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Chapter 31

Coal in Alaska

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INTRODUCTION

This chapter is an updated synthesis of information on an enormous, largely untapped natural resource—Alaskan coal. Herein we discuss the major fields as well as the smaller occurrences in the state, their geologic setting, depositional history, and, where known, the rank and chemistry of the coal and the size of the resources. Physiographic terminology is from Wahrhaftig (1965; this volume, Plate 2). Major basins of Alaska are delineated and discussed by Kirschner (this volume, Chapter 14 and Plate 7). Geographic or physiographic features referred to in this chapter that are not shown on the accompanying figures may be found in Plate 2 of this volume; geologic features not shown on the figures may be found in Plate 1 (Beikman, this volume).

Coal in Alaska was used by Inuit and Indian cultures before the advent of European explorers. The Beechy expedition of 1826–1827 reported the occurrence of coal in Alaska (Huish, 1836), and whaling ships 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, operated by the Russians at Port Graham on the southwest tip of the Kenai Peninsula, opened in 1855 and closed in 1867 (Martin, 1915) after the United States took possession of the Alaska Territory. Many mines were active after 1931, when Congress authorized the building of the Alaska Railroad, which created a market and transportation necessary for large-scale coal production. The first coal lease sale in the state in more than 17 years was held in 1983 in conjunction with an oil lease sale. In 1984, export of Alaskan coal began with shipments to South Korea. Other developments include 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, which hauls coal to Seward. In 1985, coal production increased by 60% over the previous year, with a gross value on production of 1.27×10^6 metric tons valued at \$39.7 million (Bundtzen and others, 1986). An estimate of total coal in place is 9.4×10^{12} metric tons (Fig. 1), or about 50% of total United States resources.

Alaska's coal resources are enormous. Though little exploited, they will probably be a major component of industrial energy and hydrocarbon raw materials, at least for the nations bordering the Pacific, when the world's more easily won resources of oil and natural gas are depleted.

CONDITIONS OF COAL ACCUMULATION

Coal is defined as a "readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits" (Schopf, 1956). The terrestrial vegetal remains that became coal accumulated under mainly anoxic conditions beneath stagnant or slowly moving swamp or marsh waters. The acidity of the water ultimately had to be high enough to kill off bacteria and fungi that would otherwise have digested and completely oxidized the peat.

Swamp peat appears to accumulate at rates of 0.1–2.3 m per thousand years (McCabe, 1984), and the most reliable estimates of the compaction ratio from peat to coal range from 7:1 to 20:1 (Ryer and Langer, 1980); thus 1 m of coal may have taken from 3,000 to 200,000 years to accumulate. Widespread, long-persisting swamps on extensive plains close to a stable base level (commonly sea level) were the sites of accumulation of the most extensive beds of coal.

The swamp vegetation has to be dense enough at the margins of the swamp to still any floodwater and filter out all inorganic sediment. It has been assumed that most deltaic or coastal-plain swamps do this; however, according to McCabe (1984), only modern swamp peats with convex surfaces where the water is introduced solely as precipitation are sufficiently low

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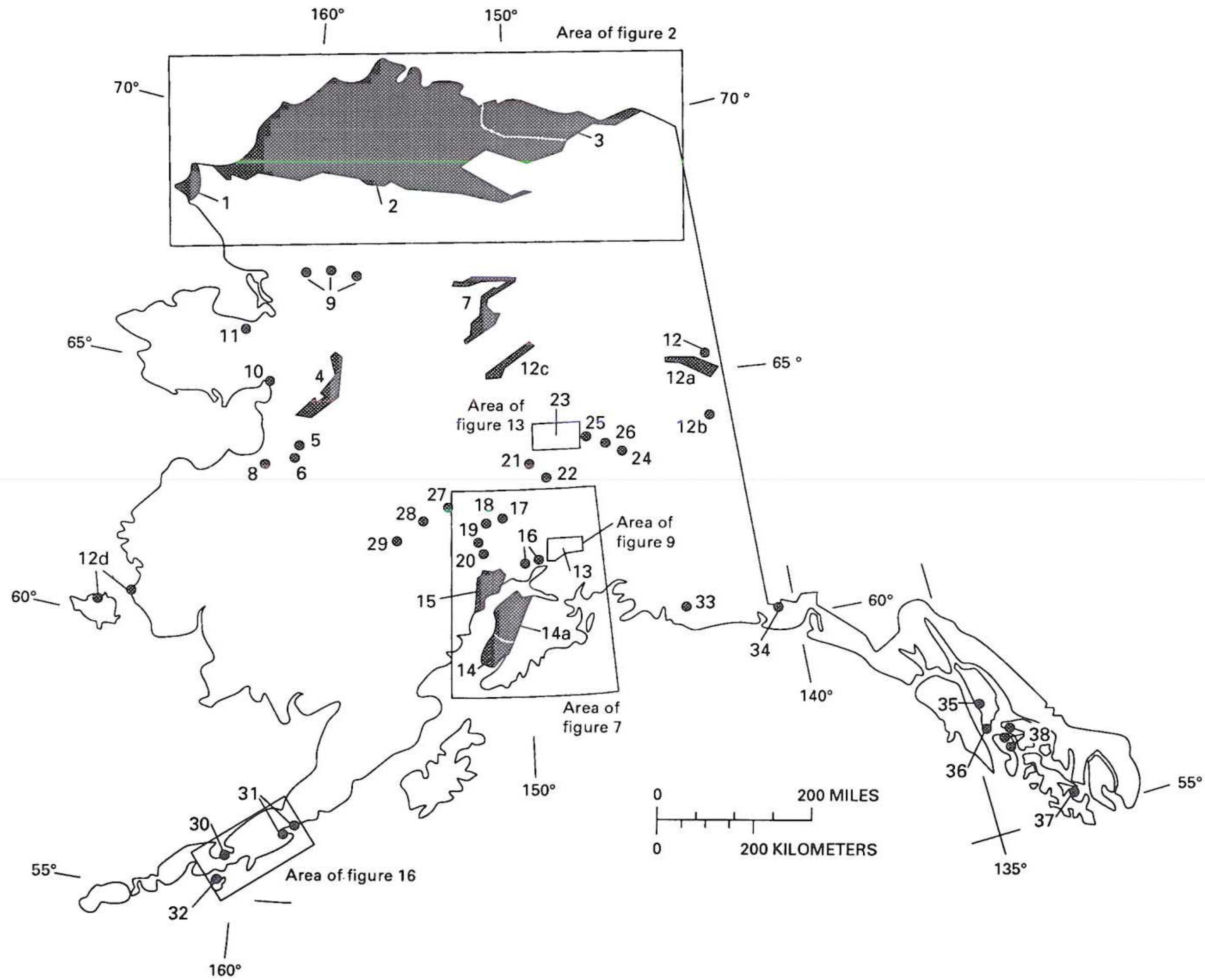


Figure 1. Coal occurrences and coal fields in Alaska. Compiled and modified from Merritt and Hawley (1986); Barnes (1967a, 1967b); Brew and others (1984); Magoon and others (1976); Plafker (1987). Base from Merritt and Hawley (1986). 1: Cape Lisburne field. 2: Cretaceous bituminous coal fields of the North Slope. 3: Cretaceous and Tertiary subbituminous coal and lignite fields of the North Slope. 4: Nulato field. 5: Williams Mine. 6: Coal Mine No. 1 (Blackburn). 7: Tramway Bar. 8: Anvik River coal occurrence. 9: Kobuk River coal occurrence. 10: Koyuk coal occurrence. 11: Chicago Creek coal deposit. 12: Nation River coal occurrence. 12a: Eagle-Circle district. 12b: Chicken district. 12c: Rampart district. 12d: Nunivak Island and Nelson Island occurrences. 13: Matanuska coal field. 14: Homer district, Kenai coal field. 14a: Kenai coal field. 15: Tyonek-Beluga coal field. 16: Little Susitna district. 17: Peters Hills district. 18: Fairview Mountain district. 19: Johnson Creek district. 20: Canyon Creek district. 21: Costello Creek coal field. 22: Broad Pass coal field. 23: Nenana coal field. 24: Jarvis Creek coal field. 25: Dry Creek– Newman Creek coal occurrence. 26: Delta Creek–Ptarmigan Creek coal occurrence. 27: Little Tonzona River coal occurrence. 28: Windy Fork coal occurrence. 29: Cheeneetnuk coal occurrence. 30: Herendeen Bay coal field. 31: Chignik coal field. 32: Unga Island coal occurrence. 33: Bering River coal field. 34: Samovar Hills coal occurrence. 35: Kootznahoo coal field. 36: Murder Cove coal occurrence. 37: Kasaan Bay coal occurrence. 38: Port Camden coal occurrence.

in ash to be precursors of commercial coal. Such peats have been found in deltaic and fluviatile environments in Borneo, Malaysia, and southwestern British Columbia (McCabe, 1984; Styan and Bustin, 1984).

Preservation of the swamp peat resulted from either (1) more rapid subsidence than peat accumulation, resulting in flooding of the swamp into a lake or marine embayment where shale or limestone would accumulate to cover the coal, or (2) burial by sheets of sand and gravel, such as crevasse splays or overbank and levee deposits, in migrating or avulsed channels.

Therefore, the geologic environments conducive to coal accumulation include delta plains, broad coastal plains with gentle slopes, and wide alluvial plains where swamps and flood basins can exist alongside naturally leveed rivers. Preservation of peat accumulations and their compaction and metamorphism into coal require input of sediment. A marine invasion, which brings peat accumulation to a stop, commonly leads to a roofrock of marine shale or limestone; in this setting, the sulfur content of the coal is likely to be high (Gluskoter and Simon, 1968; Gluskoter and Hopkins, 1970). Low-sulfur coals are preserved when burial is by crevasse splay or channel sand deposited by shifting fluvial or estuarine channels. Thus, the accumulation of thick sequences of sandstone and shale including low-sulfur coals, such as those that characterize the coal deposits in most of Alaska, require an enormous input of clastic sediment and a subsiding basin. Such large volumes of sediment may be derived from drainage of a huge tributary area, such as the Mississippi River system, or from streams that drain a tectonically active and mountainous hinterland, as has been characteristic of many Alaskan terranes since at least Early Cretaceous time.

CONSTITUTION AND METAMORPHISM OF COAL

The organic constituents of coal, comparable to minerals in an inorganic rock, are known as macerals. Three classes of macerals are recognized: (1) vitrinite, initially high in both oxygen and hydrogen and derived mainly from the cellulose and lignin of wood, leaves, roots, and their decay products; (2) exinite, high in hydrocarbons (fats and oils) and derived mainly from cuticles, resin, spores, and algae; and (3) inertinite, initially relatively high in carbon, the product of oxidation of organic matter (for example, fusinite, which is thought to be fossil charcoal) or originally sclerotinous tissue of fungi. Huminite is the maceral class in lignite and subbituminous coal equivalent to vitrinite, and liptinite is the maceral class equivalent to exinite (Stach, 1968; Neavel, 1981; Stach and others, 1982; McCabe, 1984). Macerals are identified by microscopic study of polished surfaces in reflected light on the basis of their form and reflectance—vitrinites have medium reflectance and appear gray, exinites have low reflectance and appear black, and inertinites have high reflectance. Many of the economic properties of coals depend on the proportions of macerals, and the classification into types is based on these proportions. Petrographic study of Alaskan coals is still in its early stages (Rao and Wolff, 1981; R. D. Merritt, 1986, written commun.).

The rank of a coal is a measure of the metamorphism it has undergone since the initiation of burial. The classification of coal by rank is listed in Table 1. Metamorphism of coal is due primarily to temperature, time, and, probably less significant, pressure (Teichmuller and Teichmuller, 1968). Temperature is that of Earth's geothermal gradient and increases with depth of burial; it probably has not exceeded 150–200 °C for most coals. Time plays an important role in determining coal rank. In general, coal buried for 50 m.y. at 50 °C will be subbituminous, whereas coal buried for 200 m.y. at 50 °C would be low-volatile bituminous. Tertiary coals are generally subbituminous, and Carboniferous coals are usually bituminous. This broad generalization is invalid in many geologic settings in Alaska at ancient plate margins, where heat produced by intrusions or by increased pressure brought on by tectonic activity can elevate coal rank, as in the Bering River field.

The grade of coal is its suitability for various economic uses, and it varies with the use. Grade depends on both type and rank, as well as on such deleterious factors as moisture content, ash content, and content of such undesirable elements as sulfur.

Terminology used in this report for coal classification and

TABLE 1. RANK CLASSIFICATION OF COAL*

Rank		Basis for classification†,§	Approximate carbon content (wt %)**
Lignite B	>31% volatile matter§	<3,500 cal/gm	72
Lignite A	>31% volatile matter§	3,500 to 4,600 cal/gm	
Subbituminous C	>31% volatile matter§	4,600 to 5,280 cal/gm	
Subbituminous B	>31% volatile matter§	5,280 to 5,840 cal/gm	76
Subbituminous A	>31% volatile matter§	5,840 to 6,400 cal/gm‡	
High-volatile bituminous C	>31% volatile matter§	6,400 to 7,230 cal/gm	
High-volatile bituminous B	>31% volatile matter§	7,230 to 7,780 cal/gm	80
High-volatile bituminous A	>31% volatile matter§ / >7,780 cal/gm		84
Medium-volatile bituminous	>7,780 cal/gm	22 to 31 wt % volatile matter	90
Low-volatile bituminous	>7,780 cal/gm	14 to 22 wt % volatile matter	
Semianthracite	>7,780 cal/gm	8 to 14 wt % volatile matter	
Anthracite	>7,780 cal/gm	<8 wt % volatile matter	>90

*From Neavel (1981, p. 134).
†cal/gm calculated on moist, ash-free (wt%) basis. Note: Neavel states mineral-free, but with saturated pore-moisture content.
§Volatile matter calculated on dry, mineral-free (wt %) basis.
**Total carbon calculated on dry, ash-free (wt %) basis.
‡Bituminous if agglomerating, subbituminous if nonagglomerating.

reserve estimates, as well as supplementary terms, were defined by Wood and others (1983). Measured (or identified) reserves have the highest degree of geologic assurance; that is, they refer to coal deposits that have been studied in detail and for which there are many field and laboratory data. Indicated reserves have a moderate degree of geologic assurance; they are based on projecting thickness and other geologic data from nearby outcrops, trenches, workings, and drill holes, or from other measured reserves. Demonstrated reserves commonly refer to the sum of coal classified as measured and indicated resources. Inferred resources have a low degree of geologic assurance; estimates in this category are based on inferred continuity beyond measured and indicated reserves, for which there is geologic evidence, and estimates are computed by projection of coal data for a specified distance and depth beyond coal deposits classed as indicated. There are no sample or measurement sites in the area of inferred deposits. Hypothetical (or undiscovered) reserves have a low degree of geologic assurance; for these coal deposits, estimates of rank, thickness, and extent are based not on measurements at the coal site, but on assumed continuity of coal beyond inferred deposits.

Measurements are generally reported here in metric units, except where original measurements were in American units, in which cases the original units are given in parentheses following the metric units.

OCCURRENCE OF COAL IN ALASKA

The bulk of the known coal resources of Alaska are in two coal provinces: a province north of the Brooks Range, of mainly Cretaceous age (the Northern Alaska fields or North Slope province); and a province centered on Cook Inlet, of Tertiary age (the Southern Alaska–Cook Inlet province) (Fig. 1). The North Slope province is in the sedimentary wedge shed northeastward and northward from the Brooks Range during and after the Brookian orogeny, and eastward from now-collapsed highlands on the site of the present Chukchi basin, into a deep trough that lay between the Brooks Range and the Barrow arch. The coal-bearing section includes delta-plain and fluvial sediment that was deposited after the basin was filled to sea level and above, a filling that progressed mainly from west to east. These are the largest coal deposits in Alaska, but owing to their remoteness and formidable logistic and environmental problems inherent in Arctic exploitation, they are not yet of commercial value.

The Southern Alaska–Cook Inlet province is centered on the deep trough in the arc-trench gap between the Aleutian volcanic arc and the Aleutian Trench. Estuarine deposits in the southwestern part of this trough interfinger northeastward with deltaic and fluvial deposits of the lower end of a river system that had tributaries during middle Tertiary time as far north as the Yukon-Tanana Upland. Basins of coal accumulation that straddle these tributaries, such as the Nenana and Jarvis Creek coal fields, are included in this coal province. The Nenana coal field in the Southern Alaska–Cook Inlet province is the most commercially significant deposit in the state, followed by the Cook Inlet fields (a composite of several fields in the Cook Inlet region).

Outside these two large coal provinces, smaller deposits include, from north to south, scattered coal occurrences of Paleozoic and Tertiary age in northern and eastern Alaska, coal deposits of Cretaceous and Tertiary age in the Intermontane Plateaus and the Herendeen Bay, Chignik, and Bering River areas, and the coal deposits of southeastern Alaska (Fig. 1). Other minor coal occurrences in Alaska are shown in Figure 1 (Wood and Bour, 1988), but are not discussed herein.

On the basis of limited data and interpretations of onshore outcrops, onshore to offshore stratigraphic trends, wells located both onshore and offshore, and offshore seismic lines, 13 areas on the continental shelf of Alaska have potential of undiscovered coal. The resource potential of shelf areas in the Chukchi and Beaufort Seas and in the Norton, Bristol Bay, Navarin, and Cook Inlet basins is estimated to total 5.5×10^{12} metric tons (Affolter and Stricker, 1987b). Very meager information exists on these undiscovered offshore deposits, and they are not shown in entirety in Figure 1 (except those beneath the Beaufort Sea and Cook Inlet) or discussed further herein.

NORTH SLOPE PROVINCE

The northern Alaska coal fields are generally situated north of lat 69°N and include about 82,880 km^2 of coal-bearing rocks, both near the surface and in the deep subsurface (Fig. 2). Rocks on the North Slope range in age from Precambrian to Holocene; a representative columnar section is shown in Figure 3. The most important coal-bearing units of the North Slope are the Brookian sequence Nanushuk Group, but coal deposits of lesser quantity and quality occur on the western and eastern North Slope in the Ellesmerian Endicott Group and the Brookian Colville Group (the Fortress Mountain, Torok, and Sagavanirktok Formations) (Collier, 1906; Tailleur, 1965; Barnes, 1967b; Conwell and Triplehorn, 1976; Molenaar and others, 1984). Coal-bearing nonmarine sedimentary facies mainly of Cretaceous and Tertiary age prograde northward and northeastward from the Brooks Range to interfinger with coeval marine units.

As early as 1879, coal for fueling whaling ships was mined from Corwin Bluff on the Chukchi Sea north of Cape Lisburne (Schrader, 1904). Since 1944, various mining companies have carried out preliminary investigations, and during the Barrow fuel shortage in 1943–1944, at least one small mine was in operation on the Meade River (Clark, 1973). Operation of the Meade River coal mine demonstrated the technical feasibility of coal mining under arctic (permafrost) conditions, but no mining activity has taken place as of 1992. The coal deposits at Corwin Bluff were first described by Collier (1906). Later studies showed that coal is widespread in rocks that crop out in the foothills belt (Chapman and Sable, 1960; Moore and others, this volume), and is buried beneath the Arctic coastal plain (Tailleur and Brosgé, 1976; Moore and others, this volume); coal-bearing sequences are also likely to exist beneath the Chukchi Sea (Grantz and others, 1975; Grantz and others, this volume) and the Beaufort Sea (Affolter and Stricker, 1987b).

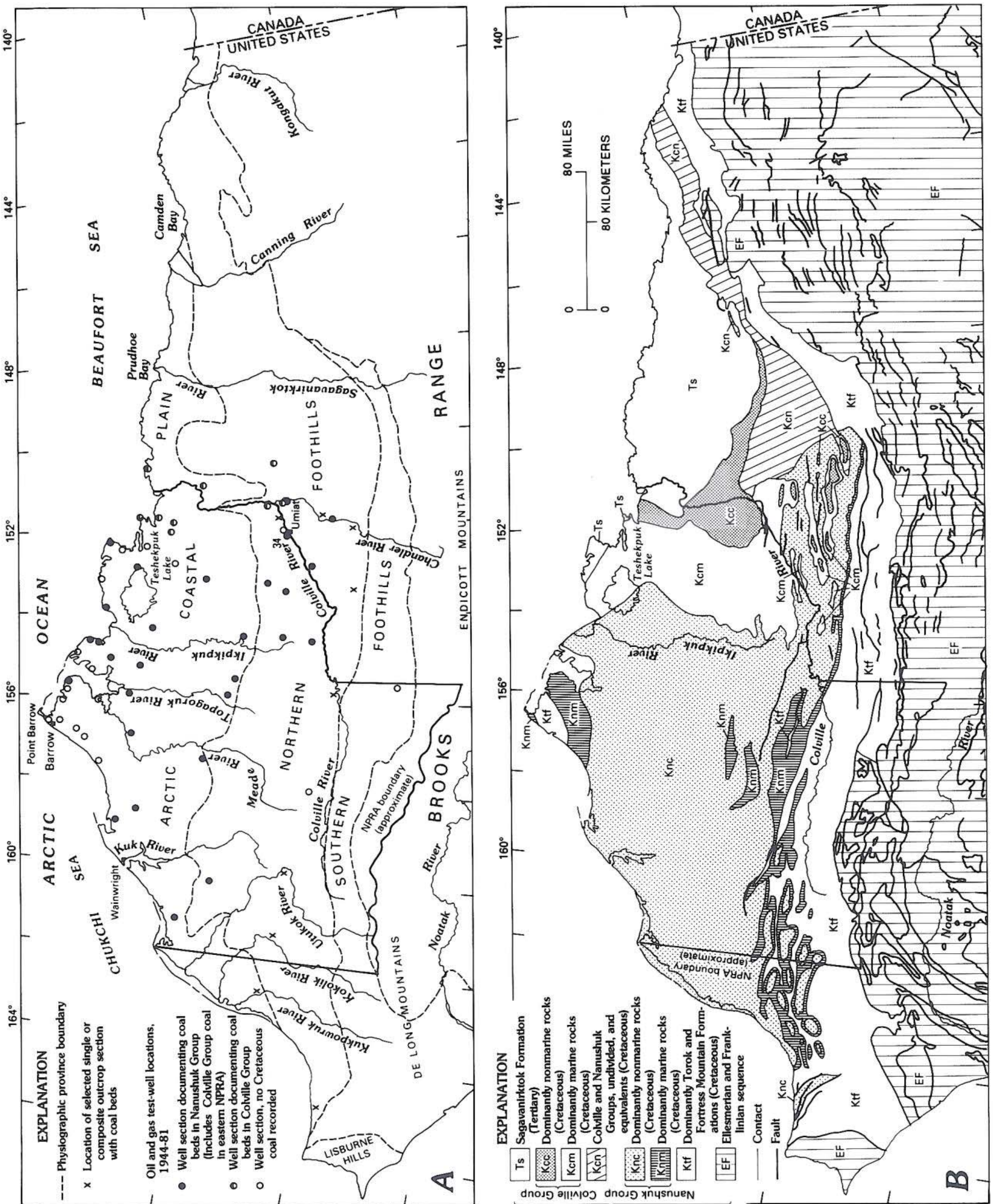


Figure 2. Maps of northern Alaska showing (A) physiographic provinces, National Petroleum Reserve Alaska (NPRA) boundary, and test well locations, and (B) generalized bedrock geology (from Sable and Stricker, 1987). Well location 34 near Umiat in (A) referred to in text.

