STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

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January 1982

This is a preliminary publication of the Alaska Division of Geological and Geophysical Surveys and has not received final editing and review. The author will appreciate candid comments on the accuracy of the data and will welcome suggestions to improve the report.

Alaska Open-file Report 142

COAL INVESTIGATION OF THE SUSITNA LOWLAND, ALASKA

By

Roy D. Merritt, Gilbert R. Eakins, and James G. Clough

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In addition, the Division shall collect, evaluate, and publish data on the underground, surface, and coastal waters of the state. It shall also process and file data from water-well-drilling logs.

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Beluga River coal seams, Susitna Lowland, Alaska.

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ABSTRACT

The Susitna Lowland of south-central Alaska contains large reserves of subbituminous and lignite coals within the Tertiary Kenai Group. The strategic location near tidewater; thickness, extent, and quality of the numerous coal seams; and overburden, interburden, and seatrock characteristics combine to make these deposits economically attractive for new mine development. Exploratory drilling by leaseholders in the southwestern part of the lowland has proved major coal reserves suitable for surface mining. Undoubtedly other reserves exist in the Susitna Lowland, but the lack of subsurface information has inhibited their definition and development.

Tertiary exposures are confined to the foothills of the Alaska Range and to isolated, usually steep, incised, and largely inaccessible stream-canyon walls within the lowland. Tertiary units are deposited on igneous, volcanic, and sedimentary Mesozoic rocks and are often covered by Pleistocene glacial, fluvial, or glaciofluvial unconsolidated sediments. Sedimentary basins within the region are tectonically controlled and the coal deposits are locally faulted. North of the Castle Mountain fault the Susitna basin is relatively shallow and the Kenai Group strata are usually less than 2,000 ft thick. Because the basin subsided more rapidly south of this major discontinuity, the Kenai Group may attain thicknesses over 16,000 ft in the southern Susitna Lowland (Calderwood and Fackler, 1972; Hartman, Pessel, and McGee, 1972). Detailed stratigraphy of the Kenai Group remains poorly understood and correlation of beds is difficult.

The coals and associated strata of the Susitna Lowland have been described at 48 outcrop locales and several representative sections measured. The following preliminary maps have been constructed: 1) a composite geology and structure map which emphasizes the coal-bearing formations of the region; 2) a simple Bouguer gravity map of the southern Susitna Lowland (from Hackett, 1977); 3) a land status map; and 4) a coal potential map.

Although research on the coal deposits of the region continues, several conclusions may be drawn at this stage. The sedimentary rocks of the Kenai Group display many characteristics of a continental fluvial system. Rapid lateral and vertical lithologic changes are common. The coals of this paleoenvironment are typically low in sulfur and high in ash; they are locally thick, but laterally discontinuous.

No major environmental problems are expected during mining and reclamation. However, the effects of mining in areas of discontinuous permafrost need to be investigated.

INTRODUCTION

Government agencies and industry have made sporadic investigations of the coals in Alaska since about 1900, but uniform reserve figures and information on the geology and extent of most occurrences are scarce.

Nevertheless, it is clear that Alaska has extensive coal resources. In January 1979, the U.S. Department of Energy reported a 'demonstrated' coal-reserve base for Alaska of 6 billion tons. Estimates of the total coal resources---including inferred and hypothetical reserves---have varied from 2 to 4 trillion tons.

Despite the immense resources, Alaska's coal production has been minimal because of the remote locations of the deposits and lack of markets. Coal was produced on a small scale from numerous sites for local use and to fuel ships during the early part of the century; substantial quantities were produced from the Matanuska coal field for the Anchorage market until Cook Inlet gas became available in 1967. Coal production in Alaska is now limited to the Usibelli mine near Healy, which produces about 700,000 tons per year from the Nenana Coal Field for interior military bases and the city of Fairbanks.

The high cost of petroleum fuels and uncertainty of supply have created a strong interest by industry, government, and the public in Alaska's coal resources and in the feasibility of producing them for local use, export, and the generation of synthetic fuels. Accordingly, the Alaska Division of Geological and Geophysical Surveys (DGGS) has initiated a program to investigate various coal fields to assess the coal resources of the state. DGGS will compile a separate "coal atlas" for each important coal field. Each atlas will be an assemblage of all available geological and resource information pertinent to coal development. The purposes of these investigations are: a) to aid land classification and management as well as in issuing coal-prospecting permits and coal leases; b) to more accurately determine coal reserves and the potential for coal development; c) to address the numerous inquiries of industry interested in developing the coal resources and of Pacific rim countries seeking coal supplies; and d) to provide a single source of information on the coal deposits of an area.

The first region selected for study by the DGGS is the Susitna Lowland, which includes a broad area drained by the Susitna River and its tributaries. Subbituminous and lignite beds exposed along the major drainages of the lowland and along the southern foothills of the Alaska Range indicate abundant, relatively shallow subsurface coal deposits. Exploratory drilling by leaseholders in the southwestern Susitna Lowland has already proven major coal reserves suitable for surface mining. Whether similar extensive economic deposits exist in the northern Susitna Lowland is not known. Barnes (1966) estimated the coal reserves within the Beluga-Yentna region at 2.4 billion tons in beds over 2.5 ft thick; most of this (2.1 billion tons) is concentrated in the Beluga and Chuitna River basins.

The strategic location near tidewater; thickness, extent, and quality of the numerous coal seams; and overburden, interburden, and seatrock characteristics combine to make the deposits of the Susitna Lowland (particularly the southern fields) the most economically attractive for near-term new mine development in Alaska.

Although the Susitna Lowland includes several coal fields, all coal-bearing units are of similar age and character, and the entire region contitutes a distinct physiographic province. Detailed studies are difficult because of the scarcity of outcrops and subsurface data over most of the lowland. Therefore, this project has taken the form of a regional basin study to provide a current estimate of coal potential and to aid in conducting additional research.

The Susitna Lowland was originally selected because: a) it includes the Capps and Chuitna Coal Fields, which have the highest potential for large-scale production in Alaska and which are located relatively near Anchorage; b) enough geologic data exist to permit a preliminary compilation without extensive fieldwork, and c) the state has received numerous applications for coal-prospecting permits on the area and needs information on the coal potential.

The Susitna Lowland is relatively unexplored in the subsurface so the structure and stratigraphy are poorly understood. Several oil and gas exploratory wells have been drilled in the southernmost portion of the Susitna Lowland near Cook Inlet and provide some information in this area, but only two deep wells have been drilled farther north and the data on one of these will not be released for 2 years.

The present report is preliminary and represents the compilation done during 1981. Fieldwork by the primary author during the summer of 1981 was aimed at determining the types of research that would be useful for constructing a model for the basin, understanding the environments of deposition, and arriving at methods for correlating units within the coal-bearing sequences. A geologic report summarizing these findings will be completed in 1982.

LOCATION AND SETTLEMENTS

The approximate area of the Susitna Lowland includes Tps. 11-30 N., Rs. 5-16 W., and encompasses about 8,000 mi^2. The region is covered by the following U.S. Geological Survey 1:250,000-scale topographic maps: Anchorage, Talkeetna, Talkeetna Mountains, and Tyonek. The general location and bounds for the Susitna Lowland (Wahrhaftig, 1965), as considered in this report, is shown in figure 1. The lowland is bounded by the arcuate Alaska Range on the north and west, the Talkeetna Mountains on the east, and the Cook Inlet on the south. Surface elevations of the lowlands increase from sea level at Cook Inlet northward to about 1,000 ft at the northern limit. Isolated mountains of intrusive and pre-Tertiary rocks rise above the surrounding areas by as much as 4,000 ft.

The Susitna Lowland overlaps the northern part of the Cook Inlet. Some writers (for example, Miller and others, 1959, p. 47) consider the Susitna Lowland to be the northwestern extension of the Cook Inlet Tertiary basin. Barnes (1966) terms the area the Beluga-Yentna region. Work completed during the last several years by leaseholders in the southwestern part of the lowland has resulted in the division of the so-called Beluga Coal Field into three separate deposits: the Capps, Chuitna, and Threemile fields.

The presence of the Castle Mountain fault, a major northeast-trending discontinuity, creates a break in the subsurface between the Cook Inlet on the south and the Susitna Lowland on the north, and most stratigraphic studies on the Cook Inlet petroleum province terminate at the fault. However, important coal leases in the Beluga area lie on both sides of the fault zone.

The upper Cook Inlet, site of the Anchorage metropolitan area and of nearby settlements in the Matanuska Valley and on the Kenai Peninsula, is the most densely populated region in Alaska. The state's principal agricultural region

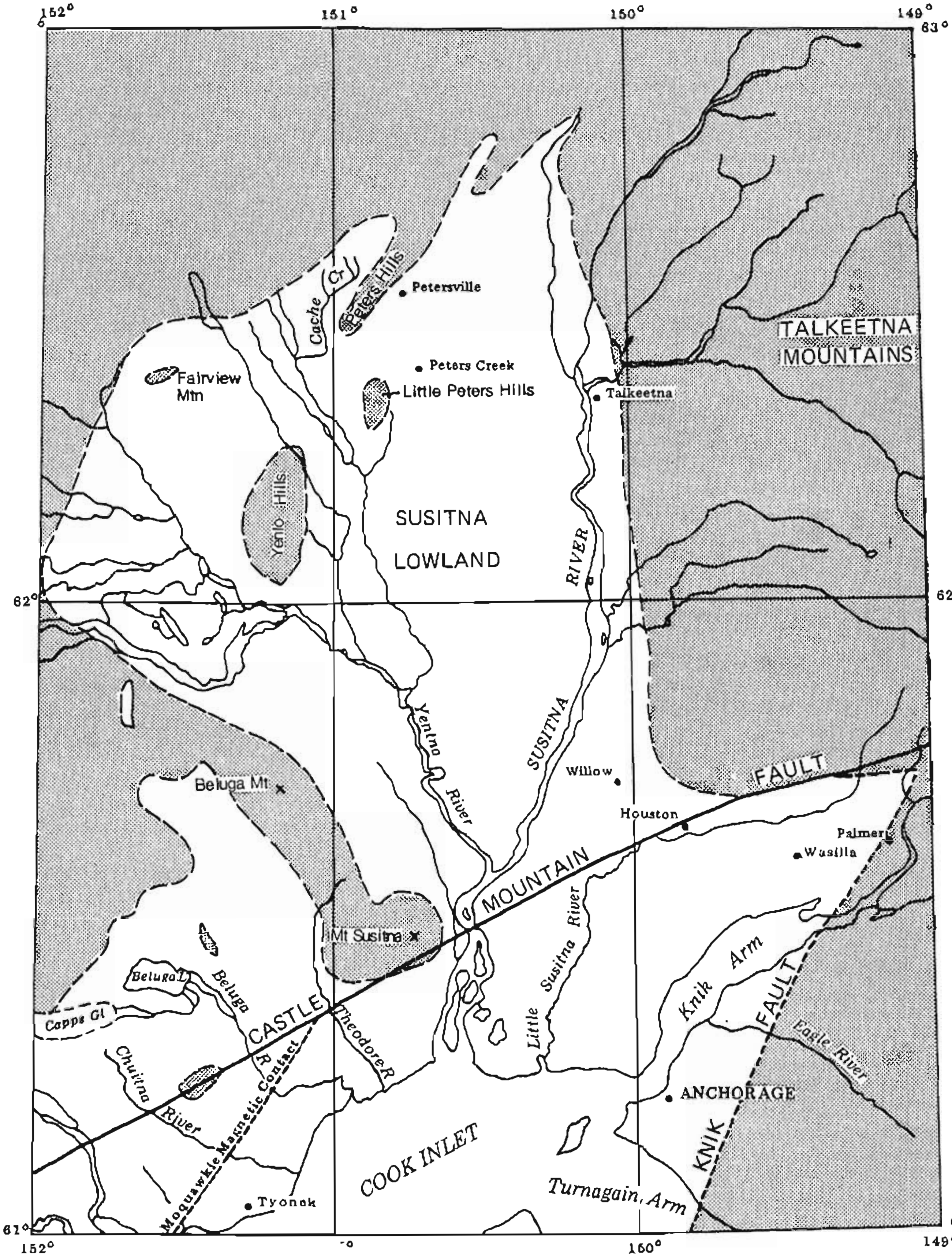

Figure 1. General location map of the Susitna Lowland. Pre-Tertiary rocks are shaded (after Wolfe and others, 1966).

is located in the lower Matanuska Valley, and plans are underway by the state to make additional lands available for agricultural development at MacKenzie Point, across Knik Arm from Anchorage. Except for small settlements along the Parks Highway and the Alaska Railroad, the Susitna Lowland is essentially uninhabited. Activity in the summer includes placer miners in the Petersville-Cache Creek area in the northern part of the lowland, and drillers on active coal leases in the southwestern portion.

A new site for the state capital has been selected near Willow about 40 air miles north of Anchorage. If the move is carried out, there will be a significant increase in industrial growth and population, which will affect the adjoining Susitna Lowland.

ACCESS

The Parks Highway and the Alaska Railroad transect the Susitna Lowland in a north-south direction roughly paralleling the Susitna River. The Parks Highway and a 10-mile extension to Talkeetna are the only paved roads. A gravel road from the Parks Highway connects with the placer mining district on Peters and Cache Creeks northwest of Talkeetna. The remaining parts of the lowland are accessible only by aircraft. (Helicopters are generally used for field investigations.) Surface conditions and environmental concerns limit the use of off-road vehicles. There are a few private landing strips of varying quality near some of the mining claims, but permission for their use is required. Facilities are available to the public at the Talkeetna airfield.

CLIMATE

The climate in the Susitna Lowland is not as severe as it is in the interior of the state and at higher elevations, but heavy snowfalls and high winds are not unusual during winter months. The average annual precipitation at Talkeetna is 28 in., and the mean temperature is about 33°F. By comparison, the totals at Anchorage International Airport are about 15 in. and 36°F (U.S. Department of Commerce, 1968).

Although permafrost is not uncommon in northern regions, Ferrians (1965) indicates that the lower parts of the Susitna Lowland near the Cook Inlet and along the Susitna River are generally free of permafrost. Flanking these areas is a zone underlain by isolated masses of permafrost; nearer to the mountains 'discontinuous' permafrost is present.

TOPOGRAPHY

Rugged alpine features of the Alaska Range and the Talkeetna Mountains bound the Susitna Lowland on three sides. The lowland consists of broad, relatively flat to gently rolling terrain over its central parts, increasing significantly in relief toward the basinal-rim areas in the foothills of the Alaska Range. Large glaciers extend from the mountains down to near the margins of the lowland. During Pleistocene time five periods of glaciation are recorded (Nelson and Reed, 1978) and evidence indicates that ice filled the upper Cook Inlet to elevations over 4,000 ft (Péwé, 1965, p. 115). Retreat of glaciers from the Susitna Lowland left a landscape dominated by glacial and glaciofluvial landforms: moraines, drumlins, fluted till, ridges, lakes, ponds, marshes, bogs, and scoured bedrock (Dean, 1980). Valley features created by periglacial activity and mass movement include talus slopes, landslide scours, avalanche chutes, and rock glaciers. Fluvial processes continue to modify and incise the glacial deposits.

PREVIOUS WORK

Geological investigations and reports of the presence of coal in the Susitna Lowland were made by the U.S. Geological Survey as early as 1900 (Barnes, 1966, p. C4). The 1957 discovery of oil and gas beneath the Cook Inlet, increasing interest in the coal and agricultural potentials of the region, state and Native land selections under the Alaska Statehood Act and the Alaska Native Claims Settlement Act, and a vote to move the state capital to the Willow area have resulted in a growing number of reports bearing on the resources and environment of the region. The publications which are most helpful for a study of the coal resources are listed under References Cited and Bibliography. The single most conclusive and thorough report on the coal in the Susitna Lowland is "Geology and Coal Resources of the Beluga-Yentna Region, Alaska" by F.F. Barnes (1966).

STRUCTURAL GEOLOGY

The major structural features of the Susitna Lowland are depicted on plate 1. The Tertiary coal-bearing strata of the Susitna Lowland occupies the northern part of a roughly elliptical basin known as the Shelikov trough. A major structural discontinuity consisting of the Bruin Bay fault, the Moquawkie magnetic contact, and that part of the Castle Mountain fault lying east of the Theodore River divides this basin into a deeper southeastern segment and a shallow northwestern segment. The southeastern portion subsided much more rapidly than the northwestern portion during the accumulation of Kenai Group strata. Broad and gentle northeast-trending folds are superimposed on the major basinal structure (Grantz and others, 1963; Wolfe and others, 1966).

The Castle Mountain fault is formed by the mergence of the Lake Clark and Bruin Bay faults near the southwestern margin of the Susitna Lowland. The Beluga Mountain fault intersects the Castle Mountain fault at a near right angle east of Mount Susitna, forming a thrust wedge which has been moved relatively upward and eastward. Smaller scale block faulting, folding, tilting, and slumping are characteristic of other restricted areas within the region. In addition, certain coal-bearing sections may be repeated, which suggests (erroneously) either a much thicker coal or two beds.

Hackett (1977) pointed out that the Tertiary sedimentary basins within the upper Cook Inlet region were tectonically controlled by large basement faults or fault systems. He proposed that the Castle Mountain, Bruin Bay, and Beluga Mountain fault systems were of a high-angle reverse nature. He was the first to recognize the Beluga Mountain fault and believes it to have a vertical displacement over 10,000 ft (3,000 m).

These basement faults and smaller scale high-angle block faults within the region have definitely offset the coal deposits. Their ultimate effect on future coal exploration and development has not yet been fully ascertained. In addition to displacing the coal, downthrown blocks may localize channeling and result in the erosion of the coal seam(s).

TERTIARY LITHOSTRATIGRAPHY

The stratigraphic nomenclature presently used for the Tertiary (Oligocene-Miocene) coal-bearing strata of the Susitna Lowland was first proposed by Calderwood and Fackler (1972) for the Cook Inlet basin (fig. 2). Because of the thickness and complexity of the Tertiary coal-bearing sequence, they raised the 'Kenai Formation' originally adopted by Dall and Harris (1892) to group status. Within this classification, Calderwood and Fackler recognized five separate units as distinct formations. Their divisions were based to some degree on the five lithologic units distinguished by Kelly (1963) from subsurface well data in the central part of the Cook Inlet basin. These zones are:

Zone 1 - massive sand beds (5,000 ft thick)
Zone 2 - sandstone, shale, and lignite (several thousand feet thick)
Zone 3 - siltstone, shale, and low rank coal (several thousand feet thick)
Zone 4 - sandstone and conglomerate ("Hemlock producing zone," 700 ft thick)
Zone 5 - siltstone and shale (several hundred feet).

Barnes (1966) differentiated three units within the "Kenai Formation": lower, middle, and upper. His coal-bearing middle member contains sandstone, siltstone, claystone, and conglomerate lithologies, whereas the enclosing upper and lower stratigraphic units consist predominantly of pebbly sandstone and conglomerate. Based principally on the paleobotanical and palynological work by Wolfe and others (1966) and Calderwood and Fackler's Tertiary stratigraphy for the Cook Inlet region (1972), tentative correlations of equivalent rock units on a formational level have been made and are included on geologic maps compiled by Magoon and others (1976) and Reed and Nelson (1980). Table 1 compares correlations from these maps with those of Barnes' 1966 geologic map.

The Kenai Group consists predominantly of sandstones, siltstones, claystones, conglomerates, and coals. Tertiary sediments north of the Castle Mountain fault are relatively thin (typically 2,000 ft or less) and lie on granitic rocks. The Kenai Group is commonly less than 10,000 ft thick south of the Castle Mountain fault in the southern Susitna Lowland but ranges up to 16,000 ft thick; in this region it usually overlies older Tertiary or Mesozoic sedimentary rocks. In the central part of the Cook Inlet basin the group attains thicknesses over 26,000 ft (Calderwood and Fackler, 1972; Hartman, Pessel, and McGee, 1972). These sedimentary rocks have many of the characteristics of a continental (nonmarine) fluvial system. Rapid lateral and vertical changes in lithology are common. Exposures are confined to the basinal rim areas (foothills) of the Alaska Range and to isolated, usually steep, incised, and largely inaccessible stream canyon walls within the lowlands. Minor outcrops of Tertiary rocks also occur along coastal areas (for example, a 10-mile exposure on Beshta Bay, fig. 3). The Tertiary deposits are usually overlain by Pleistocene glacial drift or fluvial surficial deposits. They are deposited on igneous, volcanic, and sedimentary rocks of Mesozoic age.

In addition to the Kenai Group strata, five other formations crop out in the southeastern part of the Susitna Lowland. The Chickaloon Formation is a Paleocene coal-bearing sequence which also contains well-indurated claystones, siltstones, sandstones, and conglomerates. The Chickaloon grades upward into the Wishbone Formation, also a well-lithified Paleogene (Paleocene to Eocene) unit; the Wishbone consists of conglomerates, sandstones,

SYSTEM	SERIES	GROUP	FORMATION	DESCRIPTION
CENOZOIC	QUAT		Alluvium and glacial deposits	
CENOZOIC	TERTIARY	KENAI GROUP	Sterling Formation	Massive sandstone and conglomerate beds with occasional thin lignite bed
CENOZOIC	TERTIARY	KENAI GROUP	Beluga Formation	Claystone, siltstone, and thin sandstone beds; thin sub-bituminous coal beds
CENOZOIC	TERTIARY	KENAI GROUP	Tyonek Formation	Sandstone, claystone, and siltstone interbeds and massive subbituminous coal beds
CENOZOIC	TERTIARY	KENAI GROUP	Hemlock Conglomerate	Sandstone and conglomerate
CENOZOIC	TERTIARY	KENAI GROUP	West Foreland Formation	Tuffaceous siltstone and claystone; scattered sand-stone and conglomerate beds
CENOZOIC	TERTIARY	Rests unconformably on older Tertiary, Cretaceous, and Jurassic rocks		

Figure 2. Stratigraphic nomenclature for Kenai Group (after Calderwood and Fackler, 1972).

