	151.5820	Beluga	0.22
VO-3095	Seldovia	59.7080	151.4580	Sterling	0.27
VO-3100	Seldovia	59.7150	151.8080	Kenai	0.38
VO-3101	Seldovia	59.7180	151.2420	Beluga	0.28
VO-3106	Seldovia	59.7320	151.2170	Kenai	0.31
VO-3117	Seldovia	59.8770	152.9820	Unnamed	0.46
VO-3118	Seldovia	59.9300	151.7450	Beluga	0.24
VO-3202	Talkeetna	62.0558	151.9050	Kenai Gp	0.37
VO-3219	Talkeetna Mountains	62.0530	149.7350	Kenai	0.25
VO-3289	Tyonek	61.0317	151.3075	Kenai Gp	0.45
VO-3290	Tyonek	61.1203	151.3156	Kenai Gp	0.36
VO-3292	Tyonek	61.1544	151.4872	Kenai Gp	0.42
VO-3293	Tyonek	61.1564	151.5086	Kenai Gp	0.38
VO-3294	Tyonek	61.1610	151.5190	Kenai	0.33
VO-3295	Tyonek	61.1844	151.6272	Kenai Gp	0.37
VO-3296	Tyonek	61.1880	152.8430	Unnamed	0.18
VO-3297	Tyonek	61.1883	151.5922	Kenai Gp	0.39
VO-3298	Tyonek	61.2030	151.5200	Beluga	0.18
VO-3299	Tyonek	61.2128	151.1842	Kenai Gp	0.34
VO-3304	Tyonek	61.2806	151.7708	Kenai Gp	0.38
VO-3311	Tyonek	61.2880	151.7370	Tyonek	0.24
VO-3312	Tyonek	61.2992	151.7175	Kenai Gp	0.36

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-3313	Tyonek	61.3019	151.7583	Kenai Gp	0.41
VO-3314	Tyonek	61.4044	151.3806	Kenai Gp	0.38
VO-3316	Tyonek	61.4200	151.5230	Kenai	0.33
VO-3317	Tyonek	61.4270	151.5830	Kenai	0.33
VO-3318	Tyonek	61.4361	151.5106	Kenai Gp	0.36
VO-3320	Tyonek	61.5542	150.8344	Kenai Gp	0.41
VO-3324	Tyonek	61.5867	150.8281	Kenai Gp	0.37
VO-3326	Tyonek	61.5920	150.8200	Kenai	0.38
VO-3327	Tyonek	61.6783	151.5700	Kenai Gp	0.38
VO-3328	Tyonek	61.6797	151.5767	Kenai Gp	0.38
VO-3329	Tyonek	61.6814	151.5842	Kenai Gp	0.34
VO-3333	Tyonek	61.6933	151.5867	Kenai Gp	0.38
VO-3334	Tyonek	61.7183	151.4525	Kenai Gp	0.44
VO-3335	Tyonek	61.7558	151.7025	Kenai Gp	0.33
VO-3346	Tyonek	61.7575	151.7039	Kenai Gp	0.34
VO-3352	Tyonek	61.7656	151.6869	Kenai Gp	0.39
VO-3353	Tyonek	61.7783	151.7572	Kenai Gp	0.34
VO-3354	Tyonek	61.7930	150.7300	Kenai	0.22
VO-3355	Tyonek	61.8014	151.6933	Kenai Gp	0.34
VO-3356	Tyonek	61.8028	151.7100	Kenai Gp	0.31
VO-3357	Tyonek	61.9783	151.9575	Kenai Gp	0.35
VO-3375	Umiat	69.0356	150.8853	Shale Wall Mbr	0.46
VO-3376	Umiat	69.0703	150.8458	Ayiyak Mbr	0.47
VO-3377	Umiat	69.0625	150.8586	Unnamed	0.45
VO-3378	Umiat	69.0578	150.8675	Unnamed	0.56
VO-3379	Umiat	69.0544	150.8725	Unnamed	0.55
VO-3380	Umiat	69.0503	150.8792	Unnamed	0.49
VO-3381	Umiat	69.0431	150.8886	Unnamed	0.45
VO-3382	Umiat	69.0400	150.8875	Unnamed	0.45
VO-3383	Umiat	69.1564	151.0178	Schrader Bluff	0.45
VO-3386	Umiat	69.1575	151.0178	Schrader Bluff	0.50
VO-3387	Umiat	69.1597	151.0181	Schrader Bluff	0.52
VO-3388	Umiat	69.1614	151.0197	Schrader Bluff	0.51
VO-3389	Umiat	69.2994	152.7381	Colville Gp	0.68
VO-3390	Umiat	69.3792	152.5250	Shale Wall Mbr	0.51
VO-3391	Umiat	69.4081	151.8414	Schrader Bluff	0.31
VO-3392	Umiat	69.4258	151.6181	Schrader Bluff	0.37
VO-3393	Umiat	69.4306	151.7267	Schrader Bluff	0.45
VO-3394	Umiat	69.5000	151.4903	Prince Creek	0.37
VO-3395	Umiat	69.5044	151.4808	Prince Creek	0.39
VO-3396	Umiat	69.6325	151.4550	Prince Creek	0.37
VO-3397	Umiat	69.9944	151.6083	Prince Creek	0.40
VO-3427	Utukok River	69.0717	161.4622	Nanushuk Gp	0.78
VO-3429	Utukok River	69.0750	161.2989	Nanushuk Gp	0.85

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-3430	Utukok River	69.0839	161.2925	Nanushuk Gp	0.77
VO-3431	Utukok River	69.0975	161.4244	Nanushuk Gp	0.89
VO-3432	Utukok River	69.0997	161.3397	Nanushuk Gp	0.71
VO-3433	Utukok River	69.0997	161.3806	Nanushuk Gp	0.80
VO-3434	Utukok River	69.1008	161.5031	Nanushuk Gp	0.72
VO-3435	Utukok River	69.1019	161.5756	Nanushuk Gp	0.72
VO-3436	Utukok River	69.1067	161.4217	Corwin	0.68
VO-3437	Utukok River	69.1167	161.4267	Corwin	0.64
VO-3438	Utukok River	69.1381	161.4231	Corwin	0.67
VO-3439	Utukok River	69.1431	161.4242	Corwin	0.70
VO-3440	Utukok River	69.1494	161.4167	Corwin	0.77
VO-3441	Utukok River	69.1550	161.4164	Corwin	0.80
VO-3442	Utukok River	69.1594	161.4161	Corwin	0.72
VO-3443	Utukok River	69.1617	161.4158	Corwin	0.68
VO-3444	Utukok River	69.1625	161.5847	Corwin	0.77
VO-3445	Utukok River	69.1064	161.5756	Nanushuk Gp	0.72
VO-3446	Utukok River	69.1097	161.4025	Nanushuk Gp	0.78
VO-3447	Utukok River	69.1131	161.4214	Nanushuk Gp	0.85
VO-3450	Utukok River	69.1142	161.5472	Nanushuk Gp	0.74
VO-3451	Utukok River	69.1153	161.4686	Nanushuk Gp	0.86
VO-3452	Utukok River	69.1153	161.5064	Nanushuk Gp	0.78
VO-3453	Utukok River	69.1233	161.3708	Nanushuk Gp	0.86
VO-3454	Utukok River	69.1250	159.6083	Corwin	0.62
VO-3455	Utukok River	69.1319	159.6653	Unnamed	0.64
VO-3456	Utukok River	69.1389	159.6778	Unnamed	0.62
VO-3457	Utukok River	69.1411	159.6806	Unnamed	0.53
VO-3458	Utukok River	69.1431	159.6889	Unnamed	0.62
VO-3459	Utukok River	69.1267	161.4181	Nanushuk Gp	0.83
VO-3460	Utukok River	69.1619	160.5517	Unnamed	0.63
VO-3461	Utukok River	69.1683	160.6439	Unnamed	0.82
VO-3462	Utukok River	69.1753	160.6444	Unnamed	0.83
VO-3463	Utukok River	69.1403	161.8842	Corwin	0.64
VO-3464	Utukok River	69.1431	161.8850	Unnamed	0.63
VO-3465	Utukok River	69.1528	161.8808	Unnamed	0.70
VO-3466	Utukok River	69.1592	161.8828	Unnamed	0.87
VO-3467	Utukok River	69.1611	161.8833	Unnamed	0.89
VO-3468	Utukok River	69.1697	161.8844	Unnamed	0.96
VO-3469	Utukok River	69.1444	159.6917	Torok	0.57
VO-3470	Utukok River	69.1489	160.7333	Nanushuk Gp	0.84
VO-3471	Utukok River	69.1650	161.5847	Torok	0.82
VO-3472	Utukok River	69.1731	161.8850	Torok	0.94
VO-3473	Utukok River	69.1747	160.7272	Nanushuk Gp	0.96
VO-3474	Utukok River	69.1786	160.6411	Torok	0.88
VO-3475	Utukok River	69.2472	159.4972	Corwin	0.80

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-3476	Utukok River	69.2500	159.4964	Unnamed	0.70
VO-3477	Utukok River	69.2542	159.4958	Unnamed	0.72
VO-3478	Utukok River	69.2611	159.5472	Unnamed	0.73
VO-3479	Utukok River	69.2625	159.5444	Unnamed	0.65
VO-3480	Utukok River	69.2664	159.5389	Unnamed	0.70
VO-3481	Utukok River	69.2722	159.5325	Unnamed	0.69
VO-3482	Utukok River	69.2897	159.5222	Unnamed	0.51
VO-3483	Utukok River	69.2622	160.5919	Nanushuk Gp	0.76
VO-3484	Utukok River	69.2656	160.5856	Nanushuk Gp	0.76
VO-3485	Utukok River	69.2811	160.5761	Nanushuk Gp	0.74
VO-3486	Utukok River	69.2881	159.0128	Nanushuk Gp	0.70
VO-3487	Utukok River	69.2881	161.1744	Nanushuk Gp	0.77
VO-3488	Utukok River	69.2950	161.1078	Nanushuk Gp	0.75
VO-3489	Utukok River	69.2972	159.5111	Torok	0.72
VO-3490	Utukok River	69.2972	161.1808	Nanushuk Gp	0.80
VO-3491	Utukok River	69.3039	159.1428	Nanushuk Gp	0.72
VO-3492	Utukok River	69.3058	160.4842	Nanushuk Gp	0.69
VO-3493	Utukok River	69.3092	160.4808	Nanushuk Gp	0.68
VO-3494	Utukok River	69.3161	160.2428	Nanushuk Gp	0.60
VO-3495	Utukok River	69.3172	161.1525	Nanushuk Gp	0.77
VO-3496	Utukok River	69.3250	161.9544	Nanushuk Gp	0.76
VO-3497	Utukok River	69.3353	159.3600	Nanushuk Gp	0.79
VO-3498	Utukok River	69.3361	160.4683	Nanushuk Gp	0.72
VO-3499	Utukok River	69.3361	160.5000	Nanushuk Gp	0.68
VO-3502	Utukok River	69.3372	160.4269	Nanushuk Gp	0.80
VO-3503	Utukok River	69.3394	160.5636	Nanushuk Gp	0.65
VO-3504	Utukok River	69.3453	160.4586	Nanushuk Gp	0.70
VO-3505	Utukok River	69.3453	160.5572	Nanushuk Gp	0.74
VO-3506	Utukok River	69.3486	160.5508	Nanushuk Gp	0.72
VO-3507	Utukok River	69.3508	160.5508	Nanushuk Gp	0.69
VO-3508	Utukok River	69.3519	160.5892	Nanushuk Gp	0.72
VO-3514	Utukok River	69.3542	160.5444	Nanushuk Gp	0.69
VO-3515	Utukok River	69.3542	160.6369	Nanushuk Gp	0.74
VO-3520	Utukok River	69.3542	160.6622	Nanushuk Gp	0.74
VO-3521	Utukok River	69.3564	160.3092	Nanushuk Gp	0.76
VO-3522	Utukok River	69.3575	160.7036	Nanushuk Gp	0.75
VO-3523	Utukok River	69.3586	160.5414	Nanushuk Gp	0.68
VO-3524	Utukok River	69.3589	161.4236	Nanushuk Gp	0.72
VO-3525	Utukok River	69.3608	160.4172	Nanushuk Gp	0.78
VO-3526	Utukok River	69.3608	160.5350	Nanushuk Gp	0.66
VO-3527	Utukok River	69.3611	161.2006	Nanushuk Gp	0.69
VO-3528	Utukok River	69.3611	161.2581	Nanushuk Gp	0.63
VO-3529	Utukok River	69.3611	161.4681	Nanushuk Gp	0.96
VO-3530	Utukok River	69.3611	161.5128	Nanushuk Gp	0.70

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces.
— Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-3531	Utukok River	69.3611	161.5256	Nanushuk Gp	0.75
VO-3532	Utukok River	69.3611	161.5444	Nanushuk Gp	0.75
VO-3533	Utukok River	69.3611	161.5508	Nanushuk Gp	0.79
VO-3534	Utukok River	69.3622	161.4300	Nanushuk Gp	0.72
VO-3535	Utukok River	69.3622	161.4744	Nanushuk Gp	0.75
VO-3536	Utukok River	69.3633	161.3344	Nanushuk Gp	0.76
VO-3537	Utukok River	69.3633	161.3631	Nanushuk Gp	0.71
VO-3538	Utukok River	69.3633	161.4394	Nanushuk Gp	0.75
VO-3539	Utukok River	69.3633	161.4556	Nanushuk Gp	0.70
VO-3540	Utukok River	69.3642	160.3567	Nanushuk Gp	0.73
VO-3541	Utukok River	69.3642	160.7706	Nanushuk Gp	0.72
VO-3542	Utukok River	69.3644	161.0256	Nanushuk Gp	0.86
VO-3543	Utukok River	69.3644	161.2900	Nanushuk Gp	0.77
VO-3544	Utukok River	69.3644	161.2994	Nanushuk Gp	0.73
VO-3545	Utukok River	69.3644	161.3853	Nanushuk Gp	0.82
VO-3546	Utukok River	69.3644	161.3981	Nanushuk Gp	0.77
VO-3547	Utukok River	69.3653	160.5286	Nanushuk Gp	0.76
VO-3548	Utukok River	69.3656	161.0733	Nanushuk Gp	0.77
VO-3549	Utukok River	69.3656	161.2453	Nanushuk Gp	0.81
VO-3550	Utukok River	69.3656	161.2708	Nanushuk Gp	0.75
VO-3551	Utukok River	69.3697	160.5094	Nanushuk Gp	0.72
VO-3552	Utukok River	69.3697	160.5158	Nanushuk Gp	0.66
VO-3553	Utukok River	69.3700	161.2039	Nanushuk Gp	0.78
VO-3554	Utukok River	69.3733	160.5128	Nanushuk Gp	0.80
VO-3555	Utukok River	69.3733	161.0256	Nanushuk Gp	0.58
VO-3556	Utukok River	69.3733	161.2039	Nanushuk Gp	0.78
VO-3557	Utukok River	69.3744	161.2611	Nanushuk Gp	0.59
VO-3558	Utukok River	69.3756	161.3886	Nanushuk Gp	0.73
VO-3559	Utukok River	69.3767	159.8344	Nanushuk Gp	0.71
VO-3560	Utukok River	69.3767	160.5064	Nanushuk Gp	0.74
VO-3561	Utukok River	69.3811	160.7611	Nanushuk Gp	0.76
VO-3562	Utukok River	69.3814	161.2486	Nanushuk Gp	0.78
VO-3563	Utukok River	69.3844	159.7897	Nanushuk Gp	0.79
VO-3564	Utukok River	69.3878	160.4906	Nanushuk Gp	0.68
VO-3565	Utukok River	69.3892	161.0700	Nanushuk Gp	0.57
VO-3566	Utukok River	69.3892	161.1147	Nanushuk Gp	0.72
VO-3567	Utukok River	69.3892	161.2072	Nanushuk Gp	0.81
VO-3568	Utukok River	69.3892	161.2578	Nanushuk Gp	0.69
VO-3569	Utukok River	69.3989	160.5192	Nanushuk Gp	0.63
VO-3570	Utukok River	69.4036	161.0447	Nanushuk Gp	0.69
VO-3571	Utukok River	69.4047	160.4969	Nanushuk Gp	0.65
VO-3572	Utukok River	69.4047	160.6083	Nanushuk Gp	0.79
VO-3573	Utukok River	69.4058	161.2894	Nanushuk Gp	0.74
VO-3574	Utukok River	69.4069	160.4553	Nanushuk Gp	0.68