Geologic units and setting

Details of the stratigraphy, structure, and tectonic setting of the North Slope and contiguous areas are presented by Grantz and others (this volume) and Moore and others (this volume). Three separate tectonic and genetic rock sequences exist on the North Slope (Figs. 3 and 4): the Franklinian, Ellesmerian, and Brookian sequences. The pre–Upper Devonian Franklinian sequence, of no importance for coal, is composed of weakly metamorphosed rocks; it is separated from the overlying Ellesmerian sequence by a regional erosional unconformity. The Upper Devonian to Lower Cretaceous Ellesmerian sequence consists of shallow-marine shelf and basinal clastic rocks, including the coal-bearing Upper Devonian to Lower Permian(?) Endicott

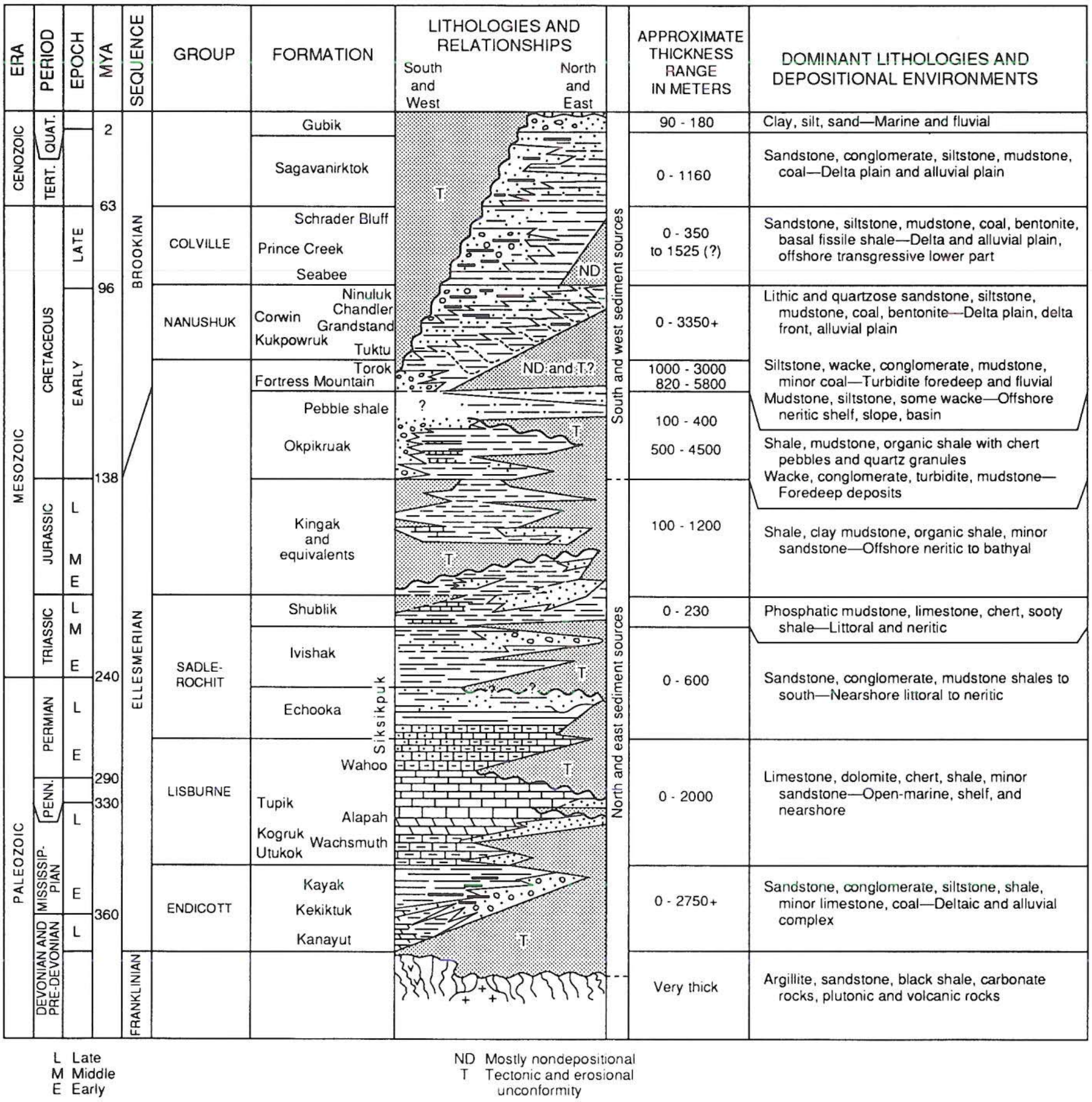


Figure 3. Generalized columnar section of rocks in the National Petroleum Reserve Alaska (from Sable and Stricker, 1987).

Group derived from northerly sources (Fig. 4). In the southern foothills belt, uppermost Ellesmerian rocks are represented by the Neocomian Okpikruak Formation (Fig. 4B), whereas farther north, uppermost Ellesmerian rocks are overlain by the pebble shale unit (Fig. 4B), which may be coeval with part of the Okpikruak Formation (Sable and Stricker, 1987). The lowermost Cretaceous to Quaternary Brookian sequence includes rocks deposited to the north and northeast into a foredeep north of the Brooks Range (Figs. 3 and 4). These rocks were deposited into the Cretaceous Colville basin and the Tertiary Camden basin (Fig. 5; Grantz and Eittreim, 1979). The Brookian sequence is broken by disconformities and unconformities or by nondeposition (Fig. 3; Sable and Stricker, 1987).

The Brooks Range, adjacent to and south of the North Slope

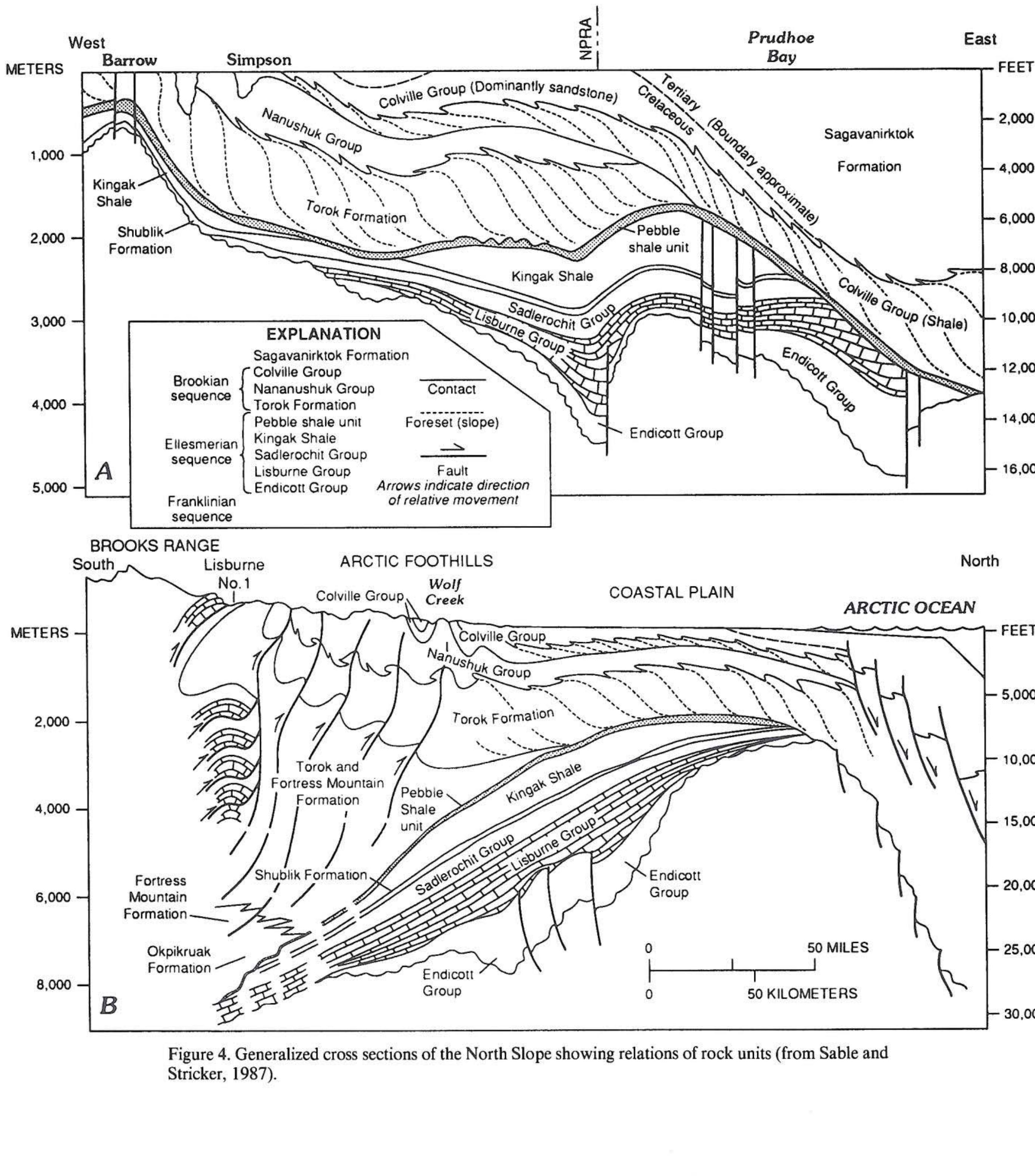


Figure 4. Generalized cross sections of the North Slope showing relations of rock units (from Sable and Stricker, 1987).

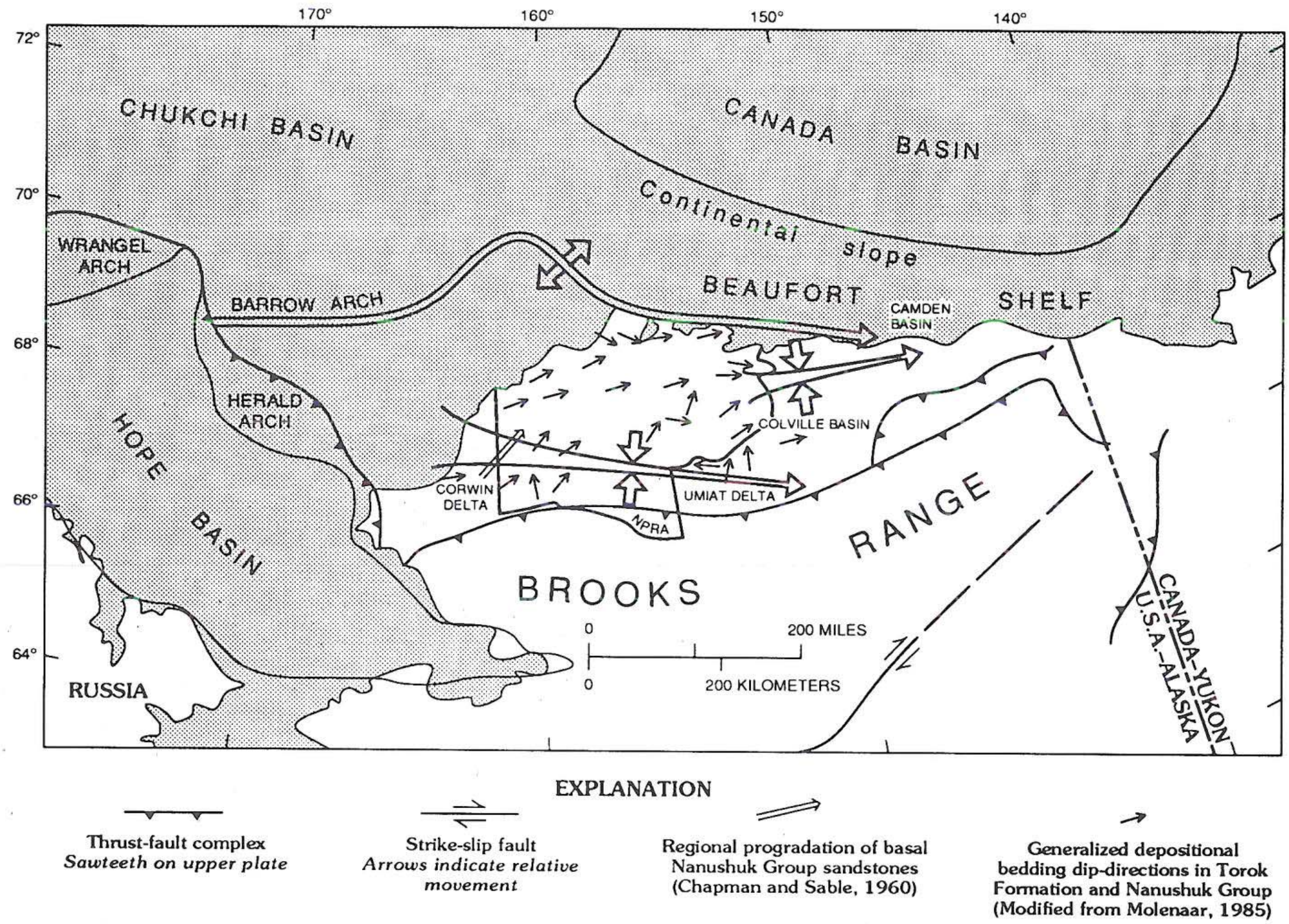


Figure 5. Structural elements of northern Alaska and adjoining regions pertinent to the depositional history of the Brookian sequence (from Sable and Stricker, 1987).

province (Fig. 5), is characterized by multiple, folded, generally east-west–striking and south-dipping, imbricate thrust sheets consisting mostly of Ellesmerian rocks (Mull, 1982; Mayfield and others, 1988; Moore and others, this volume). North of the Brooks Range, in the southern foothills belt of the North Slope province, these deformed strata include complexly overturned folds and thrust-sheet remnants of Ellesmerian and lower Brookian strata (Fig. 5). To the north in the northern foothills belt, Brookian rocks crop out; thrust faults and deformational features in anticlines in this area indicate that decollement thrust sheets also underlie the northern foothills, but die out to the north in the Coastal Plain province (Mayfield and others, 1988; Moore and others, this volume). The amount of deformation and tectonism is reflected in the rank of Nanushuk coal. Coal samples from the folded belt are generally subbituminous to bituminous, whereas those from undisturbed beds in the coastal plain are subbituminous to lignite A (Affolter and Stricker, 1987a; Sable and Stricker, 1987).

Paleozoic (Endicott Group) coal deposits

Paleozoic coal in the Kekiktuk Conglomerate occurs in wells on the Barrow arch east of Point Barrow (Sable and Stricker, 1987). Low-volatile bituminous coal beds, as thick as 3.3 m (11 ft), are exposed at several localities in highly folded and faulted Mississippian rocks beneath strata of the Lisburne Group in the Lisburne Hills between Cape Lisburne and Cape Thompson (Collier, 1906; Tailleur, 1965; Conwell and Triplehorn, 1976).

Endicott Group—the Kekiktuk Conglomerate. Coal beds of the Lower Mississippian Kekiktuk Conglomerate crop out 285 km west of the National Petroleum Reserve in Alaska (NPRA) in the Cape Lisburne region (location [loc.] 1, Fig. 1; Collier, 1906; Tailleur, 1965; Barnes, 1967b) and in the eastern Brooks Range (Sable and Stricker, 1987), and were penetrated in deep test wells (Husky Oil NPR Operations, Inc., 1982–1983). These Ellesmerian deposits, which have been described as anthracite to lower-rank coals, are as much as 1.5 m thick in wells south and southeast of Barrow (Sable and Stricker, 1987). They range in depth from 2,190 to 6,060 m and are of unknown lateral extent. Presumably coeval coal of Mississippian age that crops out at Cape Lisburne is low-volatile bituminous and low in sulfur (Tailleur, 1965). Tailleur reported 13 beds more than 0.7 m thick totaling 21 m in 366 m of section exposed in a seacliff south of Kapaloak Creek. Conwell and Triplehorn (1976) reported one bed 1.8 m thick of semianthracite on the Kukpuk River.

According to Moore and others (1984), this coal-bearing section, which they informally called the Kapaloak sequence, consists of nonmarine stream and levee sedimentary rocks as much as 70 m thick. The coal beds are associated with carbonaceous shale layers having detrital textures at the boundary between the marine and nonmarine units, interpreted to be interdistributary-bay deposits. The sequence is of Early Mississippian age. Moore and others (1984) regarded the Kapaloak sequence as most closely related to the autochthonous Endicott Group of the central Brooks Range and considered that the sequence can be regarded as a distal interfingering of elements of the fluviatile Kekiktuk Conglomerate with elements of the Kayak Shale.

Both the Kapaloak sequence of the Cape Lisburne area and the subsurface occurrences of coal in the Barrow arch appear to lie on the margins (possibly close to the shorelines) of a huge delta plain, defined by the Endicott Group of the Brooks Range, that was apparently fed from the Canadian shield before the counterclockwise rotation of Arctic Alaska away from the Canadian craton during the opening of the western Arctic Ocean (Canada basin) in Mesozoic time (Taylor and others, 1981; Mayfield and others, 1988; Grantz and others, this volume; Moore and others, this volume).

Coals of the Paleozoic Endicott Group are low in ash, with an apparent rank of low-volatile bituminous to semianthracite, and have a low moisture content (Conwell and Triplehorn, 1976) and a sulfur content of 0.5–1.1 wt% (Tailleur, 1965). No offshore trends are apparent for Mississippian coal deposits, and no assessments of offshore coal resources have been made (Affolter and Stricker, 1987b).

Cretaceous and Tertiary (Brookian) coal deposits

Fortress Mountain and Torok Formations. In the Fortress Mountain Formation, 12 beds less than 3 m thick of lignitic to subbituminous coal were described in the log of Seabee Test Well No. 1 at 3,260–3,960 m depth in the NPRA (well 34, Fig. 2; Husky Oil NPR Operations, Inc., 1982–1983). These beds occur with gilsonite-like hydrocarbons in the type area (Molenaar and others, 1987). The Torok Formation contains minor coal and carbonaceous shale beds in the southern NPRA and areas to the south (Sable and Stricker, 1987), and at 640–2,408 m depth in several NPRA wells.

Nanushuk Group. During Albian and Cenomanian time, equilibrium was apparently established between basin subsidence and sediment accumulation, resulting in very thick sequences of swamp and shallow-marine deposits that were subsequently compacted and preserved as coal of the Nanushuk Group (loc. 2, Fig. 1). These coal-bearing sequences are much thicker than the coal-bearing intervals in most basins in the conterminous Western United States (Sable and Stricker, 1987). The Cretaceous Corwin, Kukpowruk, Ninuluk, Chandler, Grandstand, and Tuktu Formations that compose the Nanushuk Group are about 3,000 m thick (Fig. 3; Smiley, 1969), and coal occurs in the middle and upper parts of the section (Callahan and Sloan, 1978). The sedimentary rocks are postorogenic molasse deposits representing offlap-delta and delta-plain environments (Huffman and others, 1988). The dominantly nonmarine coal-bearing rocks, principally within the Nanushuk Group (Martin and Callahan, 1978), are thickest and gently to moderately folded and faulted in the foothills belt (Fig. 6), but the bedding thickness and amplitude of folding apparently decrease in the subsurface to the north and east beneath the coastal plain (Bird and Andrews, 1979; Mull, 1985). Two major delta systems, the western (early Albian to Cenomanian) Corwin Delta and the eastern (middle Albian to Cenomanian) Umiat Delta of the Nanushuk Group (Ahlbrandt and others, 1979), prograded to the north and east (Fig. 5). The Corwin Delta, a large river-dominated system comparable to the Mississippi Delta in area and volume of sediment, contains numerous coal deposits as thick as 6 m (20 ft) in interdistributary-bay platforms and splay deposits within the middle (transitional) and upper delta plain (Roehler and Stricker, 1979). The Umiat Delta, which began as a high-constructional system higher in the section, had a lesser sediment volume and, presumably, a smaller source area than the Corwin Delta; it was progressively influenced by marine conditions (Huffman and others, 1985). Coal deposits become more sparse, thin, and discontinuous upward in the Umiat Delta section (Stricker, 1983). It is probable that most northern Alaska coal beds are lenticular and irregular, because they accumulated in interdistributary basins, infilled bays, or inland flood basins; some widespread tabular beds may have formed on broad, subsiding delta lobes. Nanushuk Group rocks exposed at Corwin Bluff include coal beds 1.7–2.7 m thick. At Cape Beaufort, these rocks contain coal beds 3.4 and 5.2 m thick, and on the Kukpowruk River, a coal bed 6.1 m thick has been described (Sanders, 1981).

Approximately 150 coal beds have been described in Nanushuk Group rocks; 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 vol%) and sulfur (0.1–1.4 wt%) (Sanders, 1981; Affolter and Stricker, 1987a), and has environmentally safe contents of such elements as As, Be, Hg, Mo, Sb, and Se (Affolter and Stricker, 1987a).

Colville Group. The Upper Cretaceous Colville Group (Fig. 3) and the Tertiary rocks on the North Slope are of less economic potential than older units for oil and gas and coal deposits (loc. 3, Fig. 1), and these rocks have not been as well investigated as the older units. The coal beds in the Colville Group and in the Cretaceous and Tertiary Sagavanirktok Forma-

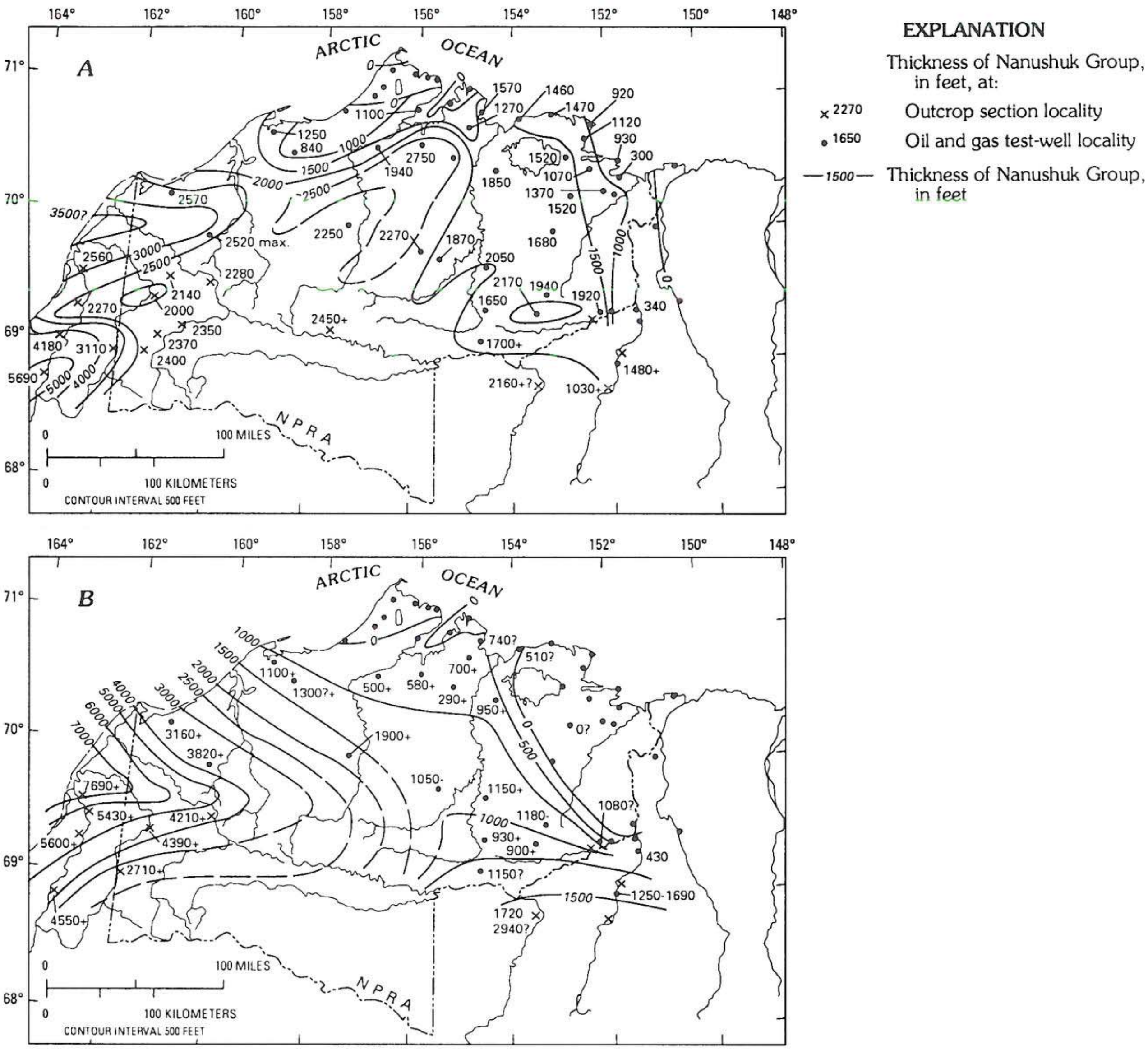


Figure 6. Map showing generalized thickness of Nanushuk Group rocks in and adjacent to National Petroleum Reserve Alaska (NPRA). A: Marine sequences including the Kukpowruk, Tuktu, and Grandstand Formations; contour interval 500 ft. B: nonmarine sequences including the Corwin Formation and the Killik Tongue of the Chandler Formation; contour interval 500 ft (152 m) (from Sable and Stricker, 1987).

tion are generally thinner and lower in rank than the Nanushuk Group coals.