Table 1. Tentative correlations of geologic units

Area	Barnes (1966): "Kenai Formation" Member	Magoon and others (1976): Kenai Group Formation
	Tyonek Quadrangle	
1. South of Capps Glacier	a. Lower b. Middle	a. West Foreland b. Tyonek
2. North of Lone Ridge	Lower	West Foreland
3. Beluga River		
a. North of Lake Clark fault	a. Lower	a. West Foreland
b. Between Lake Clark and Bruin Bay faults	b. Middle	b. Tyonek
c. South of Bruin Bay fault	c. Middle	c. Beluga
4. Chuitna River -- between Lake Clark and Bruin Bay faults	Middle	Tyonek
5. Tributaries of Nikolai Creek--south of Lake Clark fault	Lower	Tyonek
6. Threemile River/Lewis River area--south of Little Mt. Susitna and north of Lake Clark fault	Lower	West Foreland
7. Drill Creek and Coal Creek	Middle	Tyonek
8. Talachulitna River; Friday and Saturday Creeks	Middle	Tyonek
9. Canyon Creek	Middle	Tyonek
10. Skwentna River, northeast of Porcupine Butte	Middle	Tyonek
11. Kahiltna River, north of confluence with Yentna River	Middle	Tyonek

Area	Barnes (1966): "Kenai Formation" Member	Reed and Nelson (1980): Kenai Group Formation
	Talkeetna Quadrangle	
12. Johnson Creek	a. Middle b. Upper	a. Sandstone Member of Tyonek b. Sterling

13. Kichatna River	Upper	Sandstone Member of Tyonek or Sterling
14. Nakochna River	a. Middle b. Upper	a. Conglomerate Member Tyonek b. Sterling
15. Yenlo Creek, Lake Creek, and Kahiltna River (northwest of Shulin Lake)	Middle	Sandstone Member of Tyonek
16. Bear Creek east of Little Peters Hills	Middle	Sandstone Member of Tyonek
17. Drainages southeast of Peters Hills	Middle	Sandstone Member of Tyonek
18. Cache Creek	Middle	Sandstone Member of Tyonek or Sterling
19. Dollar Créek	Middle	Sterling
20. Long Creek/Cottonwood Creek	Middle	Sterling
21. Tributaries of Long Creek/ Cottonwood Creek north-west of Peters Hills---Willow, Poorman, Pass, and Divide Creeks	Upper	Sterling
22. Treasure Creek east of Chelatna Lake	Upper	Sterling
23. Fairview Mtn and region south of Mtn Kliskon	Upper	Sterling
24. Cottonwood Creek	Middle	Conglomerate Member of Tyonek
25. Sunflower Creek	Middle	Sterling
26. Bluff Creek, southwest margin of Ruth Glacier	Upper	Conglomerate Member of Tyonek or Sterling

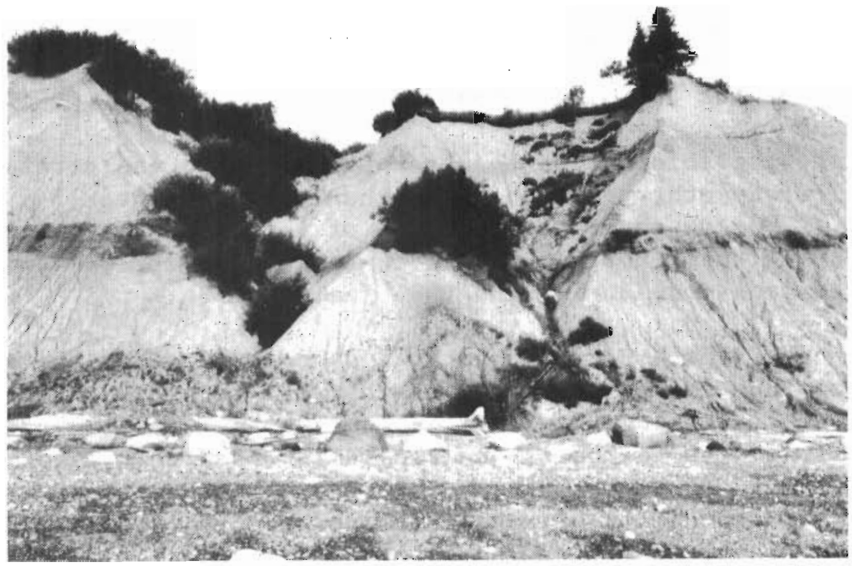

Figure 3. Coal-bearing Tertiary outcrop on the coast at Beshta Bay, Cook Inlet.

and siltstones. The Chickaloon and Wishbone formations (pl. 1) are exposed in an area south of Willow Creek in the southwestern Talkeetna Mountains. The units are conformable. However, the Tsadaka Formation of the Wishbone Hill district (correlatively time equivalent of the lowest beds of the Kenai Group) overlies the Wishbone and Chickaloon formations in a distinct angular unconformity. The Tsadaka Formation (Miocene), a poorly lithified unit, is believed to represent a "marginal conglomeratic facies of the Kenai" (Wolfe and others, 1966, p. A1). The Arkose Ridge Formation, a coarse-grained clastic unit also of this region, is considered to be of Mesozoic age (Albian to Cenomanian) by Wolfe and others (1966) and is believed to be correlative with the lowest marine strata of the Matanuska Formation. Magoon and others (1976) include the Arkose Ridge Formation as a Paleocene unit. The Arkose Ridge Formation consists of arkose, conglomerates and shales, whereas the Matanuska Formation consists of marine clastics (siltstones, sandstones, and conglomerates). The Matanuska Formation is Cretaceous (Albian to possibly Maestrichtian) in age (Wolfe and others, 1966).

Most of the locales studied by Merritt during the 1981 field season (pl. 1) belong to the Tyonek Formation of the Kenai Group as distinguished by Calderwood and Fackler (1972); tentative correlations are based on Wolfe and others (1966), Magoon and others (1976), and Reed and Nelson (1980). However, all the formations except the Hemlock Conglomerate have been recognized within the Susitna Lowland. Within the Capps region, there are large exposures which belong to either the Tyonek or West Foreland Formation. Most of the Chuitna River

Tertiary exposures belong to the Tyonek Formation except for about 5 miles along its lower reaches, which is included in the Beluga Formation. All Tertiary coal-bearing outcrops in the northern Susitna Lowland have been assigned to either the Tyonek or the Sterling Formation.

Little lithologic information has been published on the stratigraphic units within the Kenai Group other than that for the Tyonek and Sterling Formations by Reed and Nelson (1980) on their geologic map of the Talkeetna Quadrangle. We will summarize below the important points of their descriptions and include, in addition, observations made during the 1981 field season.

They divide the Tyonek Formation into a sandstone member and a conglomerate member. The sandstone member is either conformable with the underlying conglomerate member or interfingers with it. The Tyonek Formation overlies Mesozoic rocks within the Talkeetna Quadrangle in an angular unconformity. In addition, the Sterling Formation unconformably overlies the Tyonek Formation as suggested by the incorporation of coal fragments derived from the Tyonek within the Sterling. Exposures of Tyonek and Sterling strata are restricted to the basinal rim areas (foothills) of the Alaska Range and to outcrops along streams within the lowlands. These beds consistently dip either gently or moderately to the southeast.

TYONEK FORMATION (MIOCENE)

Sandstone Member. This unit consists predominantly of sandstones (up to 80 percent) that are typically medium to coarse grained, pebbly, and poorly indurated. The beds locally are reported (Reed and Nelson, 1980) to be up to 60 m thick, although they occur in much thinner lenses as described by Merritt at locale FM1 (App. A and B). Mineralogically, these sandstones are composed of mafic grains (biotite, hornblende, clinozoisite, and chlorite). Interbedded siltstones and claystones make up 20 percent of the Sandstone Member. They are commonly light to medium gray, rooted, and locally include coal stringers, and may attain thicknesses up to 50 m. Conglomerate, coal, and volcanic ash compose less than 1 percent of the Sandstone Member, as estimated by Reed and Nelson (1980). The conglomerate occurs in beds up to 5 m thick, with incorporated clast sizes ranging up to 10 cm but averaging 2-6 cm. The coals occur within these fining upward (i.e., conglomerate, sandstone, siltstone, claystone, coal) cyclic sequences above the claystones (underclays). The quality of the coals varies and they often have carbonaceous shale or bone partings; they average less than 1 m thick but locally attain thicknesses of 3 m within the Sandstone Member. The volcanic ash partings (tonsteins) within the coal beds may be up to 30 cm thick and consist of "partially devitrified glass shards altered to illite(?) and less than 0.5 percent biotite" (Reed and Nelson, 1980). The ash partings are often rooted. An example of a volcanic ash parting from the Capps Seam (Tyonek Formation) is shown in figure 4.

Conglomerate Member. Reed and Nelson, from samples collected and analyzed from Fairview Mountain, describe its constituents as 40 percent conglomerate, 20 percent sandstone, and less than 40 percent siltstone, claystone, and coal. Figure 5 shows an outcrop of the upper four coal beds exposed at Fairview Mountain (from bottom to top, these have been labeled the C, D, E, and F seams by Merritt; A and B are poorly exposed below this section). The unit is massively bedded and poorly indurated, and is buff to blue gray. Clasts range up to 15 cm in diameter but average 5-10 cm. Proportions of the different clast lithologies

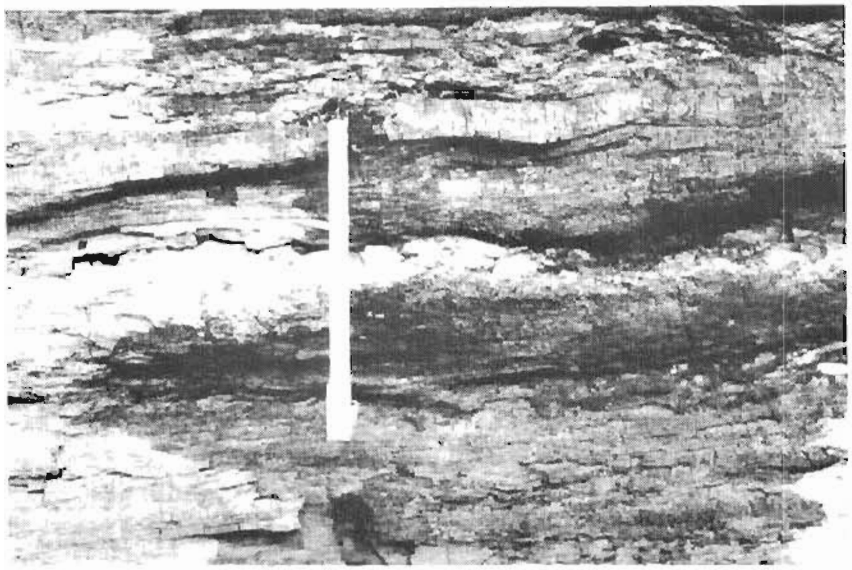

Figure 4. Volcanic ash parting from the Capps seam.

Figure 5. Fairview Mountain coal seams (from bottom to top) C, D, E, and F.

obvious, and in actuality, such correlation often is not possible. Time-stratigraphic marker beds are rare within the Susitna Lowland. Probably our best markers are well-defined and relatively continuous time-parallel key beds such as volcanic ash partings or occasional thin fresh-water limestones. Additional paleobotanical and palynological work will greatly advance our understanding of the stratigraphic complexities in the Kenai Group.

DEPOSITIONAL ENVIRONMENTS OF KENAI GROUP COALS

There has been very little published on the depositional environments of coals in Alaska. Paleoenvironmental interpretation is important to gaining an understanding of coal seam and overburden characteristics within a given basin. Furthermore, it should be utilized as a tool for the development and implementation of premine plans. The simple application of relationships established in other coal mine regions within the "lower-48" will reap huge benefits when large-scale mining begins in Alaska. Of course, these concepts must be applied with consideration given to certain unique Alaskan conditions.

The construction of depositional continuum models (paleoenvironmental profiles) allows the coal explorationist to predict coal trends from one area to another within a coal basin. A key to understanding these trends is recognizing various subenvironments within the fluvial system (backswamp, levee, channel, flood plain, lake, point bar, crevasse splay deposits, etc.). This recognition can lead to explanations of physical and chemical changes observed in coal seams and their enclosing strata.

The coals and associated strata of the Susitna Lowland are characteristic of continental fluvial (fresh-water) paleoenvironments and differ significantly from those associated with marine and brackish-water systems. The following brief discussion of fluvial deposits can be applied to the coal-bearing units within the Susitna Lowland. Much of it is based on methods developed by the Carolina Coal Group during the 1970's in the Appalachian Coal Province.

Paleogeographic reconstructions are important for understanding coal-seam characteristics, including the effects of topography on the developing coal swamp. Thicker coals may characterize paleo-lows, whereas thinner coals may occur over paleo-highs. Terrigenous clastic wedges typically thin or pinch out over flexures, and this may result in the thinning or merging of interbedded coal seams. The longer periods of exposure and deeper soil development over paleo-highs may bring about increased root penetration. Thus, thin coals often have thick underclays, whereas thick coals may have thin underclays. The lateral continuity of a seam may be altered or disrupted because of paleochannels. In figure 6, a small paleochannel (in cross section) cuts out much of the Saturday Creek coal seam. Channel scouring may completely remove, or 'wash out,' a coal seam. These channels directly affect the minability of a particular seam (Horne and others, 1978).

Fluvial coals have low sulfur and trace-element contents but commonly high ash; they are discontinuous laterally, but can be very thick locally. However, this is not a rigid association. There are, for example, many relatively low-ash coals within the Susitna Lowland. These relationships, established as broad generalizations, have been extensively studied by the Carolina Coal Group. The influence of contemporaneous tectonism---more specifically, subsidence rates---on coal quality is also very significant. Horne and others (1978) noted

Figure 6. Paleochannel fill (in cross section) within Saturday Creek coal seam.

that rapid subsidence with accompanying sedimentation results in lower sulfur and trace-element abundances and rapid changes within coals. Because of the usually abundant contributions of detrital materials associated with continental fluvial regimes, coals of this paleoenvironment are characterized by higher ash (mostly silica) contents. Slower subsidence during deposition results in more laterally continuous coal seams with higher contents of chemically precipitated minerals.

Tectonic influences and subsidence rates also affect coalification and coal diagenesis (catagenesis) as well as coal petrography. Depositional sedimentary facies tend to prograde rapidly laterally in a gradually subsiding to tectonically stable area; conversely, they prograde slowly in a rapidly subsiding area. In the latter more tectonically active setting, depositional facies tend to be stacked vertically. Channel sandstones of the fluvial paleoenvironment are described (Horne and others, 1978) as "multistoried units"; that is, they commonly display many directions of lateral migration.

Figures 7 and 8 are diagrams illustrating the subenvironments of continental fluvial coal deposits. Table 2 lists broad criteria for recognizing fluvial depositional environments. Backswamp deposits consist of the basal seatrock (often underclay), coal, and suprajacent carbonaceous shale. Discontinuities or splits in coal seams often represent ancient levee deposits of active channels, including crevasse splays. Localized, pod-shaped coal bodies

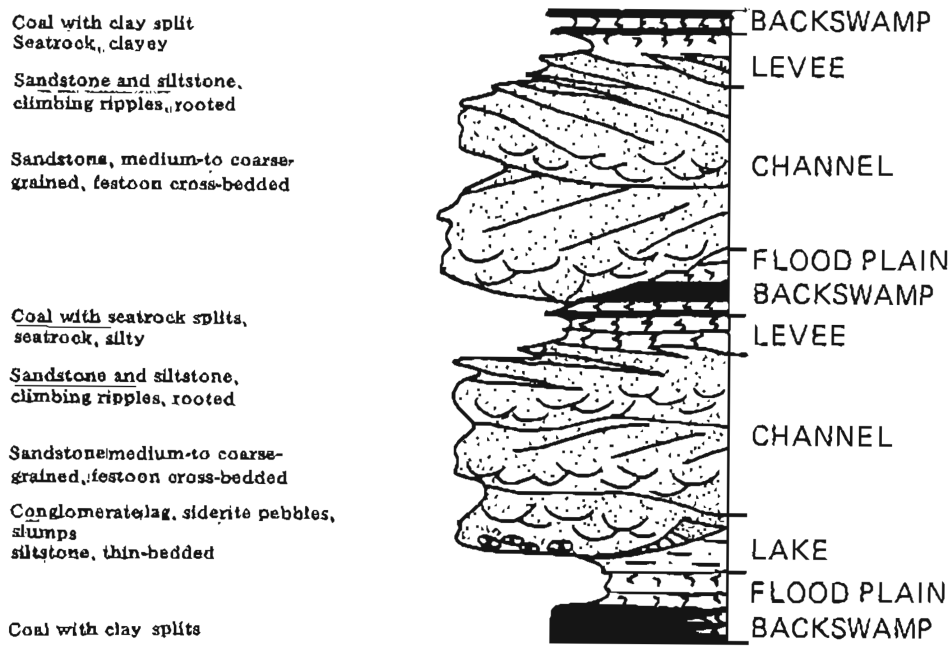

Figure 7. Illustration of continental fluvial environments in a generalized vertical sequence (from Horne and others, 1978, p. 2390).

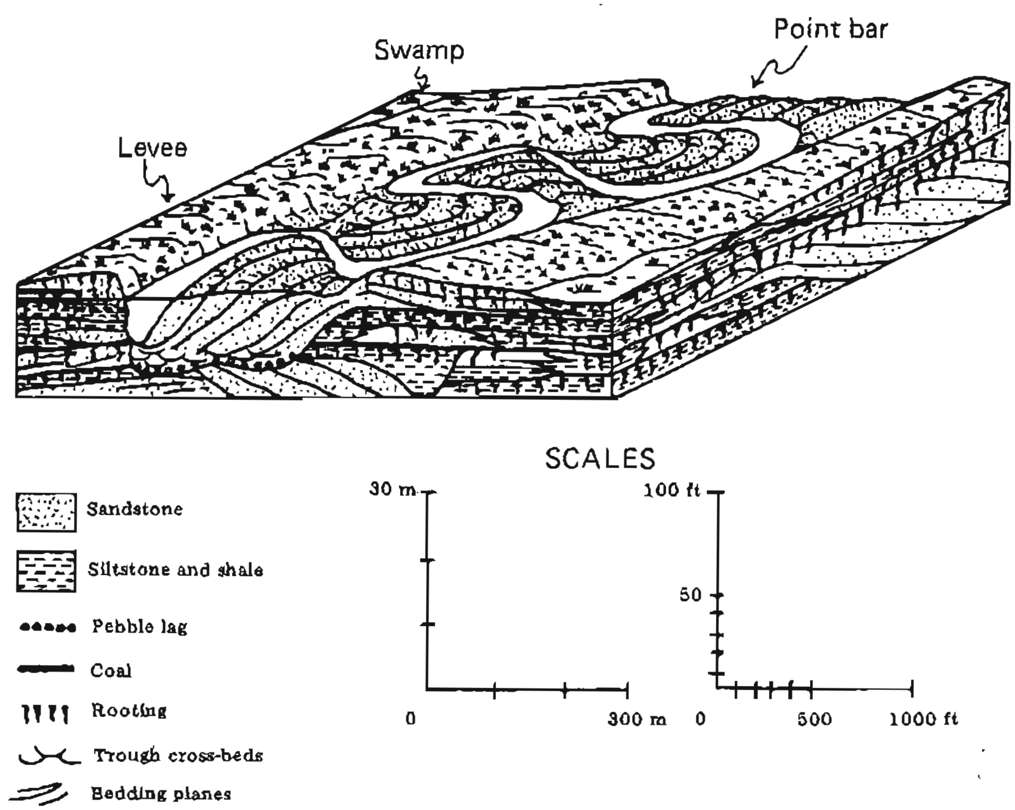

Figure 8. Reconstructed block diagram for continental fluvial environments (from Horne and otheers, 1978, p. 2390).

Table 2. Criteria for recognition of fluvial depositional environments (from Horne and others, 1978)

I. Coarsening upward	
A. Shale and siltstone sequences	common to rare
1. Greater than 50 ft	not present
2. 5 to 25 ft	common to rare
B. Sandstone sequences	rare to not present
1. Greater than 50 ft	not present
2. 5 to 25 ft	rare
II. Channel deposits	
A. Fine-grained abandoned fill	rare
1. Clay and silt	rare
2. Organic debris	rare
B. Active sandstone fill	abundant
1. Fine grained	common
2. Medium and coarse grained	abundant
3. Pebble lags	abundant
4. Coal spar	abundant
III. Contacts	
A. Abrupt (scour)	abundant
B. Gradational	common to rare
IV. Bedding	
A. Cross-beds	abundant
1. Ripples	common
2. Ripple drift	common-abundant
3. Herringbone festoon	abundant
4. Graded beds	rare
5. Point bar accretions	abundant
6. Irregular bedding	abundant
V. Levee deposits	abundant
VI. Mineralogy of sandstones	
A. Lithic graywacke	abundant
B. Orthoquartzites	not present
VII. Fossils	
A. Marine	not present
B. Brackish	rare
C. Fresh	common to rare
D. Burrow structures	rare

may represent accumulations of organic materials adjacent to meander channels of ancient flood plains. These broad flood plain platforms (alluvial plains) were characterized by abundant plant growth. Rapid sedimentation by floods buried these plant materials. Upright stumps ('kettles') are abundant in continental fluvial paleoenvironments (Horne and others, 1978).

As further interpretations are made from surface exposures of the Kenai Group strata within the Susitna Lowland and more subsurface and detailed physical and geochemical data are collected, depositional models for the coal basins of the region can be developed and refined. These models can then be related to general coal-quality assessments and overburden characterization during premine planning, to coal exploration drilling programs on lease tract areas, to the prediction of geologic and geochemical (environmental) problems during mining, and to postmining reclamation.