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-3575	Utukok River	69.4081	160.3853	Nanushuk Gp	0.72
VO-3576	Utukok River	69.4081	160.4425	Nanushuk Gp	0.71
VO-3577	Utukok River	69.4081	160.7297	Nanushuk Gp	0.70
VO-3578	Utukok River	69.4114	160.4489	Nanushuk Gp	0.68
VO-3579	Utukok River	69.4136	160.4969	Nanushuk Gp	0.72
VO-3580	Utukok River	69.4158	160.4489	Nanushuk Gp	0.74
VO-3581	Utukok River	69.4169	160.7361	Nanushuk Gp	0.74
VO-3582	Utukok River	69.4183	161.2042	Nanushuk Gp	0.73
VO-3583	Utukok River	69.4206	161.1244	Nanushuk Gp	0.74
VO-3584	Utukok River	69.4214	160.7331	Nanushuk Gp	0.73
VO-3585	Utukok River	69.4258	160.7331	Nanushuk Gp	0.77
VO-3586	Utukok River	69.4269	159.5861	Nanushuk Gp	0.78
VO-3587	Utukok River	69.4283	159.7414	Nanushuk Gp	0.84
VO-3588	Utukok River	69.4283	160.2189	Nanushuk Gp	0.71
VO-3589	Utukok River	69.4283	161.8319	Nanushuk Gp	0.80
VO-3590	Utukok River	69.4339	160.2189	Nanushuk Gp	0.85
VO-3591	Utukok River	69.4406	161.9089	Nanushuk Gp	0.72
VO-3592	Utukok River	69.4450	160.5511	Nanushuk Gp	0.63
VO-3593	Utukok River	69.4461	160.5192	Nanushuk Gp	0.75
VO-3595	Utukok River	69.4528	160.3242	Nanushuk Gp	0.84
VO-3596	Utukok River	69.4550	160.3211	Nanushuk Gp	0.79
VO-3597	Utukok River	69.4575	160.3178	Nanushuk Gp	0.71
VO-3598	Utukok River	69.4619	160.3592	Nanushuk Gp	0.72
VO-3599	Utukok River	69.4619	160.7206	Nanushuk Gp	0.80
VO-3600	Utukok River	69.4653	160.7175	Nanushuk Gp	0.79
VO-3601	Utukok River	69.4664	160.6950	Nanushuk Gp	0.74
VO-3602	Utukok River	69.4675	160.3528	Nanushuk Gp	0.69
VO-3603	Utukok River	69.4697	160.7175	Nanushuk Gp	0.78
VO-3604	Utukok River	69.4753	160.3272	Nanushuk Gp	0.82
VO-3605	Utukok River	69.4753	160.3400	Nanushuk Gp	0.76
VO-3606	Utukok River	69.4867	161.8394	Nanushuk Gp	0.72
VO-3607	Utukok River	69.4933	161.8394	Nanushuk Gp	0.68
VO-3608	Utukok River	69.5000	160.0225	Nanushuk Gp	0.75
VO-3609	Utukok River	69.5158	161.2308	Nanushuk Gp	0.80
VO-3610	Utukok River	69.5192	160.6956	Nanushuk Gp	0.74
VO-3611	Utukok River	69.5225	159.1347	Nanushuk Gp	0.74
VO-3612	Utukok River	69.5247	160.6956	Nanushuk Gp	0.79
VO-3613	Utukok River	69.5325	159.5867	Nanushuk Gp	0.76
VO-3614	Utukok River	69.5336	161.2336	Nanushuk Gp	0.76
VO-3615	Utukok River	69.5347	159.1283	Nanushuk Gp	0.81
VO-3616	Utukok River	69.5381	160.2689	Nanushuk Gp	0.74
VO-3617	Utukok River	69.5483	160.3169	Nanushuk Gp	0.76
VO-3618	Utukok River	69.5539	160.3425	Nanushuk Gp	0.78
VO-3619	Utukok River	69.5539	160.6797	Nanushuk Gp	0.84

Table 8a. Vitrinite reflectance values of coals across the surface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces.
— Continued

Record number	Quadrangle scale of 1:250,000	North latitude	West longitude	Formation	Mean R_o (%)
VO-3620	Utukok River	69.5561	160.3619	Nanushuk Gp	0.73
VO-3621	Utukok River	69.5594	160.6800	Nanushuk Gp	0.85
VO-3622	Utukok River	69.5628	161.8406	Nanushuk Gp	0.73
VO-3623	Utukok River	69.5639	160.4261	Nanushuk Gp	0.71
VO-3624	Utukok River	69.5706	160.6736	Nanushuk Gp	0.67
VO-3625	Utukok River	69.5797	160.1897	Nanushuk Gp	0.89
VO-3626	Utukok River	69.5842	160.2878	Nanushuk Gp	0.70
VO-3627	Utukok River	69.5897	161.2425	Nanushuk Gp	0.79
VO-3628	Utukok River	69.5919	160.6736	Nanushuk Gp	0.70
VO-3629	Utukok River	69.5986	160.6706	Nanushuk Gp	0.69
VO-3630	Utukok River	69.6033	160.6675	Nanushuk Gp	0.73
VO-3631	Utukok River	69.6067	161.2456	Nanushuk Gp	0.79
VO-3632	Utukok River	69.6200	161.2456	Nanushuk Gp	0.83
VO-3633	Utukok River	69.6414	161.0161	Nanushuk Gp	0.69
VO-3634	Utukok River	69.6425	161.2419	Nanushuk Gp	0.86
VO-3635	Utukok River	69.6456	160.6614	Nanushuk Gp	0.77
VO-3636	Utukok River	69.6458	159.0708	Nanushuk Gp	0.58
VO-3637	Utukok River	69.6458	161.0356	Nanushuk Gp	0.66
VO-3638	Utukok River	69.6617	159.0614	Nanushuk Gp	0.65
VO-3639	Utukok River	69.6758	160.6486	Nanushuk Gp	0.67
VO-3640	Utukok River	69.6917	160.6389	Nanushuk Gp	0.70
VO-3641	Utukok River	69.6994	160.6358	Nanushuk Gp	0.69
VO-3642	Utukok River	69.6997	161.1928	Nanushuk Gp	0.63
VO-3643	Utukok River	69.7042	161.2153	Nanushuk Gp	0.64
VO-3644	Utukok River	69.7108	160.6294	Nanushuk Gp	0.67
VO-3645	Utukok River	69.7131	161.2669	Nanushuk Gp	0.60
VO-3646	Utukok River	69.7167	161.2800	Nanushuk Gp	0.60
VO-3647	Utukok River	69.7211	161.2992	Nanushuk Gp	0.63
VO-3648	Utukok River	69.7458	161.4092	Nanushuk Gp	0.60
VO-3649	Utukok River	69.7500	160.6264	Nanushuk Gp	0.61
VO-3650	Utukok River	69.7903	160.6169	Nanushuk Gp	0.78
VO-3651	Wainwright	70.0089	160.4542	Nanushuk Gp	0.52
VO-3652	Wainwright	70.0203	160.3358	Nanushuk Gp	0.60
VO-3653	Wainwright	70.0292	160.6839	Nanushuk Gp	0.57
VO-3654	Wainwright	70.0336	159.3061	Nanushuk Gp	0.58
VO-3655	Wainwright	70.0358	160.2536	Nanushuk Gp	0.55
VO-3656	Wainwright	70.0403	160.2239	Nanushuk Gp	0.54
VO-3657	Wainwright	70.0450	160.1942	Nanushuk Gp	0.60
VO-3658	Wainwright	70.0797	160.8689	Nanushuk Gp	0.51
VO-3659	Wainwright	70.0842	160.7339	Nanushuk Gp	0.57
VO-3660	Wainwright	70.1033	160.6253	Nanushuk Gp	0.52
VO-3661	Wainwright	70.1122	160.7539	Nanushuk Gp	0.54
VO-3662	Wainwright	70.1156	160.7606	Nanushuk Gp	0.63
VO-3663	Wainwright	70.1414	160.5661	Nanushuk Gp	0.52

Table 8b. Vitrinite reflectance values of coals across the subsurface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. [Modified from Johnsson and others, 1992]

Record number	Quadrangle scale of 1:250,000	Well name	North latitude	West longitude	Mean R_o (%)
VW-0045	(Offshore)	OCS-Y-0280-1 (Antares #1)	71.0361	152.7236	0.25
VW-0119	Anchorage	American Quasar Big Lake #1	61.5546	149.8004	0.43
VW-0142	Anchorage	Beaver Lakes State #1	61.6092	149.8597	0.49
VW-0173	Anchorage	Fishhook #1	61.6753	149.2613	0.51
VW-0175	Anchorage	Lorraine State #1	61.2989	149.9956	0.22
VW-0179	Anchorage	Needham #1	61.5835	149.3534	0.59
VW-0180	Anchorage	Pittman #1	61.6056	149.6390	0.47
VW-0185	Anchorage	USA Big Lake #1	61.4172	149.9142	0.47
VW-0208	Anchorage	Wallace-Knuston #1-A	61.5442	149.4145	0.49
VW-0226	Barrow	Avak #1	71.2506	156.4681	0.50
VW-0232	Barrow	North Simpson #1	71.0569	154.9567	0.43
VW-0238	Barrow	South Barrow #1	71.3200	156.7042	0.45
VW-0250	Barrow	South Barrow #12	71.2372	156.3378	0.37
VW-0253	Barrow	South Barrow #13	71.2581	156.6192	0.42
VW-0260	Barrow	South Barrow #14	71.2317	156.2992	0.45
VW-0264	Barrow	South Barrow #15	71.2400	156.3436	0.52
VW-0268	Barrow	South Barrow #16	71.2822	156.5461	0.33
VW-0276	Barrow	South Barrow #17	71.2333	156.2594	0.50
VW-0286	Barrow	South Barrow #18	71.2503	156.2892	0.24
VW-0307	Barrow	South Barrow #19	71.2414	156.3336	0.48
VW-0321	Barrow	South Barrow #2	71.2619	156.6342	0.49
VW-0335	Barrow	South Barrow #3	71.1581	156.5669	0.45
VW-0351	Barrow	South Barrow #4	71.2642	156.6306	0.37
VW-0352	Barrow	South Barrow #9	71.2675	156.6147	0.56
VW-0355	Barrow	Tulageak #1	71.1889	155.7094	0.61
VW-0369	Barrow	Walakpa #1	71.0986	156.8856	0.43
VW-0391	Barrow	Walakpa #2	71.0503	156.9517	0.72
VW-0405	Barrow	West Dease Test Well #1	71.1592	155.6306	0.35
VW-0423	Barter Island	Aurora # 1	70.1092	142.7850	0.27
VW-0488	Barter Island	Belcher # 1	70.2752	141.5128	0.35
VW-0535	Beechey Point	Beaufort Sea Blk. 54 #1	70.4917	147.9842	0.30
VW-0572	Beechey Point	BF-57 #1 (Seal Island #3)	70.4914	148.6935	0.32
VW-0592	Beechey Point	Delta State #2	70.2606	148.0139	0.17
VW-0606	Beechey Point	Gwydyr Bay South #1	70.4017	148.8981	0.46
VW-0608	Beechey Point	Gwydyr Bay State #1	70.4200	149.0178	0.44
VW-0624	Beechey Point	Jeanette Island #1	70.3617	147.4072	0.28
VW-0659	Beechey Point	Kavearak Point #32-25	70.4553	149.4356	0.30
VW-0697	Beechey Point	Kuparuk River Unit #3A-9	70.4028	149.9378	0.25
VW-0711	Beechey Point	Long Island #1	70.4867	149.0161	0.42

Table 8b. Vitrinite reflectance values of coals across the subsurface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	Well name	North latitude	West longitude	Mean R_o (%)
VW-0734	Beechey Point	No Name Island #1	70.4608	147.9350	0.46
VW-0778	Beechey Point	Northwest Eileen #1	70.3653	149.3586	0.46
VW-0779	Beechey Point	OCS-Y-370-1 (Sandpiper #1)	70.5848	149.0969	0.22
VW-0794	Beechey Point	Placid Et Al State #1	70.2494	148.8186	0.24
VW-0802	Beechey Point	Point McIntyre #1	70.3968	148.6062	0.32
VW-0810	Beechey Point	Prudhoe Bay #36-11	70.2686	148.4753	0.39
VW-0818	Beechey Point	Prudhoe Bay Unit #R-1	70.3453	148.8792	0.33
VW-0844	Beechey Point	Put River #24-10-14	70.2019	148.4664	0.38
VW-0851	Beechey Point	Put River (J-1) #9-11-13	70.3272	148.8389	0.46
VW-0855	Beechey Point	Sag Delta #31-10-16	70.1828	148.1550	0.48
VW-0866	Beechey Point	Sag Delta #33-12-16	70.3408	148.1044	0.44
VW-0867	Beechey Point	Sag Delta #8	70.3697	148.0514	0.50
VW-0890	Beechey Point	Sag River #1	70.2544	148.3425	0.26
VW-0900	Beechey Point	Simpson Lagoon #32-14A	70.4828	149.7328	0.10
VW-0918	Beechey Point	Toolik Federal #1	70.0731	148.3928	0.52
VW-0926	Beechey Point	Toolik Federal #2	70.0717	149.2067	0.32
VW-0938	Beechey Point	Toolik Federal #3	70.0764	149.9006	0.26
VW-0943	Beechey Point	W Mikkelson Unit #3	70.1981	147.3153	0.37
VW-0955	Beechey Point	W. Mikkelson Unit #2	70.2206	147.1880	0.52
VW-0965	Beechey Point	West Beach State #2	70.3581	148.4744	0.48
VW-0967	Beechey Point	West Kuparuk #3-11-11	70.3350	149.3067	0.44
VW-0987	Beechey Point	West Mikkelsen Unit #4	70.2174	147.3442	0.17
VW-1034	Chandler Lake	Grandstand #1	68.9658	151.9169	0.48
VW-1039	Chandler Lake	Tulugak #1	68.9758	151.1169	0.38
VW-1111	De Long Mountains	Eagle Creek #1	68.7086	162.5522	1.46
VW-1127	Fairbanks	Nenana #1	64.5797	149.6375	0.31
VW-1149	Flaxman Island	Alaska Island #1	70.2275	146.5000	0.34
VW-1191	Flaxman Island	Alaska State #D-1	70.2031	146.2072	0.35
VW-1214	Flaxman Island	Alaska State #F-1	70.2267	146.3603	0.36
VW-1254	Flaxman Island	Challenge Island #1	70.2356	146.6178	0.15
VW-1273	Flaxman Island	E. De K. Leffingwell #1	70.0178	146.5168	0.30
VW-1295	Flaxman Island	East Mikkelsen Bay #1	70.1519	146.9028	0.29
VW-1316	Flaxman Island	OCS-Y-849-1 (Hammerhead)	70.3646	146.0244	0.37
VW-1401	Flaxman Island	OCS-Y-849-2 (Hammerhead #2)	70.3783	146.0312	0.51
VW-1445	Flaxman Island	OCS-Y-871-1 (Corona #1)	70.3146	144.7591	0.23
VW-1504	Flaxman Island	Point Thompson #3	70.1714	146.2522	0.48
VW-1526	Flaxman Island	Point Thomson #2	70.1631	146.5142	0.31
VW-1548	Flaxman Island	Point Thomson #1	70.1739	146.3533	0.46
VW-1592	Flaxman Island	West Staines State #2	70.1103	146.4161	0.37
VW-1677	Harrison Bay	Atigaru Point #1	70.5561	151.7169	0.32
VW-1696	Harrison Bay	Cape Halkett #1	70.7672	152.4664	0.22
VW-1710	Harrison Bay	East Harrison Bay #1	70.4928	150.0317	0.48