Three formations make up the Colville Group, which is more than 1,525 m thick: the non-coal-bearing marine Seabee, the coal-bearing nonmarine Prince Creek, and the non-coal-bearing marine Schrader Bluff Formations. The sandstone, conglomerate, bentonitic shale, coal, bentonite, and tuff of the Prince Creek Formation probably represent delta-plain fluvial and delta-front foreshore environments of deposition (Fox and others, 1979). The uppermost nonmarine units of the Prince Creek Formation interfinger northward and eastward with marine strata of the 825-m-thick Schrader Bluff Formation, which also contains minor coal (Sable and Stricker, 1987).

In the vicinity of Umiat and Maybe Creek in the southeastern NPRA, coal beds as thick as 4 m occur, and some coaly zones are as much as 12 m thick (Brosgé and Whittington, 1966). On the lower Colville River, nine beds of coal and coaly beds as much as 4 m thick are exposed, and a 15-m-thick zone of interbedded shale and coal has been reported (Brosgé and Whittington, 1966). Subsurface coaly intervals are typically less than 15 m thick, but one 6-m-thick zone of coal interbedded with black shale and bentonite has been described from the Square Lake

Test Well No. 1 core (Collins, 1959). The coaly deposits in these units probably formed in lower delta-plain, alluvial-plain, and upper delta-plain environments (Sable and Stricker, 1987).

Sagavanirktok Formation. The Upper Cretaceous to Pliocene Sagavanirktok Formation underlies 19,400 km^2 in the eastern part of the North Slope in the Camden basin and under the Beaufort Sea shelf (Molenaar and others, 1987; Sable and Stricker, 1987). The coals accumulated in interdistributary bays and on platforms constructed by overbank splays. The Sagavanirktok consists of clastic deltaic rocks containing minor carbonaceous shale, coal, lignite, and bentonite, and sedimentary structures and facies indicate a continuation in Tertiary time of east-northeastward progradation. The formation has a 460-m-thick coal-bearing deltaic unit at its base (Roberts and others, 1991). Near Prudhoe Bay, a coal-bearing interval as thick as 400 m contains coal beds 0.6–6.7 m thick (Roberts, 1991); one 2-m-thick coal zone has been reported on the lower Shaviovik River (Roberts, 1991). Lignite and coaly shale as thick as 6 m occur in the lowermost part of the formation (Detterman and others, 1975; Molenaar and others, 1984). The coals accumulated in interdistributary bays on platforms constructed by overbank splays and alluvial-plain environments.

Coals of the Upper Cretaceous and Tertiary Colville Group and Sagavanirktok Formation are subbituminous C and low in sulfur, with a mean of 0.4 wt% (0.08–2.2 wt%) (Roberts and others, 1991).

Coal assessment of the North Slope Province

Barnes (1967a) calculated a total of 2.2 × 10^9 metric tons of demonstrated and 107 × 10^9 metric tons of undiscovered coal resources on the North Slope. Tailleur and Brosgé (1976) estimated the coal resources in northern Alaska by calculating the product of coal-bearing area and coal concentration. Using surface data and two oil and gas test wells, they estimated the coal resources on the North Slope at 109 × 10^9 metric tons of identified plus 104 × 10^9 to 34 × 10^{12} metric tons of hypothetical resources. A calculation based on the methodology of Sable and Stricker (1987) indicates that the Nanushuk Group contains an estimated 2.9 × 10^{12} metric tons of hypothetical coal resources on the surface and in the subsurface of onshore northern Alaska (Table 2); of this total, 1.2 × 10^{12} metric tons is subbituminous, and 1.7 × 10^{12} metric tons is bituminous (Stricker, 1991). In situ speculative Cretaceous Nanushuk coal under the Chukchi Sea has been estimated at 2.0 × 10^{12} tons of lignite A to high-volatile bituminous A (Affolter and Stricker, 1987b). Tertiary Sagavanirktok lignite coal beneath the Beaufort Sea is estimated to total 300 × 10^9 metric tons (Affolter and Stricker, 1987b).

A realistic assessment of the resources contained in the northern Alaska coal fields is probably not possible with the relatively meager geologic information available. The estimate by Martin and Callahan (1978) of 44 × 10^9 metric tons of demonstrated coal resources in an area of 65,000 km^2 of coal-bearing rocks illustrates the paucity of coal-data density. In comparison with the estimate of 2.9 × 10^{12} metric tons of hypothetical coal resources in this report, the estimate of identified coal resources does not give a true indication of the resource potential of the northern Alaska coal fields.

TABLE 2. COAL RESERVES FOR THE NANUSHUK GROUP, NORTH SLOPE PROVINCE

Rank	Attitude	Overburden (ft)	Resource estimate (tons)*
Subbituminous	Dips generally 15° or less	0 to 500	1,041
		500 to 1,000	18
		1,000 to 2,000	9
		>2,000	1
		Total	**1,068**
	Dips generally 15° or more	0 to 500	91
		500 to 1,000	5
		1,000 to 2,000	5
		>2,000	1
		Total	**102**
	Subbitimunious	**Total (Rounded)**	**1,170**
Bituminous	Dips generally 15° or less	0 to 500	1,216
		500 to 1,000	0
		Total	**1,216**
	Dips generally 15° or more	0 to 500	518
		500 to 1,000	0
		Total	**518**
	Bituminous	**Total (Rounded)**	**1,734**
North Slope		**Total (Rounded)**	**2,904**

*Reported in billions of metric tons.

YUKON-KOYUKUK PROVINCE

On the south side of the western Brooks Range is the Yukon-Koyukuk province, a large triangular area underlain by Cretaceous rocks containing some coal but with very little potential for coal resources. The Yukon-Koyukuk province was once an oceanic basin with an island arc that collided with and overrode terranes to the north, southeast, and west. The abrupt, almost catastrophic filling of this basin to sea level and above during mid-Cretaceous time gave little opportunity for long-lived paralic swamps in which the precursors of coal would accumulate, such as on the North Slope, and the intense episodes of deformation that followed accumulation greatly disturbed the small amount of coal that did form. In keeping with its age and deformation, the bulk of this coal is bituminous, and some is coking coal—a combustible, gray, hard, porous and coherent coal type, produced from bituminous coal that has undergone metamorphism in the absence of air (Wood and others, 1983). The geology of this region has been described by Patton (1973) and Patton and others (this volume, Chapter 7), and the paragraphs that follow are summarized from that work.

Geologic observations on the coal at Nulato (loc. 4, Fig. 1) were made in 1865 by W. H. Dall (Dall and Harris, 1892), who assigned it to the Neogene. Several small mines on the west bank of the Yukon River between the mouths of the Melozitna and Anvik Rivers provided coal for river steamers and blacksmithing during the gold rushes to the Klondike and other regions of Alaska at the turn of the twentieth century (Collier, 1906). Collier (1906) described the coal beds and mining operations; Martin (1926) wrote detailed lithologic descriptions of the sections containing the coals; and Patton and Bickel (1956) published detailed structure sections of the bluffs along this stretch of the Yukon River.

Geologic units and setting

Outcrops in the Yukon-Koyukuk province include a central section of Lower Cretaceous (Neocomian) andesitic, volcaniclastic, and associated plutonic rocks, extending eastward from the Seward Peninsula, through the Selawik drainage, into the adjacent Koyukuk drainage. These rocks represent the remains of a volcanic island arc built, presumably, on oceanic crust; they crop out in a belt that is convex to the north and east. Surrounding this central volcanic terrane are thick sedimentary-basin accumulations—to the north along the Kobuk drainage and to the east, southeast, and south along the Koyukuk and Yukon Rivers and into the Kuskokwim drainage. The sedimentary fill of these basins was derived partly from the volcanic island arc, but mostly from the surrounding highland provinces that include the Brooks Range to the north and the crystalline rocks of the Kokrines-Hodzana Highlands and Kaiyuh Mountains to the southeast. The crystalline highlands bordering the Yukon-Koyukuk province adjacent to its boundary contain overthrust sheets composed of an ophiolite sequence with Jurassic radiometric ages; these sheets are presumably parts of the original oceanic crust beneath the Yukon-Koyukuk province that were obducted onto the surrounding highlands. Thrusting of the ophiolite onto the highlands, between Neocomian and Albian time, provided much of the source for the Albian to Santonian basin fill.

The lower part of this basin fill is a turbidite sequence of mid-Cretaceous (Albian and Cenomanian) age, and the upper part, especially around the margins of the province, is a nonmarine to shallow-marine sequence of Late Cretaceous (Cenomanian to Santonian) age. The Cretaceous coal beds occur in the upper, continental part of the basin fill.

Cretaceous coal

At several localities, thin coal beds occur within continental and interbedded continental–shallow-marine sequences of mid-Cretaceous age. Barnes (1967a, p. B20) summarized the principal occurrences and thicknesses as follows.

"Twenty miles above Galena, one foot; ten miles above Nulato (Pickart mine), one and one-half to three feet; one mile above Nulato, six inches; four miles below Nulato (Bush mine), probably less than two feet; nine miles below Nulato (Blatchford mine), thickness unknown, sheared pockets eight feet across; 50 miles below Kaltag (Williams mine) [loc. 5, Fig. 1], three and one-half feet; and 16 miles above Blackburn (Coal Mine No. 1) [loc. 6, Fig. 1] two and one-half to three feet. The only localities where conditions are favorable for appreciable resources are the Williams and No. 1 mines, from each of which several hundred tons of coal was mined prior to 1903."

Additional occurrences of coal are (1) at Tramway Bar (loc. 7, Fig. 1) on the Middle Fork of the Koyukuk River, about 40 km (25 mi) downstream from Wiseman, in the extreme northeast corner of the Yukon-Koyukuk province, where Schrader (1900, p. 477, 485, 1904, p. 107, 114) reported a bed 3.5 m thick, the middle 3 m of relatively pure, high-volatile bituminous coal; (2) on the Anvik River, about 160 km upstream from its confluence with the Yukon River (loc. 8, Fig. 1), where Harrington (1918, p. 65) reported information from a local prospector that several beds as much as 3 m thick and other beds about 0.6 m thick are exposed along an 8-km-long stretch of the river; (3) on the Kobuk River above Kiana (loc. 9, Fig. 1), where small coal remnants occur as float (Patton and Miller, 1968); and (4) adjacent to the town of Koyuk on the beaches of Norton Sound (loc. 10, Fig. 1), where coal of Albian-Cenomanian age was mined until about 1970. This last deposit is now buried by beach gravel. The Tramway Bar locality was visited by members of the Alaska Division of Geological and Geophysical Surveys in 1985, who confirmed the presence of one coal bed at least 3.7 m thick and of two additional coal beds at least 1.2 m thick in a section of siltstone, sandstone, and quartz-rich conglomerate at least 90 m thick (Katherine Goff, 1985, written commun.; John Murphy, 1986, oral commun.). The Anvik River locality has not been visited by any geologist and is not shown on the reconnaissance geologic map of the Unalakleet quadrangle by Patton and Moll (1985).

Coal assessment of the Yukon-Koyukuk province

The overall poor coal prospects of the Yukon-Koyukuk province are exemplified in the measured section shown by Martin (1926, p. 404–406) at the Pickart mine, where 355 m of section included no more than 1.5 m of coal and only one bed as much as 0.6 m thick, giving a coal content of less than 0.5 vol%. Deposits in this province are of economic interest primarily for local use.

TERTIARY COAL OF THE SEWARD PENINSULA

Numerous small coal deposits occur on the Seward Peninsula (Fig. 1; Barnes, 1967a). Of these deposits, only one is of any significance—the Chicago Creek deposit of Tertiary age on the Kugruk River, about 40 km west of Candle (loc. 11, Fig. 1) (Henshaw, 1909; Toenges and Jolley, 1947). Two lignite beds have been mined: one is about 5.5 m thick, and the other at least 30 m thick, and both are known to extend at least 21 m below the surface (Barnes, 1967a). This lignite may be developed for use in Kotzebue (Sanders, 1981).

PALEOZOIC(?) COAL ON THE NATION RIVER

A bed of deformed and partially crushed coal, in pods as much as 2.4 m thick and 4 m long, was mined in 1897 and 1898 (Collier, 1906) from the south bank of the Nation River, about 1.5 km from its confluence with the Yukon River (loc. 12, Fig. 1). At the time of Collier's visit, the mine had already caved, and no exposures of coal were visible. The reported occurrence is in rocks of the Nation River Formation of latest Devonian age (Brabb and Churkin, 1967), a deep-sea turbidite fan deposit (Nilsen and others, 1976). The coal reported at the site by Collier (1903) may have occurred in a sliver of the coal-bearing continental rocks of Late Cretaceous to Pliocene age that were mapped by Brabb and Churkin (1969) in the Charley River south of the Yukon River. Subsequent mapping of the surrounding area disclosed no other coal exposures, and the original exposure has never again been found.

MINOR OCCURRENCES OF TERTIARY COAL IN THE YUKON BASIN

Coal of subbituminous or lignite rank occurs in association with rocks of apparent Tertiary age at the following localities (Barnes, 1967a): Eagle-Circle district (loc. 12a, Fig. 1), Chicken district (loc. 12b, Fig. 1), Rampart district (loc. 12c, Fig. 1), and Nunivak and Nelson Islands (loc. 12d, Fig. 1). Except for the Chicken district, which is reported to contain a coal bed at least 7 m thick, none of the coal reported in these occurrences is of commercial thickness or quality. Even in the Chicken district, where the bed was penetrated in a tunnel at the base of a 11-m-long shaft (Mertie, 1930) there are inconsistencies in the description, and the shaft is caved and inaccessible (Barnes, 1967a).

SOUTHERN ALASKA–COOK INLET COAL PROVINCE

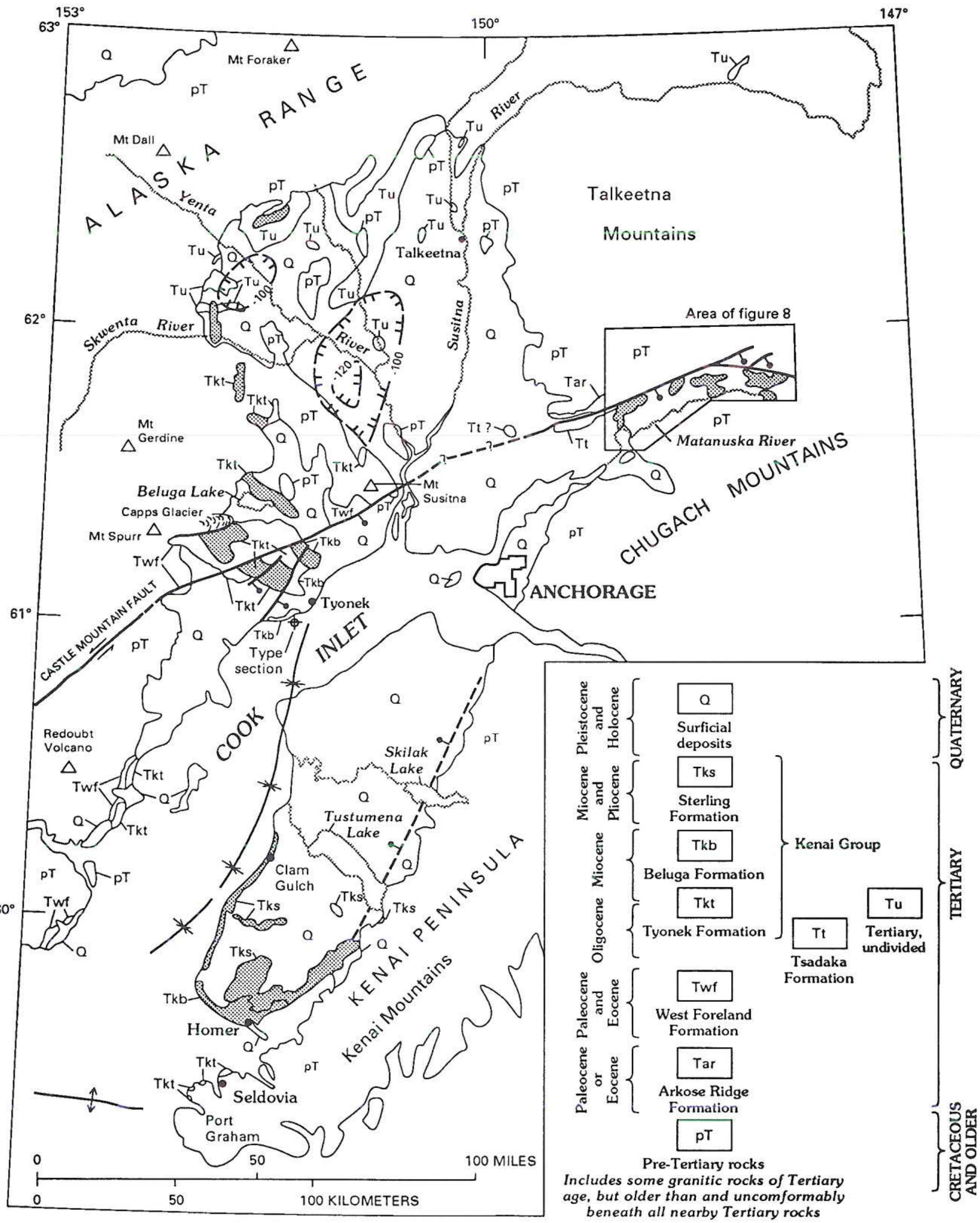
Geologic setting

Many isolated occurrences of coal-bearing rocks of Tertiary age in southern and central Alaska appear to have been parts of a large river system that emptied into the Pacific Ocean through Cook Inlet (Fig. 1). The major coal resources of southern Alaska, beneath the Cook Inlet–Susitna Lowland and in the Matanuska Valley, appear to have accumulated in a basin of deep subsidence where this river system joined the Pacific (Kirschner, 1988). The two major forks of the trunk stream, the alluvial valley of which is now occupied by Cook Inlet, extended northward through the area now occupied by the Susitna Lowland and Broad Pass coal fields and eastward through the valley that contains the Matanuska coal field (Fig. 7). Three important coal fields along the north side of the Alaska Range—the Nenana, Jarvis Creek, and Tonzona (Farewell)—appear to have been places where tributaries of this river system flowed southward across areas of tectonic subsidence. The Yukon-Tanana Upland may have been in its headwaters. All the coal occurrences thought to have once been in this integrated drainage system are here considered parts of the Southern Alaska–Cook Inlet province (see Fig. 1). The Cook Inlet depression, the main basin of subsidence in this coal province, is a fore-arc basin that lies on the site of a middle Mesozoic open shelf between the volcanic arc represented by the Lower Jurassic Talkeetna Formation and the Middle Jurassic Talkeetna batholith on the north and an ancient Pacific oceanic crust at the site of the Kenai and Chugach Mountains on the south. A thick, mainly terrigenous, epiclastic sequence, ranging from Middle Jurassic to Late Cretaceous in age, accumulated on this shelf and lies, relatively undeformed, unconformably beneath the coal-bearing Tertiary deposits (Kirschner and Lyon, 1973; Fisher and Magoon, 1978; Magoon, this volume). The McHugh Complex and the Valdez Group, oceanic crust and deep-sea turbidite sequences, were accreted to southern Alaska during Late Cretaceous time to form the Chugach and Kenai Mountains, thus widening the arc-trench gap, which is now about 450 km wide, owing to accretion of Cenozoic oceanic terranes. The Cook Inlet basin lies in the northwesternmost part of this arc-trench gap (Fisher and Magoon, 1978). Irregular subsidence of some parts of the fore-arc basin began in latest Cretaceous time but continued sporadically throughout Cenozoic time, interrupted by mild uplift and erosion. Subsidence was greatest during Neogene time in a 250-km-long segment of Cook Inlet that became the trunk drainage system for much of central and southern Alaska and received sufficient sediment to remain mostly terrestrial during all of this period.

Paleocene precursors

The bulk of the coal in the Southern Alaska–Cook Inlet province is of Oligocene to early Pliocene age and is mostly subbituminous and lignite. However, during Paleocene and possibly early Eocene time, before the integration of this drainage system, coal-bearing continental sediment derived in large part from adjacent mountains accumulated in two narrow, approximately east-west–trending troughs. The coals in these Paleogene fields are of bituminous or higher rank.

Cantwell Formation. At the site of the present central Alaska Range, between Mount McKinley on the west and Mount Hayes on the east, at least 3,000 m of conglomerate, sandstone, shale, and rare thin coal beds accumulated to form the Paleocene Cantwell Formation (Wolfe and Wahrhaftig, 1970). An attempt was made to mine coal in the Cantwell Formation at mile 341 on the Alaska Railroad, but owing to structural complexity (the bed was displaced by faulting), the project was abandoned (Capps,



153°
63°
150°
147°
62°
61°
60°
59°
Mt Foraker
ALASKA RANGE
Mt Dall
Yenta
Tu River
Talkeetna
Mountains
Talkeetna
Susitna
River
Skwenta River
Area of figure 8
Tar
Tt ?
Tt
Matanuska River
Mt Gerdine
Beluga Lake
Capps Glacier
Mt Spurr
Mt Susitna
CHUGACH MOUNTAINS
ANCHORAGE
CASTLE MOUNTAIN FAULT
Tyonek
Type section
COOK INLET
Redoubt Volcano
Skilak Lake
Tustumena Lake
Clam Gulch
KENAI PENINSULA
Kenai Mountains
Homer
Seldovia
Port Graham
0
50
100 MILES
0
50
100 KILOMETERS
Q
Surficial deposits
Tks
Sterling Formation
Tkb
Beluga Formation
Tkt
Tyonek Formation
Kenai Group
Tt
Tsadaka Formation
Tu
Tertiary, undivided
Twf
West Foreland Formation
Tar
Arkose Ridge Formation
pT
Pre-Tertiary rocks
Includes some granitic rocks of Tertiary age, but older than and uncomformably beneath all nearby Tertiary rocks
Pleistocene and Holocene
Miocene and Pliocene
Miocene
Oligocene
Paleocene and Eocene
Paleocene or Eocene
QUATERNARY
TERTIARY
CRETACEOUS AND OLDER

EXPLANATION FOR FIGURE 7

Contact

Fault with vertical displacement—Ball and bar on downthrow side; dashed where uncertain or concealed

Near-vertical fault with horizontal displacement—Arrows indicate relative movement

Axis of tectonic arch or anticline

Axis of major basinal downwarp

-120 Isostatic gravity anomaly (in milligals) around major gravity lows in Susitna basin

Coal field and other area of significant coal outcrops

Figure 7. Generalized geologic map of the Cenozoic rocks in the Cook Inlet–Susitna lowland, showing coal fields and other areas of significant coal exposures (compiled from F. Barnes, 1966; D. Barnes, 1977; Barnes and Cobb, 1959; Barnes and Payne, 1956; Barnes and Sokol, 1959; Beikman, 1980; Capps, 1913, 1927, 1935, 1940; Detterman and others, 1976; Magoon and others, 1976; Reed and Nelson, 1980). For geology of inset, see Figure 9.

1940, p. 114). No study has been made of the coal, and reserves, if any, are unknown.