COAL QUALITY

The major coal deposits within the Susitna Lowland can generally be ranked as either subbituminous B, subbituminous C, or lignite. A large number of coal beds within the Kenai Group (mostly within the Tyonek Formation) are more than 50 ft thick. One bed of thermally altered coal of small areal extent was discovered in the upper reaches of Canyon Creek (see locales CnC2, CnC3, and CnC4 on pl. 1 and in app. A and B). At CnC2 the bed was locally severely contorted as a result of the surrounding intrusives (fig. 9). Gradational zones of burn material associated with the metamorphic aureole separating Mesozoic intrusive bodies and intervening Tertiary metasediments from the remaining Kenai Group strata are shown in figure 10 (site CnC3). The bed shown here thickens to over 20 ft at CnC3. Figure 11 is a close-up view of one of the thermally altered coal beds within the seam.

There has been very little coal-quality data published on the Susitna Lowland. Coal companies holding leases within the southern portion have gathered extensive data but are keeping the information confidential. Barnes (1966) reported analyses on several coals; these analyses were performed by the U.S. Bureau of Mines in Pittsburgh, Pennsylvania (table 3).

Table 3. Analyses of 16 coal samples from Beluga-Yentna region, Alaska. (listed as a range for different parameters analyzed; adapted from Barnes, 1966, p. C26-C27.)

Rank: Subbituminous B, subbituminous C, and lignite
Calculated moist mineral-free heating value (Btu): 7,650-9,800

Sample condition	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Heating value (Btu)
As received	19.7-33.1	30.1-39.9	26.4-40.6	2.0-16.8	0.1-0.4	7,030-9,520
Moisture-free	- - -	39.8-56.1	38.0-50.5	2.7-22.2	0.1-0.6	9,470-12,070
Moisture- and ash-free	- - -	47.2-57.9	42.1-52.8	- - -	0.1-0.6	11,860-12,600

Figure 9. Contorted coal bed at upper Canyon Creek locale.

The chief attraction of Alaskan coals is their extremely low sulfur content. Locally, the ash content is low to moderate. Heating values are comparable to other western U.S. coals. Seams range from dull and blocky with occasional vitrain bands to dull and platy, to woody and papery, and to bone. Beds of bright coal are rare. Volcanic ash and carbonaceous shale or claystone partings occur locally within seams observed throughout the lowland. In addition, coal seams have burned in several areas, baking the adjacent rock materials. The burn often weathers to varicolored gleys. The baked shales and claystones often contain abundant plant fossils (see locale CR7, for example, pl. 1 and app. A). Two areas where coal beds have been burned---the Capps Seam and a Chuitna River seam---are shown in figs. 12 (locale CG4) and 13 (locale CR10). Locally, coal beds have been converted largely to graphite; for example, graphite and graphitic claystones are common at Johnson Creek (fig. 14) and Nakochna River. These beds often contain quartz veins and nodules with altered calcite rims.

Figure 10. Gradational zones of burn material at upper Canyon Creek locale.

Figure 11. Thermally altered coal bed at upper Creek locale.

Figure 12. Burn associated with the Capps seam.

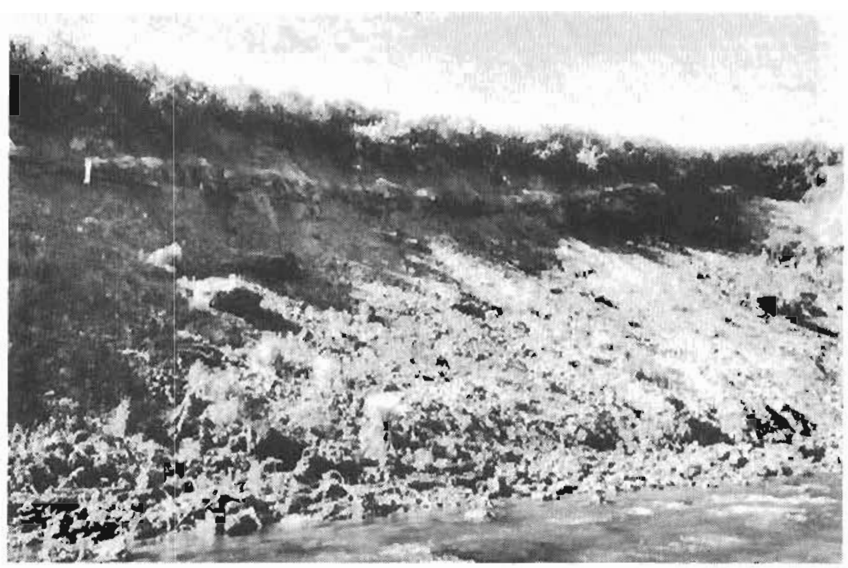

Figure 13. Burn associated with a Chuitna River coal bed.

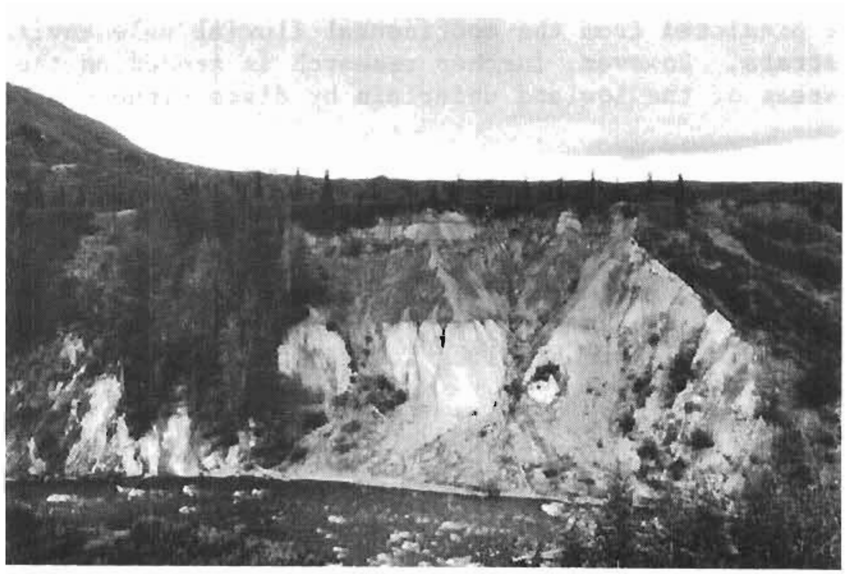

Figure 14. Graphite bed on Johnson Creek.

OVERBURDEN CHARACTER

The coal seams of the Kenai Group within the Susitna Lowland are interbedded with claystones, siltstones, sandstones, and conglomerates. Locally, the coal beds are covered by Pleistocene fluvial, glacial, or glaciofluvial unconsolidated sediments. These range from glacial till (sometimes a diamicton) and outwash gravel (including cobbles and boulders) to colluvium and alluvium, widely scattered areas of slump and landslide material, and beach deposits. Roof rocks are usually sandstones, carbonaceous shales, or unconsolidated sediments. Seatrocks are commonly claystones or carbonaceous shales.

Again, very little geochemical and physical data have been published in relation to overburden characterization in Alaska. General field observations suggest that few environmental problems can be expected in regard to the quality of overburden, interburden, and seatrock materials within the Susitna Lowland. Soils, although often thin, appear to be rich, brown sandy loams with abundant organic matter and nutrients. Most of the rock materials are high chroma, that is, usually buff to light brown or are oxidized to yellow and orange. Although very little pyrite was observed in any of the coal-bearing strata, certain dark-gray and black (low chroma) carbonaceous shales, claystones, and bony coal should not be left on the reclaimed surface.

Most material handling problems during mining will undoubtedly be related to texture, especially in regard to the large glacial-till boulders. It is highly unlikely that either an acid or alkaline spoil will develop during mining, and abundances of potentially toxic trace elements should be extremely low. This can be predicted from the continental fluvial paleoenvironment of the Kenai Group strata. However, further research is needed on the effects of mining on those areas of the lowland underlain by discontinuous or isolated permafrost.

For mining to be economic in most areas of the Susitna Lowland and to maximize resource recovery, a multiple-seam mining plan will have to be implemented. In addition, the stripping ratio (overburden: coal) must be low. Large draglines would be unsuited for mining on most lease tracts within the Susitna Lowland. A small dragline, or shovels and tandem equipment, will produce the greatest flexibility in handling interburden materials and winning the multiple coal seams.

DESCRIPTION OF PLATES

Geology and structure map of the Susitna Lowland (pl. 1). The Tertiary coal-bearing units are stippled. The darkened circles and appended blocked-in code numbers refer to locales described in app. A and B. Most of the coal geology was taken from Barnes (1966); following this, no attempt has been made to divide the Kenai Group into its formations. The major structural features of the region are also shown.

Simple Bouguer gravity map of the Susitna Lowland (pl. 2). (From S.W. Hackett, 1977, Gravity survey of Beluga Basin and adjacent area, Cook Inlet region, south-central Alaska; DGGS Geologic Report 49.)

The gravity map presented on this plate covers only the southern part of the Susitna Lowland; the northern region is still unsurveyed. The following brief discussion has been summarized from Hackett's 1977 report.

The gravity highs correlate with exposures of pre-Tertiary basement rocks, whereas the gravity lows indicate areas underlain by Tertiary sediments. The Beluga, Susitna, and Yentna basins are characterized by steep gravity gradients and low Bouguer anomaly values. This indicates the presence of large basement discontinuities and implies that these basins are tectonically deep. The regional gravity gradient over the upper Cook Inlet region suggests a gradual westward thickening of the earth's crust. Relief on the pre-Tertiary basement surface generates the larger anomalies over the lowlands.

Land-status map of the Susitna Lowland (pl. 3). The following general categories of land status information are indicated:

a. Alaska Division of Lands (ADL) coal leases, including a description of each lease and the name of the lessee
b. State parks
c. State game refuges (Goose Bay, Palmer Hay Flats, Potter Point, Susitna Flats, and Trading Bay)
d. Native lands
e. Boroughs
f. National parks
g. Petroleum and gas wells with the well name and owner, and Bureau of Mines coal-test drill holes.

The current state of flux between U.S. and Alaska lands precludes an attempt to distinguish the status of all areas within the Susitna Lowland at this time.

An individual wishing to enter any area of the Susitna Lowland should check the land status first, because many areas require special permits. These include Native lands, lease tract areas, mining claims, and state game refuges. Particularly, the state game refuges have been classified as essential to wildlife and fisheries resources and are managed by the Alaska Department of Fish and Game (ADF&G). For any exploration, construction, or development work in a designated refuge, a State Game Refuge Permit from the ADF&G is required.

Coal-potential map of the Susitna Lowland (pl. 4). This map was based solely on previous geology and coal resource maps of the Susitna Lowland with very little subsurface information. Hence, this map is highly interpretive and open to question; major revisions will be required as information becomes available.

We have subdivided the area according to relative potential for future coal development, recognizing that this is only a preliminary classification.

Four categories have been established, and the numbers indicate areas of decreasing coal potential as follows:

1 - highest potential;
2 - moderate potential;
3 - little potential or areas of scarce information; and
4 - no potential for coal development (chiefly restricted to exposures of pre-Tertiary basement).

Many areas judged to have a high potential for coal development have already been leased (pl. 3). However, there are undoubtedly other large areas in the Susitna Lowland with large coal reserves which are poorly defined or unknown because of the lack of available subsurface information.

CONCLUSIONS

The Kenai Group of the Susitna Lowland of south-central Alaska contains substantial reserves of subbituminous and lignite coals suitable for surface mining. The chief attractions of these coals are their extremely low sulfur content and favorable location with respect to potential markets. The coals are all products of continental fluvial depositional environments. Although these coals are laterally discontinuous and often high in ash, the large number of seams, particularly within the Tyonek Formation, and the geochemical and physical character of the enclosing strata result in economically attractive deposits within several fields. However, due to the lack of subsurface information over much of the Susitna Lowland, the true extent of these deposits is presently unknown.

Research related to the coal deposits of the region continues, and a summary geologic report is scheduled for completion in 1982. Current research topics include coal and overburden geochemical characterization (of nearly 400 samples collected during the 1981 field season), coal and rock petrography, and compilation of subsurface data from the region. When combined with work already completed, these studies will enable the development of basinal paleoenvironmental models. These models in turn will be important for predicting coal trends within the region, for developing and implementing premine plans, and for assuring successful reclamation.

Alaska has about half of the total coal resources of the United States and their development should begin in earnest within the next 5 to 10 years. The availability of detailed geologic information on the nature of these coals and their enclosing strata will enable industry to extract this coal economically in an environmentally sound manner. The advantages to the reasonable and orderly development of the huge coal reserves within the Susitna Lowland are obviously significant for the state of Alaska and its people, and also for Pacific rim countries desperate for new supplies of energy. Coal mines have proved that they can exist in harmony with the unique Alaskan environment. Indeed, mined land can be improved with conscientious reclamation (Conwell, 1976). The time to begin the judicious development of these coal resources is at hand.

ACKNOWLEDGMENTS

This report has been produced through the efforts of many individuals. The authors would like to take this opportunity to recognize and extend our gratitude to them. Don M. Triplehorn reviewed the original manuscript and made many helpful comments, as did Frank Larson and Cheri Daniels of the DGGS editorial staff. Roberta Mann typed the manuscript. Jonathan Sperber served as a field assistant for the primary author during the 1981 field season; he also took the photographs, assembled the bibliography, and aided in drafting. Karen Pearson and Ann Schell directed the cartography and helped to produce the plates as well as the geologic columns of appendix B. Kristie MacDonald drafted the text figures.

The cooperation of the following individuals and corporations is greatly appreciated: Benno J.G. Patsch of Placer Amex (Beluga Coal Company); John W. Blumer of Mobil Oil Corporation; Robert Sanders of Diamond Shamrock; Cook Inlet Region Native Corporation and Tyonek Native Corporation; and pilots of Trans-Alaska Helicopters, Inc.

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APPENDIX A

General description of coal outcrops shown on plate 1.

APPENDIX A - COAL LOCALES

Locale no.	Locale name	Locale code	Township	Range	Section	Outcrop section thickness	No. of coal beds	Maximum coal bed thickness	Dip	General comments
1	Beluga River	BR	13	11	14	Approximately 150 ft described	Over 12 observed; 7 described in section	10 ft	35°	Numerous seams exposed laterally along river. Coals appear to be of good quality, predominantly dull, blocky, and hard; locally platy and bony. Thicker seams toward basal portion of section have thin claystone partings. Underclays typically medium-gray sandy claystones. Sand content generally increases upward in the section. See app. B for description of coal-bearing section.
2	Beshta Bay	BB	11	12	19	80 ft	1	5 ft	30°	Dull, blocky coal with occasional thin vitrain bands; seam exposed along coast for nearly 10 miles. Overburden and seatrock consist predominantly of pebbly sandstone and conglomerate; sandstone, light brown, medium grained, locally clayey. Top of section contains very large boulders to several feet in diameter.
3	Camp Creek (Fairview Mtn area)	CpC	27	12	27	20 ft	1	15 ft exposed	37°	Predominantly dull, platy coal, becoming blocky toward basal portion, locally bony. Highly weathered on surface outcrop. Exposed for about 200 ft along Camp Creek. Overburden and seatrock not exposed.
4	Canyon Creek	CnC1	19	13	6	Approx 150 ft, only part of section described	1	14 ft	40°	Predominantly dull, blocky coal but with abundant thin vitrain bands. Isolated block of Tertiary Kenai strata surrounded by Mesozoic igneous intrusives. Gravel (with cobbles generally less than 1 ft in. diameter) covers overburden section.
5	Canyon Creek	CnC2	19	13	7	20 ft exposed	1	10 ft	35° where bedded, locally contorted	Metamorphosed coal bed locally severely contorted as result of surrounding intrusives. Rim of highly oxidized ironstone (hematite) occurs as aureole between coal and intrusive bodies.

Locale no.	Locale name	Locale code	Township	Range	Section	Outcrop section thickness	No. of coal beds	Maximum coal bed thickness	Dip	General comments
6	Canyon Creek	CnC3	19	13	7	- -	- -	- -	- -	Gradational zones of burn associated with metamorphic aureole separating Mesozoic intrusives and metasediments from Tertiary Kenai strata. The zones include: a) light-gray baked claystone with abundant plant fossils; b) cream-colored (beige) baked claystone; c) pink to light-red clinker (scoriaceous) with abundant hematite; and d) dark-red to maroon burn (pure hematite, locally specular).
7	Canyon Creek	CnC4	19	13	7	60-80 ft	1	Over 20 ft	Slight dip	Site about 50 yd south of the large burn area at CnC3. Coal thermally altered (bright, vitreous, with conchoidal fracture). Large talus slope beneath the coal prevent both exact determination of thickness and sampling the seatrock.
8	Canyon Creek	CnC5	19	13	6	50 ft exposed	1	Approx 20 ft exposed	15°	Locale is just south of CnC1. Good exposure of seatrock. See app. B for description of coal-bearing section.
9	Canyon Creek	CnC6	20	14	35	Only 10-15 ft to first terrace above stream	1	6 ft exposed to creek level	Nearly horizontal	Seam extends below stream. Locally slightly slumped. Roof and floor not exposed.
10	Canyon Creek	CnC7	20	13	19	25 ft	1	10 ft	Steep	Surface weathering pattern on coal very distinctive---similar to drusy quartz. Possible volcanic ash parting (tonstein). See app. B for description of coal-bearing section.
11	Canyon Creek	CnC8	20	13	19	Varies laterally	1	14 ft	Strong	Complete seam thickness exposed with claystone overburden and seatrock. Quality of seam deteriorates noticeably in basal 2-3 ft. See app. B for description of coal-bearing section.

Locale no.	Locale name	Locale code	Township	Range	Section	Outcrop section thickness	No. of coal beds	Maximum coal bed thickness	Dip	General comments
12	Capps Glacier area	CC1	14	14	15	Approx 25 ft exposed and accessible	2 beds, Waterfall and Capps seams; only Waterfall accessible	Top 6 ft exposed	10°	Capps and Waterfall seams exposed across the valley. Area heavily vegetated and largely inaccessible. Seatrock (underclay): claystone, medium gray, sandy, firm, breaks in conchoidal blocks, with local yellow to orange goethitic staining.
13	Capps Glacier area	CC2	14	14	23	25 ft	- -	- -	- -	Section underlying the Capps seam includes iron-oxide-stained, coarse-grained sandstone with interlayered hematite bands and medium-gray, medium-grained hard sandstone.
14	Capps Glacier area	CC3	14	14	13	30 ft	1, Capps seam	Top 6 ft exposed	3°	Overburden strata includes predominantly medium- to dark-gray carbonaceous claystone and dark-gray to black fissile, carbonaceous shales. One thin bed of calcareous sandstone (possibly siderite) with plant-leaf fossils. Seatrock inaccessible. See app. B for description of coal-bearing section.
15	Capps Glacier area	CC4	14	14	27	50 ft	1	Approx 20 ft exposed	Slight	Good lateral exposure of Capps seam along headland tributary of Capps Creek. One prominent volcanic ash parting and several other minor partings occur within the coal seam. Locally burned. See app. B for description of the coal-bearing section.
16	Capps Glacier area	CC5	14	14	24	130 ft	2, Capps and Waterfall seams	Approx 30 ft	Slight	Observed from across the valley on the south wall of Capps Creek canyon along inaccessible cliffs; full thickness of coal beds exposed. See app. B for description of coal-bearing section.
17	Chuitna River	CR1	13	13	29	30 ft exposed	- -	- -	- -	White-weathering pebbly sandstone beneath the Chuitna bed, coarse grained, locally slightly clayey, coal forms an anticlinal rim around top of outcrop.
18	Chuitna River	CR2	13	13	29	20 ft exposed	1	10 ft exposed	30°	Back of anticline, exposure of Chuitna coal bed.

Locale no	Locale name	Locale code	Township	Range	Section	Outcrop section thickness	No. of coal beds	Maximum coal bed thickness	Dip	General comments
19	Chuitna River	CR3	13	13	28	10 ft	1	Approx 6 ft exposed	30°	Exposure of Chuitna bed along stream drainage; one limb of anticline on bottom of stream bed. See app. B for description of coal-bearing section.
20	Chuitna River	CR4	13	13	28	Usually less than 10 ft	1	Varies, generally 4-6 ft exposed	30°	Coal at this locale is contained within the northeast-trending anticline described at CR2 and CR3.
21	Chuitna River	CR5	12	13	24	20 ft	2	8 ft	4°	Two seams or one separated by a 1.5-ft parting of claystone. Coal extremely weathered at this exposure. See app. B for description of coal-bearing section.
22	Chuitna River	CR6	12	13	6	Up to 80 ft exposed but largely inaccessible	1	Over 20 ft	Nearly hori-zontal	Outcrop of seatrock of Chuitna bed -- weathered, friable sandstone and loose sand, relatively clean, fine to medium-grained, predominantly quartz but with disseminated black organic matter and extremely fine muscovite flakes.
23	Chuitna River	CR7	12	13	35	- -	- -	- -	- -	Outcrop of baked sandstone and shale with imprints of leaf fossils. Burn material -- scoria, porcellanite, clinker, "red dog." Different stages of oxidation and varieties of vesicular hematite; local admixtures of pyrolusite (MnO_2).
24	Chuitna River	CR8	12	13	1	60 ft	1	10 ft	5°	Distinctive differential weathering surfaces (anastamoses) on sandstone roof rock of Chuitna coal bed. The basal portion of the coal bed (1-2 ft) appears to be burned. Described from across river. See app. B for description of coal-bearing section.
25	Chuitna River	CR9	12	13	1	80 ft	1	30 ft	Less than 5°	Good exposure of Chuitna bed along southwest wall of promontory. Possible volcanic ash parting within coal seam. See app. B for description of coal-bearing section.