Table 8b. Vitrinite reflectance values of coals across the subsurface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	Well name	North latitude	West longitude	Mean R_o (%)
VW-1723	Harrison Bay	Fish Creek #1	70.3206	151.9689	0.31
VW-1733	Harrison Bay	Itkillik River Unit #1	70.0658	150.8531	0.73
W-1779	Harrison Bay	Nechelik #1	70.3928	150.9789	0.28
VW-1811	Harrison Bay	North Inigok #1	70.2569	152.6639	0.28
VW-1830	Harrison Bay	North Kalikpik #1	70.5092	152.3678	0.28
VW-1860	Harrison Bay	OCS-Y-0302-1 (Mars)	70.8430	152.0718	0.25
VW-1869	Harrison Bay	OCS-Y-334-1 (Mukluk #1)	70.6833	150.9200	0.30
VW-1923	Harrison Bay	OCS-Y-338-1 (Phoenix #1)	70.7169	150.4278	0.24
VW-1948	Harrison Bay	OCS-Y-804-1 (Orion)	70.9562	152.0630	0.26
VW-1957	Harrison Bay	South Harrison Bay # 1	70.4247	151.7311	0.24
VW-1990	Harrison Bay	W T Foran # 1	70.8322	152.3031	0.23
VW-2006	Harrison Bay	West Fish Creek #1	70.3264	152.0606	0.33
VW-2021	Ikpikpuk River	East Oumalik#1	69.7914	155.5442	0.46
VW-2030	Ikpikpuk River	Knifeblade #1	69.1508	154.8892	0.55
VW-2035	Ikpikpuk River	Knifeblade #2A	69.1386	154.7367	0.63
VW-2038	Ikpikpuk River	Koluktak Test Well #1	69.7778	154.5308	0.35
VW-2048	Ikpikpuk River	Oumalik #1	69.8381	155.9900	0.36
VW-2074	Ikpikpuk River	Square Lake #1	69.5667	153.3000	0.49
VW-2090	Ikpikpuk River	Titaluk #1	69.4225	154.5678	0.55
VW-2097	Ikpikpuk River	Wolf Creek #1	69.3864	153.5206	0.58
VW-2100	Ikpikpuk River	Wolf Creek #3	69.3864	153.5233	0.51
VW-2109	Iliamna	Iniskin Beal #1	59.7411	153.2261	0.60
VW-2173	Iliamna	Iniskin Zappa #1	59.7458	153.2458	0.48
VW-2257	Kenai	ARCO/CIRI Funny River #1	60.4222	150.9633	0.39
VW-2280	Kenai	Beaver Creek Unit #4	60.6561	151.0297	0.26
VW-2295	Kenai	Clam Gulch 1-X	60.2044	151.5256	0.37
VW-2322	Kenai	Deep Creek #1	60.0081	151.4847	0.39
VW-2325	Kenai	Edna Mae Walker #1	60.0456	151.2881	0.29
VW-2372	Kenai	Kustatan River #1	60.8087	151.9145	0.25
VW-2380	Kenai	Soldotna Creek Unit #22-32	60.6548	150.8984	0.33
VW-2400	Kenai	Soldotna Creek Unit #33-33	60.7372	150.8619	0.56
VW-2425	Kenai	SRS MGS State #1	60.8123	151.4828	0.48
VW-2436	Kenai	Swanson River Unit #34-10	60.7931	150.8333	0.35
VW-2437	Killik River	East Kurupa Unit # 1	68.8402	153.3036	0.63
VW-2464	Killik River	Lisburne #1	68.4783	155.6506	0.43
VW-2584	Lookout Ridge	Awuna Test Well #1	69.1478	158.0242	0.55
VW-2599	Meade River	Brontosaurus #1	70.8995	157.2494	0.61
VW-2603	Meade River	Kugrua #1	70.5869	158.6619	0.49
VW-2650	Meade River	Kuyanak #1	70.9325	156.0322	0.58
VW-2666	Meade River	Meade #1	70.0417	157.4894	0.50
VW-2766	Mount Michelson	Beli Unit #1	69.7106	146.5353	0.46
VW-2782	Mount Michelson	Canning River Unit #A-1	69.6061	146.3353	0.72

Table 8b. Vitrinite reflectance values of coals across the subsurface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	Well name	North latitude	West longitude	Mean R_o (%)
VW-2804	Mount Michelson	Canning River Unit #B-1	69.6636	146.2753	0.57
VW-2837	Mount Michelson	Kavik #1	69.6317	146.5694	0.84
VW-2898	Point Lay	Akulik #1	68.9919	163.4872	0.45
VW-2931	Point Lay	Tungak Creek #1	69.8828	162.2722	0.54
VW-2954	Sagavanirktok	Aufeis Unit #1	69.1497	149.5717	0.50
VW-2976	Sagavanirktok	Bush Federal #1	69.6583	149.0331	0.38
VW-3047	Sagavanirktok	Echooka Unit #1	69.4000	148.2686	0.38
VW-3088	Sagavanirktok	Fin Creek Unit #1	69.5000	147.6000	0.45
VW-3121	Sagavanirktok	Kemik #1	69.4397	147.2658	0.64
VW-3167	Sagavanirktok	Kemik Unit #2	69.3864	147.1556	1.18
VW-3200	Sagavanirktok	Lupine Unit #1	69.1011	148.6183	0.83
VW-3213	Sagavanirktok	Nora Federal #1	69.5517	148.7519	0.16
VW-3230	Sagavanirktok	Shaviovik Unit #1	69.5419	147.5206	0.52
VW-3254	Sagavanirktok	West Kavik #1	69.7700	147.1856	0.85
VW-3275	Seldovia	Anchor Point #1	59.7533	151.8226	0.21
VW-3285	Seldovia	Coal Bay State # 1	59.6611	151.3522	0.29
VW-3292	Seldovia	Lwr Cook Inlet COST #1	59.5183	152.6433	0.29
VW-3328	Seldovia	North Fork Unit 41-35	59.7925	151.6257	0.38
VW-3341	Seldovia	OCS-Y-086-1	59.7083	152.1578	0.40
VW-3388	Seldovia	OCS-Y-097-1 (Raven #1)	59.6039	152.5822	0.48
VW-3414	Seldovia	OCS-Y-113-1 (Ibis #1)	59.4139	152.6842	0.40
VW-3419	Seldovia	OCS-Y-243-1 (Falcon Prospect)	59.7794	152.6000	0.47
VW-3436	Seldovia	South Caribou Hills Unit # 1	59.8217	151.2522	0.22
VW-3442	Seldovia	South Diamond Gulch Unit #1	59.6914	151.7164	0.27
VW-3464	Teshekpuk	Drew Point #1	70.8797	153.8997	0.30
VW-3496	Teshekpuk	East Simpson #1	70.9178	154.6178	0.33
VW-3529	Teshekpuk	East Simpson #2	70.9783	154.6736	0.29
VW-3548	Teshekpuk	East Topagoruk #1	70.5769	155.3725	0.47
VW-3556	Teshekpuk	Ikpikpuk #1	70.4556	154.3325	0.37
VW-3612	Teshekpuk	Inigok #1	70.0000	153.0944	0.40
VW-3702	Teshekpuk	J. W. Dalton #1	70.9200	153.1378	0.45
VW-3738	Teshekpuk	Simpson #1	70.9531	155.3642	0.59
VW-3748	Teshekpuk	South Simpson #1	70.8067	154.9817	0.62
VW-3757	Teshekpuk	Topagoruk #1	70.6250	155.8931	0.34
VW-3779	Tyonek	Albert Kaloa #1	61.0197	151.3484	0.34
VW-3824	Tyonek	Bell Island # 1	61.4009	152.4610	0.44
VW-3827	Tyonek	Chuitna Riv St 3193 #1	61.1354	151.3728	0.48
VW-3852	Tyonek	Cook Inlet St. 17589 #1	61.0667	150.9533	0.24
VW-3893	Tyonek	Cook Inlet Unit #A-12	61.0767	150.9481	0.60
VW-3905	Tyonek	Fish Creek #1	61.5620	150.2716	0.32
VW-3906	Tyonek	Ivan River 44-1	61.2404	150.7967	0.12
VW-3909	Tyonek	Lewis River 13-2	61.3310	150.8485	0.37

Table 8b. Vitrinite reflectance values of coals across the subsurface in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces. — Continued

Record number	Quadrangle scale of 1:250,000	Well name	North latitude	West longitude	Mean R_o (%)
VW-3944	Tyonek	Long Lake #1	61.0831	151.4307	0.31
VW-3947	Tyonek	Moquawkie #1	61.0739	151.3189	0.29
VW-3985	Tyonek	Nicolai Creek Unit #4	61.0140	151.4299	0.26
VW-4026	Tyonek	Pretty Creek St. #1	61.3264	151.0057	0.27
VW-4027	Tyonek	Red Shirt Lake #1	61.6410	150.0941	0.31
VW-4127	Umiat	Gubik #1	69.4228	151.4472	0.35
VW-4139	Umiat	Gubik #2	69.4325	151.4644	0.41
VW-4151	Umiat	Itkillik Unit #1	69.4547	150.5747	0.51
VW-4171	Umiat	Seabee #1	69.3794	152.1731	0.52
VW-4211	Umiat	Umiat #1	69.3964	152.3281	0.48
VW-4219	Umiat	Umiat #11	69.4047	152.0953	0.50
VW-4233	Umiat	Umiat #2	69.3819	152.0825	0.64
VW-4258	Utukok River	Kaolak #1	69.9331	160.2475	0.56
VW-4285	Wainwright	Peard #1	70.7156	159.0006	0.46
VW-4318	Wainwright	Tunalik #1	70.1967	161.0719	0.56

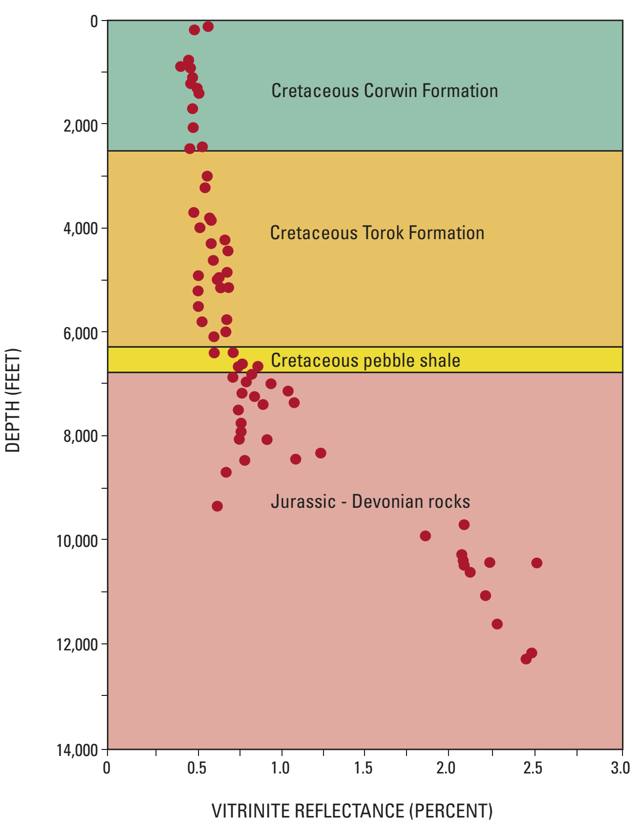


Figure 105. Vitrinite reflectance values for the Meade Quadrangle, National Petroleum Reserve in Alaska. Modified from Magoon and Bird (1988).

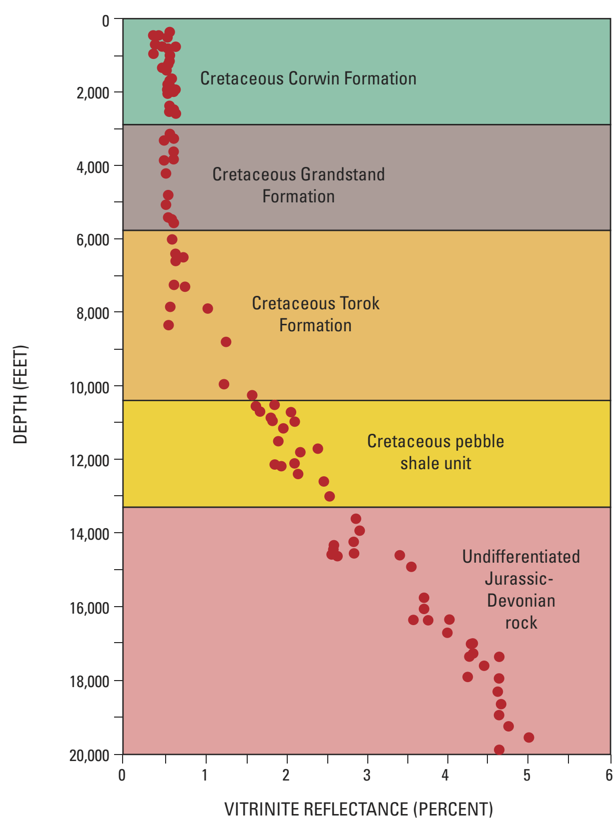


Figure 106. Vitrinite reflectance values for the Tunalik No. 1 well, National Petroleum Reserve in Alaska. Modified from Magoon and Bird (1988).

Cook Inlet are in the Tyonek area where the coal beds in the Tyonek are as much as 50 ft (15 m) thick occurring at shallow depths of less than 2,000 ft (610 m). Also, the infrastructure (for example, pipeline) of existing petroleum development is readily available in the area.