Matanuska Coal Field. The most important Paleocene coal field in Alaska is the Matanuska coal field (loc. 13, Fig. 1), which occupies the graben of the Matanuska Valley, between the Talkeetna Mountains on the north and the Chugach Mountains on the south (Figs. 7, 8). The part of the valley that contains coal is about 100 km long, from Moose Creek on the west to Anthracite Ridge on the east. The coal is found in the Chickaloon Formation, a 1,000–1,500-m-thick, Paleocene and lower Eocene sequence of claystone, siltstone, and sandstone, including minor conglomerate beds and many beds of coal (Triplehorn and others, 1984). The Chickaloon Formation rests with angular unconformity on the Lower and Upper Cretaceous Matanuska Formation, a sequence of marine sandstone and shale (Barnes and Payne, 1956; Grantz and Jones, 1960). The Chickaloon Formation is overlain by the Wishbone Formation (Fig. 9), a massive conglomerate about 900 m thick that contains clasts characteristic of the Talkeetna Mountains to the north. The Wishbone Formation, in the Talkeetna Mountains north of the east end of the coal field, is apparently unconformably overlain by nearly flat-lying Ter-

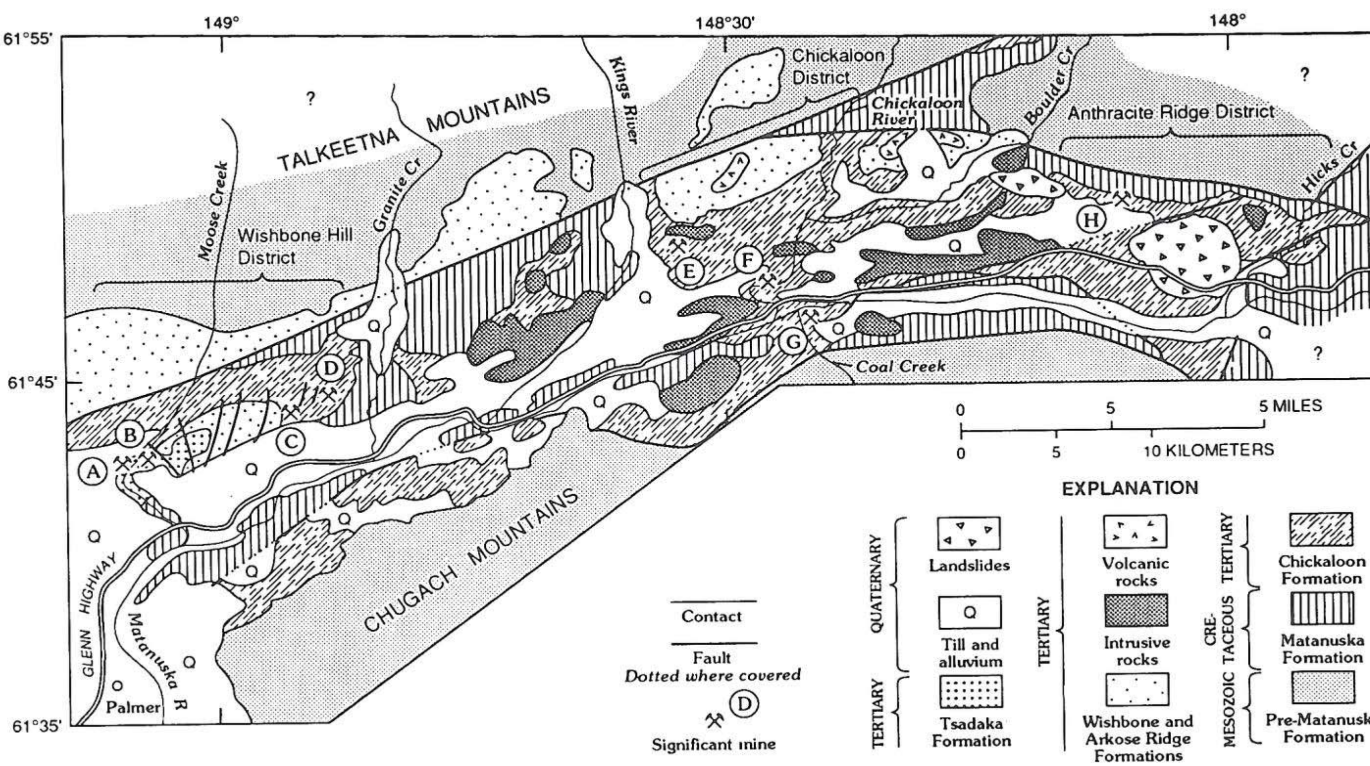


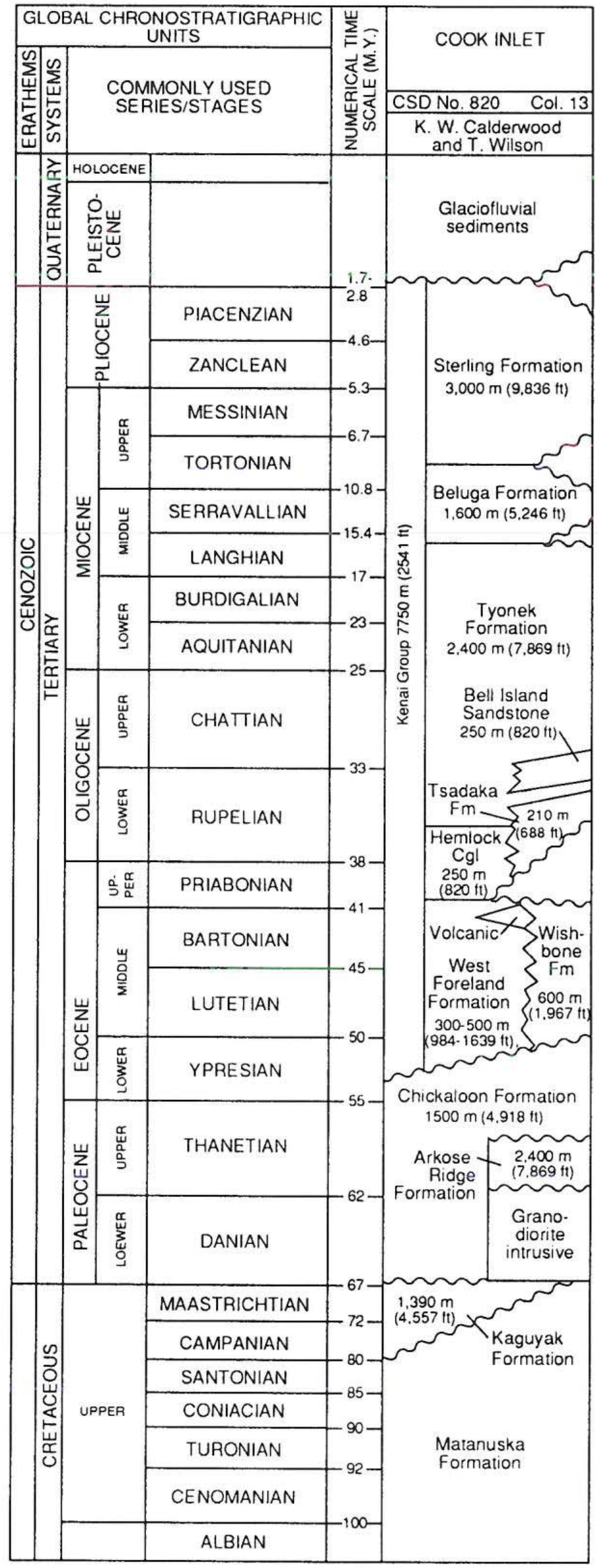
Figure 8. Simplified geologic map of the Matanuska Valley, showing location of coal districts and significant mines. A, Premier mine; B, Baxter mine; C, Evan Jones mine; D, Eska mine; E, Castle Mountain mine; F, Chickaloon mine; G, Coal Creek mine; H, Anthracite Ridge anthracite locality (compiled from Magoon and others, 1976; Detterman and others, 1976; Waring, 1936, plate 1). Blank areas, with question marks, geology not shown.

tiary basalt. Gabbro sills and dikes, some large and possibly related to the Tertiary volcanic rocks, intrude the Chickaloon Formation, most commonly east of Granite Creek.

Coal-bearing areas within the Matanuska Valley include (1) the Wishbone Hill district, an open faulted syncline between Moose and Granite Creeks at the west end of the valley, where there has been the most production (Barnes and Payne, 1956); (2) an area around Young Creek, just west of Kings River (Fig. 8) (Martin and Katz, 1912); (3) the Castle Mountain and Chickaloon districts, both on the north side of the Matanuska River and between the Kings and Chickaloon Rivers (Fig. 8) (Merritt and Belowich, 1984, plate 2); and (4) the Anthracite Ridge district, at the east end of the outcrop area of the Chickaloon Formation (Fig. 8; Waring, 1936; Merritt and Belowich, 1984). The coal in the Wishbone Hill district and around Young Creek is high-volatile bituminous; coal in the Castle Mountain and Chickaloon districts is predominantly low-volatile bituminous; and coal in the Anthracite Ridge district is mainly low-volatile bituminous, with patches of semianthracite and anthracite (Merritt and Belowich, 1984; Waring, 1936; Barnes, 1962).

The Matanuska coal field is important in the history of the settlement of Alaska. In 1914, the Alaska Railroad from the coast to the interior was routed to pass near the Matanuska Valley, owing to the availability of steaming coal from the coal field; until the early 1950s, when the railroad converted to oil, all coal for the locomotives came from the Wishbone Hill district.

The coal-bearing areas were divided into leasing units under the Federal Coal Leasing Act of 1915, and in 1917 the first mining began at the west end of the Wishbone Hill district. Because private coal mines were proving to be an uncertain source of coal for the Alaska Railroad, the government took over the Eska mine in 1917 and started developing a second coal mine, the Chickaloon, on the Chickaloon River. Although the Chickaloon mine was never a major producer, the Eska mine was kept on a standby basis throughout the first half of the twentieth century. Nine mines operated at one time or another in the Wishbone Hill district between 1917 and 1970, and three or four mines operated at one time or another in the Chickaloon and



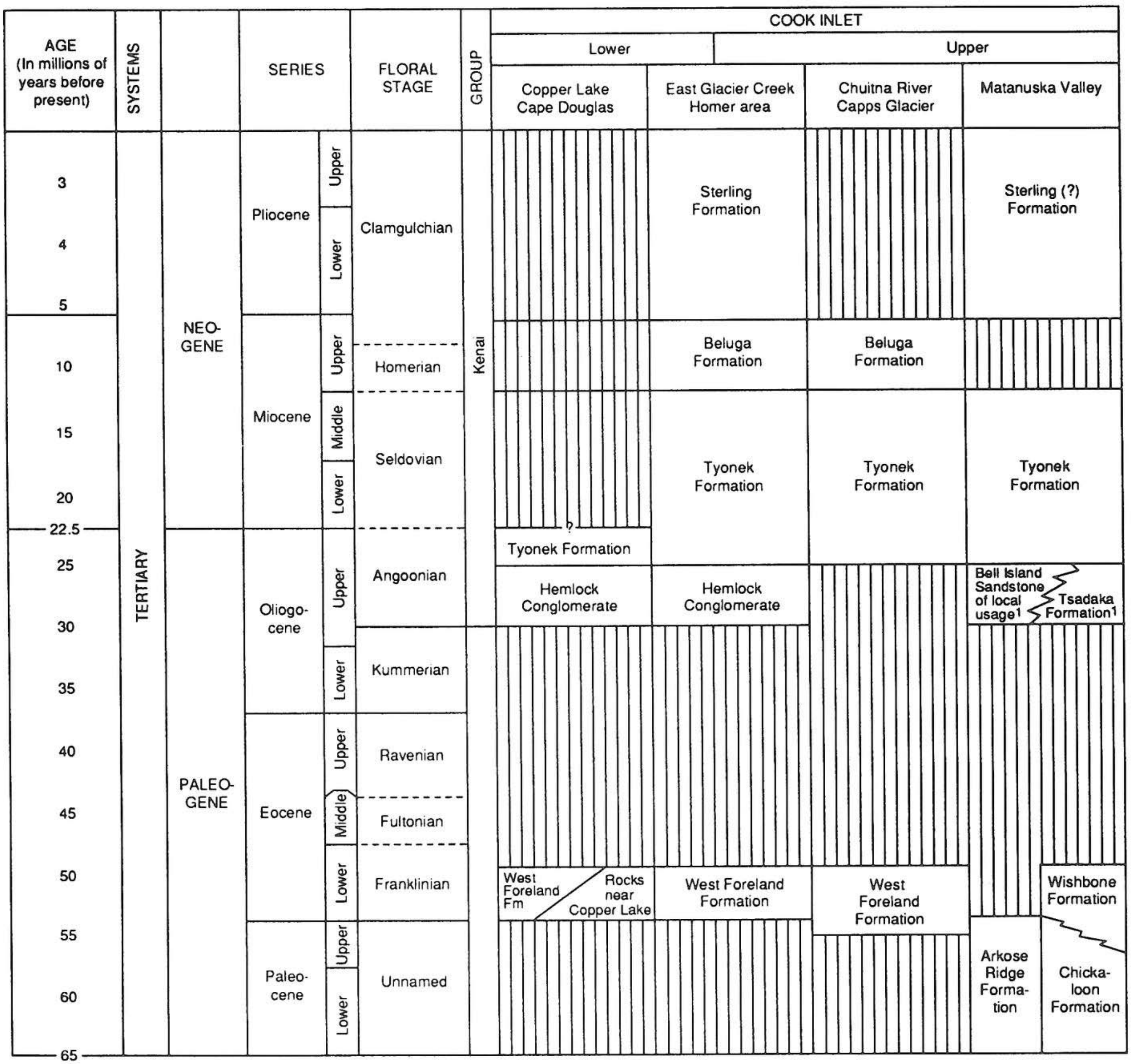
A

Figure 9, A and B: Two interpretations of the Tertiary stratigraphy of the Cook Inlet–Susitna region. A: According to Calderwood and Wilson (cited *in* Schaff and Gilbert, 1987); continuously conformable sedimentation from Eocene through Pliocene in the center of the Cook Inlet lowland, with the West Foreland Formation treated as the basal member of the Kenai Group. B (on facing page): According to Magoon and others (1976), a major hiatus between the West Foreland Formation and the Hemlock Conglomerate; the West Foreland Formation not being a member of the Kenai Group. Following U.S. Geological Survey practice, in this paper the West Foreland Formation is not treated as a unit of the Kenai Group. C (on following page): Type section of the Tyonek Formation, the major coal-bearing unit of the Kenai Group in the Cook Inlet lowland (from Calderwood and Fackler, 1972, Fig. 7). The type section extends from a depth of 1.310 m to 3,430 m in Pan American Petroleum Corp. Tyonek State 17587 No. 2 well, sec. 30, T. 11 N., R. 11 W., S.M. (see Fig. 7 for location).

Castle Mountain districts. From 1917 to 1940, production was about 50,000 tons per year; from 1940 to 1951, production was about 160,000 tons per year; and from 1952 to 1970, production averaged 240,000 tons per year. A total of 3×10^6 tons was mined from open pits, and the rest from underground mines. Total coal production was about 7×10^6 metric tons between 1915 and 1970, when the availability of oil eliminated the market for coal (Merritt and Belowich, 1984, Fig. 5).

Geologic units and setting. Representative columnar sections of the Chickaloon Formation are shown in Figure 10; representative structural cross sections of coal-bearing rocks of the Matanuska coal field are shown in Figure 11. Coal beds within the Chickaloon Formation vary in thickness considerably or pinch out altogether within short distances. Correlation from outcrop to outcrop is difficult, and only in the Wishbone Hill district has a successful districtwide correlation been accomplished. In this area, four groups of minable coal beds, one to six beds in each group, were separated by 15–90 m of barren rock in a section

TERTIARY CORRELATION CHART SURFACE AND SUBSURFACE



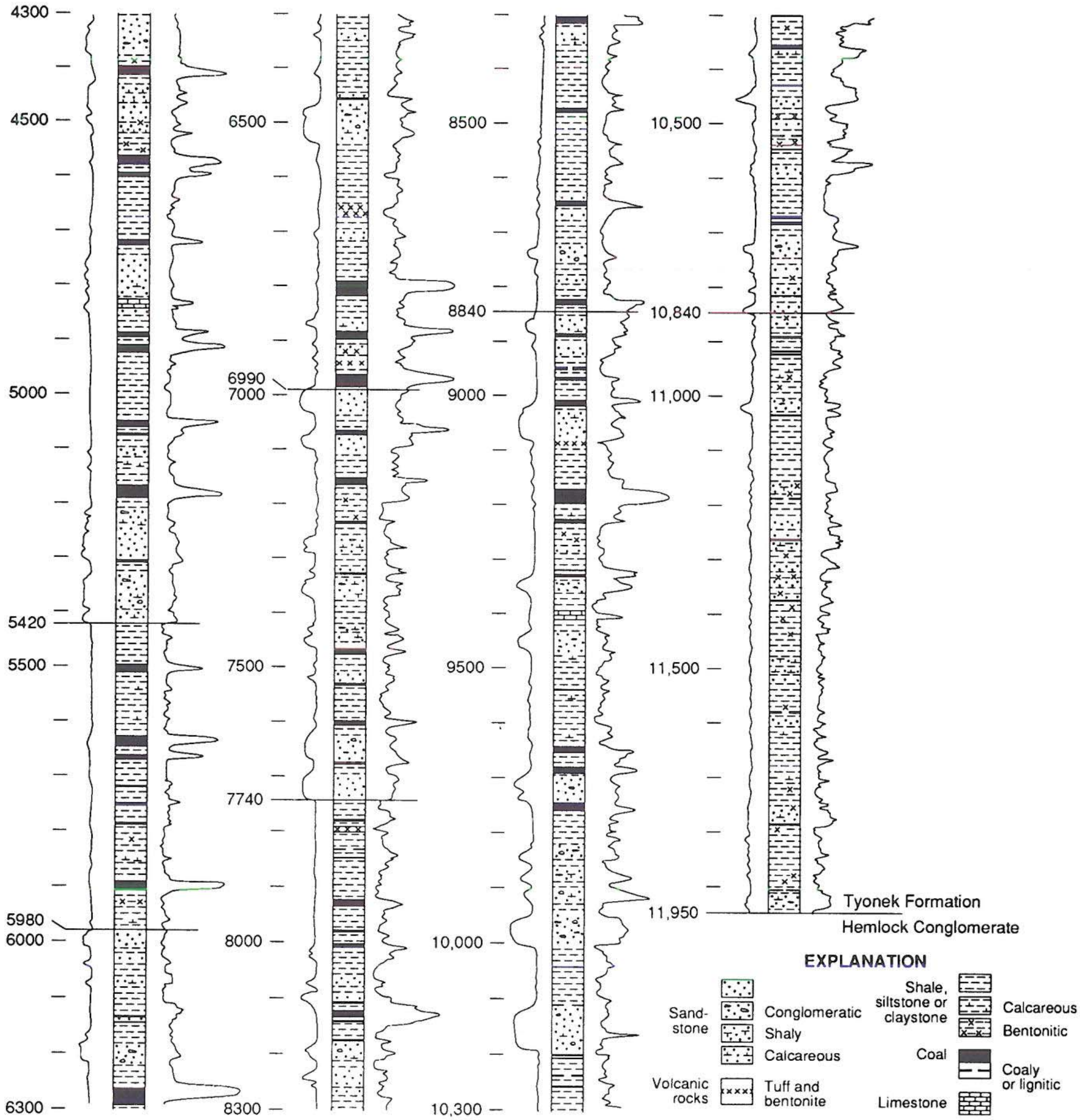
1Not considered part of Kenai Group

B

360–460 m thick. In all, 12 minable beds totaled about 15 m in thickness of minable coal; the thickest bed had about 3.3 m of coal in a total thickness of 5 m (Barnes and Payne, 1956).

Six to ten coal beds were penetrated in the Chickaloon mine, most less than 1 m thick, but one more than 5 m thick, with 4.3 m of coal. The beds are lenticular and vary in thickness within 60–90 m laterally, making correlation, reserve calculations, and prospecting across transverse faults difficult.

The number of coal beds in the Anthracite Ridge district is uncertain, owing to poor exposures and complex structure (Fig. 11). The greatest thickness of coal reported in a single bed is 12 m, but the coal may be repeated by landslides; few beds in the



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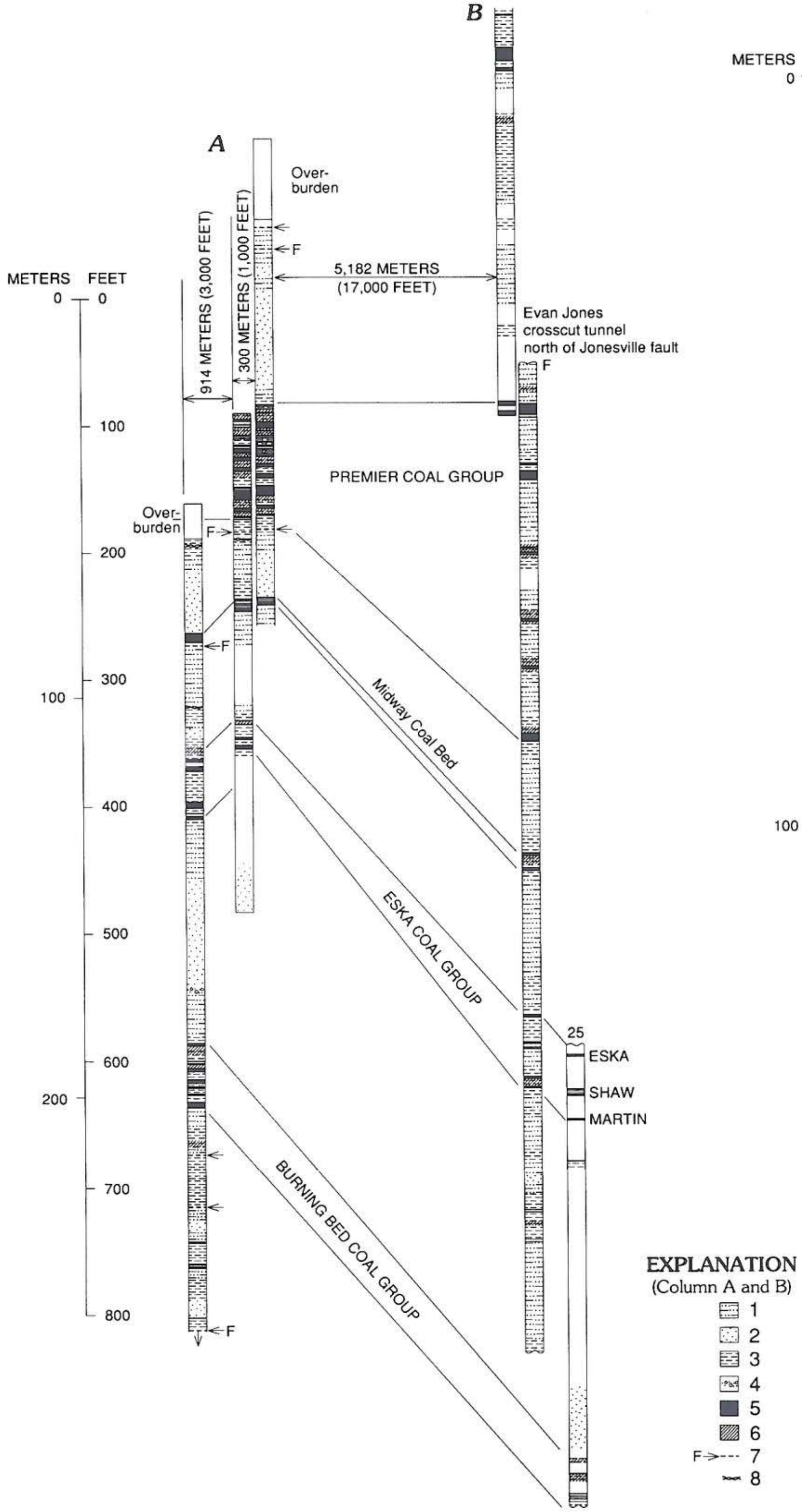

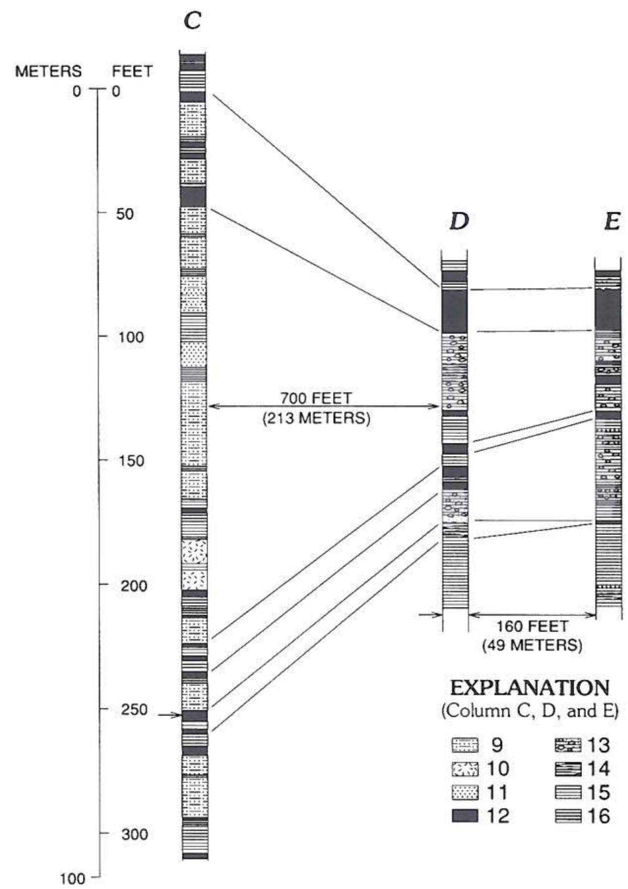

Figure 10. Representative columnar sections of the Chickaloon Formation, showing lateral variation of coals and intervening clastic units. A: Columnar sections near Buffalo Mine, near west end of Wishbone Hill district. B: Columnar sections near Evan Jones Crosscut Tunnel, near east end of Wishbone Hill district. C, D, and E: Columnar sections at the Chickaloon Mine. (Columns A and B from Barnes and Payne, 1956, plate 5; columns C, D, and E from Chapin, 1920, plate 5.) 1, siltstone and silty claystone; 2, sandstone; 3, claystone; 4, conglomerate; 5, coal and bony coal; 6, bone and coaly claystone; 7, fault; 8, ironstone concretions; 9, sandy shale; 10, igneous intrusion (sill); 11, sandstone; 12, coal; 13, nodular shale and mudstone; 14, coaly shale, carbonaceous shale, and soft black shale; 15, shale and mudstone; 16, probable carbonaceous shale.