Locale no.	Locale name	Locale code	Township	Range	Section	Outcrop section thickness	No. of coal beds	Maximum coal bed thickness	Dip	General comments
26	Chuitna River	CR10	13	13	27	90 ft	1	6 ft	15°	Exposure includes large area of scoria and baked shale above the coal bed on the south valley wall of the Chuitna River. Monocline on westward extension (possibly resulting from fault drag) flattening out to the east. Extensive burn talus slopes toward basal portion of outcrop. See app. B for description of coal-bearing section.
27	Coal Creek	CC1	16	13	26	200 ft	- -	- -	- -	Thick section of Kenai strata exposed without coal beds, predominantly petromictic conglomerates and pebbly sandstones but with thin carbonaceous shale and claystone interbeds. Section overlies coal-bearing strata downstream.
28	Coal Creek	CC2	16	13	36	10 ft exposed	1	2 ft	Nearly horizontal	Thin coal seam with roof and floor exposed. Described from across stream. See app. B for description of coal-bearing section.
29	Coal Creek	CC3	16	13	36	40 ft exposed	1	Approx 25 ft	4°	Good exposure of coal seam and seatrock but roof covered. Outcrop largely inaccessible.
30	Drill Creek	DC	15	12	11	60 ft exposed	1	More than 50 ft	20°	Coal platy to slightly blocky, firm-hard with interbands of vitrain. Coal exposed in shallow synclinal basin on the southern bank of Drill Creek. Barnes (1966) reports that the bed was exposed in 1960 in a sampling trench excavated by the U.S. Bureau of Mines.
31	Fairview Mtn	FM1	26	12	7	200 ft	6	4 ft	35°	Seams A-F. The two lower coal beds (A and B seams) are poorly exposed and highly weathered. The coal beds could thicken considerably downdip. Overburden section consists predominantly of petromictic conglomerates with included coal and graphite cobbles and gravels. See app. B for description of coal-bearing section.
32	Fairview Mtn	FM2	26	12	6	50 ft	2	4 ft	25°	Represents two lower beds exposed at FM1 - seams A and B. The coal beds were exposed only by extensive digging at an outcrop on the northwest slope of Fairview Mountain. See app. B for description of coal-bearing section.

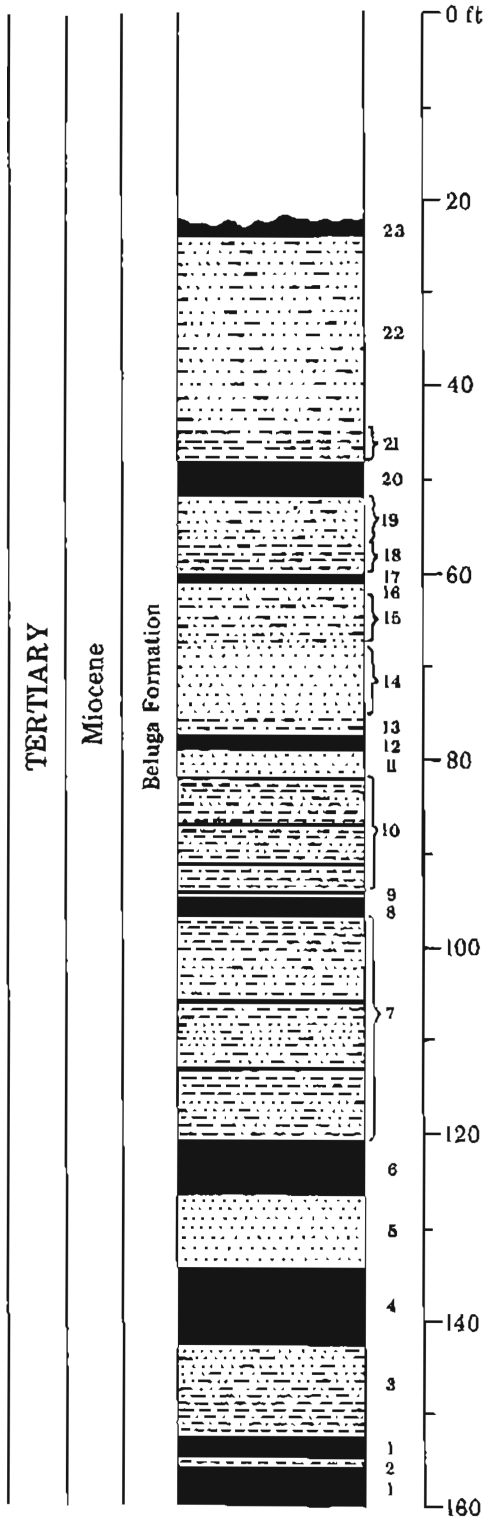
Locale no.	Locale name	Locale code	Township	Range	Section	Outcrop section thickness	No. of coal beds	Maximum coal bed thickness	Dip	General comments
33	Friday Creek	FC	19	13	35	20 ft	1	12 ft exposed down to creek level	Nearly hori- zontal	Coal hard, platy, ashy, locally vitrain-banded but predominantly dull. Roof and floor unexposed.
34	Johnson Creek	JC1	23	15	21	200 ft or more; only basal 20 ft described	- -	- -	- -	Lower section of exposure is composed of dark-gray graphitic claystone and graphite with white quartz veins, fracture fills, and nodules. A zone of white calcite and an aquamarine weathering rim forms the boundary between the graphite and the quartz.
35	Johnson Creek	JC2	23	15	23	150 ft	3, only lower bed accessible	Less than 1 ft	25°	Coal thermally altered, vitreous, conchoidal fracture. Carbonaceous shale roof and floor. See app. B for description of coal-bearing section.
36	Johnson Creek	JC3	23	14	30	50 ft exposed	1	6 ft	13°	Crops out in south wall of creek. Predominantly a dull, platy coal but with few interbanded bright coal layers. Located at the base of a quartz-pebble conglomerate and pebbly, sandstone sequence. Coal bed has a thin carbonaceous claystone parting toward the basal portion. Ironstone nodules occur locally with the roof and floor materials. Some burn within immediate area. See app. B for description of coal-bearing section.
37	Petersville area	PA1	28	10	36	172 ft	3	1 ft	Moderate	Outcrop located on west wall of Short Creek, a southward-flowing tributary of Cache Creek. Rapid vertical and lateral changes in lithologic facies. Coals thin, hard, dull, and blocky. Overburden includes a claystone with distinctive coalified rootlets toward the top of the stratigraphic sequence. See app. B for description of coal-bearing section.

Locale no.	Locale name	Locale code	Township	Range	Section	Outcrop section thickness	No. of coal beds	Maximum coal bed thickness	Dip	General comments
38	Petersville area	PA2	27	8	18	Varies laterally	1	4 ft	Near vertical	Possible volcanic ash parting in center of coal seam. Coal woody. A dark-gray carbonaceous, feldspathic graywacke stands in relief about 15 ft above coal bed. Exposure on southwest wall of tributary of South Fork Creek on the southeast flank of Peters Hills. See app. B for description of coal-bearing section.
39	Petersville area	PA3	27	8	22	50 ft	1	2 ft of coal separated by 0.5-ft parting	45°	Outcrop located on Peters Creek near Lampoon Pond. Pebbly, coarse-grained sandstone roof and floor exposed.
40	Saturday Creek	SC1	18	13	1	15 ft	- -	- -	- -	Banded claystone unit beneath coal exposed at locale SC2. The unit contains large oval-shaped concretions (up to 5 ft in diameter) with hard sandstone centers. Some of the concretions have abundant coal banding and carbonaceous root, branch, and leaf impressions, others have iron-rich (hematite) cores.
41	Saturday Creek	SC2	18	13	2	50 ft	1	8 ft	30°	Possible flow-roll (ball and pillow) structures exhibited at a prominent ledge about 6 ft below the bottom of the coal seam. See app. B for description of coal-bearing section.
42	Saturday Creek	SC3	18	13	2	40 ft	1	10 ft	32°	Channel cut-out (exposed in cross section) at the west side of the outcrop; channel filled with sandstone and conglomerate. See app. B for description of coal-bearing section.
43	Saturday Creek	SC4	18	13	2	90 ft	4	3 ft, top 2 beds separated by 2-ft parting	25°	Overburden largely covered but claystone roof of top seam exposed by trenching. One thin (0.3 ft) stringer of extremely hard coal exhibits conchoidal fracture -- possibly a cannel coal. See app. B for description of coal-bearing section.
44	Skwentna River	SR	22	15	23	60 ft exposed	2, only upper seam accessible	Upper seam 2 ft; lower seam approx 5 ft exposed	6°	Second seam of coal crops out about 100 yd to west at stream level. Claystone roof and carbonaceous shale floor exposed. Coal predominantly dull, platy, locally bony; quality deteriorates toward base of seam. See app. B for description of coal-bearing section.
45	Sunflower Creek	SC	27	12	26	70 ft	1	Over 50 ft	Top 25°, basal part of bed approx 50°	Lower portion of bed slumped. Roof and seatrock of coal not exposed. Appears to be very localized, lying near Mesozoic rocks. See app B for description of coal-bearing section.
46	Talachulitna River	TR	19	12	21	10 ft	1	3 ft	18°	Metamorphosed Jurassic-Cretaceous greenstone rocks are faulted and juxtaposed against coal about 100 ft upstream. See app. B for description of coal-bearing section.
47	Wolverine Creek	WC1	17	9	1	Varies laterally	2	7 ft	Nearly vertical	Located northern extremity of Mount Susitna. Two seams exposed but section probably repeated. Claystone roof and floor well exposed. See app. B for description of coal-bearing section.
48	Wolverine Creek	WC2	17	9	24	Varies laterally	2	2 ft	Steep	Claystone roof of upper seam contains distinctive iron-rich (hematite core; limonite rim) septarian nodules to 2-in. in diameter. See app. B for description of coal-bearing section.

APPENDIX B

Geologic columns of described coal-bearing sections within the Kenai Group.

BELUGA RIVER SEAMS
SITE: BR1



LITHOLOGIC DESCRIPTION

23 Coal (inaccessible); section discontinued.

22 Sandstone, clayey, medium-gray (N5), medium-grained, firm.

21 Claystone, slightly sandy, light-olive-gray (5Y6/1), streaked olive-gray (5Y4/1), firm.

20 Coal, brownish-black, dull, bony, hard.

19 Sandstone, slightly clayey, olive-gray (5Y4/1) with grayish-black (N2) coaly inclusions, medium-grained with disseminated, very fine muscovite, friable.

18 Claystone, slightly sandy, light-olive-gray (5Y6/1) with medium-olive-gray (5Y5/1) to olive-gray (5Y4/1) streaks, finely disseminated black organic matter and thread-like stringers of coal, locally iron-oxide-stained.

17 Coal, black, dull, platy, bony, hard.

16 Sandstone, light-olive-gray (5Y6/1) with black (N1) coaly inclusions, medium-grained, organic, firm.

15 Sandstone, clayey, light-olive-gray (5Y5/1), medium-grained, disseminated black organic matter and fine muscovite, locally friable.

14 Sandstone, medium-gray (N5), medium- to coarse-grained, abundant disseminated black organic matter ("salt and pepper"), friable, soft.

13 Claystone, sandy, light-olive-gray (5Y6/1) with pale yellowish-orange (10YR8/6) mottling, firm but weathered soft locally.

12 Coal, black, dull, platy, hard, bony.

11 Sandstone, medium-olive-gray (5Y5/1), speckled white (N9) and black (N1), organic, medium-grained, hard with coal spars at top; below sandstone, medium gray (N5), medium grained, weathered, friable, soft.

10 Claystone, sandy, medium-olive-gray (5Y5/1) with olive-black (5Y2/1) streaks, predominantly, and sandstone, clayey, medium-gray (N5), medium-grained, firm, interbedded with few thin (less 0.5 ft) coal stringers.

9 Shale, carbonaceous, brownish-gray (5Y4/1), firm to hard, iron-rich, slightly fissile.

8 Coal, black, dull, hard, bony.

7 Claystone, sandy, medium-olive-gray (5Y5/1) with fine brownish-black (5YR2/1) coaly inclusions, firm, predominantly, but interbedded with sandstone, clayey, medium-gray (N5), medium-grained, locally weathered and friable, and thin (less 0.5 ft) coal stringers.

6 Coal (inaccessible).

5 Sandstone, medium-gray, medium- to coarse-grained, friable, firm.

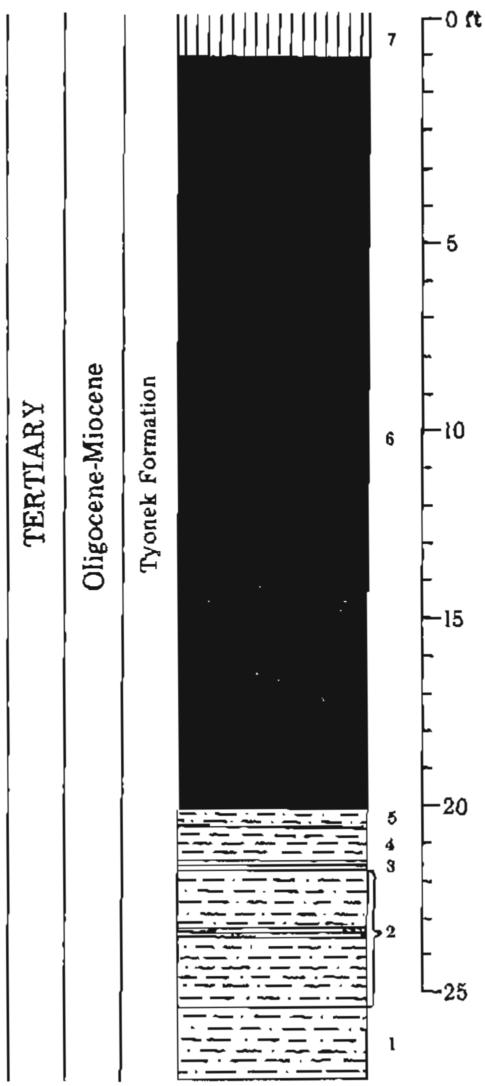
4 Coal (inaccessible).

3 Claystone, sandy, medium-gray, firm, and sandstone, clayey, medium-gray, medium-grained, soft to firm interbedded.

2 Parting, claystone, sandy, brownish-gray (5YR4/1) with dark-gray (N3) coaly inclusions, firm.

1 Coal, black, dull, platy, woody, locally bony.

CANYON CREEK SEAM
SITE CnC5



LITHOLOGIC DESCRIPTION

7 Roof covered and inaccessible.

6 Canyon Bed: coal, black, dull, blocky with few vitrain bands, hard; locally platy and ashy.

SEATROCK

5 Claystone, sandy, olive-black (5Y/1), carbonaceous, firm.

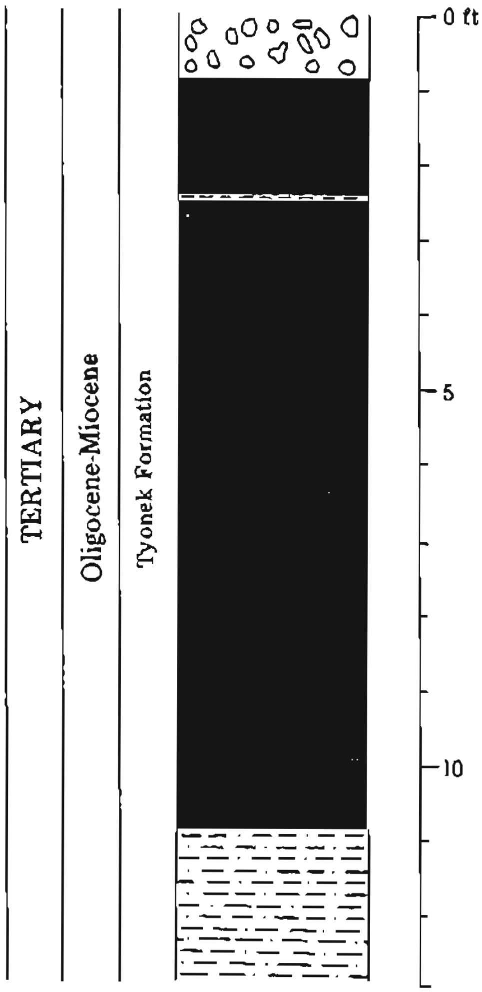
4 Claystone, pinkish-gray (5YR8/1) with grayish-black (N2) to black (N1) coaly inclusions, locally carbonaceous, rooted, weathered and soft.

3 Shale, carbonaceous, black (N1), fissile, highly weathered, soft.

2 Claystone, slightly sandy, pinkish-gray (5YR8/1) with grayish-black (N2) coaly inclusions and black (N1) disseminated organic matter, firm; 0.2 ft band of shale, carbonaceous, black (N1), fissile, highly weathered and soft in center of unit.

1 Claystone, slightly sandy, pinkish-gray (5YR8/1) with black (N1) coaly inclusions and local dark-yellowish-orange (10YR6/6) mottling, firm.

CANYON CREEK SEAM
SITE CnC7



LITHOLOGIC DESCRIPTION

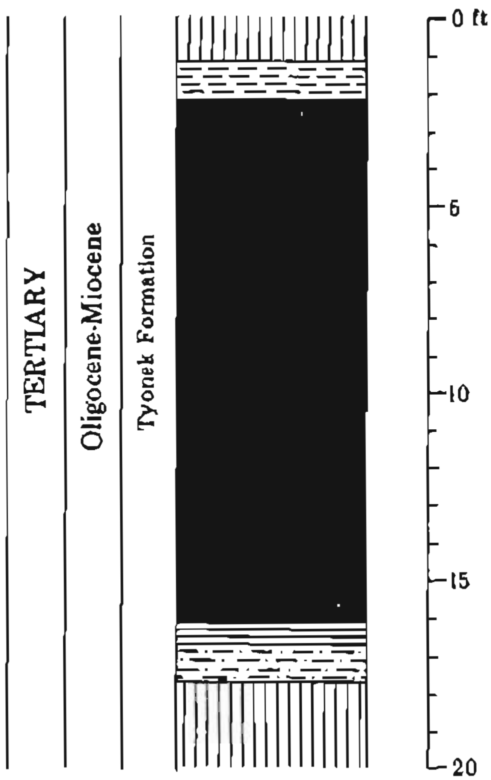
Boulders (diamicton) up to several feet in diameter.

Parting, claystone (possibly volcanic ash), pale-yellowish-orange (10YR8/6) to dark-yellowish-orange (10YR6/6), firm.

Coal, black, dull, very hard, platy, with distinctive surficial-weathering pattern similar to drusy quartz in appearance.

SEATROCK (underclay): claystone, slightly sandy, light-olive-gray (5Y6/1) with dark-yellowish-brown (10YR4/2) organic inclusions, carbonaceous plant fragments, micaceous, firm.

CANYON CREEK SEAM
SITE CnC8



LITHOLOGIC DESCRIPTION

Covered interval directly above roof but includes boulders (diamicton) to several feet in diameter toward top of section.

Roof: claystone, slightly sandy, olive-gray (5Y4/1), carbonaceous, soft

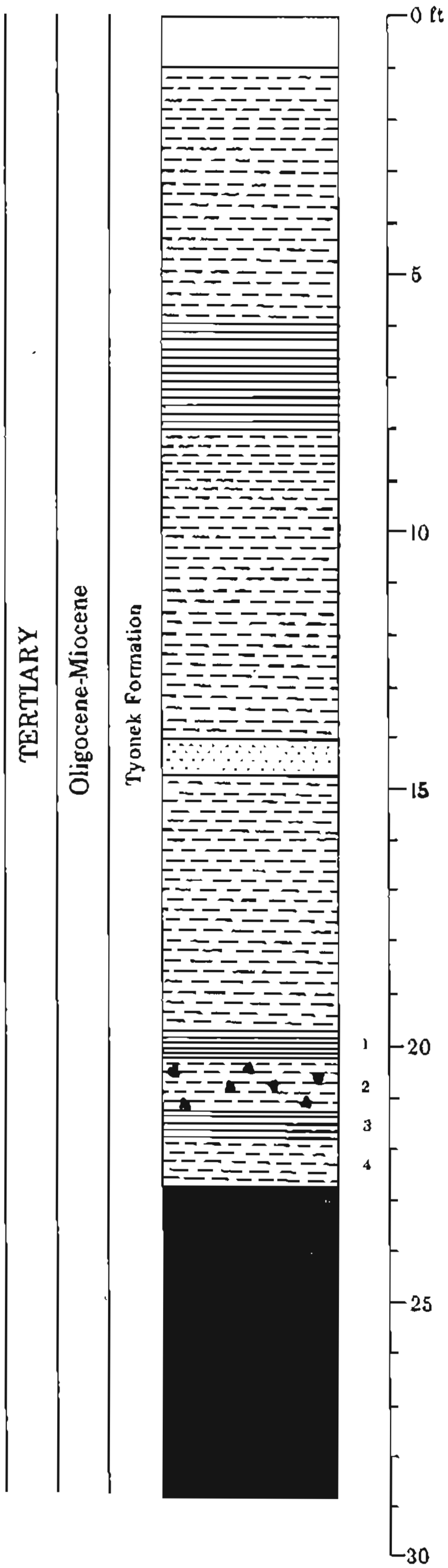
Coal, black, dull, blocky, hard, quality of coal deteriorates significantly in basal 2-3 ft.

SEATROCK

Shale, carbonaceous, brownish-black (5YR2/1), soft, smutty.

Claystone, sandy, light-olive-gray (5Y6/1), slightly carbonaceous, especially toward top, micaceous, soft to firm.

CAPPS COAL SEAM
SITE CG3



LITHOLOGIC DESCRIPTION

Surficial cover; predominantly a brown sandy loam.

Claystone, olive-black (5Y2/1) to brownish-gray (5YR4/1), carbonaceous, breaks with blocky conchoidal fracture, firm, locally has pale-yellowish-orange (10YR8/6) to light-brown (5YR5/6) goethite staining along weathered surfaces and fracture planes.