A basinwide variation in thermal maturity of the Cook Inlet Basin was determined by Johnsson and others (1993) from vitrinite reflectance values of 30 offshore and onshore wells (fig. 114). Reflectance values range from 0.24 to 0.95 percent with high values (0.6–0.8 percent) occurring at increasing depths in the northeastern and southwestern parts of the Cook Inlet Basin (see fig. 114). This indicates that tectonic deformation and volcanism along the Aleutian volcanic arc influenced the high reflectance values in the northeastern part of the basin, particularly in the Matanuska Valley. The localized upgrading of the thermal maturity in the Matanuska Valley, based on reflectance values of the Tyonek coal beds, is shown in figure 115 (Smith, 1995). Here, the Tyonek coal beds are mainly subbituminous, but the older coal beds in the eastern part of the valley range from bituminous to semianthracite. The central part of the basin maintains reflectance values from 0.4 to 0.6 percent, which indicate burial influence by thick sedimentary rock sequences of 12,000–13,000 ft (3,660–3,960 m) (see figs. 58, 59, and 60) along the basin center. Thermal maturity measured from vitrinite reflectance data is relatively low. Shi-Ming (1996) suggested, in a study of clay mineral diagenesis, that temperatures never exceeded 167°F (75°C) (fig. 116). Rapid rate of subsidence and sedimentation of the Cook Inlet Basin probably controlled the low thermal maturity of the Tyonek, Beluga, and Sterling coal beds. Generalized vitrinite reflectance lines are superimposed on the cross sections in figures 117 and 118.

Coal beds identified in lithologic logs of the Tyonek and Beluga Formations in the Edna Mae Walker No. 1 well in Kenai Peninsula (see fig. 116) are directly associated with the high gas shows indicated on the mud logs (fig. 116). These coal beds contain as much as 2.5 percent by volume of coalbed methane marked by high gas kicks (see fig. 116). However, based on the downhole hot wire total gas results (see high gas kicks in fig. 116), the coal beds in the upper part of the Tyonek Formation contain by far the most coalbed methane resources. Coal beds in the lower part of the Beluga Formation consist of moderate amounts of coalbed methane resources. Coal beds of the Sterling Formation contain very low coalbed methane concentrations. The difference in the coalbed methane content between the Beluga and Sterling coals may be related to the variation in their rank, beds in the Sterling Formation being mainly lignite and those in the Tyonek and Beluga beds being mainly subbituminous (Barnes and Cobb, 1959). Vitrinite reflectance values of the Sterling Formation coal beds range from 0.32 to 0.44 percent, the Beluga coal beds from 0.42 to 0.58 percent, and the Tyonek Formation coal beds from 0.45 to 0.66 percent; all values increase with depth (fig. 117). These vitrinite reflectance values are closely similar to the subbituminous Paleocene Fort Union coal beds (0.31–0.49 percent) in the Powder River Basin of Wyoming and Montana, which have an average gas content of 25 scf/t. Also, the gas content (based on the hot wire total gas and methane in mud logs; see fig. 116) of the Powder River Basin coal beds appears to increase with depth, from below 6,000 ft (1,830 m) to more than 13,000 ft (3,960 m). However, producibility of gas from coal-bed reservoirs at these depths may be negligible due to low permeability below 6,000 ft (1,830 m) (McKee and others, 1986). Thus, by comparison, coal beds of the upper Tyonek and lower Beluga Formations contain the best coalbed methane potential in the Kenai Peninsula, especially reservoirs less than 6,000 ft (1,830 m) deep. The upper part of the Beluga Formation is mainly exposed along the beach bluffs in the southern Kenai Peninsula. Thus, the targeted coal beds of the lower Beluga and upper Tyonek occur in subcrop and at shallower depths than in the Edna Mae Walker well along the south coast of the Kenai Peninsula.

The hypothetical coal resources of the coal-bearing Kenai Group in the Cook Inlet Basin were estimated to be as much as 1.55 trillion short tons (1.45 trillion metric tons) (see table 1). As much as 1.5 trillion short tons (1.36 trillion short tons) of these coal resources is offshore (see table 1). Based on the gas contents of the Tyonek coal beds in the upper Cook Inlet by Smith (1995), which range from 63–245 scf/t (1.97–7.6 scm^3/gm) at STP, the in-place methane resources in that part of the basin may be high. However, based on the subbituminous and lignite ranks and the similarity of the vitrinite reflectance values of the Tyonek, Beluga, and Sterling coal beds in the central and southern parts of the basin to those of the Fort Union coal beds in the Powder River Basin, these coals may provide a lower-end estimate of the gas content in the Cook Inlet Basin.

Summary

Nearly all the coal resources calculated for Alaska are in Cretaceous and Tertiary rocks distributed in three major coal provinces. The Cretaceous coal resources, generally of bituminous and lignite rank, are mainly in the Northern Alaska-Slope coal province with 3,200 billion short tons (2,902 billion metric tons) of hypothetical resources. A minor amount of Tertiary coal resources are in the Northern Alaska-Slope coal province with 670 billion short tons (608 billion short tons) of hypothetical resources. Most of the Tertiary coal resources, mainly lignite to subbituminous with minor bituminous and semianthracite, are in the Central Alaska-Nenana and Southern Alaska-Cook Inlet coal provinces with more than 1,600 billion short tons (1,451 billion metric tons) of combined measured, indicated, inferred, and hypothetical resources. These three coal provinces contain about 87 percent of the total coal resources and represent most of the minable coal beds of Alaska. Combined coal resources (measured, indicated, inferred, and hypothetical resources) in the Northern Alaska-Slope, Central Alaska-Nenana, and Southern Alaska-Cook Inlet coal provinces are about 5,526 billion short

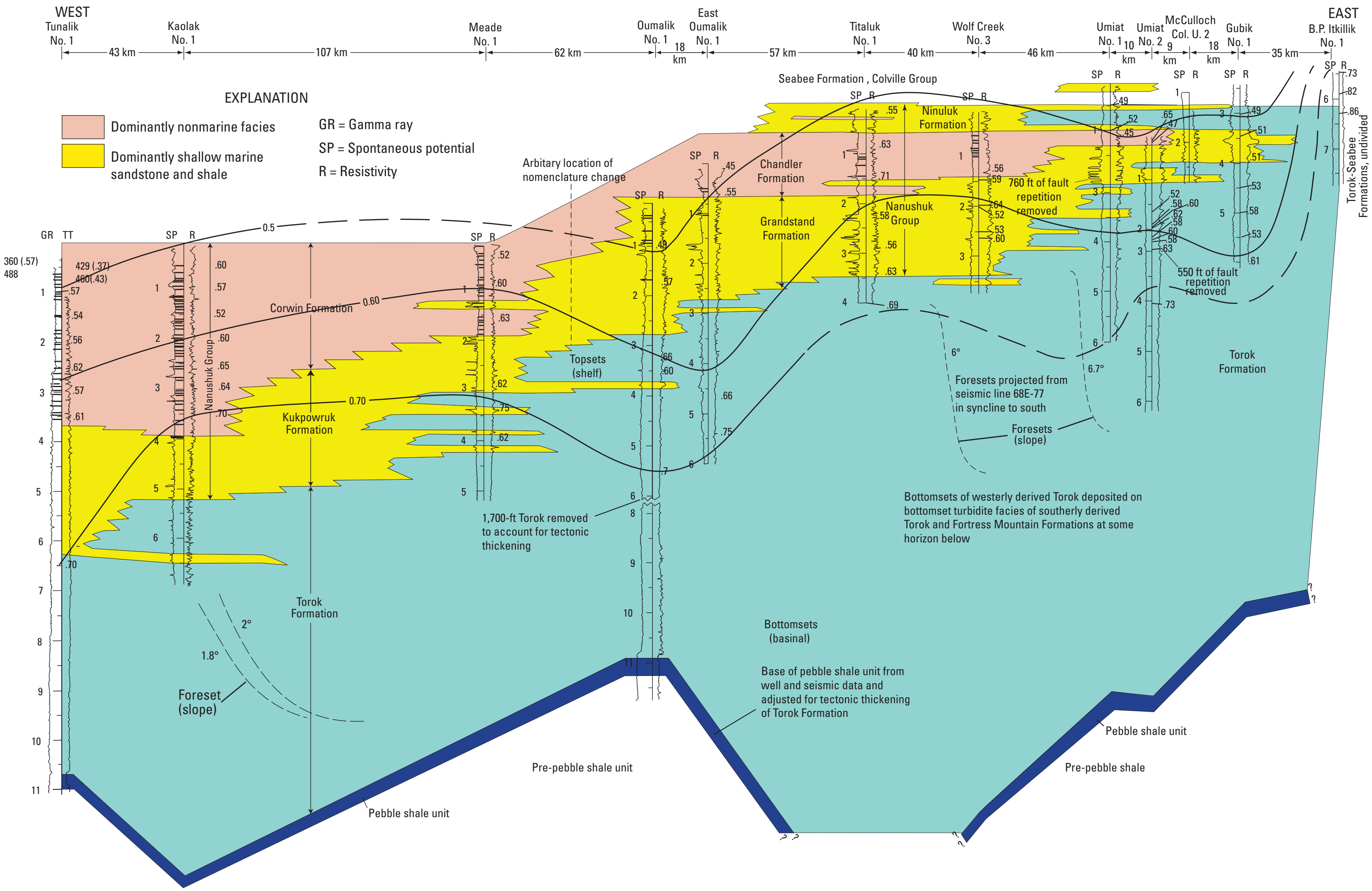


Figure 107. Stratigraphic cross section of the Nanushuk Group with superimposed vitrinite reflectance values. See figure 8 for location of cross section.

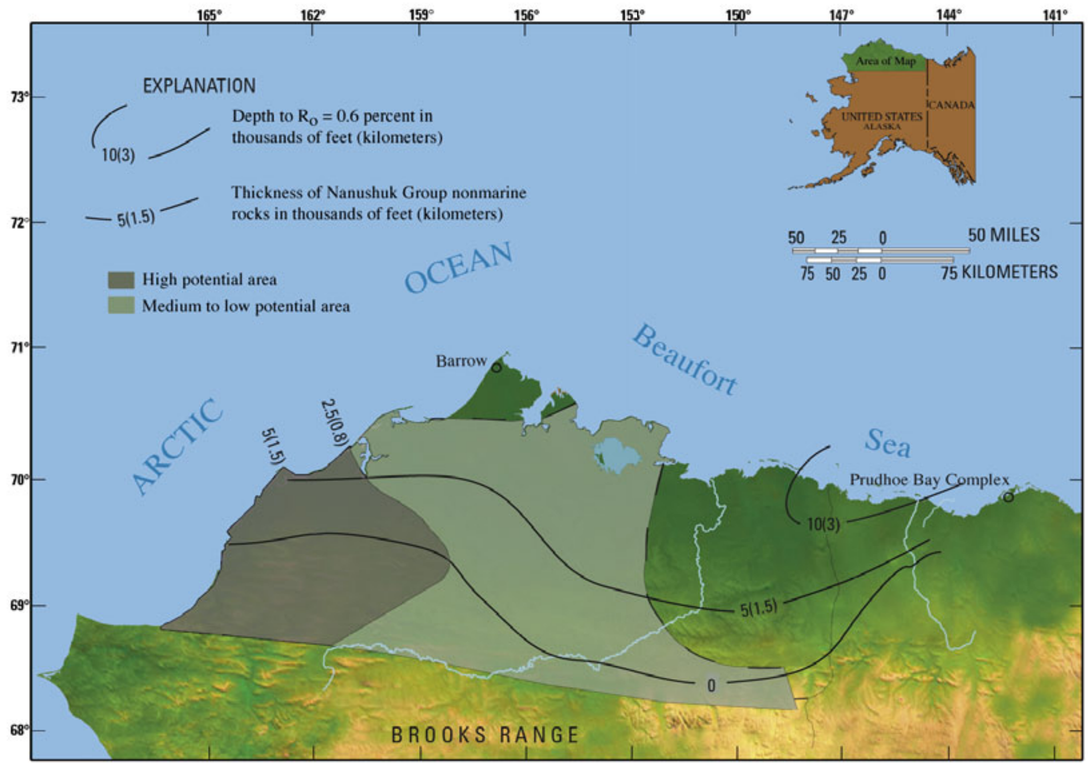


Figure 108. Coalbed methane potential in the Nanushuk Group coals based on the thickness and vitrinite reflectance of the nonmarine part of the group in the Northern Alaska-Slope coal province. Adopted from Smith (1995).

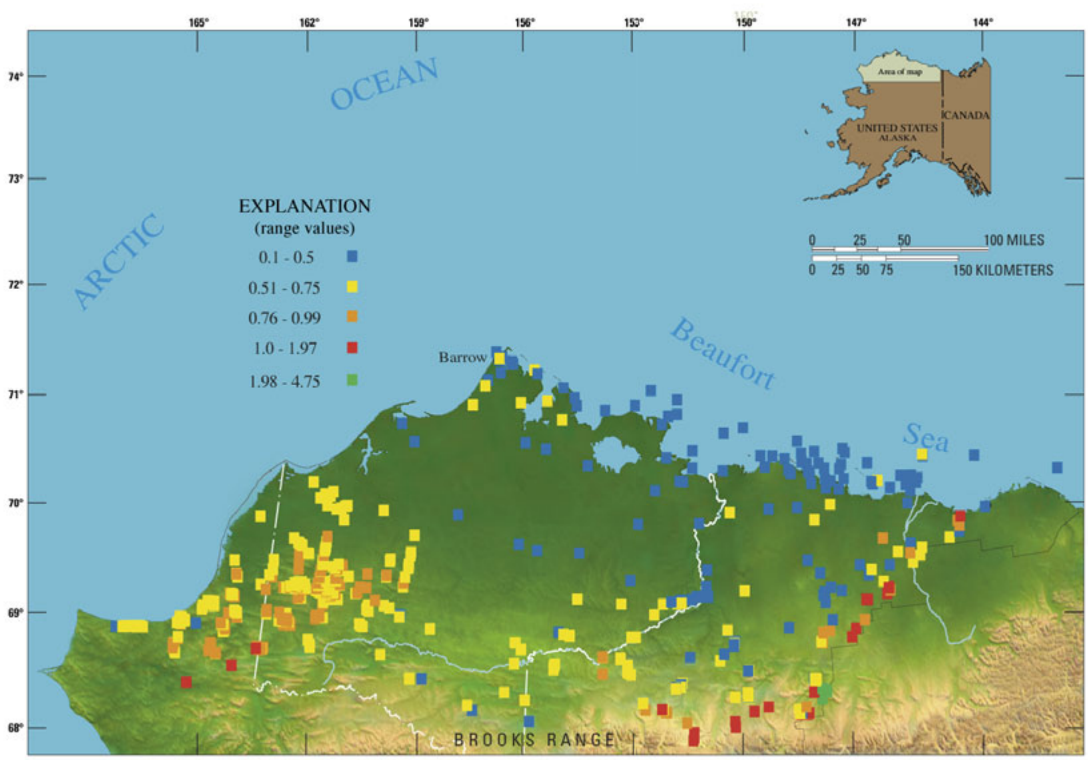


Figure 109. Distribution of surface vitrinite reflectance (R_O) values in the Northern Alaska-Slope coal province.

Table 9. Properties of sandstone reservoirs and associated gas in the Sterling and Beluga Formations. Modified from Brimberry and others (1997).