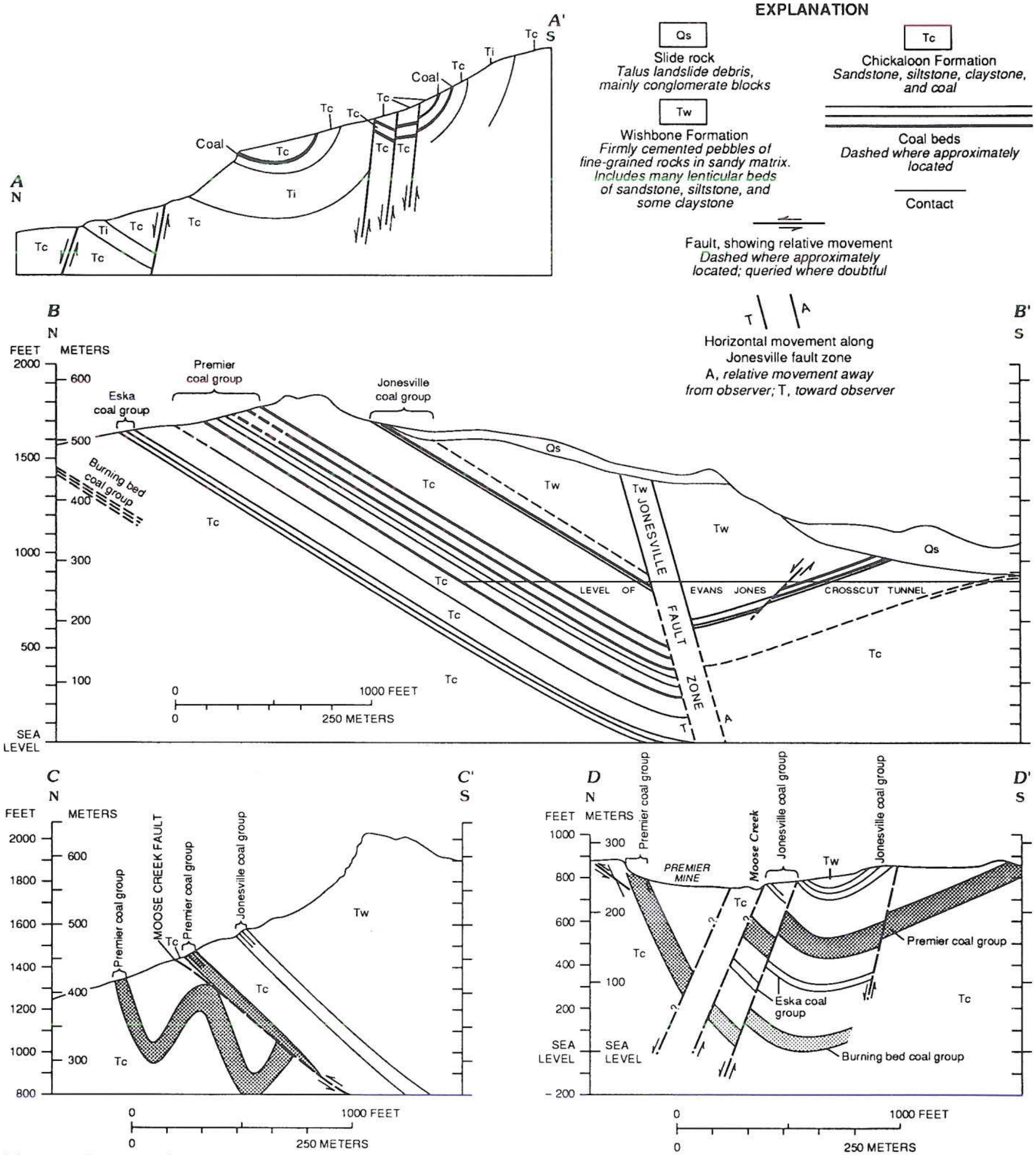

Figure 11. Representative structural cross sections in coal-bearing rocks of the Matanuska coal field. Cross section A-A′, at anthracite locality on Anthracite Ridge (from Waring, 1936, plate 8). Length of cross section A-A′ is 1.31 km; horizontal and vertical scales the same. Cross section B-B′ through Eska and Evan Jones mines, Wishbone Hill district. Cross sections C-C′ and D-D′, both near Premier Mine, Wishbone Hill district. (B-B′, C-C′, and D-D′ are slightly modified from Barnes and Payne, 1956, plates 7 and 9). Sections approximately north-south; north is to the left. Map units: Qs, Quaternary slide rock; Ti, Tertiary intrusive rocks; Tw, Paleocene and Eocene Wishbone Formation; Tc, Paleocene and Eocene Chickaloon Formation.

district are as thick as 1.2–2.0 m, and the coal beds are exceptionally lenticular.

The intensity of deformation and abundance of igneous dikes and sills increase eastward in the Chickaloon Formation of the Matanuska Valley. A few small dikes occur in the Wishbone Hill district, and thick sills are abundant in the Anthracite Ridge district. Heating induced by the igneous intrusions may be the main reason for the increase in average rank of the coal eastward in the coal field, although Barnes (1962) regarded heat generated by tectonic activity as more important. Merritt (1985a) described the natural coking of coal adjacent to an intrusive diabase sill and concluded that the temperature at the contact reached 550 °C. He also found that the bed that was locally coked had generally been raised in rank to semianthracite, whereas a coal bed about 50 m away was high-volatile bituminous A. The rank of coal in the Anthracite Ridge district also changes abruptly from low-volatile bituminous to semianthracite or anthracite within about 60 m, and the actual amount of anthracite coal appears to be quite small (Waring, 1936).

Structures in the Matanuska coal field are typically complex (Fig. 11). The doubly plunging Wishbone Hill syncline, a relatively simple structure in this field, has beds that dip 20°–40° on either flank; the structure is cut by two sets of transverse faults. Structural complications on its northwest flank make the coal beds in some structural blocks difficult to mine and reserves impossible to calculate (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°, and in the Chickaloon mine beds are overturned (Chapin, 1920) and abruptly 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.

Coal assessment of the Matanuska coal field. Estimates of coal resources reported by various workers for the coal field as a whole and for its various districts were tabulated by Merritt and Belowich (1984); they are as high as 200×10^6 tons of measured to inferred resources and as high as 2.2×10^9 metric tons of hypothetical resources. Considering the geology of the valley, the most reliable estimates appear to be those of Barnes (1967a), which are 113×10^6 metric tons of measured, indicated, and inferred resources, inclusive, and 250×10^6 metric tons of hypothetical resources. In the Anthracite Ridge district, the only identified minable bed of anthracite, 1.3–2.0 m thick, apparently underlies an area of no more than 0.01 km^2 and totals no more than 20,000 metric tons (Waring, 1936, locs. 24, 25, p. 34, 43, plate 8; Merritt and Belowich, 1984, locs. 31–32, p. 34, 55–56). One other reported anthracite occurrence (Merritt and Belowich, 1984, loc. 39), too thin to be mined, is on a large active landslide (Detterman and others, 1976).

West Foreland Formation. The West Foreland Formation, a type section of which is in a well on the West Foreland (Calderwood and Fackler, 1972), consists of tuffaceous claystone, sandstone, and conglomerate, including a few thin, probably unminable beds of coal. The formation underlies most of lower Cook Inlet southwest of the mouth of the Susitna River, and much of the lowland area of the northwestern Kenai Peninsula (Hartman and others, 1971). A maximum thickness of 1,000 m was reported at Cape Douglas (Fisher and Magoon, 1978, p. 380), but beneath most of Cook Inlet the unit has a maximum thickness of about 600 m (Hartman and others, 1971). Wolfe and Tanai (1980, p. 4) tentatively assigned it a latest Paleocene age; however, Magoon and others (1976) and Magoon and Egbert (1986) assigned it to the early Eocene (Fig. 9). It is probably correlative with the Wishbone Formation. Where exposed around the margins of the Cook Inlet lowland, the West Foreland Formation is unconformably overlain by rocks of the Kenai Group.

Calderwood and Fackler (1972) regarded the West Foreland as the basal formation of the Kenai Group, and Kirschner (1988; and 1989, written commun.) followed this assignment (see Fig. 9A). According to C. E. Kirschner (1989, written commun.), the West Foreland is conformable and probably continuous with the rest of the Kenai Group in the subsurface beneath Cook Inlet, and so it should be regarded as the basal formation of that group. He stated that the unconformity observed along the margins of the Cook Inlet lowland is between the West Foreland Formation and parts of the Tyonek Formation that are much younger than the rocks that rest on the West Foreland Formation in the subsurface.

Magoon and others (1976), however, regarded the unconformity at the top of the Wishbone Formation as regional, and so they removed the Wishbone from the Kenai Group (see Fig. 9B). Their argument for a regional unconformity stems from the observation that sections of the West Foreland Formation that have been dated are separated from rocks of the Kenai Group by a 20 m.y. hiatus. Because the assignment of Magoon and others (1976) has been adopted officially by the U.S. Geological Survey, it is followed here. However, the question of a regional unconformity at the top of the West Foreland remains undecided.

Conglomeratic rocks south of the Capps Glacier and along the north side of the Bruin Bay fault in the Beluga coal field have been correlated with the West Foreland Formation (Magoon and others, 1976). These conglomeratic rocks contain granitic boulders as much as 1 m across; the unit is about 365 m thick (Adkison and others, 1975).

The West Foreland Formation appears to have been deposited contemporaneously with the Wishbone Formation during downbowing of the Cook Inlet basin in early Tertiary time. If the 20 m.y. hiatus is real, then this period of subsidence probably was relatively short lived and was followed by little elevation change and only minor orogeny. The West Foreland Formation is not much more deformed than the overlying Kenai Group, nor is it significantly more consolidated.

Coal fields of the middle and upper Tertiary Kenai Group

The main coal deposits of the Cook Inlet–Susitna Lowland (see Fig. 7) are in the Kenai Group, which ranges in age from early Oligocene to late Pliocene. At its base is the Hemlock Conglomerate (correlated with the Tsadaka Formation and Bell Island Sandstone of Hartman and others, 1971), which is overlain successively by the Tyonek Formation, the Beluga Formation, and the Sterling Formation (Fig. 9; Calderwood and Fackler, 1972; Kirschner and Lyon, 1973; Magoon and others, 1976; Magoon, this volume). The Kenai Group contains the petroleum and natural gas reserves of the Cook Inlet petroleum province, and most information on the distribution and lithology of its formations, and on the amount of coal within them, comes from subsurface data obtained in drilling for oil and natural gas. The type localities of the formations established by Calderwood and Fackler (1972) are all subsurface well segments. Although excellent exposures of coal-bearing rocks exist in the Beluga coal field and in seacliffs near Tyonek and around the northwestern Kenai Peninsula between the head of Kachemak Bay and Kasilof (Barnes and Cobb, 1959; Barnes, 1966), those exposures are near the margins of the basin where the group is relatively thin and may contain hiatuses or unconformities.

The main basin of accumulation of the Kenai Group is between the Castle Mountain fault on the northwest and the presumably faulted northwest front of the Kenai Mountains on the southeast. The basin shallows over the transverse Augustine-Seldovia arch on the southwest and at the lower end of the Matanuska Valley on the northeast (Fig. 7). There was apparently no accumulation of sediment during Kenai time in the coal-bearing part of the Matanuska Valley. Total accumulation of sediment in the deepest part of this basin is more than 7,800 m (Hartman and others, 1971; Calderwood and Fackler, 1972). Kirschner and Lyon (1973) regarded the Kenai Group as intermittently estuarine in the central part of the basin, whereas Fisher and Magoon (1978) and Magoon and Egbert (1986) regarded the Kenai Group as continental throughout.

Hemlock Conglomerate. The Hemlock Conglomerate consists of conglomerate and conglomeratic sandstone containing quartz and chert, pebbles of metamorphic, volcanic, and plutonic rocks, and feldspathic sands with heavy minerals, predominantly epidote and garnet (Calderwood and Fackler, 1972; Magoon and Egbert, 1986). The Hemlock Conglomerate, which contains a few thin coal beds and many siltstone beds, is the main producing horizon for oil in the Cook Inlet province (Magoon, this volume); it is regarded as deltaic and estuarine in origin and apparently was derived from the north. Together with the Bell Island Sandstone and the Tsadaka Formation, temporal equivalents at the east end of the Cook Inlet basin, it makes a nearly uniform sheet 200 m thick, with a maximum thickness of about 450 m; it is Oligocene in age (Wolfe and Tanai, 1980; Magoon and Egbert, 1986).

Tyonek Formation. The lower Oligocene through middle Miocene Tyonek Formation (Wolfe and Tanai, 1980), which consists of as much as 2,330 m (Calderwood and Fackler, 1972) of sandstone, shale, and coal beds as much as 10 m thick, contains the bulk of the coal resources of the Cook Inlet basin and the Beluga coal field (see Fig. 9C). A sand/shale ratio map of the formation (Hartman and others, 1971) shows more than 50 vol% sandstone in an area along the west side of the basin between the Beluga coal field and West Foreland, and other areas of high sandstone content near Tuxedni Bay and in the extreme northeastern part of the basin. The locations of high sandstone content are thought to mark points of sediment input. An extensive clay band containing as little as 10 vol% sand extends south-southwestward along the western part of the Kenai Lowland and lies about 25 km southeast of the line of maximum thickness. Sand content increases southeastward of this zone of maximum clay content.

The cumulative thickness of coal penetrated in wells in the Tyonek Formation beneath Cook Inlet is shown in Figure 12. Coal in the Tyonek Formation is concentrated mainly along the northwest margin of the basin, from Kalgin Island northeastward along the west shore of the inlet to the Susitna River (Fig. 12). The coal concentration borders areas of highest sand input from the northwest. Secondary concentrations of coal occur beneath the lower Matanuska Valley and extend along the Kenai Lowland in a belt that coincides generally with the zone of minimum sand content. The thick Capps Glacier seam and seams along the Beluga and Chuitna Rivers (Barnes, 1966) in the Beluga coal field are in the Tyonek Formation (Magoon and others, 1976). Within a single oil field, correlation of the coal beds from well to well has proved difficult for distances of more than a few kilometers, suggesting considerable lenticularity of the coal seams and intervening sedimentary rocks. In outcrop, however, individual beds have been traced for as much as 10 km (Barnes, 1966; Ramsey, 1981).

Nearly flat-lying outliers of the Tyonek Formation along the southeast shore of Kachemak Bay near Seldovia and at Port Graham 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 (cited *in* Hollick, 1936) 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). Coal was first reported there by Portlock in 1786 (see Stone, 1906, p. 54). Coal (chiefly lignite) 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 ceded to the United States in 1867 (Stone, 1906).

Beluga Formation. The middle and upper Miocene Beluga Formation (Wolfe and Tanai, 1980) has a maximum thickness of about 1,500 m (Hartman and others, 1971). The abundance of

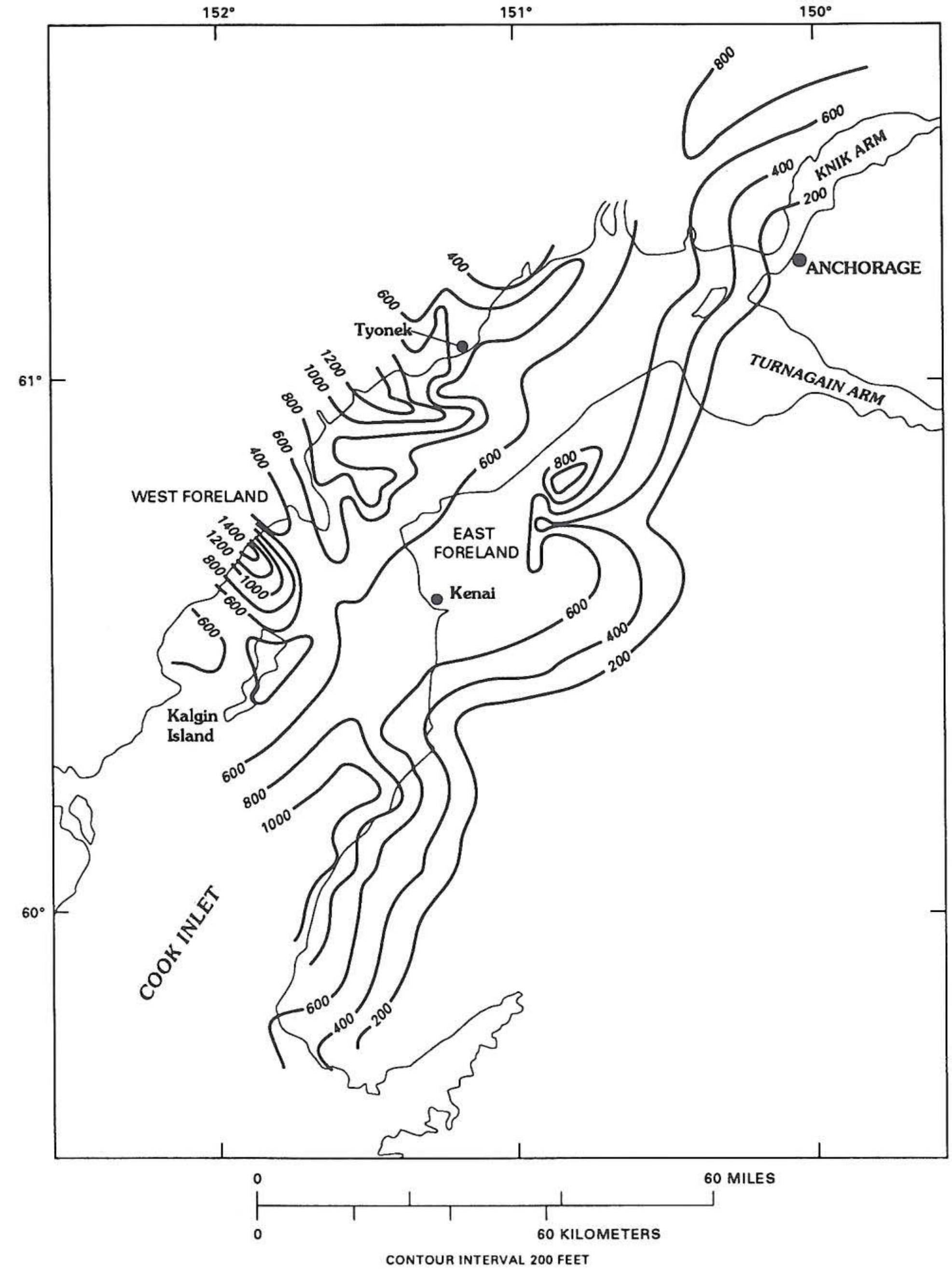

Figure 12. Cumulative thickness of coal (in feet) encountered in wells penetrating the Tyonek Formation beneath the Cook Inlet area (slightly modified from Hite, 1976).

epidote in the heavy-mineral suite (Kirschner and Lyon, 1973) and the relative abundance of metamorphic rock fragments in the locally pebbly sandstones led Hayes and others (1976) to interpret the Beluga Formation as an alluvial-fan complex derived mainly from the Kenai and Chugach Mountains. The Beluga Formation is exposed in beach bluffs along the northwest side of Kachemak Bay and the southwest end of the Kenai Peninsula south of Anchor Point (Merritt and others, 1987), and in the hills between Homer and the Anchor River (Magoon and others, 1976). It contains numerous coal beds as thick as 2 m (Barnes and Cobb, 1959).

Sterling Formation. The Sterling Formation of latest Miocene and Pliocene age (Wolfe and Tanai, 1980) consists of massive sandstone, conglomeratic sandstone, and interbedded claystone, and some thin coal and tuff beds (Kirschner and Lyon, 1973; Hayes and others, 1976; Hite, 1976), and is as thick as

3,350 m (Hartman and others, 1971; Calderwood and Fackler, 1972). Sandstone of the Sterling Formation contains abundant pumice grains and other fresh volcaniclastic detritus. Heavy minerals are predominantly hornblende and hypersthene, and volcanogenic hypersthene increases in abundance upsection; small amounts of garnet are present. These suggest that the Sterling Formation is apparently derived from the northwest, predominantly from the Alaska and Aleutian Ranges.

The Sterling Formation contains thin coal beds (generally no more than 1 m thick, but a few are as thick as 2.5 m [Barnes and Cobb, 1959; Calderwood and Fackler, 1972]). The coal is lignitic throughout much of the formation but is high-volatile subbituminous near the base. The Sterling and Beluga Formations have produced the bulk of the methane gas from the Cook Inlet petroleum province (Magoon, this volume).

Coal assessment of the Kenai Group. Coal resources of the Kenai Group in the Cook Inlet basin are large. Maps showing cumulative thicknesses of coal to depths of 610, 1,524, and 3,048 m in the subsurface, based on logs of oil wells throughout the basin, were prepared by McGee and O'Connor (1975), who calculated a speculative resource of 1.1×10^{12} metric tons of coal of apparent lignite rank to a depth of 3,048 m, and 100×10^9 metric tons to a depth of 610 m. Affolter and Stricker (1987b) estimated that 0.7×10^{12} metric tons of this coal lie beneath the waters of Cook Inlet. In addition to the isopach map of McGee and O'Connor (1975), Hite (1976) showed isopachs on cumulative thickness of coal in the Hemlock and Tyonek Formations.

Extensive exploration for, and mapping of, coal has taken place within land areas of the Cook Inlet basin, and indicated reserves have been calculated for many areas.

For the Homer district (loc. 14, Fig. 1) of the Kenai coal field, Barnes and Cobb (1959) calculated (from surface exposures only) indicated reserves of 360×10^6 metric tons of coal in beds 0.6 m thick or more, of which 45×10^6 metric tons is in beds more than 1.5 m thick. Nearly all of these coal beds are covered by $<$300 m of overburden.

The Tyonek-Beluga coal field (loc. 15, Fig. 1), northwest of Cook Inlet, is cut by the northeast-trending Castle Mountain fault, and reserves have been calculated separately for areas south and north of the fault. From surface exposures, Barnes (1966) calculated a total of 1.5×10^9 metric tons of coal in the part of the coal field south of the Castle Mountain fault. Most beds are more than 3 m thick, and some are almost 20 m thick. Ramsey (1981) identified six strippable beds averaging 3–10 m in thickness in a coal lease area of about 82 km^2 between the Chuitna and Beluga Rivers. Crude measurements from Ramsey's maps of this lease area suggest that it may contain 35 to 45×10^9 metric tons to a depth of 300 m, provided the beds maintain their thickness laterally and downdip.

Between the Capps Glacier and Mount Susitna, the Tyonek-Beluga coal field extends northward across the Castle Mountain fault. The field includes an extensive area of coal-bearing rocks, assigned by Magoon and others (1976) to the Tyonek Formation, that are in fault contact along the Castle Mountain fault with the beds whose reserves were given in the foregoing paragraph. North of these coal-bearing rocks, Mesozoic basement rocks crop out in a continuous belt south of the Skwentna River, separating the Tyonek-Beluga coal field from other bodies of coal-bearing rocks farther north in the Susitna basin. For this part of the coal field, Barnes (1966) calculated 373×10^6 metric tons of indicated reserves beneath the plateau south of Capps Glacier, 100×10^6 metric tons of indicated reserves northeast of Beluga Lake, and 14×10^6 metric tons of coal at the head of the Talachatna River, for a total of 487×10^6 metric tons of indicated reserves. The reserves calculated beneath the plateau south of the Capps Glacier were mainly for the 15-m-thick Capps bed; Patsch (*in* Schmoll and others, 1981) reported a 7.5-m-thick coal bed beneath the Capps bed. Thus, the reserves in this area are probably greater than those reported by Barnes (1966).