Shale, carbonaceous, brownish-black (5YR2/1) to olive-black (5Y2/1) to grayish-black (N2), firm to soft, locally fissile with thin interbedded lenses (less 1 in.) of sandstone, medium-gray (N5), coarse-grained, and coal (approximately 1 in. thick), black, bony, platy, soft and weathered.

Claystone, slightly sandy to sandy, medium-gray (N5), massive, firm, blocky conchoidal fracture and abundant iron-oxide staining along fracture planes and weathering surfaces.

Sandstone, light-olive-gray (5Y6/1) to medium-olive-gray (5Y5/1), coarse-grained, very hard, calcareous, with abundant plant-leaf fossils, pale-yellowish-orange (10YR8/6) iron-oxide staining along central (2 in. thick) band.

Claystone, olive-black (5Y2/1), massive, firm, with abundant black, carbonaceous, fossil-leaf films, locally with moderate-red (5R4/6) to dusky-red (5R3/4) hematitic oxidation staining.

1 Shale, black (N1) to brownish-black (5YR2/1), slightly carbonaceous, fissile, soft to firm, locally highly weathered.

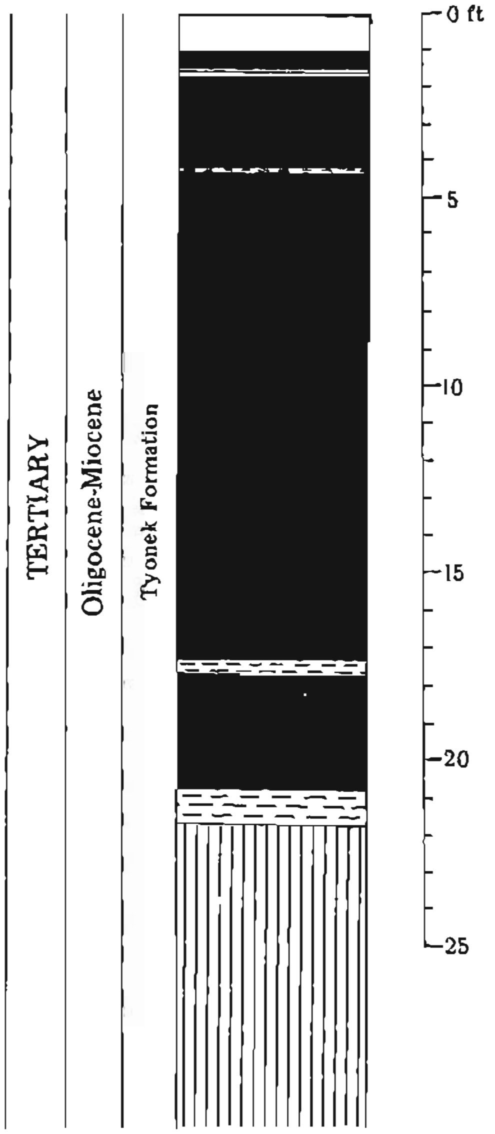
2 Claystone, moderate-brown (5YR3/4) with black (N1) coaly inclusions, soft to firm, breaks with conchoidal fracture, rounded limonite on hematite nodules to 2 in. diameter, thin streaks and contorted laminae of black carbonaceous shale.

3 Shale, carbonaceous, black (N1) with light-brown (5YR5/6)-weathering stains, fissile, soft.

4 Claystone, olive-gray (5Y4/1) to olive-black (5Y2/1), firm to soft, with blocky fracture pattern.

Capps Seam: coal, black, dull, firm to hard, locally with thin (less 3 in.) vitrain bands, surfaces and fractures covered with abundant iron-oxide and sulfate stains, local siderite.

CAPPS SEAM
SITE CG4



LITHOLOGIC DESCRIPTION

Surficial cover; unconsolidated light-brown sand and sandy loam.

Coal (top 2 ft), black, soft, highly weathered, and shale, carbonaceous, black (N1), fissile, firm.

Parting, claystone, dark-gray, carbonaceous, soft.

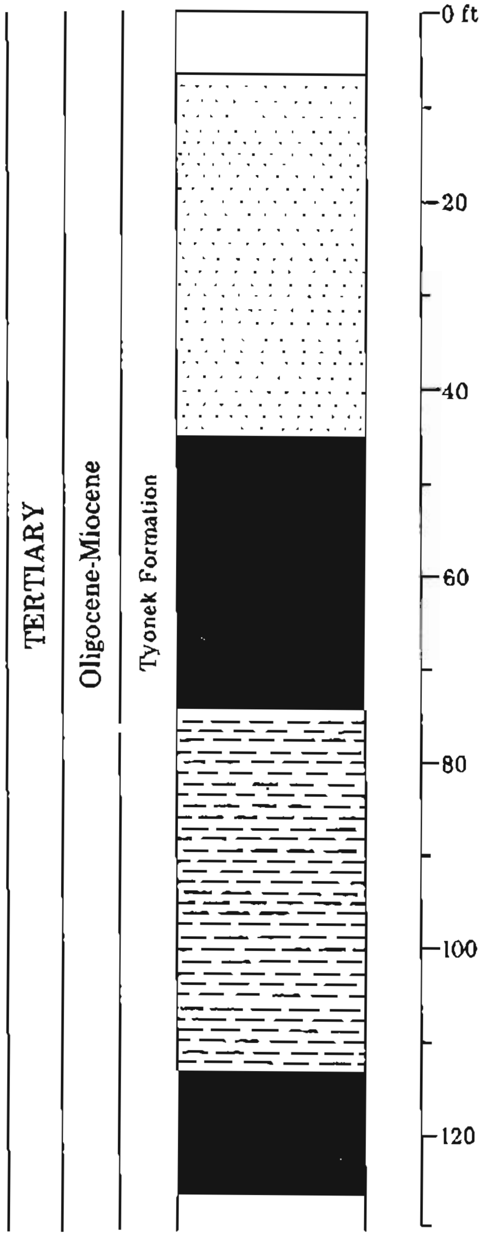
Capps Seam; coal, black, predominantly dull and blocky but locally bony and platy with increasing vitrain bands toward basal portion.

Parting: claystone (possibly volcanic ash), light-brownish-gray (5YR6/1), firm.

SEATROCK (underclay)
Claystone, medium-olive-gray (5Y5/1) with grayish-black (N2) carbonaceous inclusions, locally slightly fissile, soft to firm.

Section down to level of Capps Creek largely covered with talus and regolith but predominantly sandstone, medium-gray (N5), medium-grained, friable but firm, and claystone, sandy, medium-gray (N5), soft to firm, breaks with conchoidal fracture.

CAPPS CREEK SEAMS
CAPPS GLACIER AREA
SITE CG5



LITHOLOGIC DESCRIPTION

Surficial cover.

Sandstone, medium-gray, medium- to coarse-grained, hard, weathered with light-brown to orange-iron-oxide staining.

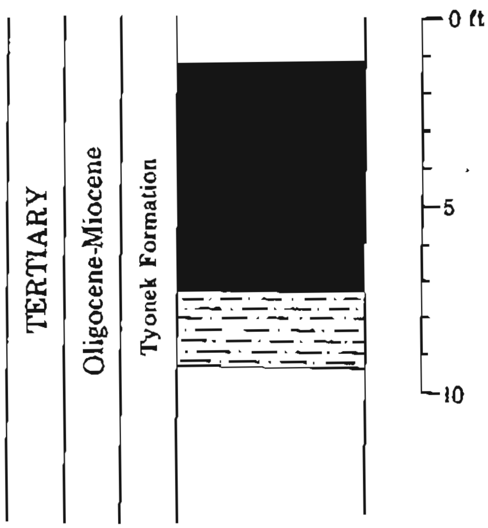
Waterfall Seam.

Claystone, medium-gray, firm.

Capps Seam.

Lower extent of section down to level of Capps Creek.

CHUITNA RIVER SEAM
SITE CR3



LITHOLOGIC DESCRIPTION

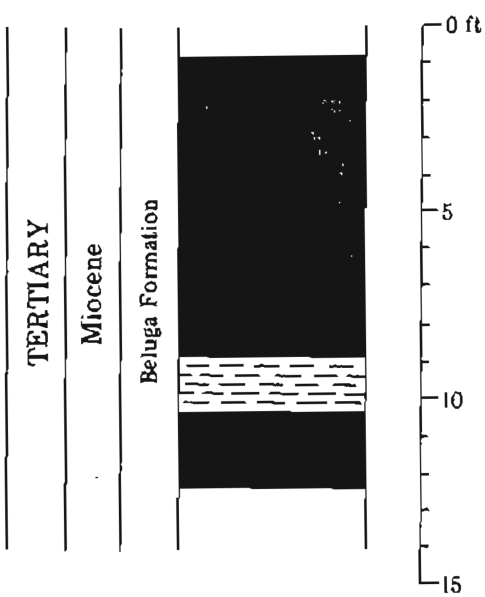
Baked shale and varicolored clays weathering from it.

Chuitna Bed (partial exposure, basal portion); coal, black, dull, blocky, highly weathered.

SEATROCK (underclay)
Claystone, sandy, medium-light-gray (N6), black carbonaceous leaf impressions, soft.

Section discontinued at water level.

CHUITNA RIVER SEAM
SITE CR5



LITHOLOGIC DESCRIPTION

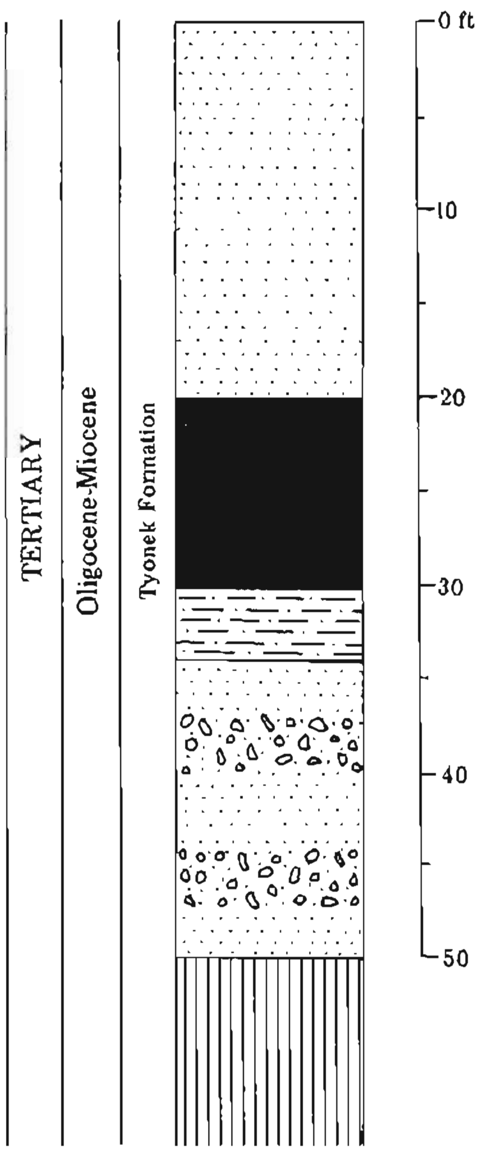
Coal, black, dull, blocky, highly weathered with abundant orange-limonite staining.

PARTING
Claystone, light-olive-gray (5Y6/1), locally carbonaceous, iron-oxide staining, firm.

Coal, black, dull, blocky, hard.

Section discontinued at creek level.

CHUITNA RIVER SEAM
SITE CR8



LITHOLOGIC DESCRIPTION

ROOF:
Sandstone, light-grayish-yellow, medium- to coarse-grained, weathered, locally limonite-stained, pockmarked differential-weathering surfaces (anastamosis).

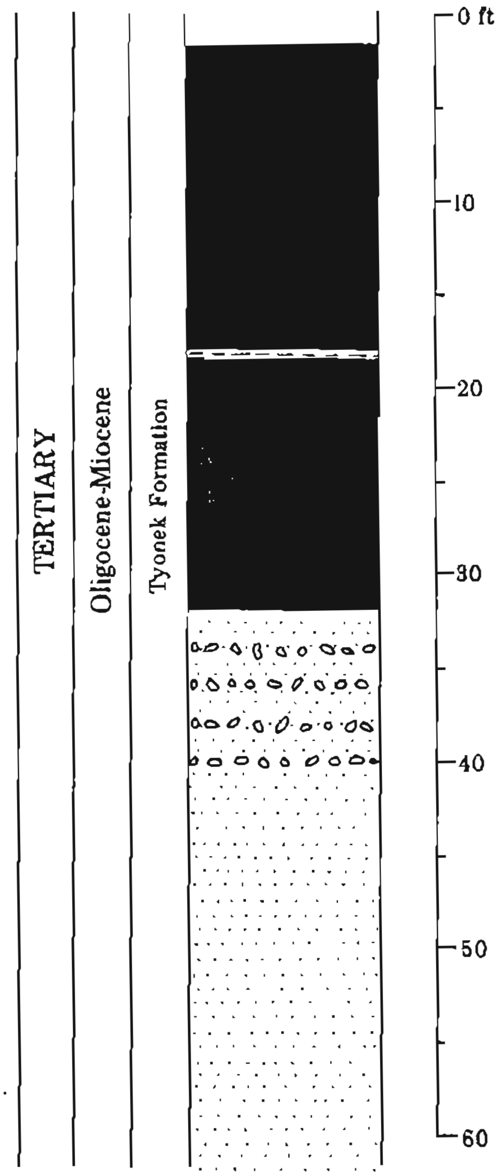
Chuitna Bed; coal, black, dull, hard, blocky, basal 1 ft appears burned.

SEATROCK (underclay)
Claystone, sandy, medium-gray, firm.

Sandstone, medium-gray, medium- to coarse-grained, hard, with quartz-pebble-conglomerate interbeds, local yellow to orange iron-oxide staining.

Covered interval to water level.

CHUITNA RIVER SEAM
SITE CR9



LITHOLOGIC DESCRIPTION

Roof of coal inaccessible.

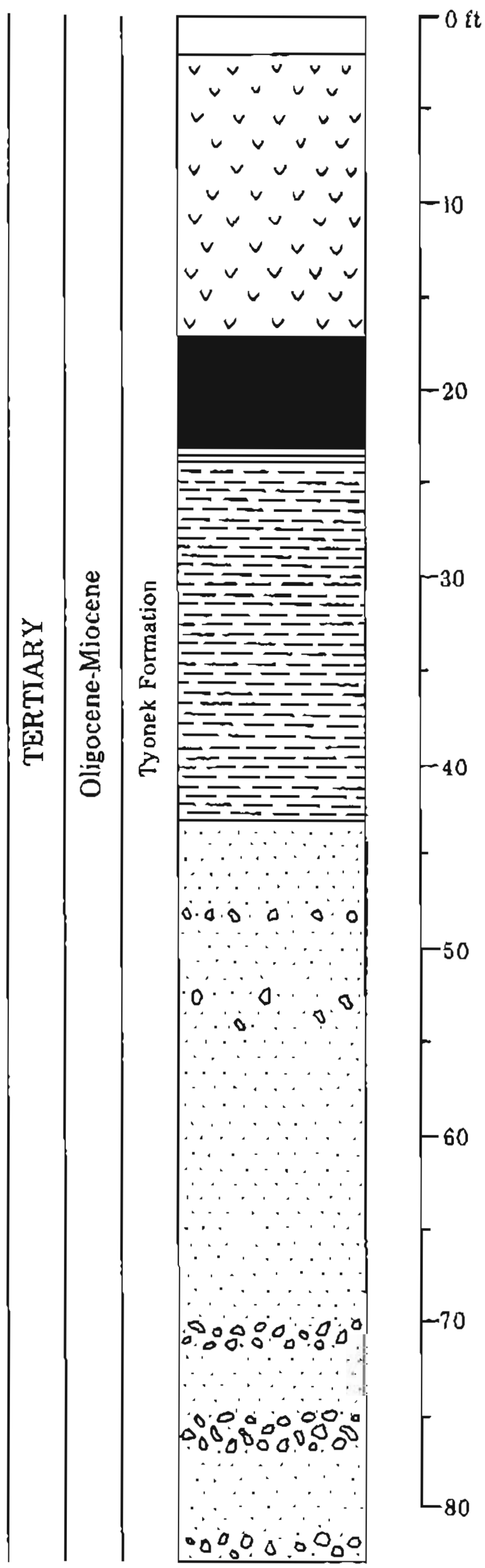
Chuitna Bed: coal, black, hard, platy, dull, locally bony.

Parting (possibly volcanic ash); claystone, silty, olive-black (5Y2/1), weathers to grayish-red (10R4/2), firm, breaks with conchoidal fracture.

Coal below parting predominantly dull and blocky, ash content appears significantly less than in upper portion; local minor pyrite and weathered-sulfate coatings.

SEATROCK
Sandstone, light-olive-gray (5Y6/1) to pinkish-gray (5YR8/1), medium-grained, relatively clean, predominantly quartz with disseminated black organic matter, subrounded to angular grains, friable, weathered, soft. Minor (near 0.5 ft) partings of quartz-pebble conglomerate and conglomeratic sandstone toward top of section beneath coal bed.

CHUITNA RIVER SEAM
SITE CR10



LITHOLOGIC DESCRIPTION

Surficial cover; brown sandy loam, sand, and gravel.

Burn (clinker, "red dog," scoria, porcellanite).

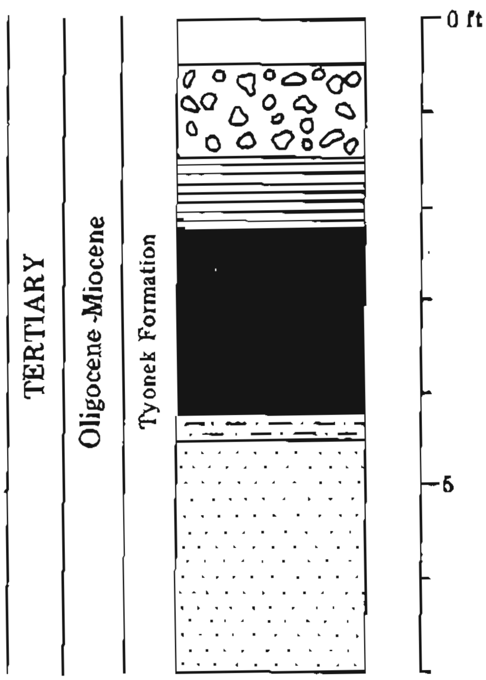
Coal, predominantly dull and blocky with thin (less 2 in.) vitrain bands and bony layers (to 0.5 ft), hard.

Shale, carbonaceous, olive-gray (5Y4/1) with light-brown (5YR5/6)-oxidation staining, firm.

Claystone, dark-gray (N3), carbonaceous, soft, locally weathered with light-brown (5YR5/6)-limonite staining.

Sandstone, medium-gray (N5), medium- to coarse-grained, locally conglomeratic with interbedded quartz-pebble-conglomerate bands, especially toward the basal portion of outcrop and light-brown (5YR5/6)-iron-oxide staining.

COAL CREEK SEAM
SITE CC2



LITHOLOGIC DESCRIPTION

Surficial cover: sand, loamy, medium-grayish-brown, soft with abundant rootlets.

Diamicton; boulders and cobbles predominantly less than 1 ft in diameter.

Shale, carbonaceous, black, fissile, soft to firm, locally goethite-stained.

Coal, black, hard, dull, blocky.

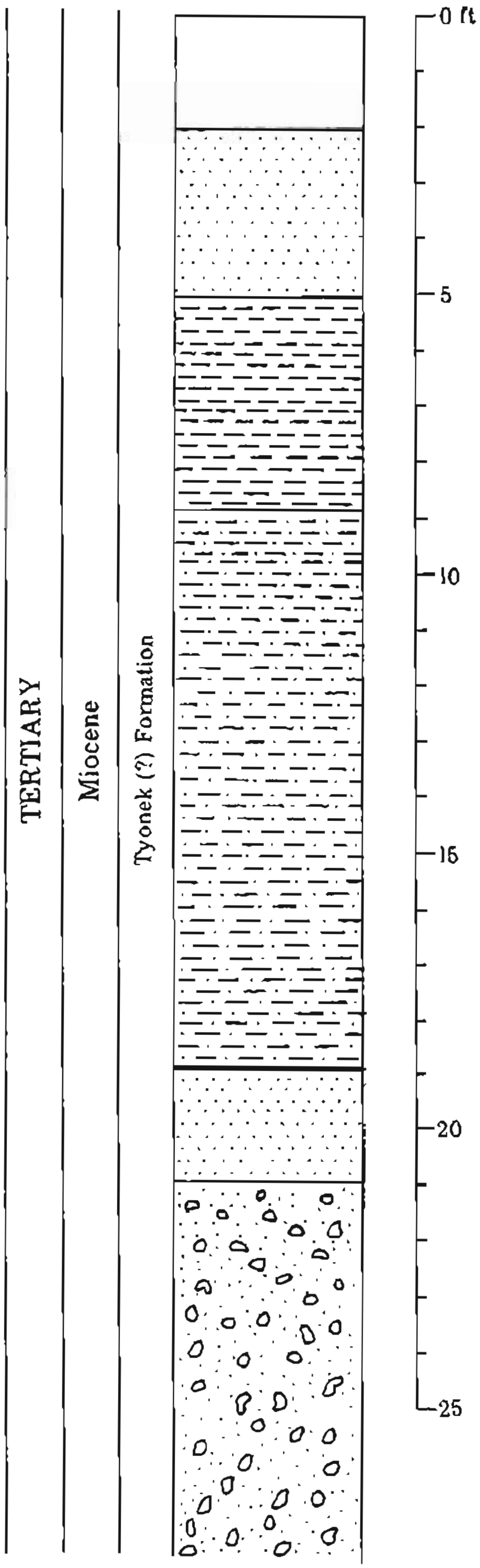
Claystone, sandy, light-gray, soft to firm.

Sandstone, light-gray, medium- to coarse-grained, friable, firm.

Section discontinued at Coal Creek water level.

FAIRVIEW MOUNTAIN SEAMS
SITE FM1

Sheet 1 of 7



LITHOLOGIC DESCRIPTION

Surficial cover; loam, sand, brown, disseminated black organic matter, soft, rooted.