Reservoir data of Kenai field	
Total completions:	69 (commingled flow, typically dual tubing strings)
Spacing:	160–320 acres
Drive:	Gas expansion
Structure:	Simple anticlines
Gas analysis:	99% methane; 0.5% nitrogen; 0.2% carbon dioxide; 1,008 Btu per cubic foot; 0.56 specific gravity

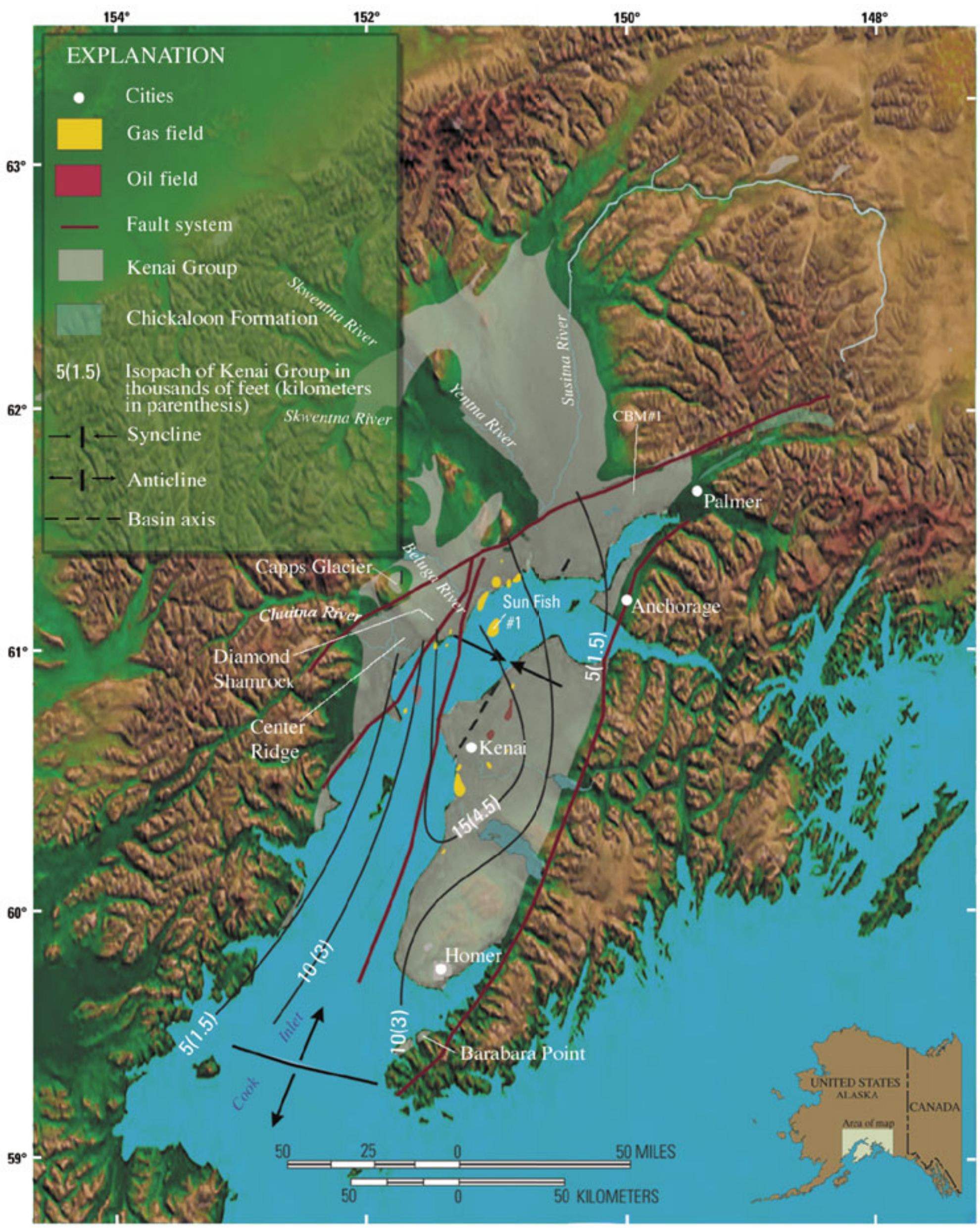


Figure 110. Map of the Cook Inlet Basin showing distribution of oil and gas fields offshore and onshore. CBM #1 is the well studied by Smith (1995).

tons (5,012 billion metric tons). Of this total, 13.5 billion short tons (13.2 billion metric tons) are identified coal resources mainly from the Central Alaska-Nenana and Southern Alaska-Cook Inlet coal provinces. Thus, only a small fraction of the total coal resources of Alaska is known, and a large amount is undiscovered.

Coal mining has been intermittently attempted in the Central Alaskan-Nenana and Southern Alaska-Cook Inlet coal provinces. A dozen or more underground and strip mines in these two coal provinces have produced over 40 million short tons (36 million metric tons). Thus, only a small fraction of the identified resources has been produced of the more than 13.5 billion short tons (billion metric tons) that are estimated to occur in these coal provinces. Alaskan coal resources have low sulfur content (averaging 0.2–0.4 percent) compared to the coal in the conterminous United States. This low-sulfur coal is within or below the minimum value mandated by the 1990 Clean Air Act amendments. The extremely large identified coal resources are located near existing infrastructure, which should aid in their development, transportation, and marketing. The short distance of these resources to countries in the western Pacific would appear to make them more marketable there than in the conterminous United States.

An untapped resource is coalbed methane. With more than 5,500 billion short tons (5,012 billion metric tons) of combined coal resources of Alaska coal, the in-place gas resource is an exceedingly large volume. A large part of the measured, indicated, inferred, and hypothetical coal resources, about 5,482 billion short tons (4,972 billion metric tons), is in the Northern Alaska-Slope and Southern Alaska-Cook Inlet coal provinces where in-place and planned infrastructure (pipelines, highways, and so on) can assist in the transportation and marketability of coalbed gas. The shallow depths to a large portion of the methane-bearing coal beds in onshore areas make the gas more accessible for future development.

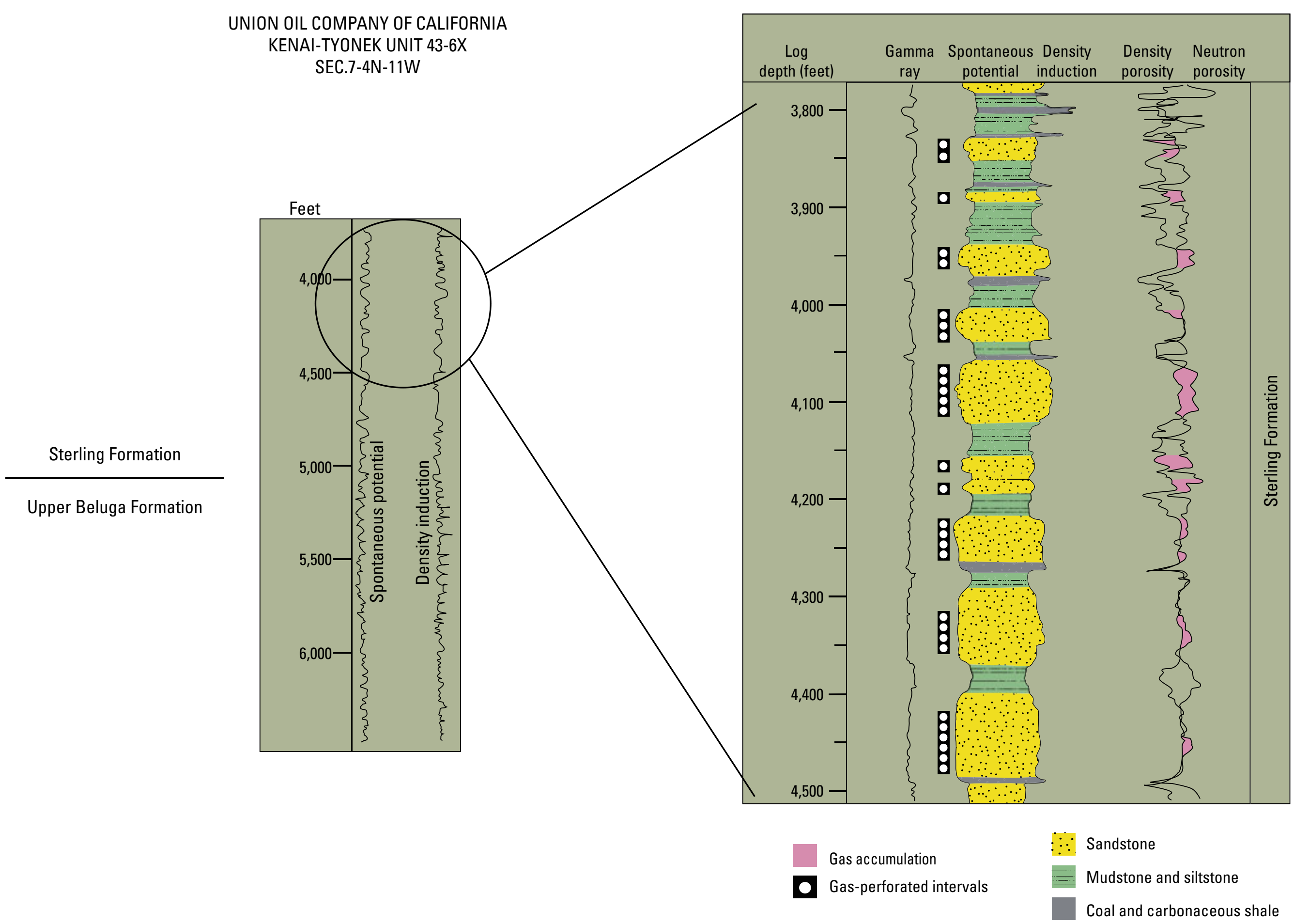


Figure 111. Facies profile of the lower part of the Sterling Formation and accompanying downhole logs showing horizons of gas accumulation. The Sterling facies include fluvial-channel sandstones and flood-plain mudstones and siltstones.

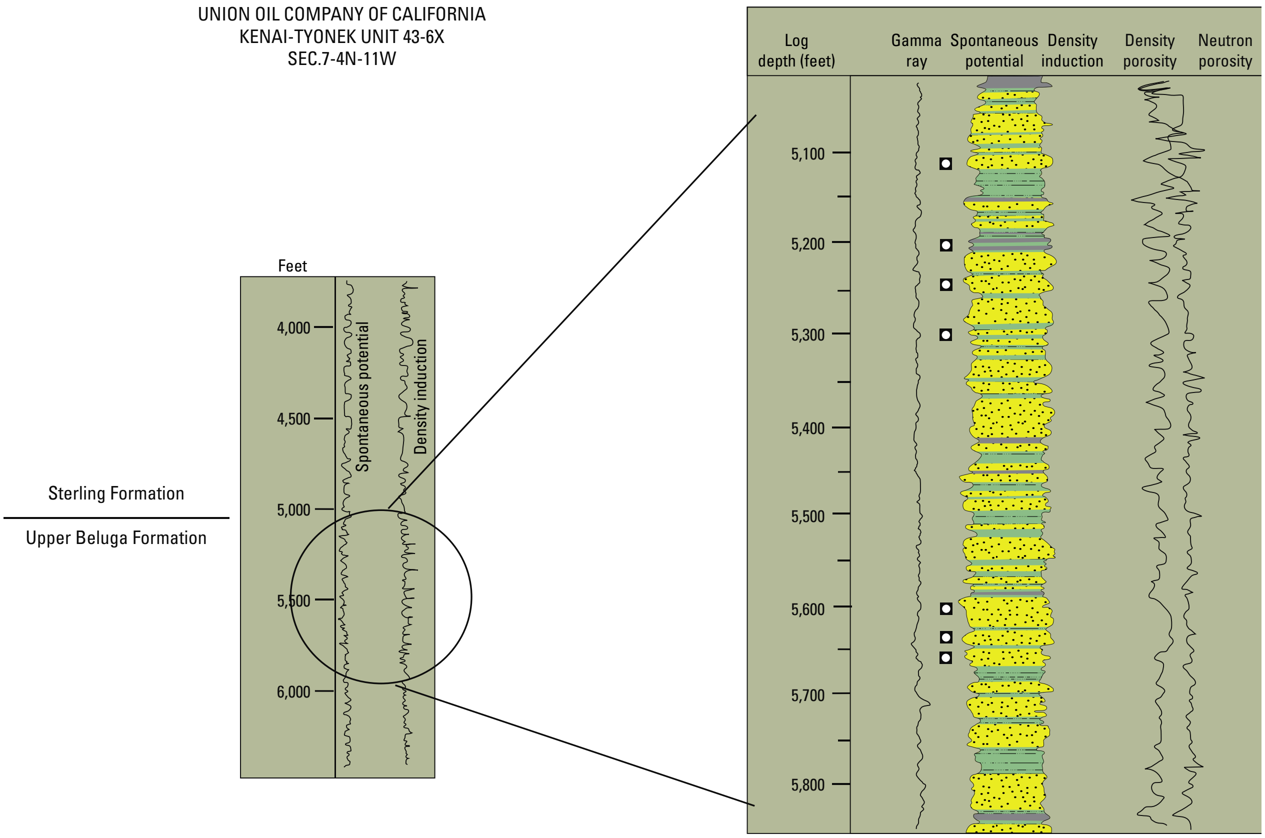


Figure 112. Facies profile of the upper part of the Beluga Formation and accompanying downhole logs showing horizons of gas-perforated intervals.

Acknowledgments

The authors acknowledge Heather Mitchell, Dean Hancock, Jennifer Goldsmith, and Steve Dunn for their assistance in generation of the digital illustrations for this paper. The data for this study were collected from 1988 to 2002 with the help of numerous geologists, too many to mention here, from the U.S. Geological Survey, Alaska Department of Natural Resources Division of Oil and Gas and Division of Geological and Geophysical Surveys, Alaska Geologic Materials Center, and Bureau of Land Management. Funding for part of this study from the Division of Oil and Gas is very much appreciated. Finally, we thank the Usibelli Coal Mine Inc., Beluga, Diamond Alaska, and Placer Dome coal companies, ARCO Alaska Inc. and International ARCO, and Marathon Oil Company, Anchorage, Alaska and Littleton, Colorado, for sharing information and permission to describe their core data.

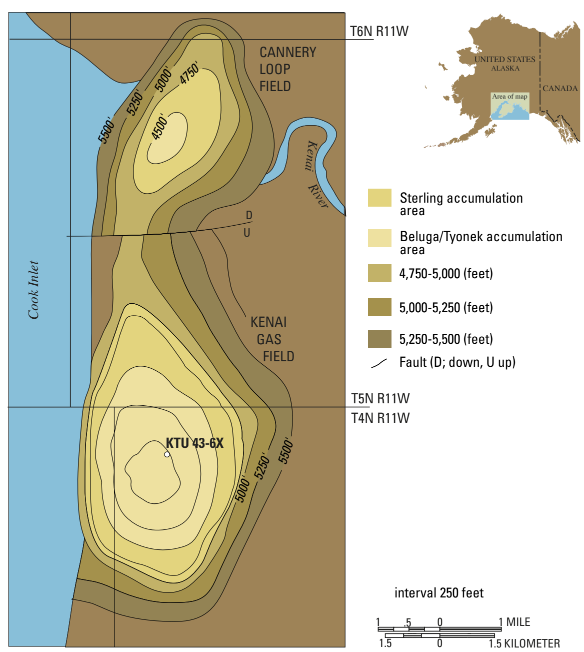
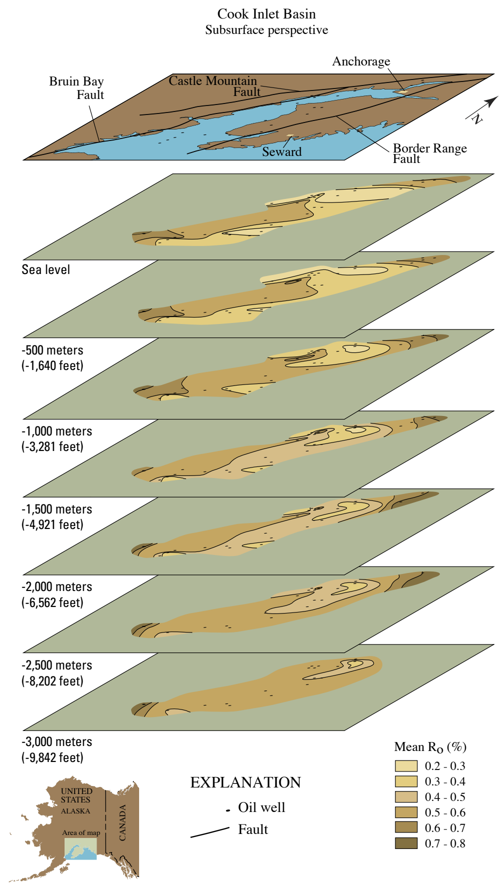


Figure 113. Location map of the Kenai gas field in the Kenai Peninsula. Gas accumulations in the Beluga and Sterling Formations occur on a doubly-plunging anticline. KTU 43-6X is the well described in figures 110 and 111.