Environmental and engineering problems connected with mining coal from the Tyonek-Beluga coal field, which were addressed by Schmoll and others (1981), include slope stability and landslide problems, earthquake hazards, volcanic hazards, and erosion and flood potential.

On the basis of surface exposures, drilling, and trenching, Barnes and Sokol (1959) concluded that the Little Susitna district (loc. 16, Fig. 1), which extends eastward from the Alaska Railroad at Houston for about 32 km along the south base of the Talkeetna Mountains, contains insufficient coal to warrant calculating reserves. The coal, in beds generally less than 0.6 m thick, is in the Tsadaka Formation, which is correlative with the Hemlock Conglomerate. About 10,000 tons are reported to have been produced from a mine at Houston.

Coal fields of the Susitna Basin

North of the bedrock barrier extending westward from Mount Susitna along the south side of the Yentna and Skwentna Rivers is the extensive Susitna Lowland, situated between the Talkeena Mountains and the Alaska Range. Most of this lowland is covered with glacial and alluvial deposits. Soft-coal-bearing continental sedimentary rocks, correlative with the Kenai Group of Cook Inlet, are exposed in a few places along the banks and tributaries of the Susitna and Yentna Rivers. Along the southeastern margin of the Alaska Range, these Kenai Group rocks generally dip toward the Susitna Lowland or lie in downfaulted or downwarped basins (Barnes, 1966; Magoon and others, 1976; Reed and Nelson, 1980). The Tertiary deposits of the Peters Hills–Cache Creek area (loc. 17, Fig. 1) and of the Mt. Fairview area (no. 18, Fig. 1) were recognized by Capps (1913) as the source for placer gold, and some coal from these deposits was used for fuel by gold prospectors. Most of the thick coal beds known from the southwestern part of the basin were not discovered until the early 1960s (Barnes, 1966).

The coal-bearing rocks were divided by Reed and Nelson (1980) into three units; from top to bottom these are: (1) an orange to light gray, massive pebble to boulder conglomerate, correlative with the Sterling Formation, as much as 770 m thick, deposited by streams flowing southeastward from the Alaska Range; (2) a predominantly sandstone unit about 170 m thick, consisting of repetitive cycles 7–23 m thick, grading from coarse-grained, pebbly sandstone at the base to silt and clay with coal or bony coal at the top; and (3) a basal member consisting of 40 vol% conglomerate, 20 vol% sandstone, and less than 40 vol% siltstone, claystone, and coal, the latter in beds as much as 17 m thick. The two lower units are correlative with the Tyonek Formation.

On the basis of surface exposures only, Barnes (1966) calculated indicated reserves of 4.1×10^6 metric tons of coal in beds less than 2 m thick in the Peters Hills, about 40×10^6 tons of coal mainly in beds more than 3 m thick in the Fairview Mountain area, 18×10^6 metric tons of coal mainly in beds more than 2 m thick in the Johnson Creek area (loc. 19, Fig. 1), and 100×10^6 tons of coal in the downfaulted half graben along Canyon Creek (loc. 20, Fig. 1). A drilling program by the Mobil Oil Corporation has demonstrated the existence of 450×10^6 metric tons of coal within 76 m of the surface in beds 3 to 15 m thick, in two leasing units totaling 9,300 ha. One unit includes the Canyon Creek coal basin and the other extends from the Skwentna River northward across Johnson Creek (Blumer, 1981).

Barnes (1977) showed two strongly negative gravity anomalies beneath the Susitna Lowland: one between the Johnson Creek coal outcrops and Yenlo Mountain and north of the Skwentna River, and the other between Yenlo Mountain and the Susitna River, centered at the junction of the Kahiltna and Yentna Rivers. He interpreted both anomalies as thick fill of low-density sediment, probably of the Kenai Group, beneath the lowland. There is a potential for large deposits of coal in the area of both of these gravity anomalies.

Coal in the Broad Pass depression

The Broad Pass depression is a narrow trough extending northeastward from the north end of the Cook Inlet–Susitna Lowland (Wahrhaftig, 1965); it is about 8 km wide, bordered by mountains that rise abruptly 1,000–2,500 m above the basin. Although most exposures consist of metamorphic and igneous rocks mainly of Mesozoic and older age, several patches and small basins of poorly consolidated, coal-bearing continental rocks, correlative with the Kenai Group, crop out on its floor. Only two of these areas have been investigated for coal resources: the Costello Creek basin (loc. 21, Fig. 1) and an area at Broad Pass station (loc. 22, Fig. 1). A detailed U.S. Bureau of Mines–U.S. Geological Survey drilling and trenching program of the Costello Creek basin during World War II (Wahrhaftig, 1944) disclosed a lower unit, 0–26 m thick, of predominantly gray sandstone, interbedded mudstone, and lenticular coal beds, overlain by an upper predominantly sandstone unit, as much as 150 m thick, lacking minable coal. Total reserves of the Costello Creek basin, calculated in 1944, were 317×10^3 metric tons of coal in two beds with a maximum thickness of 3 m. According to Barnes (1967a, p. B24), 58×10^3 metric tons of coal was mined in 1940–1954, and the rest was unminable. The coal is subbituminous, and the beds are tentatively correlated with the Tyonek Formation.

The coal at Broad Pass station, 13–16 km east of the Costello Creek basin, is lignite, interbedded with white to orange sand and gravel (Hopkins, 1951). Gently dipping Tertiary beds at this locality are correlated with the Sterling Formation of the Susitna Lowland. Hopkins estimated that at least 12.2×10^6 metric tons of coal might exist beneath the area of known exposures of Tertiary rocks at this locality, but only 270×10^3 metric tons of lignite with an ash content of 8–25 wt% were actually measured. Lignitic coal has been reported elsewhere in the Broad Pass depression, and orange to yellow gravels exposed in railroad cuts and streambanks resemble the Nenana Gravel of the north side of the Alaska Range and the Sterling Formation of the Susitna Lowland.

Nenana Coal Field

The Nenana coal field (loc. 23, Fig. 1) is the largest, most centrally located, and most thoroughly studied of the coal fields on the north side of the Alaska Range. It has produced more than half of the coal mined in Alaska. This coal field is located in the northern foothills of the Alaska Range, extending from about 80 km west to 80 km east of the Alaska Railroad (Fig. 13). It consists of several synclinal basins partly or wholly detached from each other by erosion of coal-bearing rocks from intervening structural highs.

Usibelli Group. Coal occurs in the Usibelli Group (Wahrhaftig, 1987), a poorly consolidated sequence of continental sedimentary rocks of Tertiary age, consisting of the Healy Creek, Sanctuary, Suntrana, Lignite Creek, and Grubstake Formations. The following discussions of the Usibelli Group are summarized from Wahrhaftig and others (1969), Wahrhaftig (1987), and C. Wahrhaftig (unpublished data, 1947–1963).

Healy Creek Formation. The oldest formation in the Usibelli Group is the Healy Creek Formation (Fig. 14), a sequence of lenticular beds of poorly sorted sandstone, conglomerate, siltstone, and claystone, including beds of bone and coal that abruptly thicken, split, or pinch out. The Healy Creek Formation was deposited on a surface having a few hundred meters of relief, and its thickness and number of coal beds vary markedly. As indicated by the mineral content and varying flow directions shown in crossbeds and other sedimentologic features, the clastic sediments were derived from nearby sources.

Locally, coal beds as thick as 15–20 m rest directly on deeply weathered crystalline basement rocks and persist laterally for less than 1 km. In some directions they pinch out against the buried land surface on which they were deposited, and in other directions they interfinger abruptly with clastic sedimentary deposits. They are probably ancient peat deposits that were laid down in reentrant valleys of surrounding hills on the margins of the alluvial plain of the Healy Creek Formation. The reentrants, the surrounding hillslopes of which were densely vegetated and

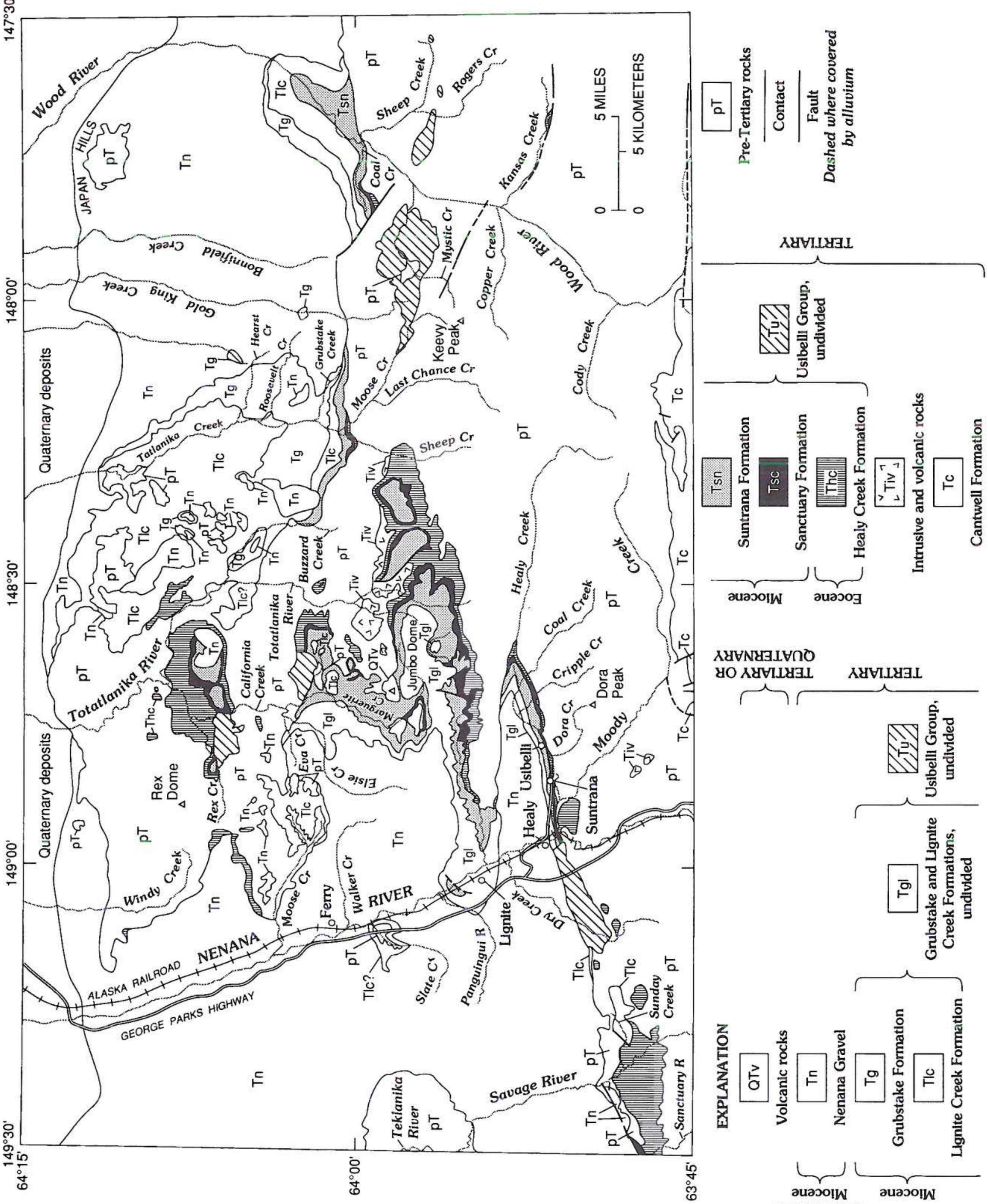

Figure 13. Geologic map of the Nenana coal field (from Wahrhaftig and others, 1969).

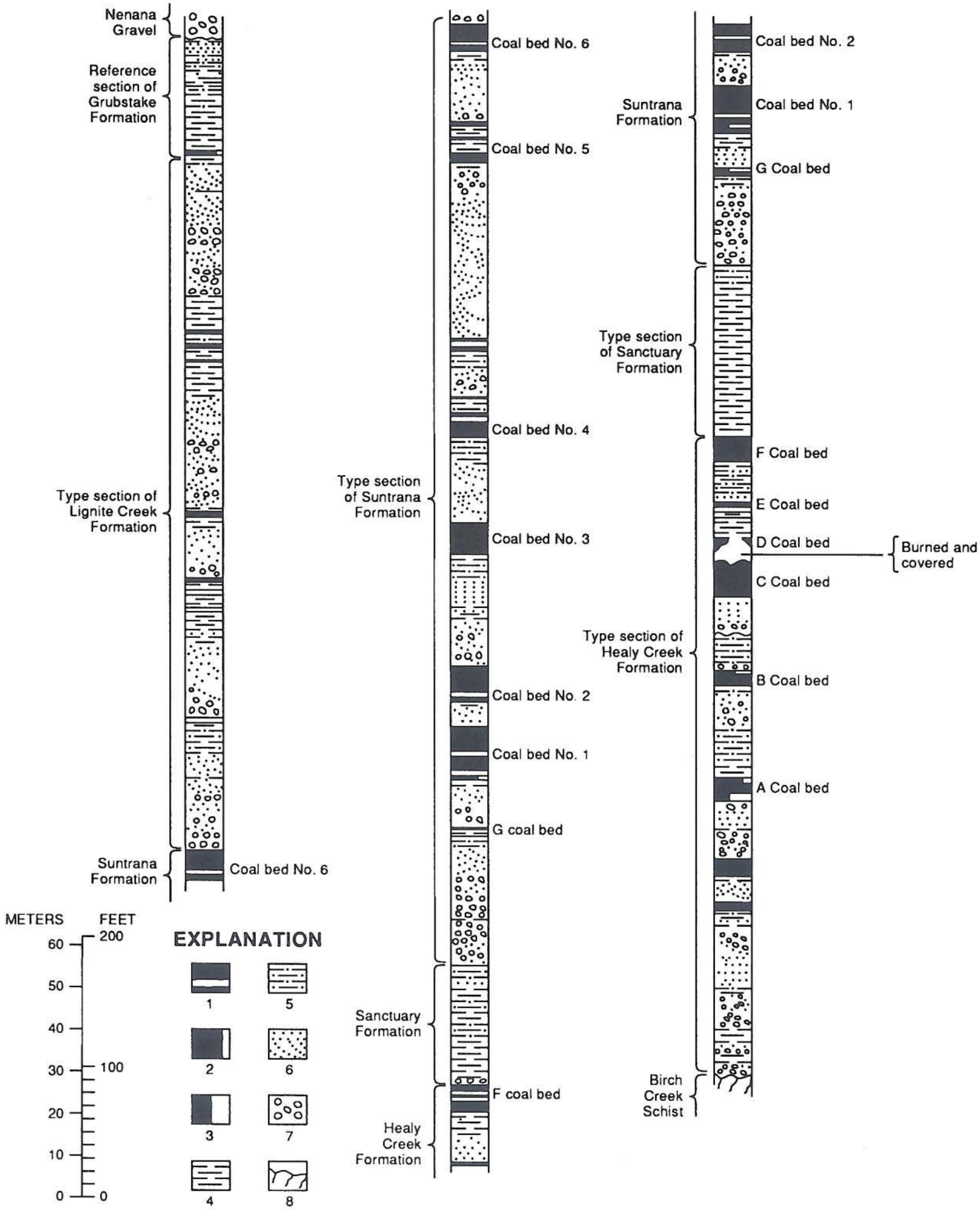

Figure 14. Type section of the Usibelli Group at Suntrana (from Wahrhaftig and others, 1969; also see Wahrhaftig, 1987). 1, coal, showing bone and clay partings; 2, bony coal; 3, bone; 4, claystone and shale; 5, siltstone; 6, sandstone, in part cross-bedded; 7, pebbles and conglomerate; 8, schist (unconformity at top).

shed no detritus, were protected from incursions of sediment from the alluvial plain by natural arboreal barriers or because they were raised bogs.

In most of the synclinal coal basins, the Healy Creek Formation is early and middle Miocene in age (Wolfe and Tanai, 1980; Wahrhaftig, 1987), but in the Rex Creek coal basin, 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).

Sanctuary Formation. The Sanctuary Formation is composed of 40 m of gray, thinly laminated (possibly varved) shale that weathers chocolate brown; the unit 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 highest coal bed of the Healy Creek Formation, the "F" bed (Fig. 14), which immediately underlies the Sanctuary Formation, is the only coal bed in the Healy Creek Formation of sufficiently continuous lateral extent to the analyzed for reserve estimates.

Suntrana Formation. The overlying Suntrana Formation is as thick as 400 m, and consists of 6–12 upward-fining cycles of well-sorted, crossbedded sandstone that is pebbly at the base. Each cycle has at its top a sequence of claystone, siltstone, and fine sandstone with one or more coal beds 0.5–20 m thick. Northward coarsening of sediment and current indicators in the crossbeds indicate that the clastic components were derived from sources to the north. Trough-crossbed sets are 1–2 m thick (C. Wahrhaftig, unpublished data, 1947–1963).

The middle Miocene Suntrana Formation (Wolfe and Tanai, 1980) contains the major coal resources of the Nenana coal field. The formation as a whole thickens gradually southeastward from a line of pinchout in the northwestern part of the coal field; most of the thick coal beds can be traced laterally over distances of as much as 25 km (Wahrhaftig, 1973). The bulk of the calculated reserves is in six coal beds 6–20 m thick. Isopachs on coal bed no. 6, the highest coal bed in the Suntrana Formation, are shown in Figure 15.

The lateral persistence of the coal beds and of the major intervening clastic units in a direction normal to the current direction poses problems in interpreting the conditions of deposition of the coal. The geometry suggests an alternation throughout the coal field of continuous peat swamps and sandy plains of fluvial sedimentation. One possible cause for this alternation would be that the clastic source area was a heavily vegetated region that underwent deep weathering beneath vegetation cover during long periods—represented by the coal beds—interrupted by short intervals of rapid erosion, possibly triggered by fires, catastrophic storms, or tectonic activity. Such a scenario, however, is not easily compatible with a system involving streams that have deposited trough crossbeds as much as 2 m thick and that flowed swiftly enough to transport pebble to cobble gravel across a plain flat enough to have acted as a peat bog at least 25 km wide in the direction of stream flow.

Lignite Creek Formation. Overlying the Suntrana Formation is the 150–240-m-thick, late middle to early late Miocene age Lignite Creek Formation (Fig. 14; Wolfe and Tanai, 1980), which is composed of repetitious sequences of well-sorted, crossbedded, pebbly and coarse-grained sandstone at the base, grading to interbedded clay and coal beds at the top. Grain mineralogy and pebble lithologies of the sandstone differ from those in the Suntrana Formation, and the coal beds are thin (generally less than 1.5 m), woody, and relatively lenticular. No coal reserves have been calculated for the Lignite Creek Formation. The coal beds pinch out northward. A non-coal-bearing conglomeratic facies, as much as 450 m thick, of the Lignite Creek Formation occurs along the north and west margins of the Nenana coal field.

Grubstake Formation. The highest formation assigned to the Usibelli Group is the Grubstake Formation, a dark gray laminated shale and claystone that is 180–300 m thick in the northeastern part of the Nenana coal field, but only 25–75 m thick in the southwestern part (Fig. 14). 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). In the eastern part of the outcrop belt, the Grubstake Formation interfingers southward with coarse-grained dark sands similar to those in the overlying Nenana Gravel. The Grubstake Formation probably accumulated in the lake formed by the damming of formerly southward-directed drainage by the rising Alaska Range.

Nenana Gravel. The Nenana Gravel, a poorly consolidated, buff to red pebble to boulder conglomerate derived from the Alaska Range, rests on the Usibelli Group and ranges in thickness from 1,200 m at the south edge of the Nenana coal field to 300–400 m along the north edge of the foothills. The gravel detritus was shed northward from the rising Alaska Range that blocked the southward-flowing drainage tributary to the Cook Inlet–Susitna Lowland (Wahrhaftig, 1970). Its age is bracketed between 8.3 and 2.75 Ma, and so it is contemporaneous with the Sterling Formation. 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 Nenana Gravel rests on rocks older than the Usibelli Group, and detritus from the Usibelli Group can be recognized in the Nenana Gravel.

Coal assessment of the Nenana coal field. The coal in the Nenana coal field ranges from lignite to subbituminous B but is mainly subbituminous C. It has an ash content of 5–20 wt%, a moisture content of 15–30 wt%, a heating value of 3,900–4,700 cal/gm (as received), and one of the lowest reported sulfur contents of any United States coal, reported to be 0.1–0.3 wt% (Rao and Wolfe, 1981; Affolter and others, 1981). Measured, indicated, and inferred resources of coal, in beds more than 0.75 m thick and within 1,000 m of the surface, are slightly less than 6.4×10^9 metric tons, of which about 5.4×10^9 metric tons is in beds more than 3 m thick (Barnes, 1967a). More than 5.4×10^9 metric tons of the resources are in the Healy Creek and Lignite

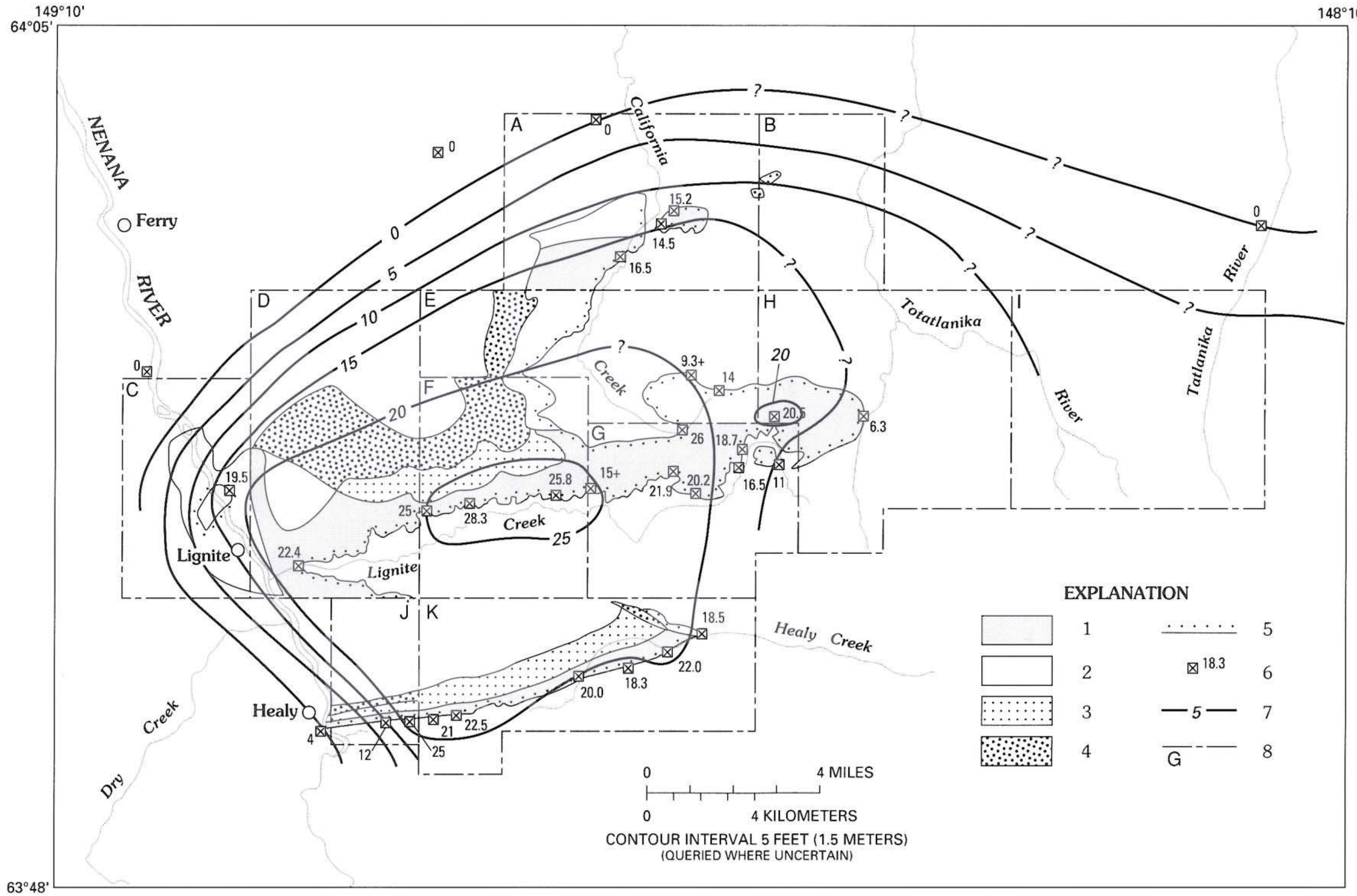

Figure 15. Isopachs and coal reserve areas of coal bed no. 6, Nenana coal field, Alaska. 1: Measured and indicated coal with less than 305 m (1,000 ft) of overburden. 2: Inferred coal with less than 305 m (1,000 ft) of overburden. 3: Measured and indicated coal with 305–914 m (1,000–3,000 ft) of overburden. 4: Inferred coal with 305–914 m (1,000–3,000 ft) of overburden. 5: Trace of outcrop of coal bed no. 6. 6: Location of measured section of coal bed no. 6, with thickness in feet (+ sign indicates measured thickness where either base or top is not exposed). 7: Isopach line for coal in bed no. 6, contour interval 1.5 m (5 ft), queried where position uncertain. 8: Boundary of coal reserve reporting unit in Table 3; letter designation in upper left or right corner of each unit (modified from Wahrhaftig, 1973).