Sand, yellowish-gray, medium-grained, slightly clayey, soft, yellow- to orange-iron-oxide mottling, rare extremely fine disseminated muscovite.

Claystone, light-gray, soft, with abundant yellow-iron-oxide staining.

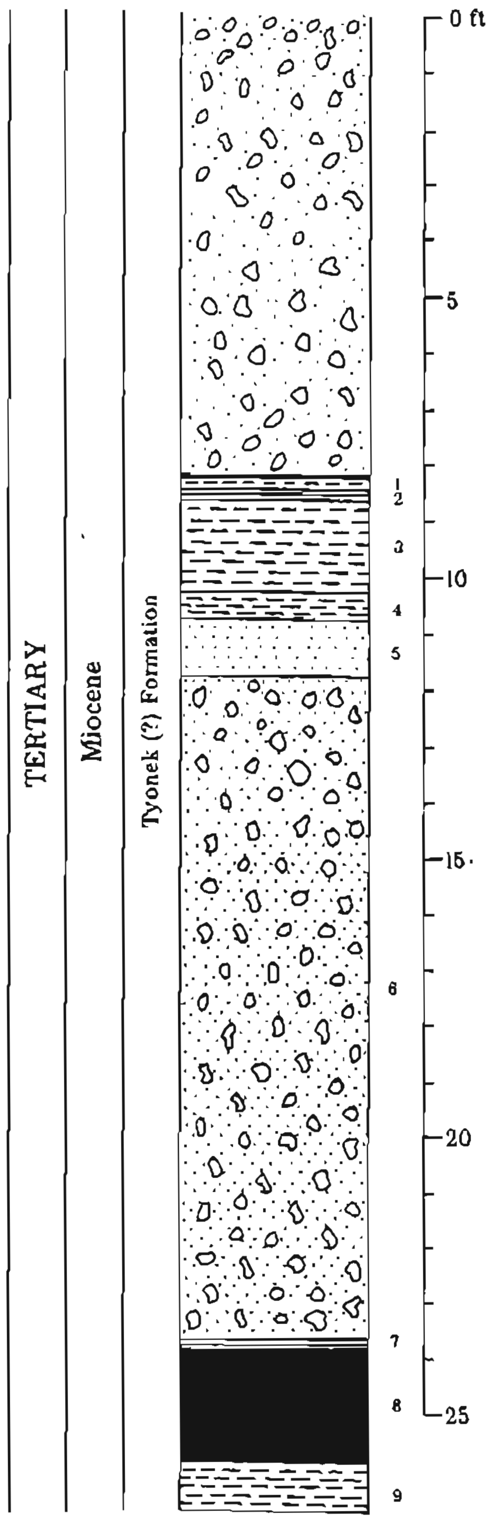
Claystone, sandy, medium-gray, fine disseminated muscovite and black organic matter, firm; thin (1 in.) stringer of coal, black, dull, very hard forming base.

Sand, yellowish-gray, coarse-grained, locally contains disseminated organic matter and abundant threadlike stringers of black carbonaceous material, weathered, loose.

Conglomerate, petromictic, light to medium-gray; sand matrix, coarse-grained, angular fragments, poorly cemented to loose, predominantly quartz and chert; "gravel" mostly in size range less 0.5 ft and includes various igneous lithologies, coal gravels, and cobbles; interspersed within unit are thin (less 2 in.) stringers and pockets of clay, light- to medium-gray, soft, plastic. Thin coal stringer (less 1 in.) at base of conglomerate.

FAIRVIEW MOUNTAIN SEAMS
SITE FM1

LITHOLOGIC DESCRIPTION



1 Claystone, dark-gray, slightly sandy, carbonaceous, firm.

2 Shale, carbonaceous, black, fissile, soft to firm, weathered.

3 Claystone, medium-brownish gray, slightly carbonaceous and sandy, firm.

4 Claystone, medium-gray, very sandy, firm.

5 Sand, medium-gray, medium- to coarse-grained with abundant limonitic and hematitic staining and black coaly stringers and bands.

6 Conglomerate, petromictic (as above) but with abundant coal cobbles and gravel inclusions; few graphite nodules to 0.5 ft diameter near base directly above coal; also contains few clean orthoquartzite-sandstone cobbles.

7 Shale, carbonaceous, black (N1), fissile, firm, weathered with abundant iron-oxide staining.

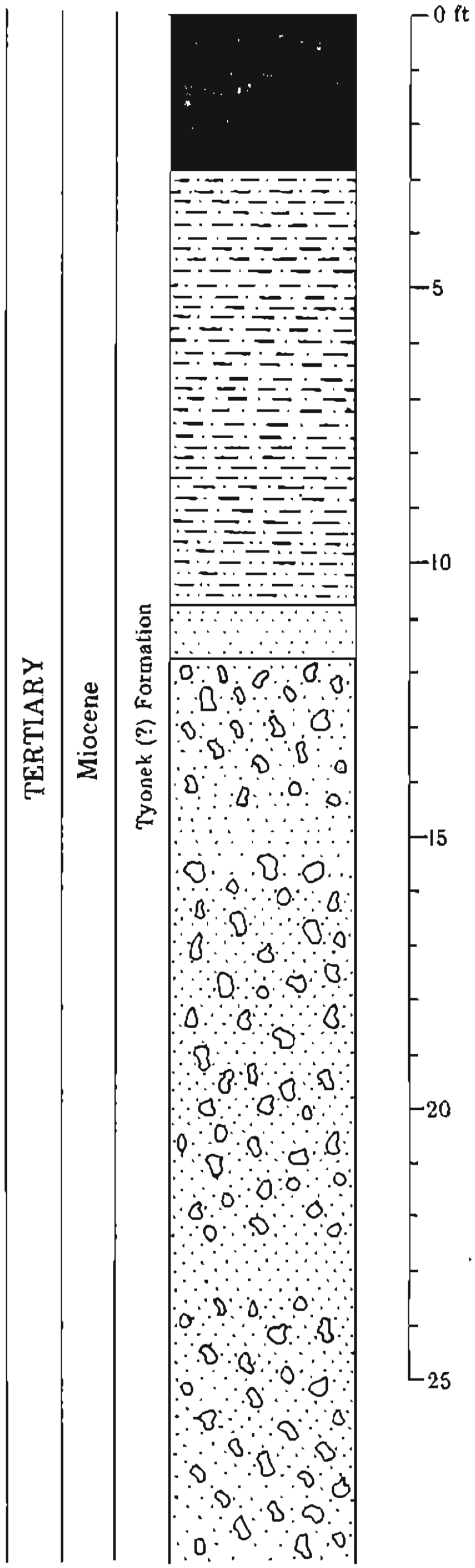
F Seam

8 Coal, black, dull, platy, ashy, weathered, poor-quality.

9 Partings, claystone, olive-black (5Y2/1), carbonaceous, slightly sandy, firm, thin (less 2 in.) coal bed in basal portion.

FAIRVIEW MOUNTAIN SEAMS
SITE FM1

Sheet 3 of 7



LITHOLOGIC DESCRIPTION

F Seam
Coal, black, dull, platy, bony, poor quality with thin laminae of claystone, sandy, medium-gray, soft and shale, carbonaceous, black, fissile, soft, intercalated for top 2 ft; lower 0.5 ft dull, blocky, hard coal.

SEATROCK (underclay)
Claystone, sandy, medium-light (N6)-gray, firm, limonite surface stains, breaks with conchoidal fracture; becomes more sandy toward basal portion with few interspersed sand lenses (less 1 in.), light- to medium-gray, medium-grained, micaceous, locally limonite-stained.

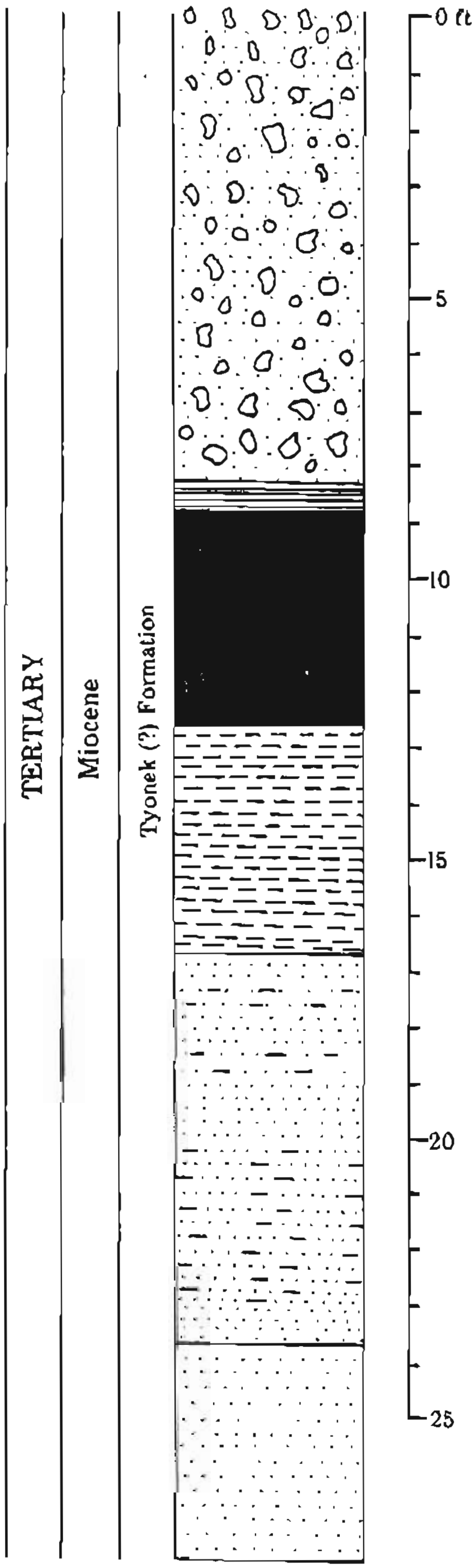
Sand, yellowish-gray, fine- to medium-grained, soft, loose with disseminated fine black organic matter and muscovite; also smutty coal stringers (around 0.5 in.) locally.

Conglomerate, petromictic pebble-cobble, with coarse-grained, poorly lithified sand matrix; pebbles and cobbles predominantly 2 in. to less than 0.5 ft of various igneous lithologies (including granite), abundant coal, quartz, chert, and clean orthoquartzite sandstone; pebbly sandstone lenses to 1 ft thick locally throughout this section.

FAIRVIEW MOUNTAIN SEAMS
SITE FM1

Sheet 4 of 7

LITHOLOGIC DESCRIPTION



Shale, carbonaceous, black (N1) with light-brown (5YR5/6) weathering stains, fissile, firm.

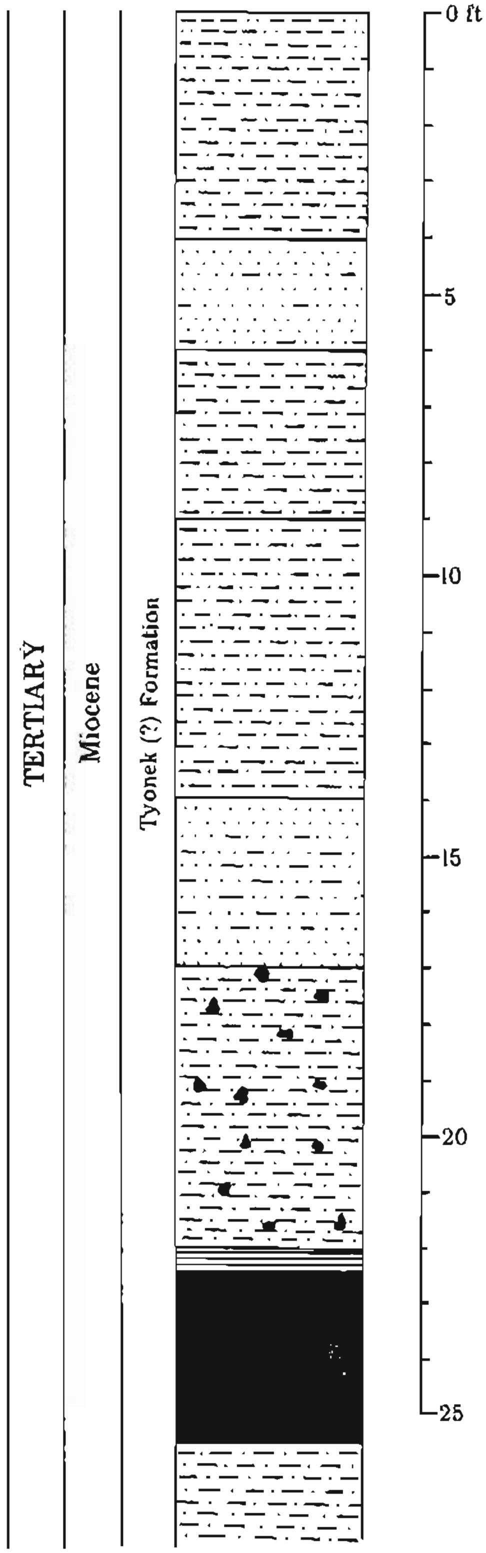
E Seam
Coal, top 2 ft, black, dull, platy, weathered, firm; basal portion dull, blocky, bony, hard.

SEATROCK (underclay)
Claystone, olive-gray (5Y4/1) with black (N1) coaly inclusion and local light-brown (5YR5/6) mottling, firm, breaks with conchoidal fracture.

Sandstone, medium-gray, fine-grained, friable, slightly clayey, with fine disseminated muscovite and black organic fragments.

Sand, medium-gray, medium-grained, loose, soft with disseminated, extremely fine muscovite and black organic matter, locally limonite-stained.

FAIRVIEW MOUNTAIN SEAMS
SITE FM1



LITHOLOGIC DESCRIPTION

Claystone, sandy to very sandy, medium-gray, firm with abundant limonite staining.

Sand, light- to medium-gray, fine- to medium-grained, slightly clayey, soft, with disseminated fine muscovite flakes and black organic matter.

Claystone, sandy, medium-grayish-brown, firm, local iron-oxide staining.

Claystone, very sandy, light-gray, firm.

Sandstone, clayey, light-gray, medium-grained, friable soft, with fine disseminated black organic matter and coaly streaks.

Claystone, sandy, light-gray, firm, with weathered ironstone nodules to 2 in. diameter.

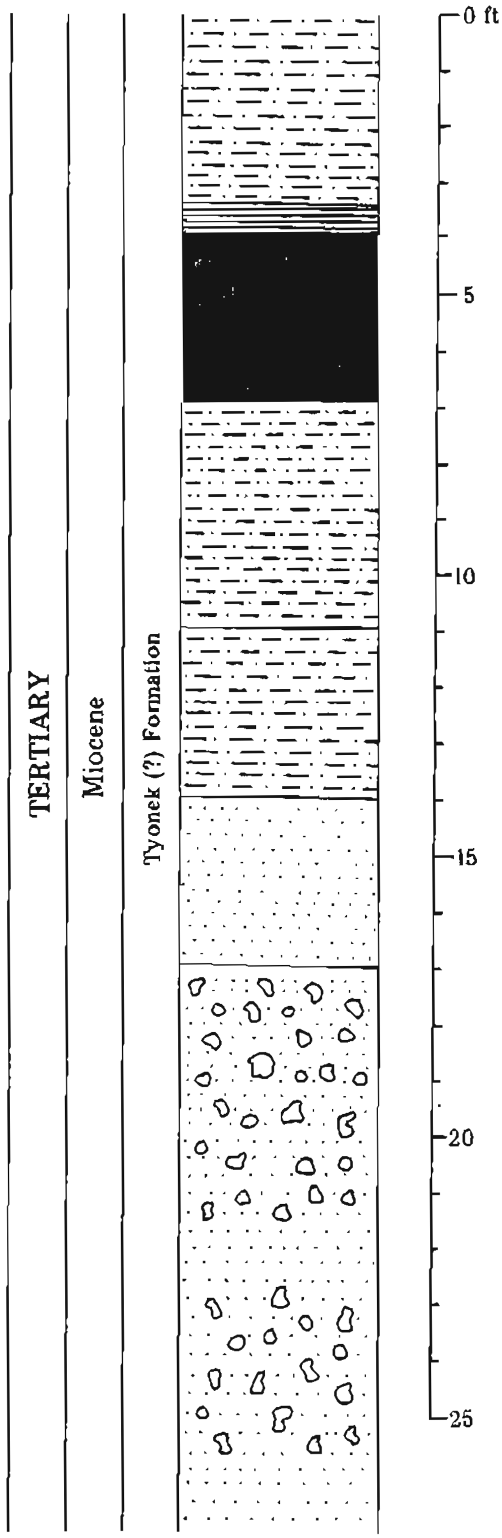
Shale, carbonaceous, dark-gray (N3) to black (N1), clayey, fissile, soft.

D Seam
Coal, black, dull, hard, platy, bony.

SEATROCK (underclay)
Claystone, sandy, olive-gray (5Y4/1) with grayish-black (N2)-threadlike stringers, firm, breaks with conchoidal fracture, locally limonite-stained.

FAIRVIEW MOUNTAIN SEAMS
SITE FM1

LITHOLOGIC DESCRIPTION



ROOF
Shale, carbonaceous, brownish-black (5YR2/1), fissile, weathered, soft.

C Seam
Coal, black, dull, hard, blocky at top to bony and platy at basal portion

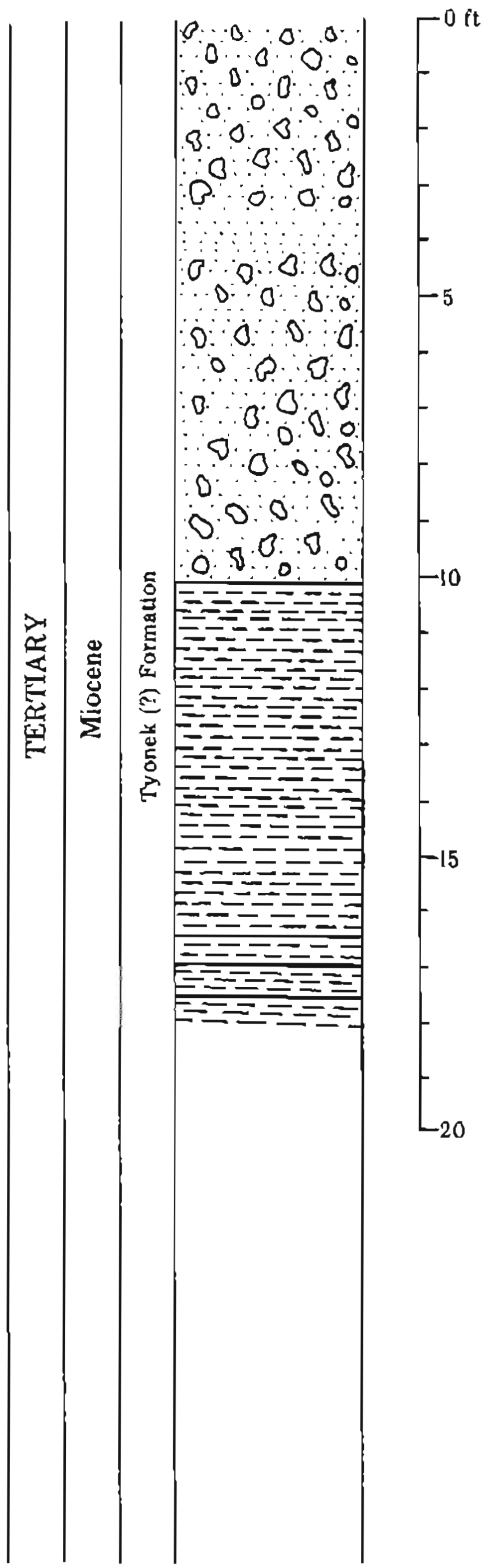
SEATROCK (underclay)
Claystone, very sandy, light-olive-gray (5Y6/1), firm.

Claystone, sandy, medium-gray, firm, with very fine disseminated muscovite.

Sand, medium-gray, very coarse-grained, angular to subangular grains, disseminated black fine coal fragments, friable, loose, weathered.

Conglomerate, petromictic, pebble-cobble (including coal); sand matrix, very coarse-grained, poorly lithified with fine disseminated coal fragments; local coarse-grained pebbly sand layers up to 1 ft thick.

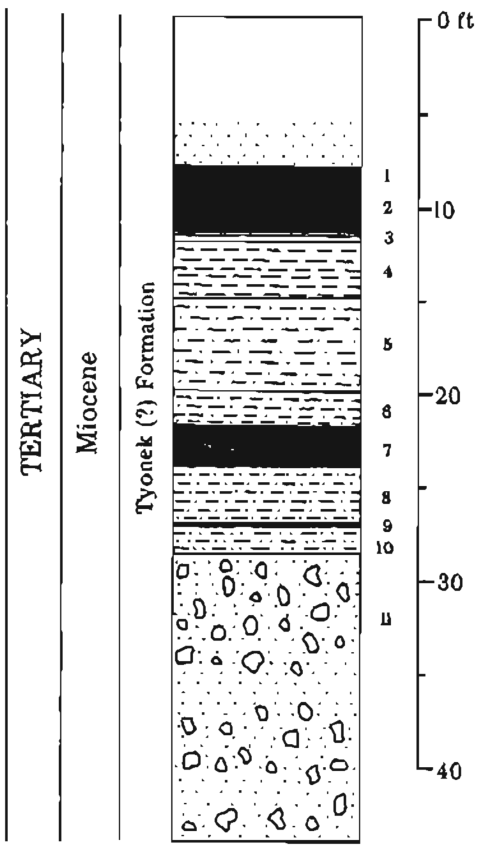
LITHOLOGIC DESCRIPTION



Claystone, medium-gray but grades to dark-gray and carbonaceous in basal portion, soft to firm; pockets and stringers of coal near bottom.

Section discontinued but remaining section includes two poorly exposed and highly weathered coal seams (A and B); see FM2.