Figure 114. Basinwide and vertical variations of vitrinite reflectance (Ro) values in the Cook Inlet Basin. Modified from Johnsson and others (1993).



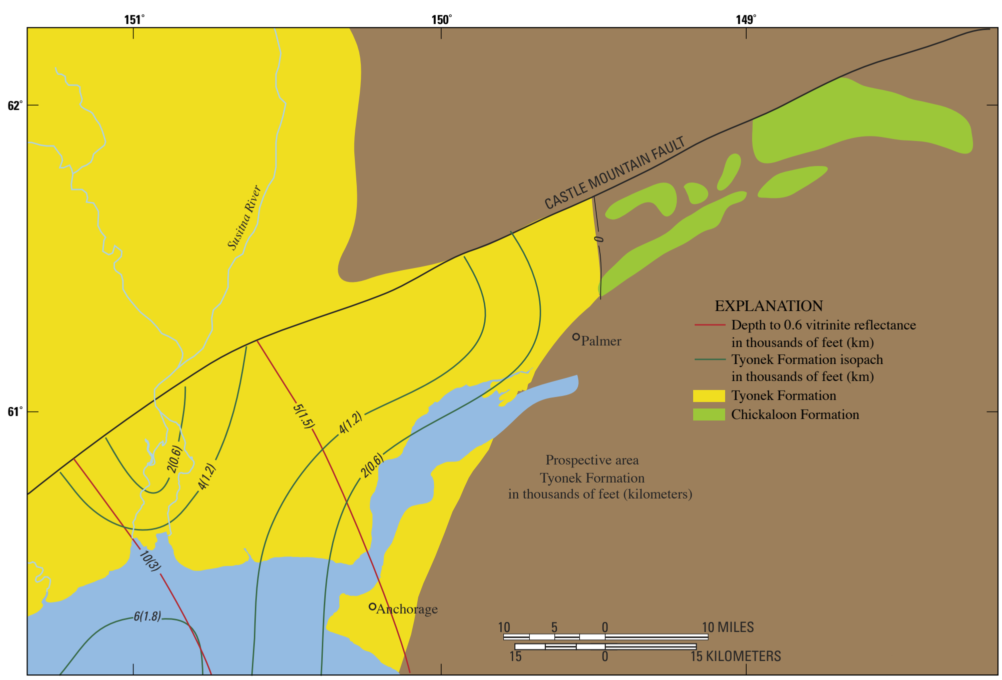


Figure 115. Coalbed methane prospect area and depths to vitrinite reflectance values of 0.6 percent superimposed on the thickness isopach of the Tyonek Formation south of the Castle Mountain fault in the northeastern part of the Cook Inlet. Adopted from Smith (1995).

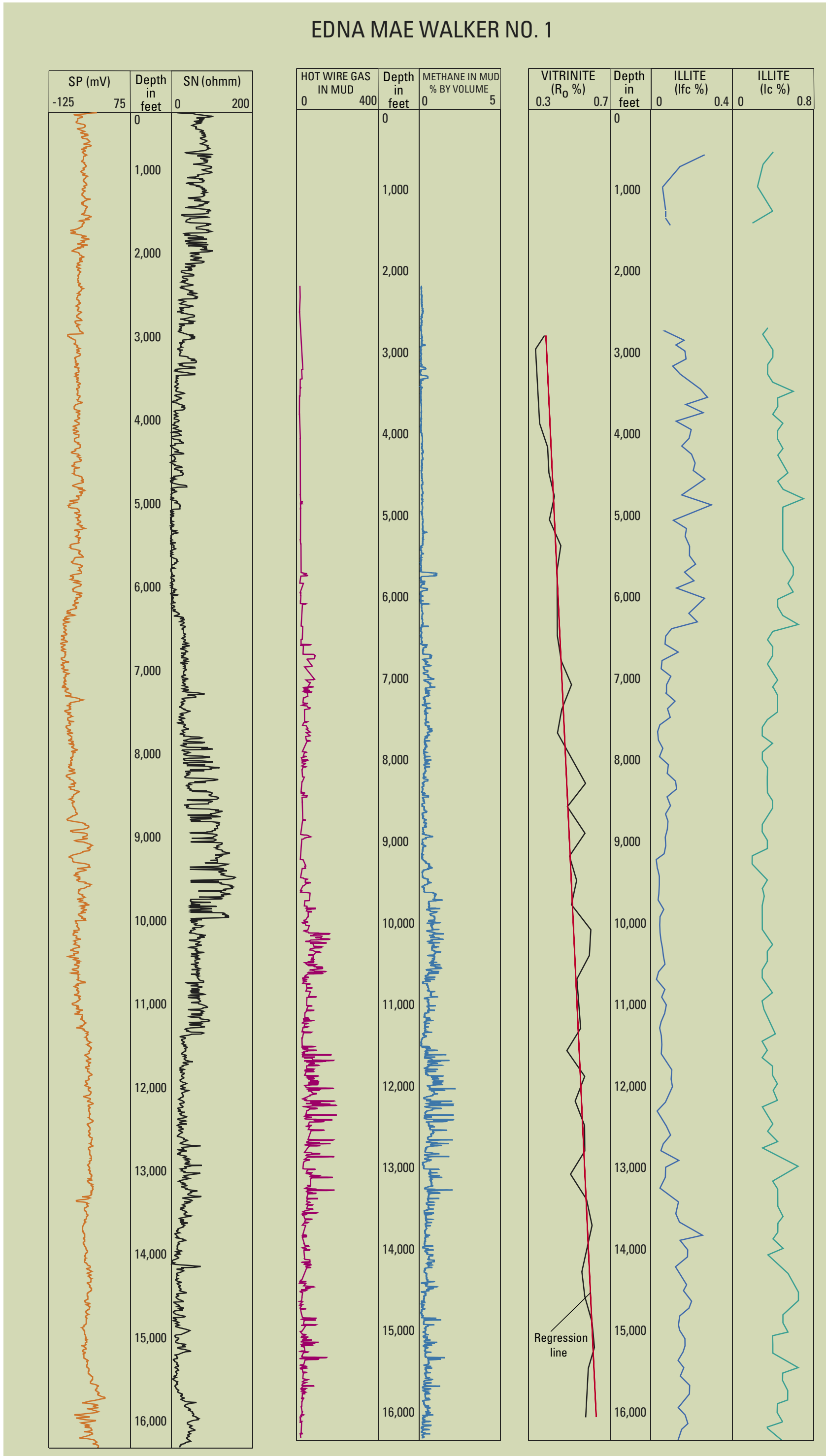


Figure 116. Downhole geophysical logs, hot wire total gas and methane contents, vitrinite reflectance values, and illite diagenetic values in the Edna Mae Walker drill hole. SP=spontaneous potential; mV=millivolt; SN=sonic; Ro=vitrinite reflectance; %=percent. Ipf=illite peak profile at 10 angstroms; Ic= illite crystallinity. Modified from Shi-Ming (1996).

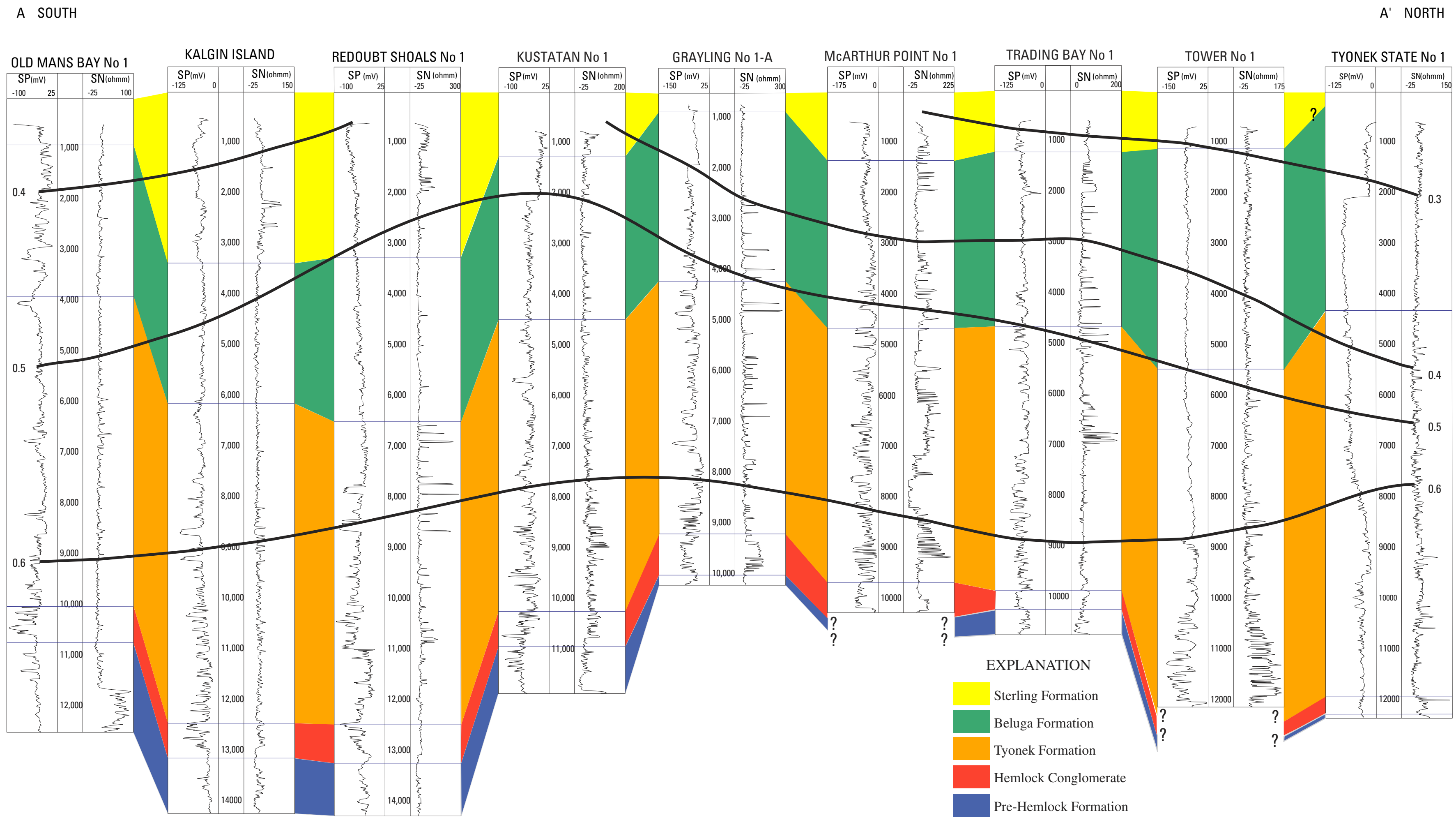


Figure 117. Stratigraphic cross section of the Kenai Group in the offshore Cook Inlet Basin with superimposed vitrinite reflectance values. See figure 58 for location.

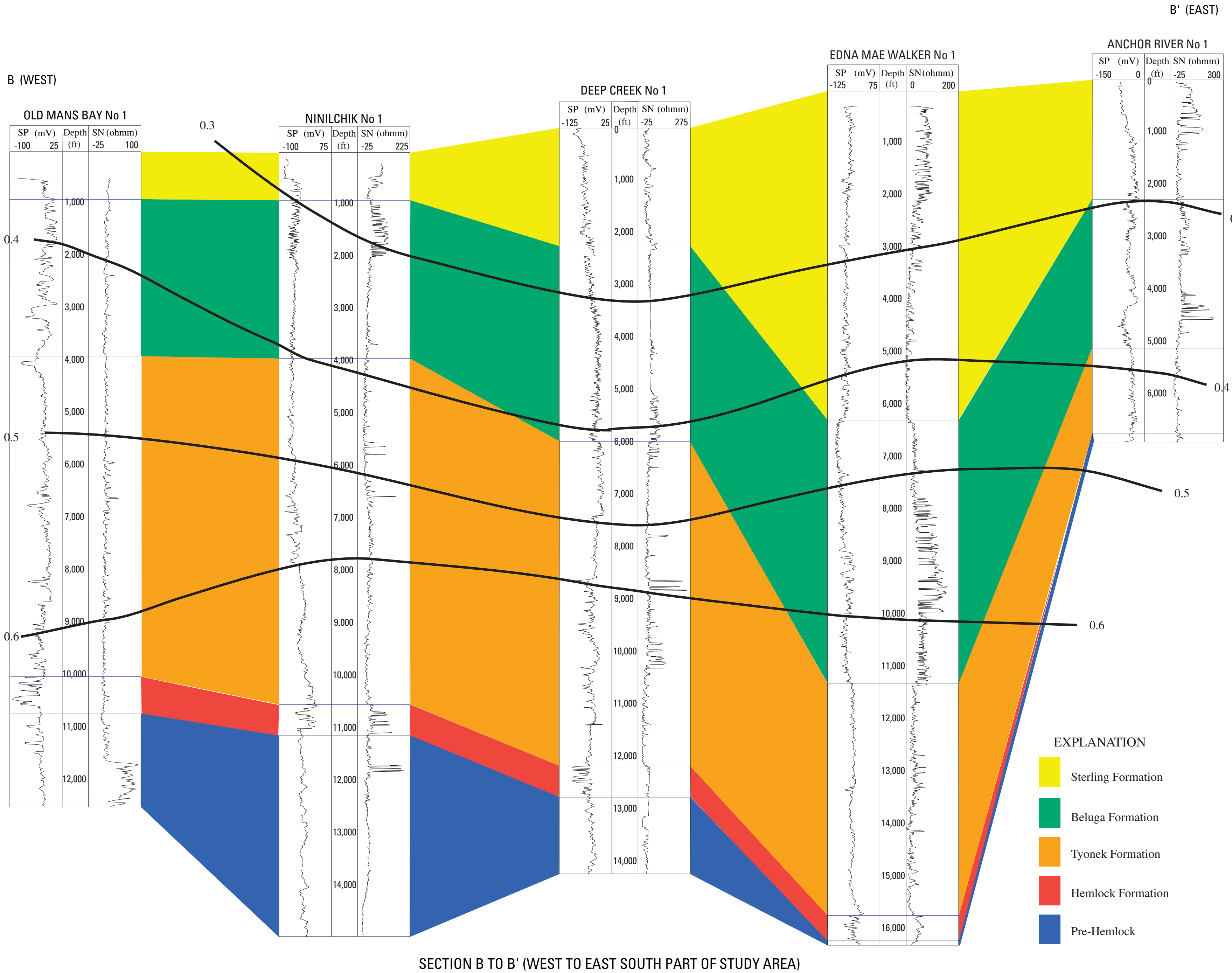


Figure 118. Stratigraphic cross section of the Kenai Group in the onshore Cook Inlet Basin with superimposed vitrinite reflectance values. See figure 58 for location.