Creek coal basins (Table 3; Wahrhaftig, 1973). Hypothetical resources are not calculated but are unlikely to be more than a fraction of the calculated reserves, because the coal-bearing rocks pinch out and are overlapped by the Nenana Gravel to the north, and because the coal beds thicken and increase in number southward, reaching their maximum thickness at the outcrops along the south margin of the coal field.

Coal was first mined when the Alaska Railroad reached the Nenana coal field in 1918. Mining was by underground methods, chiefly at the Suntrana mine, until the 1950s. Strip mining of coal, which began in 1944, is the only method used to mine coal today. Several 3–20-m-thick beds within the Suntrana Formation and Healy Creek Formation are separated by 10–60 m of poorly consolidated sandstone and are overlain at the surface by sand and gravel overburden with an overburden/coal ratio of less than 5:1. Essentially all of the stripping coal in the Healy Creek coal basin has been mined, but resources of as much as 360×10^6 metric tons may exist in the Lignite Creek coal basin. In 1985, Usibelli Coal Mine, Inc. produced about 1.4×10^6 metric tons of coal, 48% of which was consumed in Alaska; the rest was exported to South Korea (Green and Bundtzen, 1989).

Jarvis Creek coal field

The Jarvis Creek coal field (loc. 24, Fig. 1) is along the north flank of the Alaska Range on a plateau 1,000–1,300 m high, about 160 km east of the Nenana River and 3–10 km east of the Delta River and the Richardson Highway. Coal-bearing, poorly consolidated, continental sedimentary rocks totaling 600 m in thickness that underlie an area of about 40 km^2 of this plateau are correlated with the Healy Creek Formation of the Nenana coal field (Wahrhaftig and Hickcox, 1955). These coal-bearing sedimentary rocks rest on an erosional surface with at least 150 m of local relief that has been cut into crystalline rocks.

TABLE 3. RESERVES OF COAL IN THE LIGNITE CREEK AND HEALY CREEK COAL BASINS, NENANA COAL FIELD, ALASKA*

Reserve reporting unit	Average thickness of coal beds (m)	Total Number of Coal Beds	Reserves in millions of metric tons with overburden thickness of: Less than 30 m†	30–91 m†	Less than 305 m§			305–610 m			610–915 m	
			inferred	inferred	measured	indicated	inferred	measured	indicated	inferred	indicated	inferred
A	>3	3	18.1	0.3	2	25	100	....	....	....	....	....
	1.5 to 3	3	14.3	5.2	4	16	13	....	....	....	....	....
	<1.5	2	1.9	0.2	....	....	9	....	....	....	....	....
B	>3	2	7.2	3.0	....	6.0	15	....	....	....	....	....
	<3	4	6.4	0.2	....	....	8	....	....	....	....	....
C	>3	2	0.9	....	....	....	96	....	....	....	....	....
D	>3	4	20.6	46.0	....	381	73	....	23	162	....	98
	1.5 to 3	2	....	....	....	....	31	....	....	17	....	....
	<1.5	1	....	....	....	....	22	....	....	....	....	....
E(NW)	>3	5	7.8	....	....	62	46	....	....	107	....	....
	<3	1	....	....	....	....	....	....	....	10	....	....
E(SE)	>3	7	4.4	5.7	....	94	80	....	5	3	....	....
	<3	1	....	....	....	8	....	....	1	....	....	....
F	>3	6	20.4	28.3	107	150	45	....	269	20	....	199
	1.5 to 3	1	....	....	....	7	13	....	....	30	....	....
	<1.5	1	....	....	....	....	3	....	....	3	....	....
G	>3	6	40.2	68.8**	113	414	145	....	123	22	....	....
	<3	3	....	....	14	....	16	....	6	....	....	....
H	>3	8	35.6	29.1	....	232	241	....	....	1	....	....
	<3	3	....	....	....	35	66	....	....	....	....	....
I	>3	2	3.3	....	....	....	99	....	....	....	....	....
	<3	4	6.2	....	....	....	110	....	....	....	....	....
J	<3	5	....	....	....	5.9	13	....	4	13	....	20
K	>3	11	‡	‡	272	79	100	248	53	96	222	79
	<3		....	....	....	1	15	....	1	12	....	2
	Totals		**187.3**	**186.5**	**512**	**1,514.9**	**1,356**	**248**	**485**	**496**	**222**	**398**
Totals by overburden category			**373.8**		**3,382.9**			**1,229**			**620**	
	Grand total											**5,605.7**

*C. Wahrhaftig, unpublished data, 1971. Reserve calculations are based on field work completed in 1960 and do not take into account coal mined since then. For location of reserve reporting units, see Figure 15.

†All classed as inferred because of possibility that beds are burned.

§Excluding reserves in first two reserve columns.

**Overburden 100 to 200 ft.

‡Extensive deposits of coal with less than 300 ft of overburden are mined in this reporting unit. Reserves have not been calculated because of difficulty of estimating the thickness of terrace gravel deposits.

The sedimentary rocks are gently deformed into an oval basin, the flanks of which dip generally less than 10°. The clastic components appear to be from two local sources: the lowermost beds are derived from the south, and the overlying beds are derived from the north and northeast. Although no connection between the Jarvis Creek coal field and the Cook Inlet area is known, the northern source of sediment implies that drainage from the coal field was to the south.

Thin, discontinuous coal beds are present throughout the section, but most of these beds are less than 0.75 m thick. Wahrhaftig and Hickcox (1955) calculated 12×10^6 metric tons of indicated and inferred resources of coal in seven beds exposed along the south and east sides of the coal field, and suggested that the field might contain as much as 57×10^6 metric tons of additional resources for which no outcrop evidence is available. Metz (1981) reported that drilling has blocked out about 1×10^6 metric tons of stripping coal in part of the coal field. The coal is subbituminous C, with a heating value of 4,400–5,000 cal/gm and an ash content of 5–13 wt%.

The north flank of the Alaska Range, between the east end of the Nenana coal field at the Wood River and the Jarvis Creek coal field, has broad, east-west–trending anticlinal and synclinal structures marked by arcuate cuestas of the Nenana Gravel. Coal-bearing rocks of the Usibelli Group are present discontinuously along the unconformable contact of the Nenana Gravel with underlying Paleozoic and Mesozoic crystalline rocks. The Usibelli Group has been recognized at several localities along Dry Creek (long 147°15′W; loc. 25, Fig.1); at the mouth of Newman Creek the group may be as much as 750 m thick. Two beds, each about 3 m thick, dipping 66°NE, are present on the west bank of Dry Creek at this locality (Inyo Ellersieck, 1987, oral and written commun. based on helicopter reconnaissance in 1977). Here the Usibelli Group extends from around the nose of a southeast-plunging anticline having a core of Paleozoic schist southward to about 6.5 km upstream in Newman Creek and, from there, about 8 km westward to Red Mountain Creek. In this vicinity, at least three coal beds averaging 1.4 m thick are exposed in a 45-m-thick section, and a borehole nearby penetrated at least two beds of minable coal, one 1.4 and the other 2.9 m thick (Merritt, 1985b). Patches of clinker indicate the presence of coal in the Usibelli Group on Dry Creek north of the mouth of Newman Creek. If the exposures of the Usibelli Group, which extend for about 24 km, have an average of at least 10 m of minable coal, then 60–70 $\times 10^6$ metric tons of hypothetical resources may be present in this coal basin having an overburden depth of 500 m.

Coal has also been reported on the east bank of Delta Creek opposite the mouth of Ptarmigan Creek (lat 63°50′N, long 146°30′W, loc. 26, Fig. 1), where Ellersieck observed at least one coal bed more than 3 m thick in a complexly deformed exposure. Usibelli Group may also crop out in the core of an anticline that straddles the Little Delta River at lat 64°N; however, no coal has been reported there. Coal may be present elsewhere in the region between the Wood and Delta Rivers; however, a thick mantle of glacial and glaciofluvial deposits buries most of the lowland areas, and its extent, if any, is unknown.

Little Tonzona coal field

Exposures of coal of Tertiary age are present in a 145-km-long belt, locally as much as 3 km wide, along the Farewell fault on the northwest side of the Alaska Range between the Little Tonzona River on the northeast (lat 62°45′N, long 153°00′W) and the Cheeneetnuk River on the southwest (lat 62°00′N, long 155°15′W) (Barnes, 1967a; Sloan and others, 1979; Reed and Nelson, 1980; Solie and Dickey, 1982; Dickey, 1984; Gilbert and others, 1982). On the west bank of the Little Tonzona River, seven coal beds up to 9 m thick have a combined thickness of 35 m of subbituminous coal (loc. 27, Fig. 1). The beds are interbedded with ferruginous siltstone and silty shale; they strike N37°E and dip 47°–63°NW (Sloan and others, 1979; Reed and Nelson, 1980). The coal contains 6–11 wt% ash, 0.7–1.7 wt% sulfur, and is subbituminous C. Additional exposures of coal occur on Deepbank Creek, 11 km to the southwest.

Coal exposures are also on the west bank of Windy Fork of the Kuskokwim River. The section is 1,800 m thick and consists of about 90 vol% conglomerate; a 190-m-thick section of interbedded coal and shale is near the top and two or three 10-m-thick sequences of coal and shale are near the base of the section (loc. 28, Fig. 1; Solie and Dickey, 1982). According to Sloan and others (1979), who examined the 190-m-thick coal and shale section, the coal beds are mostly too bony to constitute a fuel resource. Only one bed has an ash content as low as 31 wt%; all other analyses give more than 40 wt% ash. According to Solie and Dickey (1982), within the 190-m-thick section are three beds totaling 20 m in thickness that contain 7–10 wt% ash and 0.5–0.6 wt% sulfur, and two other beds that total 6 m in thickness contain 10 and 18 wt% ash. The coal in both groups is high-volatile bituminous C or subbituminous A, and has moist ash-free heat content of 5,560–6,670 cal/cm. The beds of coal at this locality crop out on both limbs of a northeast-plunging syncline and dip 34°–70° (Gilbert and others, 1982).

About 18 km southwest of this locality, at the south edge of the alluvial plain of the Tanana-Kuskokwim lowland, an exposure of lignite was reported by Solie and Dickey (1982), apparently the same rock unit as the Windy Fork exposures. The marked difference in the rank of coal in these supposedly coeval rocks within the same structural context is puzzling. The structure of the exposure as described by Solie and Dickey (1982) is unlike that mapped by Gilbert and others (1982). About 5 km southwest of the lignite locality, where the Middle Fork of the Kuskokwim River emerges from the Alaska Range onto the Tanana-Kuskokwim Lowland, in a riverbank exposure of conglomerate, claystone, and coal striking N26°E and dipping 45°NW, Solie and Dickey (1982) observed 35 m of coal in six beds within the uppermost 100 m of the 600-m-thick section. At the southwest end of these coal occurrences, coal is exposed on the banks of the Cheeneetnuk River; the beds are within a block of Tertiary sedimentary rocks, about 1 km wide and a few kilometers long, that have been downfaulted into Paleozoic rocks (loc. 29, Fig. 1). The coal is intermediate in rank between subbituminous and high-volatile bituminous, and one bed was reported to be at least 5 m thick (Solie and Dickey, 1982).

Dickey (1984) reported that most of the clastic rocks in the Little Tonzona field were deposited by southward-flowing streams and that the abundant conglomerate in the section was probably deposited as alluvial fans along the base of a south-facing escarpment.

Both the southward-directed current indicators and the fact that the lower parts of the section are conglomeratic and resemble the section at Farewell Mountain in the Susitna Lowland suggest that the Little Tonzona field may have been one of the source regions for streams that flowed through the western Susitna Lowland to the Cook Inlet region.

CRETACEOUS COAL OF THE ALASKA PENINSULA

Coal occurs at Herendeen and Chignik Bays on the Alaska Peninsula in the Chignik Formation of Campanian (Late Cretaceous) age (Figs. 1 and 16). The coal accumulated in littoral and overbank swamps on a gentle shelf facing a major submarine trench to the south. To the north was a rolling upland underlain by plutonic, volcanic, and oceanic sedimentary rocks of Jurassic and older age.

The Chignik Formation is a four-times-repeated cyclic sequence, about 500 m thick, of shallow-water, nearshore marine, clastic sedimentary rocks overlain by continental sedimentary rocks (including coal beds). The clastic sedimentary rocks are typically calcareous and include fine- to medium-grained brown sandstone composed of quartz, chert, feldspar, and lithic fragments that are locally channeled and crossbedded; pebble and cobble conglomerate of black, gray, green, and red chert, white quartz, granitic clasts derived from the Jurassic Alaska–Aleutian Range batholith, and minor volcanic clasts; and dark, sandy micaceous siltstone (Detterman, 1978; Detterman and others, 1981). The Chignik rests with shallow angular unconformity on sedimentary rocks ranging in age from Late Jurassic to Early Cretaceous (late Neocomian) (Burk, 1965).

Rocks contemporaneous with the Chignik Formation that occur on offshore islands south of the Alaska Peninsula and beneath the Shelikof Strait are deep-marine volcaniclastic turbidites of a flysch sequence that accumulated in a deep oceanic trench (Plafker and others, this volume, Chapter 12). The shelf edge was apparently not far south of the depositional site of the Chignik Formation.

The Chignik Formation is thick and coal bearing only be-

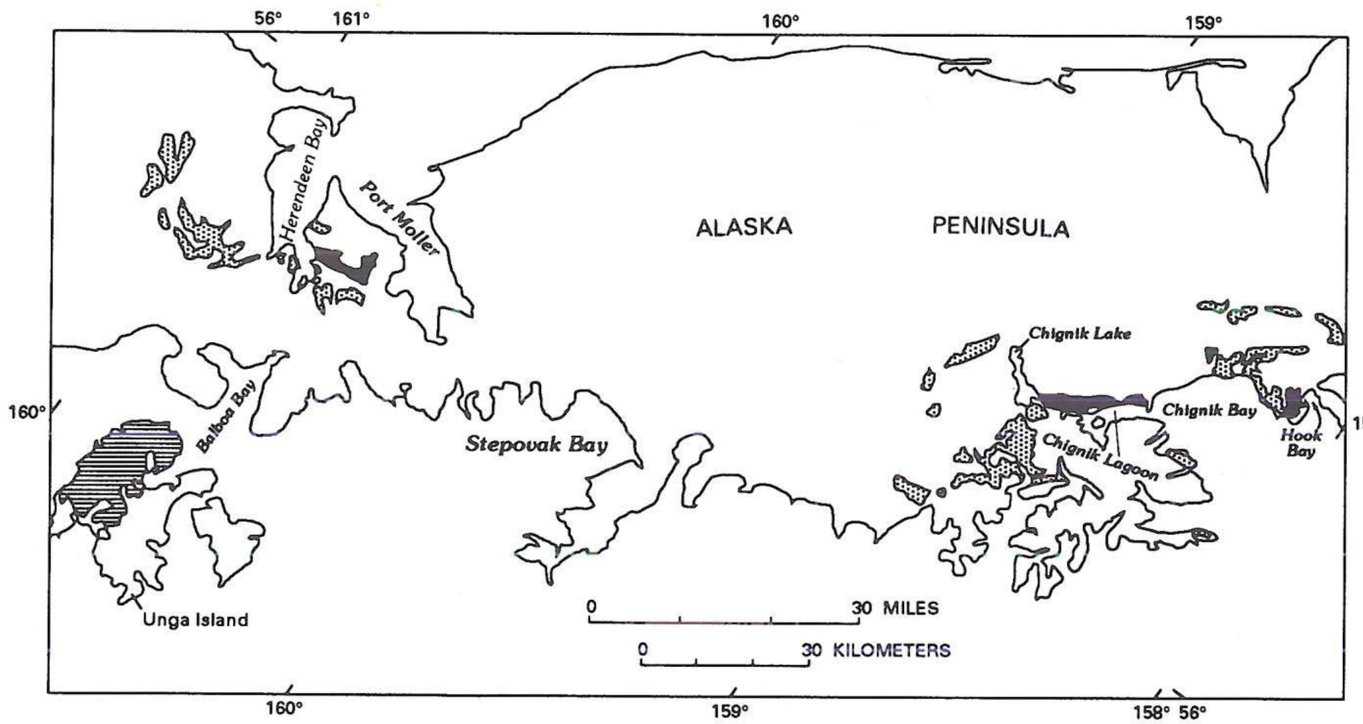

Figure 16. Map of part of the Alaska Peninsula and Unga Island, showing areas of outcrop of the Chignik and Bear Lake formations. Solid black is Chignik Formation where minable coal has been described; stippled area is Chignik Formation where it has not been examined for coal; lined area is Bear Lake Formation. North of latitude 56°00′ from Detterman and others (1981); south of latitude 56°00′ from Burk (1965).

tween Herendeen Bay and Hook Bay, a distance along the peninsula of about 200 km. Farther east (for example, just east of Aniakchak caldera) it is less than 30 m thick and contains no coal (R. L. Detterman, 1986, oral commun.). Presumably, a local highland immediately north of the Herendeen Bay–Chignik Bay area provided abundant sediment to a slowly subsiding marginal shelf, creating swampy flood plains with conditions amenable to coal accumulation.

According to F. H. Wilson and others (1991, written commun.), in the vicinity of Herendeen Bay, the Chignik Formation and other Mesozoic and lower Tertiary rocks form the upper plate of a nearly horizontal thrust fault, and the rocks in this thrust sheet are cut by numerous normal faults, resulting in almost chaotically jumbled kilometer-sized blocks.

The known coal exposures are located on the peninsula in the Herendeen Bay coal field (loc. 30, Fig. 1; also see Fig. 16) between Herendeen Bay and Port Moller, and in the Chignik Bay coal field (loc. 31, Fig. 1; also see Fig. 16) from Chignik Lake eastward along the north shore of Chignik Lagoon and Chignik Bay as far east as Hook Bay (Atwood, 1911; Conwell and Triplehorn, 1976). Several tunnels were driven along the coal seams in the syncline east of Mine Harbor on Herendeen Bay, but all penetrated faults, losing the coal within a few hundred meters of the portal. The coal mine on the Chignik River was operated between 1893 and 1911 to provide fuel for local fish canneries. The relatively high rank of the coal and its accessibility to ice-free harbors make it of economic interest.

Thicknesses of coal in the Herendeen Bay coal field have been reported for four localities (Paige, 1906; Atwood, 1911; Conwell and Triplehorn, 1976). Total thicknesses of coal in beds at least 0.8 m (2.5 ft) thick at these four localities range from 1.5 to 5 m (5–16 ft). A representative columnar section is shown in Figure 17A. All localities are in the western part of the synclinal body of the Chignik Formation that extends eastward on the peninsula from Mine Harbor in Herendeen Bay. This synclinal body covers an area of about 25 km^2, and if at least 1.2 m (4 ft) of minable coal is present throughout this area, it contains 35 × 10^6 metric tons of minable coal. The remaining areas of exposure of the Chignik Formation in the Herendeen coal field total about 85 km^2 (Burk, 1965, plate 2), and if 1.2 m (4 ft) of minable coal underlies 25% of that area, then 27–30 × 10^6 metric tons of additional coal may be present.

In view of the chaotic structure reported by F. H. Wilson and others (1991, written commun.) for the Chignik Formation in the Herendeen Bay coal field, the foregoing figures must be regarded as highly speculative, probably only an upper limit of what might prove to be minable. Thorough subsurface exploration will be necessary to establish any actual reserves.

Exposures of coal have been described at four localities between Chignik Lake and Hook Bay: on the Chignik River, north of Chignik Lagoon, north of the northeastern part of Chignik Bay, and at Hook Bay. A representative columnar section is shown in Figure 17B. The total thickness of coal in these occurrences is 1–4 m. If 1.2 m of minable coal is assumed to underlie the area north of Chignik Bay, Chignik Lagoon, and the area around Hook Bay, which together total about 39 km^2 ~55 × 10^6 metric tons of minable coal may exist beneath these areas. The area of exposure of the Chignik Formation in the Chignik coal field is 175 km^2 (Detterman and others, 1981); if 25% of this area is underlain by 1.2 m of minable coal, there could be an additional 62 × 10^6 metric tons of coal in this field. Thus, the two Cretaceous coal fields together have speculative resources amounting to slightly more than 180 × 10^6 metric tons.

According to Conwell and Triplehorn (1976), the coal is high-volatile bituminous B, with an ash content of 9.4–12.6 wt% in the Herendeen coal field and 20–40 wt% in the Chignik field. Sulfur content is less than 0.5 wt% in the Herendeen coal field and 0.3–1.4 wt% in the Chignik field. Coal beds in the Chignik field range from 0.3 to 1.5 m in thickness and are moderately folded and faulted.

TERTIARY COAL OF UNGA ISLAND

Tertiary strata, 7,600–9,140 m thick, are exposed in the western Alaska Peninsula and adjacent Shumagin Islands (Burk, 1965). A Paleogene sequence as thick as 6,100 m, largely derived from volcanic sources, is overlain unconformably by more than 1,500 m of marine and nonmarine sandstone and conglomerate of Miocene age (Bear Lake Formation). The sandstone consists of approximately equal amounts of volcanic clasts and chert, quartz, and granitic and other nonvolcanic clasts. Showings of thin lignite beds have been reported in these Tertiary rocks; however, the only minable occurrence of coal is in the northwestern part of Unga Island, on the west shore of Zachary Bay (loc. 32, Fig. 1; see Fig. 16).

Nilsen (1984) interpreted the bulk of the Bear Lake Formation to have accumulated within a broad shallow tidal-flat embayment in a back-arc setting on the north side of a middle Tertiary Aleutian arc, similar to, but larger than, the modern tidal flats at Port Heiden and Port Moller. The alluvial plain on the south margin of the tidal embayment included the site of Unga Island, accounting for the predominantly fluvial materials, abundant conglomerate, and scattered thin coal beds of Unga Island.

Northwestern Unga Island is a broad plateau, about 10 km on a side, underlain by the Oligocene(?) and lower and middle Miocene Unga Conglomerate Member of Burk (1965) of the Bear Lake Formation, which strikes northerly and dips 4°–5°W (Atwood, 1911; Burk, 1965, p. 92–93). A 10-m-thick section of fine-grained sandstone and shale containing two lignite beds, each including about 0.9 m (3 ft) of lignite, is exposed about 60 m above sea level near the south end of bluffs on the west side of Zachary Bay and is overlain by about 110 m of conglomerate and sandstone. According to Atwood (1911), the lignite was mined between 1882 and 1884 to provide fuel for coastal steamships, and a few hundred tons were reportedly shipped to San Francisco. At the time of Atwood's visit in 1908, the upper lignite bed was being developed with a crosscut tunnel, an

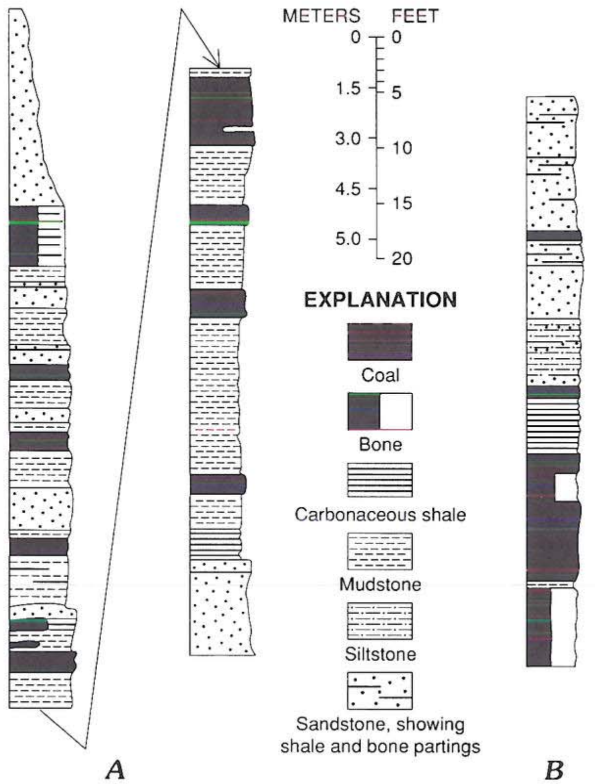

Figure 17. Measured sections of coal in the Chignik Formation. A: 2.4 km (1.5 mi) southeast of the village of Herendeen Bay. B: North bank of Chignik River near mouth (after Conwell and Triplehorn, 1978, Figs. 4 and 8).

aerial tramway, and bunkers for storing mined coal near the shore. A sample collected by Atwood contained 26 wt% ash and had a heating value of only 3,225 cal/gm. Lyle and others (1979) measured the same sequence about 1.6 km north of Atwood's locality and reported that the upper bed contained only 0.9 m of coal, 0.3 m of which is bony, and the lower bed contained only 0.5 m of coal, with a 0.2 m clay parting in the middle. There is no record of any coal being produced from this locality after Atwood's visit in 1908. Wilson and others (1991, written commun.) were unable to find the coal mine described by Atwood (1911), and have concluded that the coal will probably be used, if at all, for local purposes.