FAIRVIEW MOUNTAIN SEAMS
SITE FM2



LITHOLOGIC DESCRIPTION

Surficial cover predominantly a sandy loam grading to sand at base.

B Seam

1 & 2 Coal, top 0.5 ft black, very soft, smutty; bottom 3 ft very hard and bony, breaks blocky and locally with conchoidal fracture.

3 Shale, carbonaceous, brown, black (5Y2/1), clayey, soft.

4 Claystone, olive-gray (5Y4/1) with moderate-brown (5YR4/4) plant-fragment inclusions, slightly silty, soft to firm.

5 Claystone, sandy, light-gray, soft, with very fine disseminated muscovite.

6 Claystone, medium-gray (N5) with black (N1) inclusions and dark-yellowish-orange (10YR6/6) mottling, slightly sandy and carbonaceous, firm.

A Seam

7 Coal, black to brownish-black, lignitic toward base, poor quality; thin (less 1 in.) partings of claystone, brown, firm, and shale, carbonaceous, black, fissile, firm, toward top.

8 Claystone, sandy, olive-gray (5Y4/1) with grayish-brown (5YR3/2) and blackish-red (5R2/2) plant-fragment inclusions, disseminated extremely fine muscovite, firm.

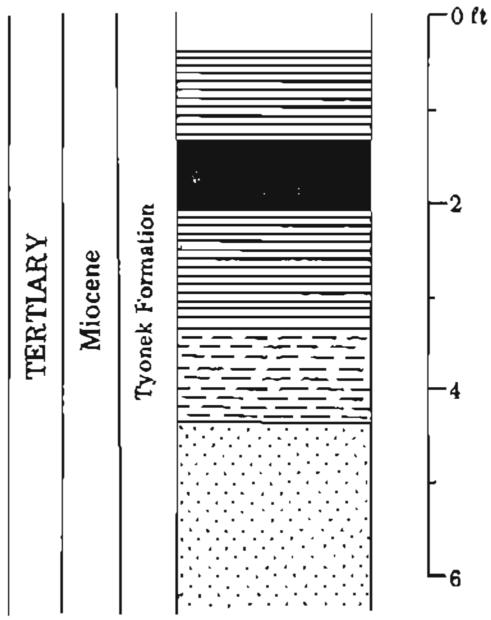
9 Coal stringer, black, hard, woody.

10 Claystone, very sandy, medium-gray (N5), extremely fine disseminated muscovite, firm.

11 Conglomerate, petromictic, pebble-cobble; pebbles, gravels, and cobbles predominantly less than 3 in. in diameter consisting of quartz, chert, orthoquartzite sandstone, coal, and granite in a poorly lithified, coarse-grained, sand matrix; also includes pebbly, coarse-grained-sand intervals to several feet thick, yellowish-gray, angular to subangular with disseminated black organic matter.

Section described down to level of Cottonwood Creek.

JOHNSON CREEK SEAM
SITE JC2



LITHOLOGIC DESCRIPTION

Section includes 60-ft ledge of sandstone, conglomerate, two other thin coal beds, gravel, and surficial cover.

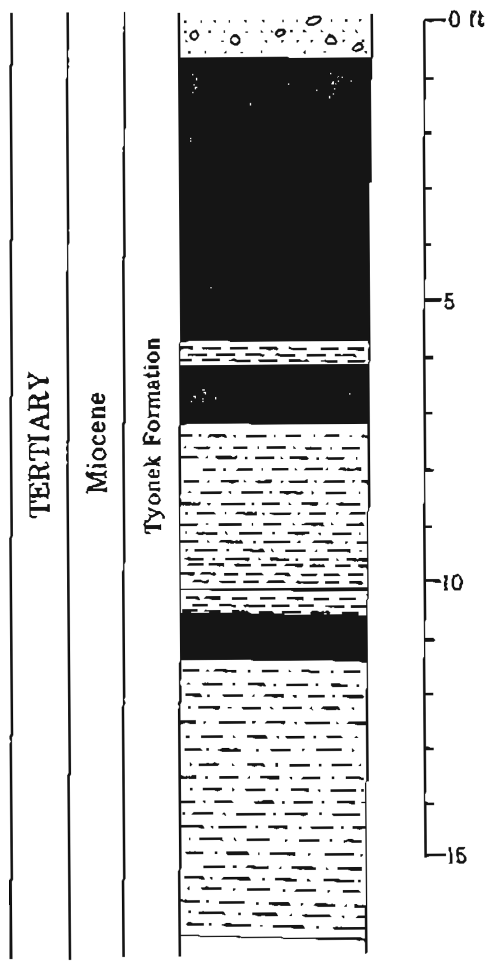
Shale, carbonaceous, black, hard, fissile, local iron-oxide staining.

Coal, black, very hard, bright, glassy fracture, semianthracitic, conchoidal fracture.

Shale, carbonaceous, olive-black (5Y2/1) to black (N1), fissile, firm.

Claystone, olive-black (5Y2/1) with black (N1) coaly stringers, firm. Approximately 8 ft of claystone is followed downsection to creek level by sandstone, medium-gray, medium-grained, hard.

JOHNSON CREEK SEAMS
SITE JC3



LITHOLOGIC DESCRIPTION

Overburden section of approximately 30 ft of pebbly sandstone, conglomerate, and unconsolidated surficial cover, locally highly washed and eroded with covered intervals.

Coal, black, dull, hard, bony, locally platy and weathered with iron-oxide staining.

Parting: claystone, light-brownish gray (5YR6/1) with dark-gray (N3) carbonaceous inclusions and coal stringers, firm.

Coal as above.

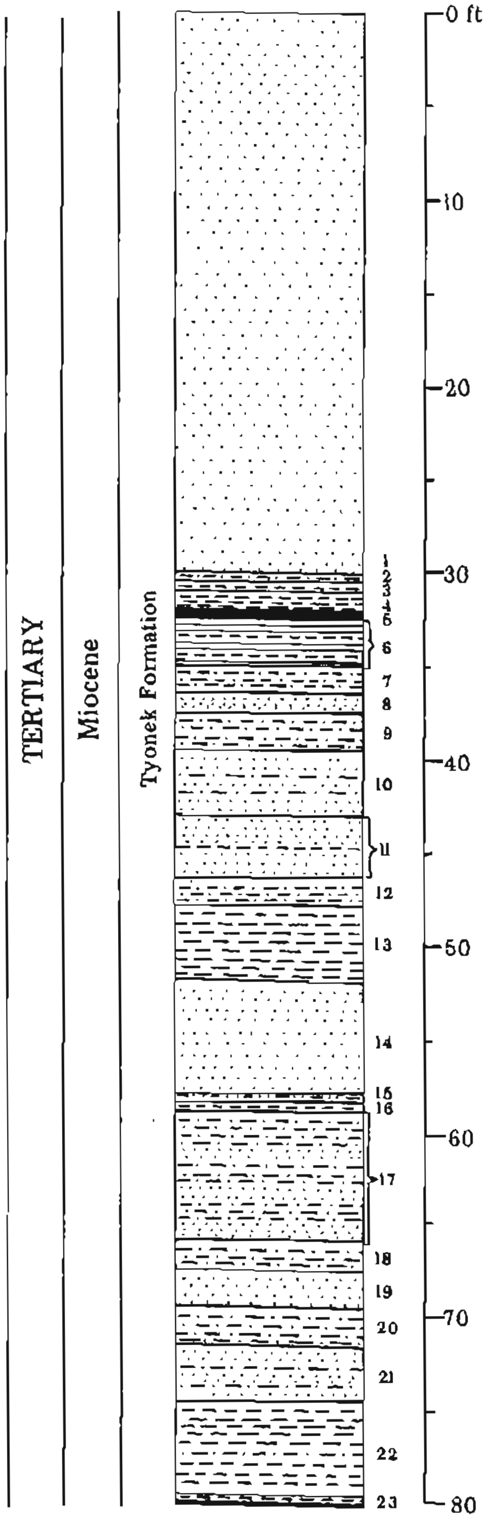
Claystone, sandy, light-olive-gray (5Y6/1) with olive-black (5Y2/1) carbonaceous inclusions and dark-yellowish-orange (10YR6/6) mottling; becomes less sandy and more silty toward base.

Claystone, dark-yellowish-brown (10YR4/2) with dark-gray (N3) carbonaceous stringers and dark-yellowish-orange (10YR6/6) mottling, firm.

Coal, black, hard, dull, bony, platy.

Claystone, sandy, light-olive-gray (5Y6/1) with black (N1) coaly inclusions and local dark-yellowish-orange (10YR6/6) mottling, firm.

PETERSVILLE AREA SEAMS
SITE PA1



LITHOLOGIC DESCRIPTION

1 Sandstone and sand, light-olive-gray (5Y6/1) with black (N1) coaly inclusions and local pale-yellowish-orange (10YR8/6) mottling, coarse-grained, angular to subrounded, predominantly quartz but arkosic, weathered, friable, soft.

2 Claystone, sandy, moderate-yellowish-brown (10YR5/4) dark-yellowish-orange (10YR6/6) and pale-yellowish-orange (10YR8/6) streaked, soft to firm, with distinctive gravels of brown amber and coalified wood laths.

3 Clay, light-olive-gray (5Y6/1), very soft, plastic, pliable.

4 Claystone, medium-gray (N5) with grayish-black (N2) coaly inclusions, firm, breaks in conchoidal blocks.

5 Coal, black, hard, dull, bony.

6 Shale, carbonaceous, medium-gray (N5) to grayish-black (N2), firm with transitions to claystone, medium- to dark-gray, locally carbonaceous, silty to sandy, soft to firm.

7 Claystone, light-olive-gray (5Y6/1) with dark-gray (N3) to black (N1) coaly inclusions and light-brown (5YR5/6) to moderate-brown (5YR3/4)-oxidation staining, slightly sandy, soft, with few inches of shale, grayish-purple (5P4/2), bounding top and basal portions.

8 Sand, clayey, light-olive-gray (5Y6/1), medium-grained, soft, loose.

9 Claystone, sandy, light-olive-gray (5Y6/1), soft.

10 Sandstone, light-olive-gray (5Y6/1) with medium-dark-gray (N4) carbonaceous plant fragments and films, firm, clayey, with interbedded claystone, sandy, medium-gray (N5), local iron-oxide staining.

11 Sandstone, light-olive-gray (5Y6/1) predominant (but "salt and pepper"), coarse-grained, subangular to subrounded grains, locally iron-stained (limonitic) bands, friable, soft; thin (4 in.) layer of claystone, light-gray (N7), silty, soft in center.

12 Claystone, sandy, medium-olive-gray (5Y5/1) and dark-yellowish-brown (10YR4/2) streaked, and black (N1) threadlike coal stringers and fragments, soft; grades to claystone, medium-gray (N5) to moderate-yellowish-brown (10YR5/4) at base with stringers of coalified wood.

13 Claystone, pale-yellowish-orange (10YR8/6) to yellowish-gray (5Y7/2) with light-brown (5YR5/6)-weathering streaks, firm.

14 Sandstone, yellowish-gray (5Y7/2) with local dark-yellowish-orange (10YR6/6) mottling, medium-grained, friable, firm.

15 Claystone, very sandy, light-olive-gray (5Y6/1) with fine grayish-black (N2) and light-brown (5YR5/6) inclusions, soft.

16 Claystone, olive-black (5Y2/1) with grayish-black (N2) coaly inclusions, firm.

17 Claystone, sandy, grayish-yellow (5Y8/4) to yellowish-gray (5Y7/2), soft; sandstone, light (N7)- to medium-gray (N5), medium-grained, friable, soft, with abundant limonite staining, and weathered loose sand, medium- to coarse-grained with iron-oxide staining.

18 Claystone, sandy, light-olive-gray (5Y6/1), firm, with a thin (approximately 0.5 in.) coal stringer along top.

19 Sandstone, yellowish-gray (5Y7/2), medium- to coarse-grained, friable, soft to firm.

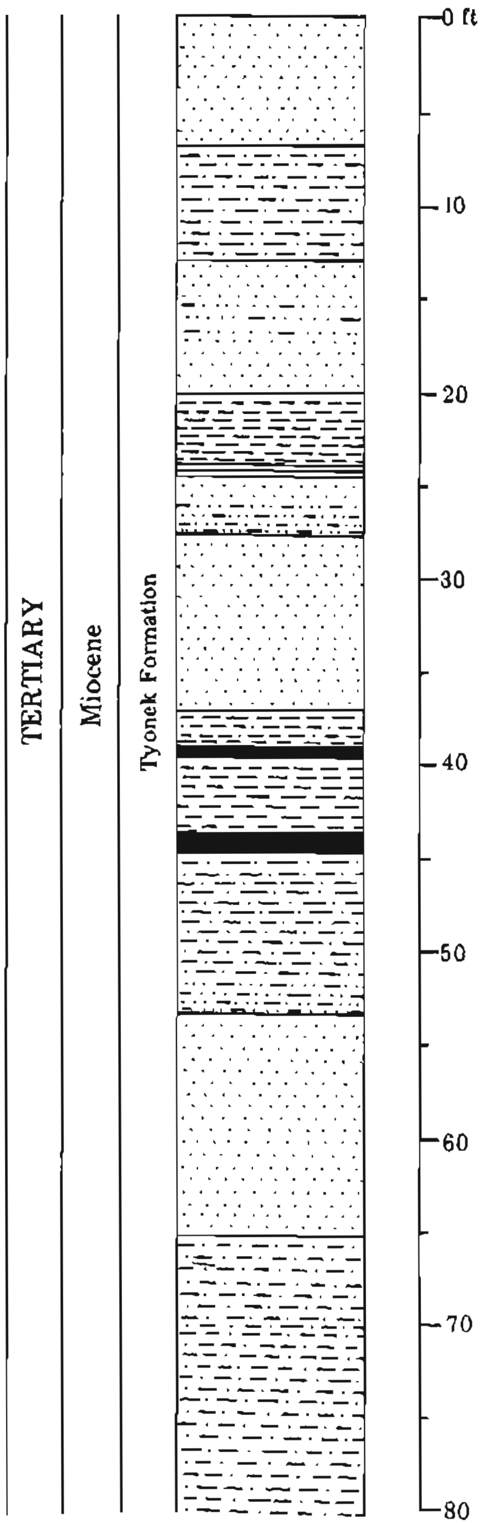
20 Claystone, olive-gray (5Y4/1), slightly sandy, soft to firm.

21 Sandstone, yellowish-gray (5Y8/1) with grayish-black (N2) inclusions ("salt and pepper"), medium-grained, soft, and claystone, sandy, firm.

22 Claystone, light-olive-gray (5Y6/1), firm, locally silty to slightly sandy with common hematitic surface staining.

23 Claystone and shale, interbanded, carbonaceous, dark-gray (N3) to olive-black (5Y2/1), firm.

PETERSVILLE AREA SEAMS
SITE PA1
Sheet 2 of 3



LITHOLOGIC DESCRIPTION

Sandstone and weathered loose sand, yellowish-gray (5Y7/2) with pale-yellowish-orange (10YR8/6) mottling, medium-grained, with disseminated black organic matter; grades to coarse-grained, loose, dark-yellowish-orange (10YR8/6),sand at base.

Claystone, olive-gray (5Y4/1), slightly sandy, firm with abundant limonite and hematite staining.

Sandstone, light-olive-gray (5Y6/1) with dark-yellowish-orange (10YR6/6)-weathering stains, medium-grained, locally slightly clayey, friable.

Claystone, light-olive-gray (5Y6/1) to medium-olive-gray (5Y5/1), slightly silty, firm.

Shale, carbonaceous, medium-gray (N6) to grayish-black (N2), fissile, firm.

Sandstone, clayey, light-olive-gray (5Y6/1) with light-brown (5YR5/6) mottling, abundant disseminated black organic matter and muscovite.

Sand, yellowish-gray (5Y7/2), medium-grained, soft, loose with abundant limonite staining.

Claystone, light-gray (N7), slightly sandy, soft.

Coal, black, firm, dull, platy.

Claystone, light-gray (N7), slightly silty, soft.

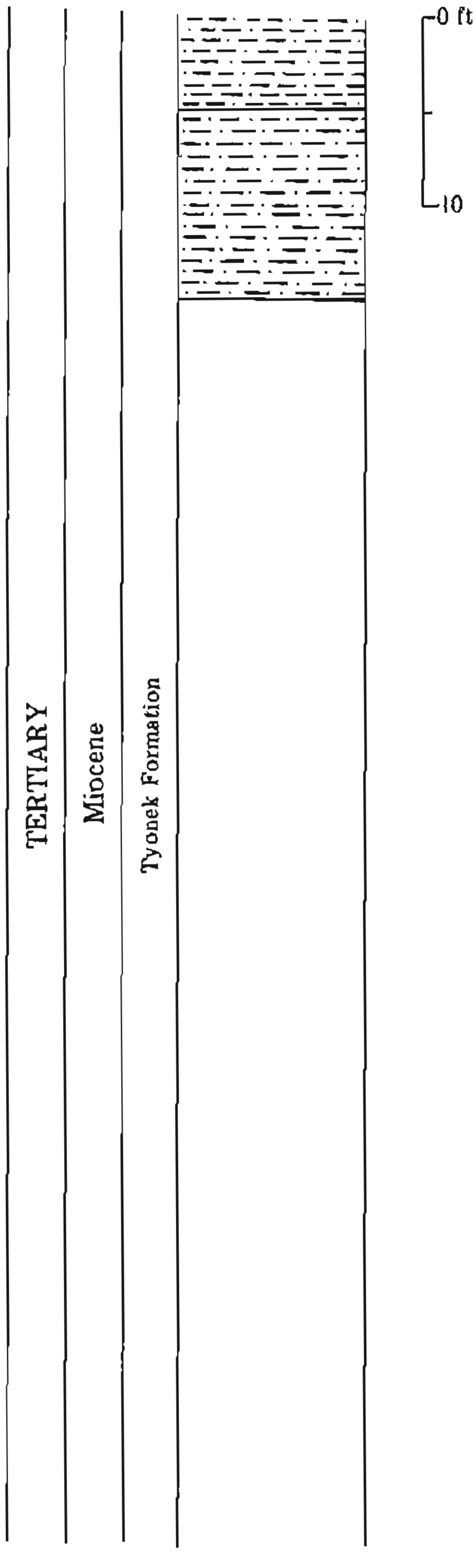
Coal, black, dull, hard, bony.

Claystone, sandy, light-gray (N7) with black (N1) coaly inclusions and local pale-yellowish-orange (10YR8/6) mottling, and soft, at top; grades to sand, medium-gray (N5), fine-grained, clayey, loose, soft toward basal portion.

Sand, grayish-orange (10YR7/4) and light-olive-gray (5Y6/1), medium-grained, soft with abundant limonite staining and disseminated black organic matter.

Claystone, medium-olive-gray (5Y5/1), slightly sandy to sandy, firm-soft.

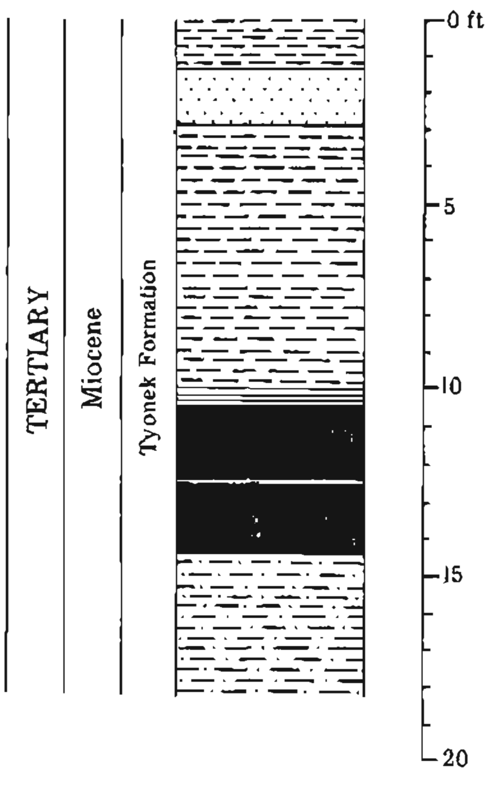
LITHOLOGIC DESCRIPTION



Claystone, sandy, light-gray (N7), firm.

Section discontinued at Short Creek level.

PETERSVILLE AREA SEAM
SITE PA2



LITHOLOGIC DESCRIPTION

Claystone, medium-gray (N5), firm.

Graywacke, predominantly olive-gray (5Y4/1) with light-olive-gray (5Y6/1) inclusions, carbonaceous, feldspathic; stands in relief within softer claystone unit.

Claystone, medium-gray (N5), slightly carbonaceous and silty, firm.

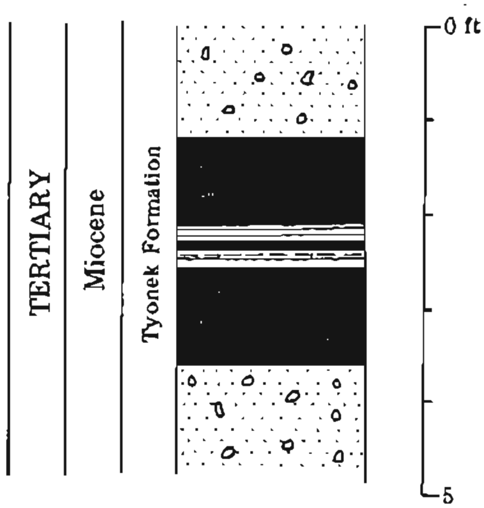
Shale, carbonaceous, black (N1), fissile, firm.

Coal, black, dull, hard, blocky in center section, woody toward top and basal portions.

Claystone (possibly volcanic ash), medium-light-gray (N6) with grayish-black (N2) coaly inclusions and dark-yellowish-orange (10YR6/6) mottling, firm.

SEATROCK (underclay)
Claystone, sandy, medium-gray (N5), firm, locally limonite-stained.