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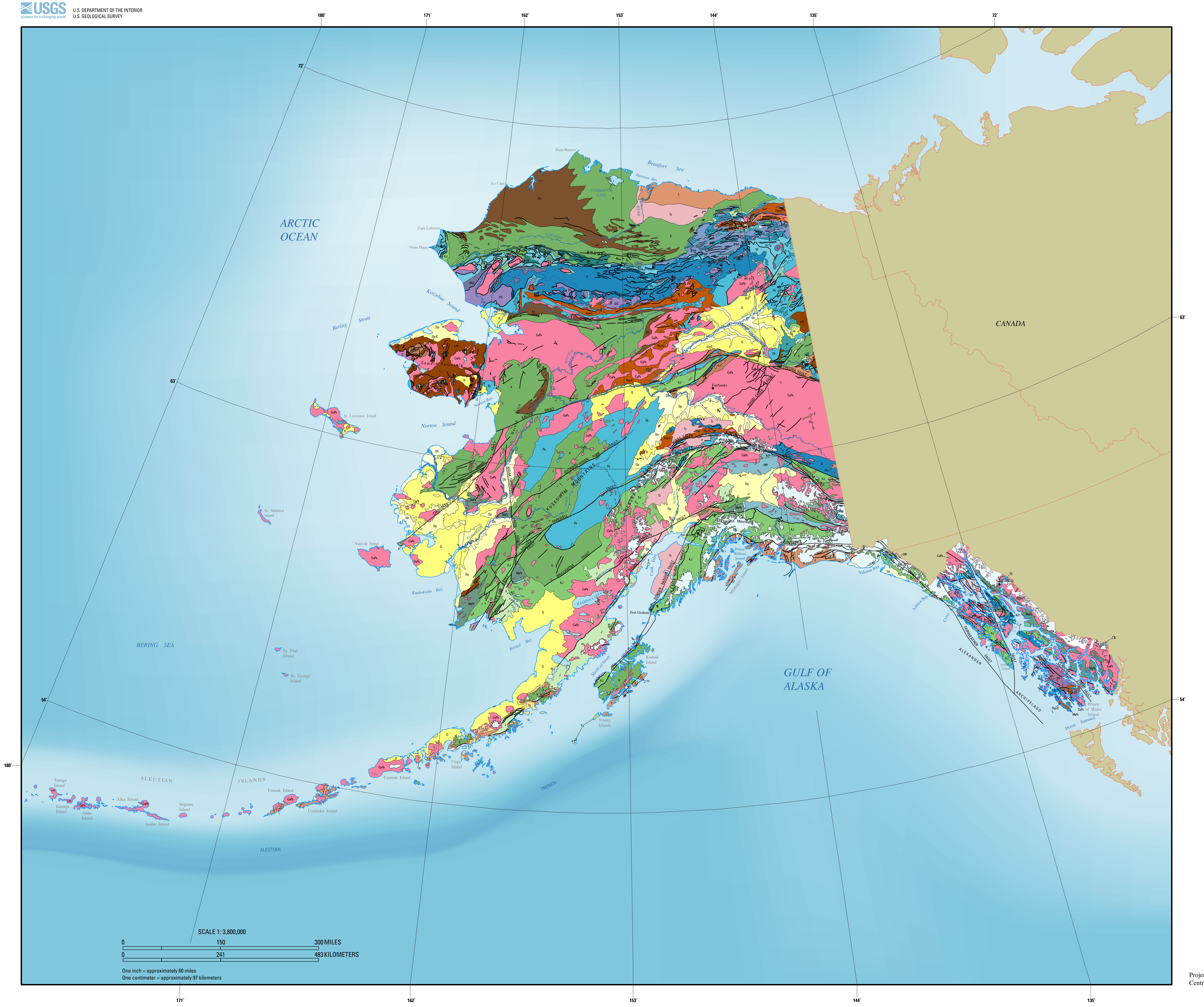
Figure 2. Map showing the coal rank and land ownership of Alaska

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY



Projection: Albers Equal Area
Central meridian: 153° W.

DESCRIPTION OF MAP UNITS

[These geologic unit descriptions are modified from Beikman (1980, Geologic map of Alaska: U.S. Geological Survey Special Map, scale 1:2,500,000, 2 sheets). Several rock units were combined to simplify and reduce the size of the digital files]

STRATIFIED SEDIMENTARY SEQUENCE

Mainly marine. Includes some volcanic rocks. In part metamorphosed

Q **QUATERNARY DEPOSITS**—Alluvial, glacial, lake, eolian, beach, and volcanic deposits. Includes the marine Bootlegger Cove Clay

Qh **HOLOCENE DEPOSITS**—Alluvial, glacial, lake, estuarine, swamp, landslide, floodplain, and beach deposits

Qp **PLEISTOCENE DEPOSITS**—Alluvial, glacial, dune sand, loess, and reworked sand and silt deposits

T **TERTIARY ROCKS**—Sedimentary rocks concealed beneath Quaternary cover on Point Hope and volcanogenic sedimentary rocks and flows, dikes, and sills on the Alaska Peninsula and Umnak Island

UPPER TERTIARY ROCKS—Sandstone, siltstone, shale, mudstone, and conglomerate of Miocene and Pliocene age. Includes upper part of the Sagavanirktok Formation on the Arctic Coastal Plain, and the Yakataga Formation in the Gulf of Alaska area

MIDDLE TERTIARY ROCKS—Siltstone, sandstone, organic shale, and, locally, volcanic rocks. Includes the Poul Creek, Katalla, and Topsy Formations ranging from Oligocene to Miocene age in Gulf of Alaska area

LOWER TERTIARY ROCKS—Interbedded sedimentary, volcanogenic, and volcanic rocks of Paleocene, Eocene, and Oligocene age on the Alaska Peninsula and Aleutian Islands and intensely deformed marine and continental clastic rocks of Paleocene and Eocene age in the Gulf of Alaska area. Includes the Tolstoi and Belkofski Formations of Burk (1965) in the Alaska Peninsula; the Ghost Rocks Formation on Kodiak Island; the Amchitka and Banjo Point Formations on Amchitka Island; the Gunners Cove Formation on Rat Island; the Krugloi Formation on Agattu Island; and the Kulthieth, Kushtaka, and Tokun Formations and clastic rocks of the Orca Group in the Gulf of Alaska area

Tp **PLIOCENE ROCKS**—Sandstone, siltstone, and conglomerate. Includes the Tachilni Formation on the Alaska Peninsula and the Tugidak Formation on Tugidak and Chirikof Islands

Tm **MIOCENE ROCKS**—Sandstone, siltstone, conglomerate, argillite, graywacke, and basaltic rocks. Includes the Bear Lake Formation on the Alaska Peninsula, the Narrow Cape Formation (Oligocene or Miocene) on Kodiak and Sitkinak Islands, and the Chuniksak Formation (Miocene?) on Attu Island

To **OLIGOCENE ROCKS**—Volcanic conglomerate, sandstone, volcanic breccia, shale, and siltstone. As shown, includes the Meshik Formation and Stepovak Formation on the Alaska Peninsula and the Sitkinak Formation on Sitkalidak, Sitkinak, and Chirikof Islands

K **CRETACEOUS ROCKS**—Volcanic graywacke, mudstone, and sandstone with some coal-bearing rocks in the Yukon-Koyukuk province; graywacke and shale of the Kuskokwim Group in the Kuskokwim Mountains; and shelf deposits of sandstone, siltstone, shale, and limestone of (1) the Kennicott, Moonshine Creek, Schulze, Chititu, and MacColl Ridge Formations in the southern Wrangell Mountains; (2) the Matanuska Formation in the Matanuska Valley; and (3) the Kaguyak Formation on the Alaska Peninsula

UPPER CRETACEOUS ROCKS—Shale, sandstone, and conglomerate of the Ninuluk Formation of the Nanushuk Group and the Seabee and Schrader Bluff Formations of the Colville Group in the Arctic 0151 Coastal Plain and Foothills; nonmarine and marine clastic rocks, siltstone, and shale of the Chignik and Hoodoo Formations on the Alaska Peninsula; graded beds of sandstone and slate of the Kodiak Formation on Kodiak and Afgonak Islands; sandstone and mudstone of the Shumagin Formation on Shumagin and Sanak Islands

LOWER CRETACEOUS ROCKS—Graywacke, sandstone, shale, siltstone, and conglomerate of part of the Tiglukpuk Formation of former usage, and the Okpikruak, Fortress Mountain, Torok, and Kukpowruk Formations in the western Arctic Foothills; the Kongakut Formation, Bathtub Graywacke, and Tuktu and Grandstand Formations in the eastern Brooks Range and Arctic Foothills; unnamed graywacke, argillite, conglomerate, and minor limestone southeast of the mouth of the Kuskokwim River; interlayered submarine and subaerial andesitic fragmental volcanic rocks, flows, tuffs, and volcanic clastic rocks of the Chisana Formation north of the Wrangell Mountains; and unnamed graywacke, argillite, and minor andesite on Etolin Island

KJ **CRETACEOUS AND JURASSIC ROCKS**—Argillite, shale, graywacke, quartzite, conglomerate, lava, tuff, and agglomerate almost barren of fossils; probably includes rocks ranging in age from Early Jurassic to Late Cretaceous. In places moderately to highly metamorphosed (amphibolite facies)

CRETACEOUS AND UPPER JURASSIC ROCKS—Graywacke, slate, argillite, minor conglomerate, volcanic detritus, and interbedded mafic volcanic rocks. Includes the Valdez Group and part of the Yakutat Groups and Sitka Graywacke. Mildly metamorphosed, locally to greenschist

LOWER CRETACEOUS AND UPPER JURASSIC ROCKS—Shallow and deep-water clastic deposits (Oxfordian to Barremian) north of the Wrangell Mountains; includes sandstone, arkose, siltstone, and limestone of the Staniukovich Formation (Burk, 1965) and the Herendeen Limestone on the Alaska Peninsula; and slate, graywacke, and conglomerate of the Seymour Canal Formation on Admiralty and Kupreanof Islands

LOWER CRETACEOUS AND UPPER JURASSIC(?) ROCKS—Melange of flysch, greenstone, limestone, chert, granodiorite, glaucophane-bearing greenschist, and layered gabbro and serpentinite. Melange consists of Upper Jurassic(?) and Lower Cretaceous pelitic matrix enclosing blocks several kilometers in dimension of Permian to Lower Jurassic rocks. Includes the Uyak Formation, McHugh Complex, melange within the Yakutat Group, and the Waterfall Greenstone and Khaz Formation of the Kelp Bay Group

J **JURASSIC ROCKS**—Shale, siltstone, and sandstone. Includes the Kingak Shale along the northern front of the Brooks Range, the Glenn Shale (which includes rocks of Triassic and Cretaceous age) in the east-central part of the State, the Nizina Mountain Formation and Kotsina Conglomerate along the southern Wrangell Mountains, and unnamed slaty detrital rocks on Gravina and Annette Islands

UPPER JURASSIC ROCKS—Sandstone, siltstone, shale, and conglomerate on the Alaska Peninsula, Cook Inlet area, and southern flank of the Talkeetna Mountains. Includes the Chinitna and Naknek Formations

MIDDLE JURASSIC ROCKS—Argillite, graywacke, and conglomerate southeast of the Kuskokwim River and sandstone, shale, siltstone, and conglomerate on the Alaska Peninsula and Cook Inlet area where it includes the Kialagvik and Shelik Formations and Tuxedni Group

LOWER JURASSIC ROCKS—Sandstone and argillite interbedded with volcanic flows and pyroclastic rocks of the Talkeetna Formation in the Cook Inlet area and southern Talkeetna Mountains

J₮ **JURASSIC AND (OR) TRIASSIC ROCKS**—Chert and argillite north of the Porcupine River; limestone with minor dolomite, shale, and chert of the Chitistone Limestone, Nizina Limestone, McCarthy Formation, and Lubbe Creek Formation along the southern Wrangell Mountains; and hornfels and phyllite of the Hazelton(?) Group in southeast Alaska

₮ **TRIASSIC ROCKS**—Shale, chert, and limestone of the Shublik Formation and quartzitic sandstone of the Karen Creek Sandstone on the north flank of the Brooks Range

UPPER TRIASSIC ROCKS—Limestone, shale, and chert of the Kamishak Formation in the Cook Inlet area; a shelf facies of limestone, tuff, tuffaceous conglomerate and breccias at the southern tip of the Kenai Peninsula (west of the Border Range's fault) and equivalent rocks on Shuyak, Afognak, and Kodiak Islands; a deep-water flysch and melange facies of chert, pillow basalt, and associated graywacke, argillite, and minor ultramafic rocks (east of the Border Ranges fault) on the southern Kenai Peninsula; and chert, limestone, sandstone, and greenstone of the (1) Whitestripe Marble and Pinnacle Peak Phyllite (both Triassic?) on Chichagof and Baranof Islands, (2) Hyd Group on Admiralty Island and Keku Straits area, and (3) Nehenta and Chapin Peak Formations on Gravina Island

₮P **TRIASSIC AND PERMIAN ROCKS**—Sandstone, siltstone, and shale of the Sadlerochit Group on the north flank of the Brooks Range; mafic volcanic rocks, red beds, limestone, and calcareous argillite in the Chulitna River area; argillite, limestone, siltstone, conglomerate, and abundant gabbroic sills in the east-central Alaska Range where it includes the upper part of the Mankomen Group; and schist, graywacke, slate, conglomerate, phyllite, and andesite flows and tuffs on Admiralty Island where it includes the Barlow Cove Formation

JP **JURASSIC, TRIASSIC, AND PERMIAN ROCKS**—Shale, siltstone, chert, and graywacke in the Brooks Range. Includes upper part of the Nuka Formation and the Siksikpuk and Shublik Formations

MzPz **MESOZOIC AND PALEOZOIC ROCKS**—Sandstone, shale, chert, dolomite, and conglomerate, in a discordant rock sequence of unknown provenance that includes rocks of Mississippian, Triassic, Jurassic, and Cretaceous age in the western Brooks Range (includes Nuka Formation); Lower Jurassic, Pennsylvanian, and Permian rocks, in part covered by Tertiary sedimentary rocks and intruded by granitic rocks of Tertiary age, in north-central Chugach Mountains; and slate, quartzite, schist, and phyllite with interlayered beds of marble, layered gneiss, and amphibolite of Ordovician to Jurassic or Cretaceous age along the west flank of the Coast Mountains

P **PERMIAN ROCKS**—Chert, shale, and siltstone of the Siksikpuk and Echooka Formations in the central Arctic Foothills and volcanic argillite and graywacke with local chert, pillow flows, limestone, and dolomite of the Cannery, Pybus, and Halleck Formations on Admiralty, Kuiu, and Kupreanof Islands