GULF OF ALASKA TERTIARY PROVINCE

Geologic setting

The Gulf of Alaska Tertiary province, a 485-km-long stretch of Tertiary rocks bordering the eastern Gulf of Alaska between Cross Sound and the Copper River, is the onland part of the Yakutat terrane, a nearly triangular, largely submarine crustal block south and west of the Chugach–St. Elias and Fairweather faults. The Yakutat terrane is still being accreted to the mainland of Alaska along the Aleutian Trench subduction zone (Plafker, 1987; Plafker and others, this volume, Chapter 12). Basement rocks that make up the east third of the Yakutat terrane consist of Mesozoic flysch and melange of the Yakutat Group, intruded by Eocene plutonic rocks; the basement of the offshore part of the rest of the Yakutat terrane is possibly Paleocene and lower Eocene oceanic crust. Along the north edge, between the shoreline and the Chugach–St. Elias fault, basement rocks are probably greenschist and zeolite facies, metamorphosed flysch and oceanic volcanic rocks of the Orca Group (Plafker and others, this volume, Chapter 12). Deposited on this basement are clastic sedimentary rocks that locally may exceed 12,000 m in thickness and range in age from late Eocene to late Pleistocene. These sedimentary rocks appear to have been derived from upland areas in present-day British Columbia and southeastern Alaska, as the Yakutat terrane migrated northwestward along the Fairweather transform fault. The bulk of this succession is marine—some of it is deep-water marine—but a thick continental and paralic sequence within it contains coal. Unlike coal elsewhere in Alaska, coal in the Gulf of Alaska Tertiary province accumulated when the Yakutat terrane was several hundred kilometers southeast of its present position relative to the rest of Alaska.

Kulthieth Formation—the Bering River coal field

The Bering River coal field (loc. 33, Fig. 1) is in the southern foothills of the Chugach Mountains, 30–65 km east of the mouth of the Copper River at the northwest corner of the Gulf of Alaska Tertiary province (Plafker, 1987). It underlies a northeast-trending area, about 35–40 km long and 3–10 km wide, between the Martin River Glacier and the Bering Glacier and River (Martin, 1908), and contains the great bulk of Alaska's known deposits of high-rank coal. The coals, which are low-volatile bituminous to anthracite, occur in the Kulthieth Formation of Eocene and Oligocene age (Fig. 18; Miller, 1957; Plafker, 1987). The Kulthieth Formation crops out in an east-west–trending belt, 3–19 km wide and 210 km long, from the Bering River coal field on the west to the Samovar Hills on the east. It lies in rugged, glacier-clad foothills at the base of the escarpment of the Chugach and St. Elias Mountains, 19–45 km north of the coast. Small outcrops of subbituminous coal on the west shore of Disenchantment Bay, 45 km north of Yakutat, are also assigned to the Kulthieth Formation. Although the Kulthieth Formation contains coal beds throughout its length of outcrop, its coal potential has been studied in detail in only two localities, the Bering River coal field and the Samovar Hills (loc. 34, Fig. 1). In most of the intervening belt, the formation is exposed on inaccessible cliffs, and long stretches of potential exposure in the belt are covered by vast glaciers.

The Kulthieth Formation is about 2,835 or more m thick in its type locality at the head of the Kulthieth River (Miller, 1957). It is overlain conformably by the 1,860-m-thick marine Poul Creek Formation, a unit composed of interbedded siltstone and sandstone of late Eocene to early Miocene age, in turn overlain

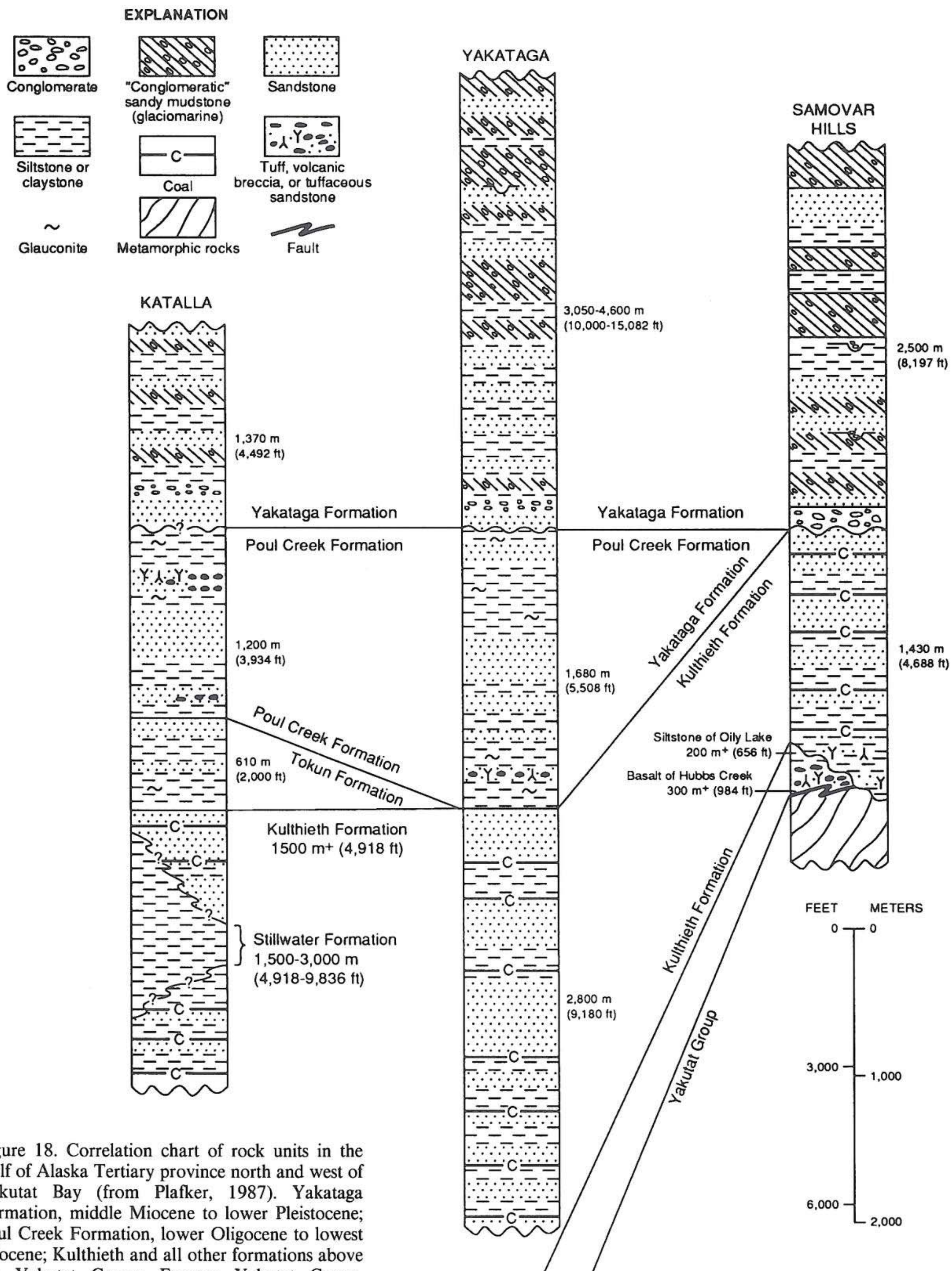

Figure 18. Correlation chart of rock units in the Gulf of Alaska Tertiary province north and west of Yakutat Bay (from Plafker, 1987). Yakataga Formation, middle Miocene to lower Pleistocene; Poul Creek Formation, lower Oligocene to lowest Miocene; Kulthieth and all other formations above the Yakutat Group, Eocene; Yakutat Group, Cretaceous.

by the 3,050–4,570-m-thick Yakataga Formation, a marine sequence that includes marine tillites of early Miocene to Pleistocene age (Fig. 18). According to Plafker and Miller (1957), The Kulthieth Formation just south of Mount St. Elias is about 3,050 m thick, but the section may be repeated by folds and thrusts. About 16–20 km east-southeast of this exposure, the Kulthieth of the Samovar Hills is more than 1,435 m thick, rests unconformably on the Yakutat Group, and is unconformably overlain by the Yakataga Formation. In the Bering River coal field, the Kulthieth Formation (Kushtaka Formation of Martin, 1908; Nelson and others, 1985) is variously reported to be 610–1,585 m thick; the unit interfingers with the underlying deep-water marine Stillwater Formation and the overlying shallow-marine Tokun Formation, which in part may be correlative with the basal part of the Poul Creek (Fig. 18).

The Kulthieth is a conspicuously banded sequence of sandstone, siltstone, shale, and coal. The sandstone is fine to medium grained, commonly crossbedded, well sorted, arkosic, cemented generally by calcite, and weathers orange. The siltstone and shale are dark gray and carbonaceous. Most of the coal beds apparently occur in the predominantly silt-shale sequences (Barnes, 1951; Miller, 1957; Plafker and Miller, 1957). Turner and Whateley (1989) regarded the lower two-thirds of the Kulthieth Formation, dominated by upward-coarsening sandstone sequences in the Bering River coal field, to be a deltaic and delta-plain sequence built onto the moderately deep sea floor on which shales of the Stillwater Formation accumulated. They interpreted the thin and discontinuous coals of this part of the formation to have accumulated as tidal-marsh deposits in the embayments between distributaries, and the upper, more coal-rich third of the deposits in the Bering River coal field to be of delta-plain and alluvial-plain origin.

The predominance of arkosic sandstones in the Kulthieth and other Paleogene formations indicates that the Yakutat terrane lay 600 km southeast of its present position, probably offshore of British Columbia or southern southeastern Alaska, when the coals accumulated (Plafker, 1987; Plafker and others, this volume, Chapter 12). Similarities between heavy-mineral assemblages of Eocene sandstones of the Yakutat terrane and the Kootznahoo Formation and related units in southeastern Alaska suggest that they both had a common source (Chisholm, 1985), possibly in the Coast Mountains of southeastern Alaska and British Columbia. Paleontologic evidence is equivocal, but is compatible with at least 600 km of displacement and, conceivably, much more (Bruns, 1983; see discussions by Plafker, 1983, 1984; Bruns, 1984; Bruns and Keller, 1984; Wolfe and McCoy, 1984; Chisholm, 1985; von Huene and others, 1985; Plafker, 1987; Marincovich, 1990). During the past 20–30 m.y., transcurrent motion along the Queen Charlotte–Fairweather transform fault has caused subduction of the leading edge of the Yakutat terrane beneath the Chugach terrane along the Chugach–St. Elias fault zone and accretion against the Chugach and Prince William terranes of the east-trending part of the Gulf of Alaska Tertiary province (Plafker and others, this volume, Chapter 12). To accommodate the change in direction of the coastline in the vicinity of Mount St. Elias, the province has been rotated counterclockwise and telescoped or shortened by progressively greater amounts of rotation to the west.

The Kulthieth Formation lies in an imbricate thrust zone characterized by south-verging overturned folds and numerous thrust faults. The intensity of deformation is greatest in the Bering River coal field, where the coal beds commonly are sheared, crushed, and squeezed from the flanks of the folds into pods along the hinges (Sanders, 1976).

Coal was discovered in the Bering River coal field in 1896 (Barnes, 1951), and was described in detail by Martin (1908). From 1912 to 1920, some experimental mines were opened, and the coal was tested by the U.S. Navy, but it was reported to be unsatisfactory for steaming, and there was essentially no interest in it until the early 1980s, when there was exploration for coal to be exported to the Far East (Eakins and others, 1983; Turner and Whateley, 1989). Most of the results of that exploration are proprietary however, and no production has yet resulted.

Assessment of the Bering River coal field. In the Bering River coal field, coal increases in rank from semibituminous at the west end of the field through semianthracite to anthracite in the Carbon Mountain area at the east end of the field (Cooper and others, 1946; Barnes, 1951). Martin (1908) described the coal as occurring in beds from a few centimeters to as much as 14 m in thickness; however, bed thickness changes abruptly, probably owing to tectonic squeezing of coal from flanks to noses of folds and to deformation along faults. According to Martin (1908) and Barnes (1951), the semibituminous coal (between bituminous and semianthracite) was found to be coking; however, Sanders (1976) stated that none of the coal is coking. U.S. Bureau of Mines analyses of 11 outcrop samples of coal collected from the Yakataga and Malaspina districts in 1952–1954 by D. J. Miller and George Plafker (1988, written commun.) show coal near the Chugach–St. Elias fault to be semianthracite, and coal in the Robinson Mountains, Samovar Hills, and Yakutat Bay to be bituminous.

The high rank of the Bering River coals appears to be due to heat provided from igneous intrusions at depth. Numerous basalt and diabase dikes and sills cut the coal-bearing rocks and are especially abundant in the east half of the coal field (Martin, 1908). Sills that intruded along coal seams are reported to have produced natural coke. The anomalously high thermal maturity of the coal-bearing and other Tertiary sedimentary rocks in comparison to that of the older Orca Group in the Chugach Mountains immediately north and west of the Yakutat block (Mull and Nelson, 1986) suggest that the thermal event that raised the rank of the coal (and presumably led to the intrusion of dikes and sills) occurred before accretion of the Yakutat block to the Alaskan continental margin.

The coal beds have been so intensely deformed that reserve estimates are highly speculative. Reserve estimates have been published only for the Bering River coal field, for which Eakins and others (1983) listed 56×10^6 metric tons of proved coal and an additional 32 to 900 × 10^6 metric tons of inferred coal. Sanders (1976) stated that the coal is mainly in the form of pods along fold axes and that coal reserves cannot be calculated in the normal way. By a technique that appears to compare the outcrop area of coal to that of the formation as a whole, Sanders (1976) calculated 3.3 × 10^9 metric tons of hypothetical coal to a depth of 914 m. It is doubtful whether mining of coal to that depth would ever be economically feasible.

A calculation made for this report (Plafker, 1987; George Plafker, 1988, unpublished data) of coal in the Samovar Hills implies that for a strike length of 4 km and a downdip distance of 1 km, the reserves are 135 × 10^6 metric tons of coal in beds more than 1 m thick, of which 100 × 10^6 metric tons is in beds more than 3 m thick. The greatest thickness reported is 12 m. The extent to which the beds have been tectonically thickened or thinned is unknown. No coal was reported in any of the 11 wells drilled for petroleum on the continental shelf southeast of the Bering River coal field (Bohm and others, 1976; Plafker and others, this volume, Chapter 12), and there is no estimate for offshore coal resources in this region (Affolter and Stricker, 1987b).

TERTIARY COAL OF SOUTHEASTERN ALASKA

Small coal deposits of little potential commercial value occur in southeastern Alaska (Fig. 1; Barnes, 1967a). All of these deposits, except the Kootznahoo deposit discussed below, are of lignite. The deposits are on Kootznahoo Inlet (loc. 35, Fig. 1) on the west side of Admiralty Island (Lathram and others, 1965); at Murder Cove (loc. 36, Fig. 1) on the south tip of Admiralty Island; at Kasaan Bay (loc. 37, Fig. 1) on Prince of Wales Island; on Zarembo Island; and at Port Camden on Kuiu Island and several nearby localities (loc. 38, Fig. 1).

The largest deposit at Kootznahoo Inlet is in rocks of Tertiary age and was mined by underground methods before 1929 for use at Juneau. The coal is bituminous rank, has a high sulfur content, and occurs only locally with many shale partings (Sanders, 1981). Coal beds range in thickness from 0.6 to 0.9 m (Affolter and Stricker, 1987a). No offshore extensions of these deposits are known (Affolter and Stricker, 1987b).

SUMMARY

The coal resources calculated for Alaska are enormous (Table 4), amounting to 3.4 × 10^{12} metric tons beneath onland Alaska, of which 210 × 10^9 metric tons are identified (measured, indicated, or inferred) and 3.2 × 10^{12} metric tons are hypothetical (based on coal penetrated in exploratory oil wells and judged to extend beneath likely basins). In addition, 5.5 × 10^{12} metric tons of hypothetical resources are thought to lie offshore of northern Alaska in the Beaufort and Chukchi Seas, and 0.7 × 10^{12} metric tons are thought to underlie the waters of Cook Inlet. These deposits amount to 50%–70% of the coal resources calculated for the entire United States (Wood and Bour, 1988).

TABLE 4. COAL RESOURCES OF ALASKA

Province or coal field	Identified resources* (refs)† (metric tons)	Hypothetical resources (refs)† (metric tons)
NORTH SLOPE PROVINCE		
On land	109 x 10^9 (A)	1.2 x 10^{12} (B, C) 1.7 x 10^{12} (B, D)
Offshore	44 x 10^9 (E)	5 x 10^{12} (F)
COOK INLET–SUSITNA PROVINCE		
Matanuska Valley	113 x 10^6 (G) 18,000 anthracite (H) 180 x 10^6 bituminous (H)	249 x 10^6 (G) 22 x 10^9 (H)
KENAI GROUP IN THE COOK INLET–BELUGA LAKE LOWLAND		
Kenai Group as a whole		1.2 x 10^{12} of which 0.8 x 10^{12} is offshore (K)
Homer District	360 x 10^6 (I)	
Tyonek-Beluga District	36–45 x 10^9 (J)	
North of Castle Mountain fault	489 x 10^6 (L)	
KENAI GROUP IN SUSITNA VALLEY		
Peter Hills and Fairview Mountain Districts	40 x 10^6 (L)	
Johnson Creek and Canyon Creek Districts	450 x 10^6 (M)	
Broad Pass District	0.27 x 10^6 (N)	12.2 x 10^6 (N)
NORTH FLANK OF THE ALASKA RANGE		
Nenana Coal Field	6.4 x 10^9 (O)	58 x 10^6 (P)
North Side of the Alaska Range east of Nenana coal field	12 x 10^6 (P)	63–73 x 10^6 (Q)
Herendeen Bay Coal Field		70–75 x 10^6 (R)
Chignik Coal Field		128 x 10^6 (S)
GULF OF ALASKA TERTIARY PROVINCE		
Bering River Coal Field	56 x 10^6 (T)	3.3 x 10^9 (U)
Samovar Hills		150 x 10^6 (V)
Totals	**197–206 x 10^9**	**10.4 x 10^{12}**

*Identified resources include measured, indicated, and inferred resources of coal; resources were not calculated for coal of Paleozoic age, the Yukin-Koyukuk province, the Little Tonzona coal field, the Seward Peninsula, or southeastern Alaska.

†A = Tailleur and Brosgé (1976); B = New calculation based on method of Sable and Stricker (1987); C = Subbituminous coal; D = Bituminous coal; E = Martin and Callahan (1978); F = Affolter and Stricker (1987b); G = Barnes (1967a); H = Merritt and Belowich (1984); I = Barnes and Cobb (1959), overburden less than 300 m (1,000 ft); J = Ramsey (1981), overburden less than 300 m; K = Affolter and Stricker (1987a); L = Barnes (1966); M = Blumer (1981); N = Hopkins (1951); O = Barnes (1967a), overburden less than 1,000 m, see also Table 3; P = Wahrhaftig and Hickcox (1955); Q = Calculations based on oral and written communications (1985) from Inyo Ellersieck; R = Calculations based on data of Conwell and Triplehorn (1976) and Burk (1965); S = Calculations based on data of Detterman and others (1981); T = Eakins and others (1983) and Sanders (1976); U = Sanders (1976); V = Calculated from data of George Plafker, written communication (1988).

Nearly all of the coal is of Cretaceous and Tertiary age. A small amount of bituminous coal occurs in highly deformed rocks of Mississippian age south of Cape Lisburne, and coal of Mississippian age has been penetrated in deep wells near Point Barrow. Information on this coal is so fragmentary that resources have not been calculated.

The major coal provinces are the North Slope province, north of the Brooks Range, and a province centered on the Cook Inlet–Susitna Lowland on the south coast of Alaska. Coal in the North Slope province is mainly in fluviatile and deltaic sedimentary rocks of the Cretaceous Nanushuk Group, where it is mainly bituminous, and in the Upper Cretacous Colville Group and Upper Cretaceous and Tertiary Sagavanirktok Formation, where it is mainly subbituminous. Coal crops out along the seacoast at Corwin Bluff and elsewhere along riverbanks, but the enormous resources, amounting to 2.9×10^{12} metric tons, are based largely on records of exploratory wells for petroleum.

Coal in the Cook Inlet–Susitna province is Tertiary in age and occurs in several isolated basins that are thought to have once been connected by a Tertiary river system. The Matanuska Valley coal field, of Paleocene age, contains 295×10^6 metric tons of identified resources of bituminous coal and 18×10^3 metric tons of identified resources of anthracite, occuring where igneous intrusions cut the coal beds. The complex structure of this coal field hinders any development.

Nearly all the rest of the coal in the Cook Inlet–Susitna province is subbituminous and Neogene in age. The entire Kenai Group contains 1.1×10^{12} metric tons of hypothetical resources of coal within 1,000 m of the surface, 0.7×10^{12} metric tons of which are beneath Cook Inlet. A total of 360×10^6 metric tons of coal has been estimated for the Kenai Peninsula, and $35–45 \times 10^9$ metric tons for the Tyonek-Beluga district. About 500×10^6 metric tons have been calculated for basins in the Susitna Lowland north of Mount Susitna. Coal fields of this province along the north side of the Alaska Range include the Nenana, Jarvis Creek, and Little Tonsona fields. The bulk of the 6.4×10^9 metric tons of identified resources of coal is in the Nenana coal field.

About 180×10^6 metric tons of hypothetical resources of coal of Cretaceous age are calculated for the Herendeen Bay and Chignik coal fields of the Alaska Peninsula. As much as 3.3×10^9 metric tons of coal may occur in lower Tertiary beds of the Bering River coal field and Samovar Hills in the Gulf of Alaska Tertiary province, but no more than 55×10^6 metric tons is considered identified.

Minor deposits of coal, valuable only for local use, occur on the Seward Peninsula, in the Yukon-Koyukuk province, near Seldovia on the Kenai Peninsula, and at Kootznahoo on Admiralty Island in southeastern Alaska.

Deposits of clinker from burned coal show that it was set on fire by natural causes long before humans arrived in Alaska. The early natives probably used some of it for their campfires. Coal was first mined near Seldovia during the Russian occupation, but coal mining was not a significant component of Alaska's economy until the construction of the Alaska Railroad in the 1920s and 1930s. Bituminous coal from the Matanuska coal field powered the locomotives of the Alaska Railroad until they were converted to oil in the 1950s. At present (1992), the Usibelli mine, a large open-pit mine in the Nenana coal field, is the only active coal mine, producing between 1.3 and 1.8×10^6-metric tons per year, about half of which is used domestically; the other half is shipped to Korea. Considerable interest has been shown in the enormous, thick, tidewater-based coal reserves of the Tyonek-Beluga district.

The coals of Alaska have an unusually low sulfur content, averaging 0.2–0.4 wt%. They represent an enormous energy and organic-materials resource that, with proper care in mining and shipment, could be removed and transported with relatively little environment impact.

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