PETERSVILLE AREA SEAM
SITE PA3



LITHOLOGIC DESCRIPTION

ROOF
Sandstone, pebbly (quartz/chert), moderate-brownish-gray (5YR5/1), coarse-grained, granular, friable.

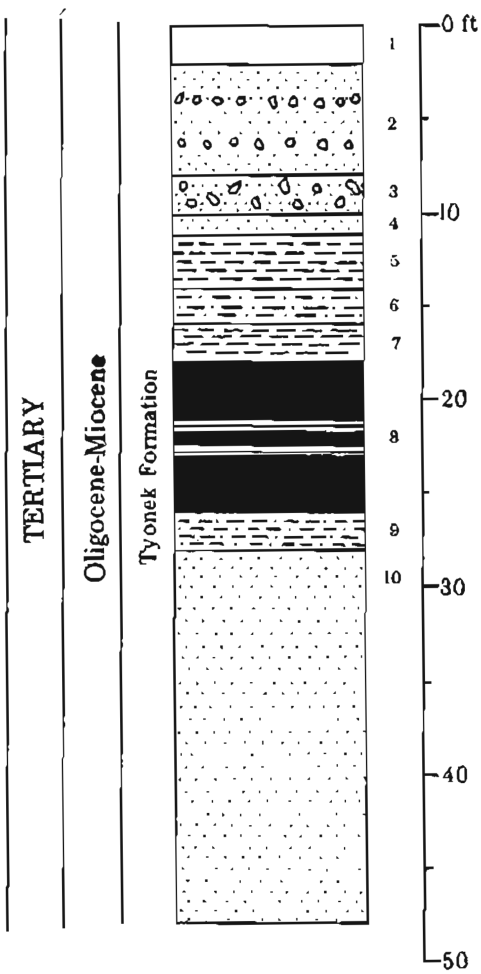
Coal, brownish-black, dull, woody, firm.

Parting, shale, carbonaceous, olive-black (5Y2/1) with grayish-black (N2) coaly inclusions and moderate-brown (5YR4/4)-weathering stains, fissile, firm, and claystone, dark-gray (N3), carbonaceous, soft, and smut, black (N1).

Coal, as above.

SEATROCK
Sandstone, pebbly, as in roof.

SATURDAY CREEK SEAM
SITE SC2



LITHOLOGIC DESCRIPTION

1 Surficial cover, brown sandy loam.

2 Sandstone, medium-gray, medium-grained, with yellow-iron-oxide staining locally; interbands of quartz-pebble conglomerate (pebbles to 2 in. diameter) up to 0.5 ft thick.

3 Conglomerate, monomictic, quartz-pebble, hard, well-cemented.

4 Sandstone, medium-yellowish-gray, medium-grained, hard, with surficial iron-oxide-weathering stains.

5 Claystone, dark-gray, carbonaceous, firm.

6 Claystone, sandy, light-gray, firm.

7 Claystone, medium-light-gray (N6) with black (N1) coaly inclusions and light-brown (5YR5/6)-weathering stains, firm, breaks conchoidal fracture.

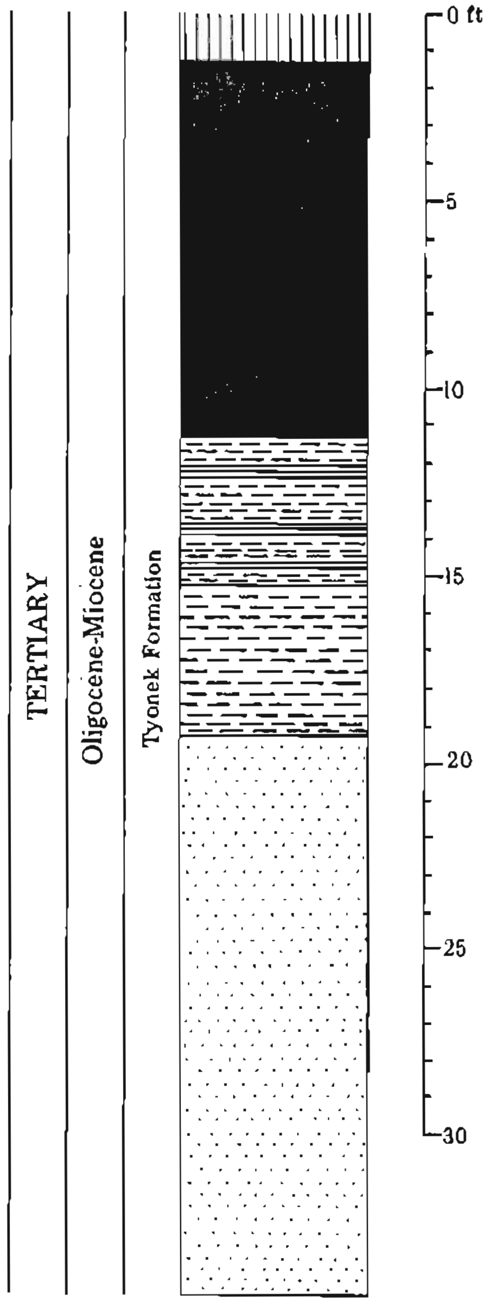
8 Coal, black, blocky, hard; middle has black, carbonaceous shale partings.

SEATROCK (underclay)

9 Claystone, light-gray, slightly sandy, firm.

10 Sandstone, medium-yellowish-gray, medium-grained, very hard, surficial iron-oxide-weathering stains.

SATURDAY CREEK SEAM
SITE SC3



LITHOLOGIC DESCRIPTION

Roof not exposed; covered interval.

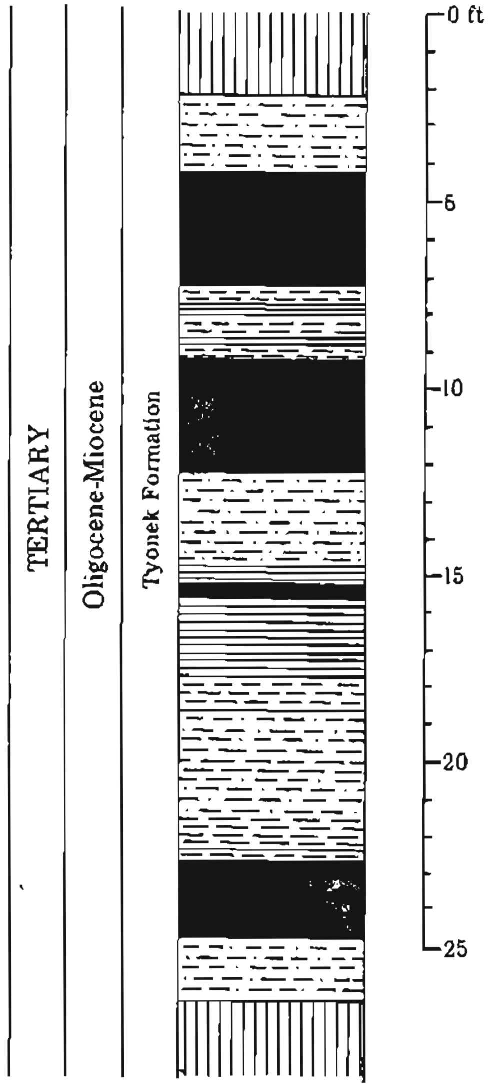
Coal, black, dull, platy, bony, highly weathered on surface.

SEATROCK
Claystone, brownish-gray (5YR4/1), locally carbonaceous, firm to soft, with light-brown (5YR5/6) iron-oxide staining; interbedded with shale, carbonaceous, black (N1), fissile, firm.

Claystone, light-gray (N7) to light-olive-gray (5Y6/1), locally slightly carbonaceous, firm to soft, breaks with conchoidal fracture.

Sandstone and sand, yellowish-gray (5Y7/2) to light-olive-gray (5Y6/1), medium- to coarse-grained, angular to subrounded grains, disseminated fine black organic matter and muscovite, but predominantly quartz sand, friable to loose.

SATURDAY CREEK SEAMS
SITE SC4



LITHOLOGIC DESCRIPTION

Covered interval for 30 ft to top of ridge.

Claystone, sandy, olive-gray (5Y4/1) with dark-yellowish-orange (10YR6/6)- to light-brown (5YR5/6)-weathering mottles.

Coal, black, hard, bright, blocky.

Claystone, grayish-black (N2), carbonaceous, firm, rooted, and shale, carbonaceous, dark-gray (N3) to black (N1), fissile and firm, intercalated.

Coal, black, bright, hard, platy; becomes bony toward basal portion.

Claystone, sandy, light-olive-gray (5Y6/1) with black (N1) coaly inclusions and local dark-yellowish-orange (10YR6/6) weather banding, firm.

Shale, carbonaeous, grayish-black (N2), fissile, weathered and soft.

Coal, black, very hard, breaks conchoidal fracture, possibly cannel coal.

Shale, carbonaceous, medium-dark-gray (N4) to black (N1), fissile, firm.

Claystone, light-olive-gray (5Y6/1), with disseminated black organic matter, rooted, hematite-stained, soft.

Claystone, light-olive-gray (5Y6/1) with medium-dark gray (N4) coaly inclusions and local dark-yellowish-orange (10YR6/6) mottling, slightly sandy, breaks with conchoidal fracture.

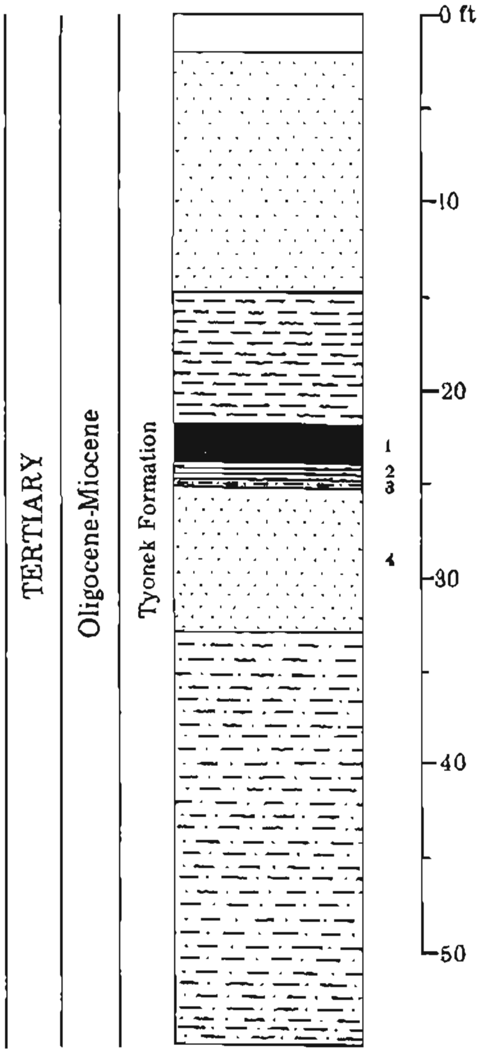
Claystone, medium-olive-gray (5Y5/1) with black (N1) coaly inclusions and local dark-yellowish-orange (10YR6/6) mottling, firm.

Coal, black, dull, hard, platy, bony.

Claystone, olive-gray (5Y4/1) with dark-gray (N3) coaly inclusions, slightly sandy, firm, locally limonite-stained.

Covered interval for 30 ft down to creek level.

SKWENTNA RIVER SEAM
SITE SR1



LITHOLOGIC DESCRIPTION

Surficial cover; light-brown sandy loam.

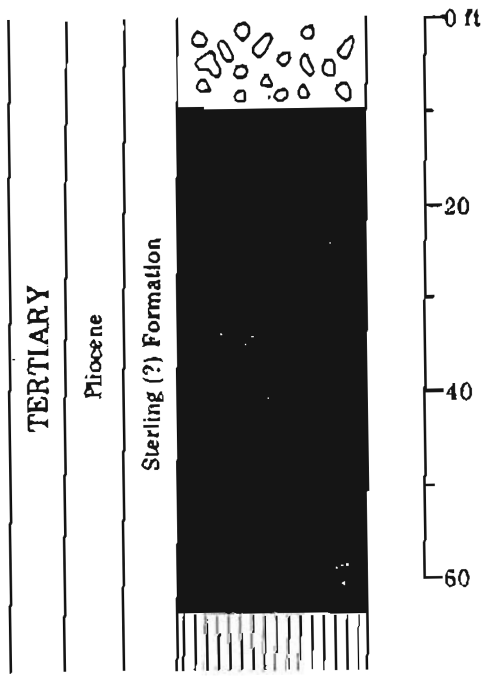
Sand, light-yellow to brownish-yellow, medium-grained, loose, soft, weathered with iron-oxide staining.

Claystone, medium-olive gray (5Y5/1), slightly carbonaceous, firm, breaks with conchoidal fracture.

1 Coal, black, dull, thinly plated, bony.
2 Shale, carbonaceous, dark-gray (N3) to grayish-black (N2), fissile, highly weathered, soft.
3 Claystone, sandy, light-olive-gray (5Y6/1) with olive-gray (5Y4/1) streaks, carbonaceous, firm.
4 Sand, yellow to orange, medium-grained, highly weathered with iron-oxide staining, disseminated black organic matter, micaceous, loose.

Claystone, sandy, dark-gray, carbonaceous, soft-firm.

SUNFLOWER CREEK SEAM
SITE SuC1



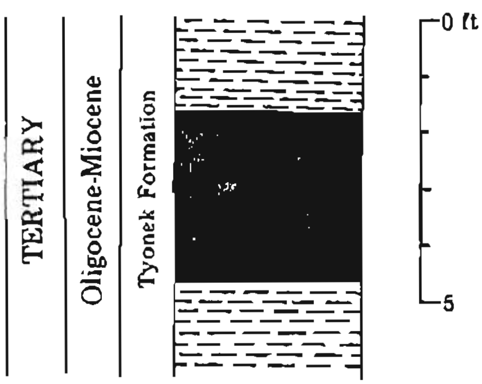
LITHOLOGIC DESCRIPTION

Diamicton.

Coal, brownish-black, woody, dull, without partings; lower part of bed (dipping at 50°) probably slumped since upper part of bed dips at only 25°.

Covered interval down to creek level.

TALACHULITNA RIVER SEAM
SITE TR1



LITHOLOGIC DESCRIPTION

ROOF
Claystone, medium-olive-gray (5Y5/1), abundant limonite and hematite staining, weathers to yellow and orange shingles and conchoidal blocks, soft.

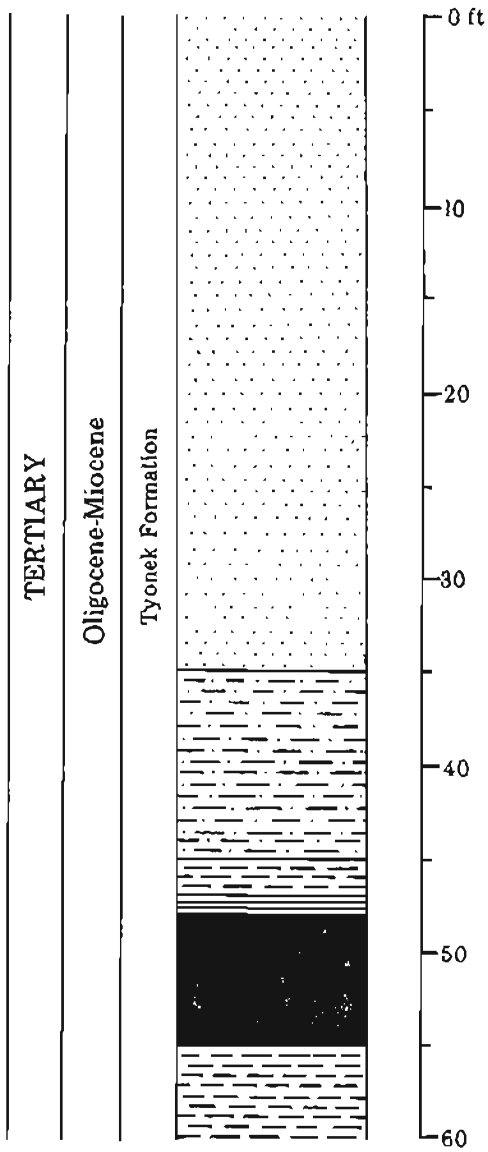
Coal, brownish-black, dull, woody, ashy, locally slightly contorted.

SEATROCK (underclay)
Claystone, light-olive-gray (5Y6/1) with local light-brown (5YR5/6) mottling and staining.

Section discontinued at water level. Metamorphosed JK greenstone faulted and juxtaposed against coal approximately 100 ft upstream.

WOLVERINE CREEK SEAM
SITE WC1

LITHOLOGIC DESCRIPTION



Sandstone, light-olive-gray (5Y6/1) speckled ("salt and pepper") with white (N9) and medium-light-gray (N6), coarse-grained, angular to subangular grains, friable, soft-firm.

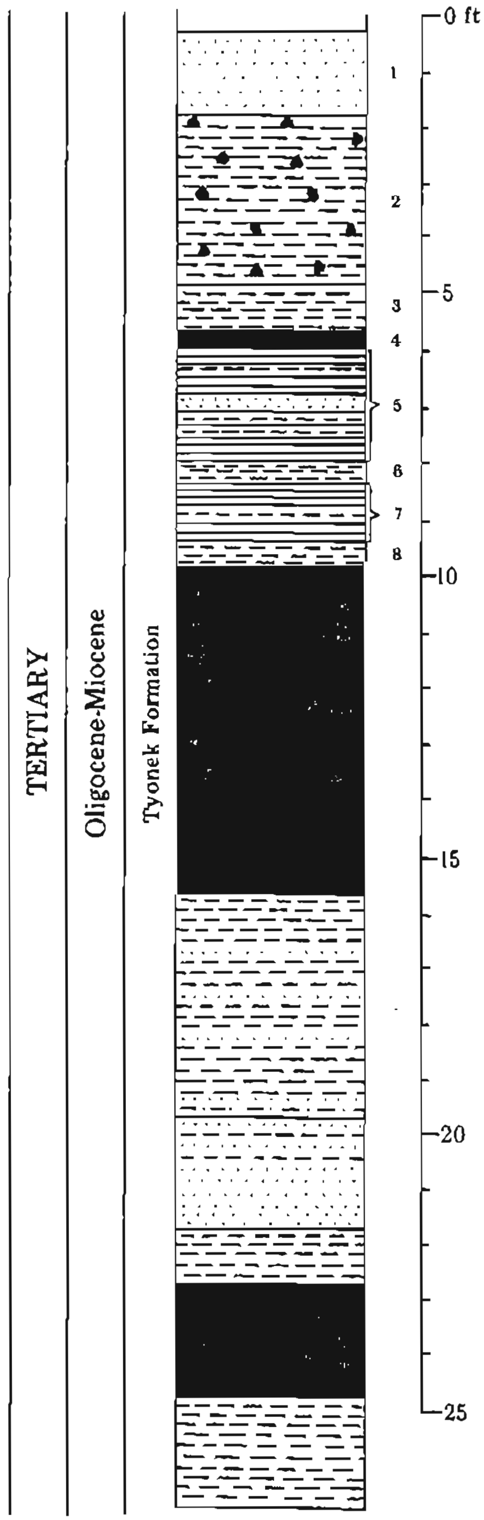
Claystone, sandy, medium-light-gray (N6) streaked medium-dark-gray (N4), soft, breaks in blocks, abundant limonite stains along surfaces and joints.

Claystone, grayish-black (N2) with olive-gray (5Y4/1) streaks, carbonaceous, soft, and shale, carbonaceous, black (N1), fissile, soft.

Coal, black, predominantly bright, hard, blocky; basal 3 ft highly weathered and limonite-stained.

SEATROCK (underclay)
Claystone, medium-gray (N5) with abundant dark-yellowish-orange (10YR6/6) staining, soft.

WOLVERINE CREEK SEAMS
SITE WC2



LITHOLOGIC DESCRIPTION

1 Sandstone, light-gray (N7) with dark-yellowish-orange (10YR6//) mottles, coarse-grained, locally clayey and slightly carbonaceous, "salt and pepper."

2 Claystone, olive-gray (5Y4/1), soft to firm, breaks in blocky masses, abundant iron-rich (limonite rim, hematite core) septarian nodules.

3 Claystone, brownish-gray (5YR4/1) with grayish-black (N2) streaks and inclusions, soft.

4 Coal stringer, black, hard, platy to slightly blocky.

5 Shale, carbonaceous, olive-black (5Y2/1) with dark-yellowish-orange (10YR6/6) mottles, fissile, firm, interlayered with claystone, brownish-gray (5YR4/1), locally silty, abundant limonite stains along surfaces and bedding planes; central (0.5 ft) layer of sandstone, grayish-brown (5YR3/2), medium-grained, hard, iron-stained.

6 Claystone, olive-gray (5Y4/1) with light-brown (5YR5/6) mottles, locally slightly carbonaceous and iron-stained, soft to firm.

7 Shale, carbonaceous, dark-gray (N3) with light-brown (5YR5/6)-weathering stains, fissile, soft to firm, interbanded with claystone, dark-gray (N3), carbonaceous, soft.

8 Claystone, dark-yellowish-brown (10YR4/2), slightly silty and carbonaceous, soft.

Coal, black, dull, firm to hard, blocky, weathered locally with abundant iron-oxide staining.

Claystone, very sandy, light-olive-gray (5Y6/1), soft, locally with abundant iron-oxide staining; interbanded with sand lenses, light-gray (N7), medium-grained, micaceous, friable, soft.

Sandstone, light-olive-gray (5Y6/1) streaked olive-gray, medium-grained, friable, soft, abundant limonite staining; thin (approximately 1 in. thick) interbands of claystone, medium gray (N5), silty, soft, toward top.

Claystone, light-gray (N7), breaks with blocky, conchoidal fracture, abundant iron-oxide staining.

Coal, black, dull, hard, blocky, locally weathered with abundant limonite staining.

Claystone, light-olive-gray (5Y6/1), silty, soft.