PIP **PERMIAN AND PENNSYLVANIAN ROCKS**—Basaltic to andesitic lavas and derivative volcaniclastic rocks, tuffs, minor gabbro, and local shallow-water sedimentary rocks metamorphosed to greenschist facies and, locally, amphibolite facies of unnamed phyllite, slate, schist, greenschist, amphibolite, gneiss, and migmatite in St. Elias Mountains

IP **PENNSYLVANIAN ROCKS**—Siltstone, sandstone, and limestone of the Klawak Formation and Ladrones Limestone on Prince of Wales Island

IPM **PENNSYLVANIAN AND MISSISSIPPIAN ROCKS**—Limestone, conglomerate, shale, dolomite, and chert of the Kekiktuk Conglomerate and Kayak Shale (both of Mississippian age) of the Endicott Group and the Alapah and Wahoo Limestones of the Lisburne Group

M **MISSISSIPPIAN ROCKS**—Conglomerate, shale, limestone with subordinate chert, and dolomite of the Kekiktuk Conglomerate and Kayak Shale of the Endicott Group and the Utukok Formation and Wachsmuth and Alapah Limestones of the Lisburne Group on the northern flank of the Brooks Range; and limestone, shale, and interbedded chert of the Iyoukeen Formation on Chichagof Island and Peratrovich Formation on Prince of Wales Island

JM **JURASSIC TO MISSISSIPPIAN ROCKS**—Unnamed slate and quartzite northwest of Porcupine River and the Lisburne and Sadlerochit Groups and Kingak Shale at northeast front of Brooks Range

₮D **TRIASSIC TO DEVONIAN ROCKS**—Radiolarian chert, slate, and phyllite

Pz **PALEOZOIC ROCKS**—Limestone, marble, dolomite, and chert on Seward Peninsula and St. Lawrence Island; limestone, slate, and conglomerate in central Alaska Range; argillite and graywacke slightly metamorphosed west of Chulitna River; flysch, conglomerate, limestone, and pillow basalt southwest of Mount McKinley; marble, in places containing tremolite, in Wrangell Mountains where it includes parts of a Devonian section designated the Kaskawulsh Group in the Yukon Territory (Canada); and sedimentary, metasedimentary, and metavolcanic rocks in southeastern Alaska

UPPER PALEOZOIC ROCKS—Argillite, chert, shale, limestone, and siltstone. Greenstone, limestone, shale, and graywacke rocks, schist, gneiss, and undifferentiated metamorphic rocks east of Juneau

MD **MISSISSIPPIAN AND (OR) DEVONIAN ROCKS**—Sandstone, graywacke, quartzite, and conglomerate. Includes the Noatak Sandstone in western Brooks Range and the Kekiktuk and Kanayut Conglomerates in eastern Brooks Range

D **DEVONIAN ROCKS**—Phyllite, hornfels, graywacke, and sandstone on the Seward Peninsula, pyroclastic rocks and ash flows interbedded with sedimentary rocks metamorphosed to schist and gneiss on north-central flank of Alaska Range; limestone east of Kuskokwim Bay; clastic rocks and limestone of the Kennel Creek Limestone (which may also include Silurian rocks) and Cedar Cove Formation on Chichagof Island; schist, phyllite, marble, and amphibolite of the Retreat Group and Gambier Bay Formation on Admiralty and Kupreanof Islands and equivalent rocks to the north and south; and limestone, shale, graywacke, conglomerate, and basaltic rocks of the St. Joseph Island Volcanics (Devonian?), Wadleigh Limestone, and Port Refugio Formation on Prince of Wales Island

UPPER DEVONIAN ROCKS—Shale, sandstone, chert, conglomerate, and quartzite in eastern and central Brooks Range and limestone and dolomite in western Brooks Range. Includes the Hunt Fork Shale, Kanayut Conglomerate, Kugururok Formation, and Eli Limestone (Middle and Upper Devonian)

UPPER AND (OR) MIDDLE DEVONIAN ROCKS—Conglomerate, graywacke, phyllite, shale, sandstone, siltstone, and limestone. Includes the Nasook Limestone in Shublik Mountains

DS **DEVONIAN AND SILURIAN ROCKS**—Limestone, dolomite, marble, and shale of the Katakturuk Dolomite and Skajit Limestone in Brooks Range and the Karheen Formation in Prince of Wales Island

S **SILURIAN ROCKS**—Graywacke, shale, siltstone, limestone, sandstone, and argillite. Includes crinoidal limestone, conglomerate, sandstone, graywacke, red beds, and volcanic rocks of the Bendo Formation and Willoughby Limestone in the Glacier Bay area; the Point Augusta Formation on Chichagof Island; and the Bay of Pillars Formation on Admiralty, Kuiu, and Prince of Wales Islands; and the Kuiu Limestone and Heceta Limestone on Prince of Wales Island

O **ORDOVICIAN ROCKS**—Limestone and shale on Seward Peninsula; argillite, chert and limestone of the Hood Bay Formation on Admiralty Island

SO **SILURIAN AND ORDOVICIAN ROCKS**—Graywacke, shale, limestone, sandstone, siltstone, tuff, lava, and local limestone of the Descon Formation on Prince of Wales Island

€ **CAMBRIAN ROCKS**—Siltstone, sandstone, and phyllite

Op€ **ORDOVICIAN, CAMBRIAN, AND PRECAMBRIAN ROCKS**—Phyllite, sandstone, siltstone, limestone, chert, and quartzite

Pzp€ **PALEOZOIC AND (OR) PRECAMBRIAN ROCKS**—Sandstone, limestone, shale, chert, phyllite, argillite, and quartzite of the Neruokpuk Formation in the northeast Brooks Range; quartz mica schist, mafic greenschist, calcareous schist, chloritic schist, phyllite, and quartzite along south flank of Brooks Range and southwest through Kokrine-Hodzana Highlands; slate and quartzite of the Birch Creek Schist of former usage in Yukon-Tanana Highlands; highly metamorphosed clastic rocks including the Keevy Peak Formation in north flank of Alaska Range; and volcanogenic greenschist with intermittent marble in Prince of Wales, Long, and Dall Islands, where it includes the Wales Group and possibly the Descon Formation

LOWER PALEOZOIC ROCKS—Rocks of Cambrian through Devonian age; in places metamorphosed to greenschist and amphibolite facies. Sedimentary rocks include limestone, dolomite, argillite, chert, and graywacke; metasedimentary rocks include schist, quartzite, slate, greenstone, carbonate rocks, and phyllite. Includes the Holitna Group in Kuskokwim Mountains; the Tolovana Group along Kuskokwim River; rocks formerly included in the Birch Creek Schist in Yukon-Tanana Upland; and unmetamorphosed rocks of the Funnel Creek, Adams, Hillard, Road River, McCann Hill, and Hillard Formations and Puppets Formation on Gravina and Annette Islands

P **LATE PROTEROZOIC ROCKS**—Schist, phyllite, graywacke, quartz-schist, and graphitic schist of slate of the York region on Seward Peninsula; schist, gneiss, and small amounts of amphibolite and marble east of Kuskokwim Bay; quartz wacke, semischist, phyllite, and argillite of the Neruokpuk Formation in northeastern Brooks Range; phyllite, slate, and siltstone east of Fort Yukon; and limestone, dolomite, sandstone, shale, and basalt of the Tindir Group north of Tintina fault

YOUNGER LATE PROTEROZOIC ROCKS—Schistose, argillaceous, dolomitic limestone and tactite on Seward Peninsula

OLDER LATE PROTEROZOIC ROCKS—Schist, gneiss, and migmatitic and metamorphic rocks, including rocks equivalent to slate of the York region, in the Kigluaik and Bendeleben Mountains on the Seward Peninsula

CONTINENTAL DEPOSITS

Tc **TERTIARY CONTINENTAL DEPOSITS**—Sandstone, siltstone, claystone, shale, conglomerate, and coal beds. Include the Sagavanirktok Formation in the Arctic Coastal Plain; the Gakona Formation in east-central Alaska Range; the Healy Creek, Suntrana, Sanctuary, Lignite Creek, and Grubstake Formations and Nenana Gravel and related unnamed rocks in west-central Alaska Range; the Chickaloon, Wishbone, and Tsadaka Formations in the Matanuska Valley; and the Kenai Group (Hemlock, Tyonek, Beluga, and Sterling Formations) in Cook Inlet area. It also includes the Kootznahoo Formation on Admiralty, Kuiu, Kupreanof and Zarembo Islands; the Frederika Formation in Wrangell Mountains; and the Cantwell Formation in central Alaska Range. Rocks range in age from Paleocene through Pliocene

TKc **TERTIARY AND CRETACEOUS CONTINENTAL DEPOSITS**—Conglomerate, breccia, sandstone, arkose, mudstone, shale, tuffaceous rocks, and lignite beds. Includes the Arkose Ridge Formation (Cretaceous?) in Matanuska Valley

Kc **CRETACEOUS CONTINENTAL DEPOSITS**—Sandstone and conglomerate, siltstone, claystone, shale, coal, coaly shale, ironstone, and bentonite beds. Includes the Corwin Formation (Lower and Upper Cretaceous) of Nanusuk Group and Killik Tongue of Chandler Formation of Nanusuk Group, the Niakogon Tongue of Chandler Formation of the Nanushuk Group, and the Prince Creek Formation of Colville Group on the Arctic Coastal Plain and in the Yukon-Koykuk Basin, and margins of the basin

CENOZOIC AND LATE PROTEROZOIC ROCKS

CzPz **UNDIFFERENTIATED METAMORPHIC, IGNEOUS, ULTRAMAFIC, AND VOLCANIC ROCKS**

METAMORPHIC AND IGNEOUS ROCKS—Small masses of metamorphosed sedimentary, volcanic, and igneous rocks largely of pre-Cretaceous age scattered throughout the Aleutian Range batholith and amphibolite facies schist along north side of Matanuska Valley. Includes intercalated blueschist, quartz mica schist, greenschist with subordinate amphibolite, and marble; metachert at southern tip of Kenai Peninsula and on Afognak Island; and metasedimentary, metaplutonic, and metavolcanic rocks near Anchorage and along south side of Matanuska Valley. Also includes hornfels, schist, amphibolite, minor marble, and undivided metamorphic rocks north of Icy Strait in southeastern Alaska; gneiss, schist, phyllite, and undifferentiated metasedimentary and metaigneous rocks in the Yukon-Tanana Upland; and metasedimentary and metaigneous rocks, including schist and gneiss of many different compositions, primarily of the greenschist and amphibolite facies, in the Yukon-Tanana Upland (formerly included in the Birch Creek Schist). Rocks range in age from Mesozoic through Paleozoic

ULTRAMAFIC AND IGNEOUS ROCKS—Granite to granodiorite, gabbro, and syenite to diorite. Rocks range in age from Cenozoic through Precambrian

VOLCANIC ROCKS—Trachyte to andesite, basalt, and rhyolite to dacite. Rocks range in age from Cenozoic to Paleozoic

EXPLANATION

Coastline

Contact

Fault—Dotted where concealed

Ice

Water

CORRELATION OF MAP UNITS

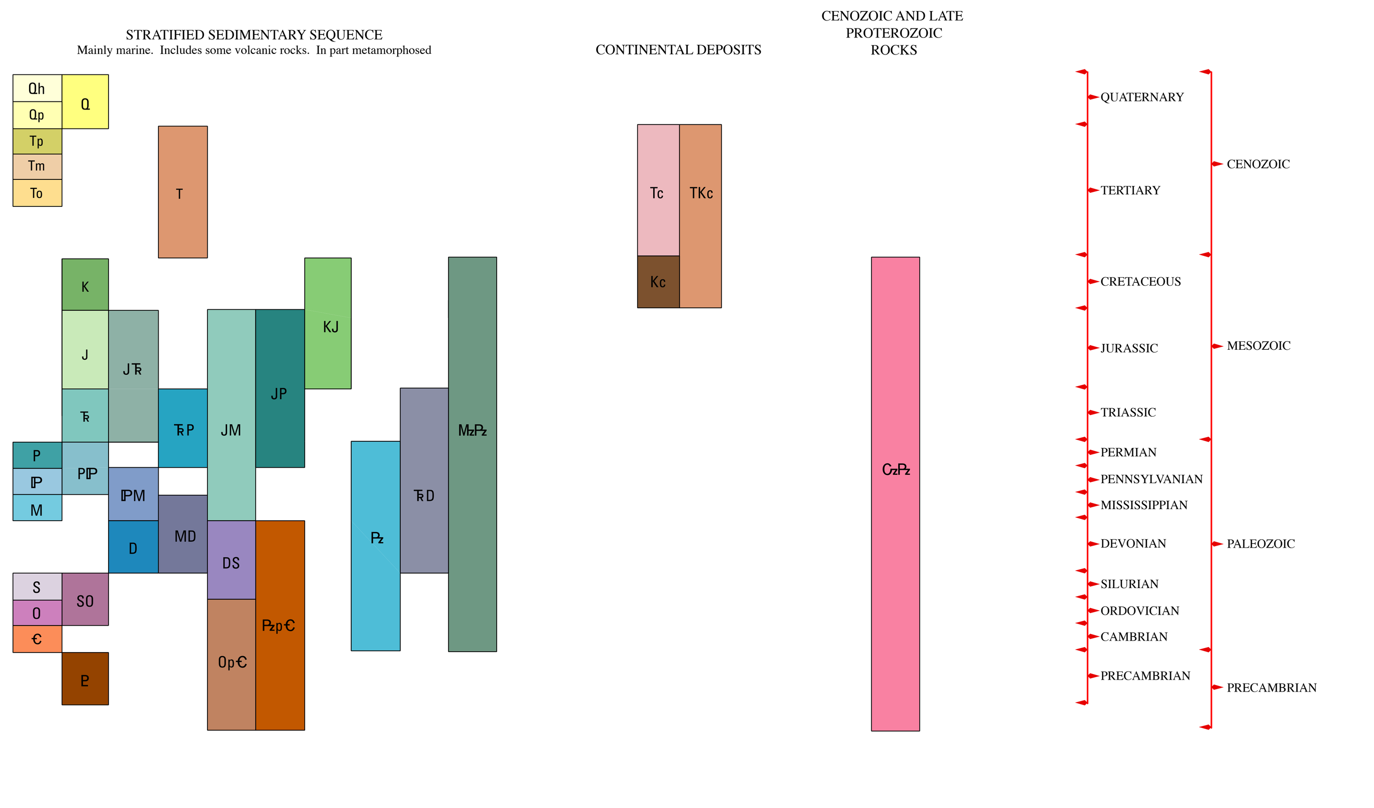


Figure 3. Map showing the geology and structure of Alaska. Modified from S.J. Moll, Scott Bie, Devon Peterson, D.C. Pray, F.H. Willson, J.W. Schmidt, J.R. Riehle, and T.P. Miller (unpublished data, 1997, U.S. Geological Survey, Reston, Virginia). After Beikman (1980).

This map shows generalized geology in Alaska and therefore a number of features that are listed in the map unit descriptions are not indicated on the map due to space limitations. Also the data that are on this CD-Rom do not duplicate this graphic, only the generalized geology and faults. The other data that are represented on this graphic (rivers, coastline, and cities) are available from the Department of Natural Resources of Alaska on the web at http://www.asgdc.state.ak.us/homehtml/pubaccess.html.

Figure 4. Map showing the physiographic regions of Alaska. Modified from Plafker and Berg (1994).