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report of investigations 7321

SAMPLING AND COKING STUDIES OF SEVERAL COALBEDS IN THE KOKOLIK RIVER, KUKPOWRUK RIVER, AND CAPE BEAUFORT AREAS OF ARCTIC NORTHWESTERN ALASKA

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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By R. S. Warfield and Charles C. Boley

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UNITED STATES DEPARTMENT OF THE INTERIOR
Walter J. Hickel, Secretary

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by

R. S. Warfield[1] and Charles C. Boley[2]

ABSTRACT

Several reconnaissance-type surface and drill core samples of Arctic Northwestern Alaska coals were taken during the summer field seasons of 1964 and 1966 for coking studies. Surface samples were taken from the Kokolik River and the Cape Beaufort areas; core samples were obtained from the Kukpowruk River and the Cape Beaufort areas. Only one Kokolik River surface sample possessed coking properties. This sample, representing an 11.6-ft coal seam, made coke approaching metallurgical quality when a 30-pct portion of selected blending coals was added. Four Kukpowruk River core samples, each representing the same 19- to 20-ft coal seam, were all of about the same coking quality. No differences of coke quality attributable to depth of permanently frozen overburden were found, but the data confirm previously reported information that the 19- to 20-ft coalbed is a potentially satisfactory base coking coal. In the Cape Beaufort area, a core sample with appreciable coking properties was taken at depth from a coalbed determined noncoking in a surface sample.

INTRODUCTION

Coal of good quality and apparently large quantity has been known to exist in Arctic Northwestern Alaska for many years. The earliest reported use of these coals was during the late 1800's and early 1900's, when small-scale mining, principally for refueling whaling ships, was done along the coast between Cape Sabine and Cape Lisburne. Since that time, extensive geological knowledge of Arctic Northwestern Alaska has been accumulated, mainly as the result of numerous geological studies and drilling programs, by both Government and private companies, undertaken as part of the search for oil and gas. However, detailed investigations of the numerous reported coalbeds have been practically nonexistent, with the exception of some describing a small area along the Kukpowruk River.

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Coking studies and sampling of this small area are described in detail in Bureau of Mines Report of Investigations 6767;[3] all but one of the samples described were taken from a 20-ft-thick (approximately) coalbed during the field seasons of 1962 and 1963. Because of the close tie-in of the earlier work to this current investigation, some of the previous results have been briefly summarized herein and several references have been made to the earlier work.

During June, July, and August 1964, an attempt was made to obtain completely fresh reconnaissance-type surface samples for coking studies from coalbeds outcropping along the Kokolik River and in the Cape Beaufort area; six samples were taken from each area.

During the same months of 1966, core drilling was used to obtain samples for studies of possible improved coking quality at regular intervals of increased depth from the same 20-ft-thick coalbed outcropping along the Kukpowruk River that had been the subject of previous near-surface sampling and coking studies. Four samples of the 20-ft bed were obtained from vertical intervals of increased depth of about 50 ft. In the Cape Beaufort area, a coalbed found to be noncoking in a 1964 near-surface sample was resampled at a depth of about 200 ft by core drilling.

Surface samples from along the Kokolik River were taken at intervals along the river bluffs over a total distance of about 6 miles; a stratigraphic interval of at least 3,000 ft was represented. In the Cape Beaufort area, surface samples were taken from coalbeds occurring across a stratigraphic interval of approximately 5,000 ft. The geologic structure of the areas sampled, including the Kukpowruk River, appears fairly simple, and the dip of beds is gentle enough so that the coal should be amenable to either surface or mechanized underground mining.

Both bench-scale and pilot plant, high temperature, carbonization studies were conducted. Bench-scale work consisted of proximate and ultimate analyses, free swelling index, low temperature carbonization assay, Gieseler plastometer, and 100-gram coking tests. The 1964 pilot plant work consisted of carbonizing 50-lb charges in a 10-in retort at the Bureau's Denver Coal Research Laboratory. In 1966, 50-lb charges were carbonized in 8-1/4-in retorts placed within a large (500-lb) experimental coke oven at the Bureau's Grand Forks Coal Research Laboratory.

These high-temperature carbonization tests were followed by appropriate testing of the physical properties of the coke produced. To measure commercial acceptability, the test data were compared with data from similar tests on a coking blend that has been used by the Kaiser Steel Corp. at Fontana, Calif.

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[3]Warfield, Robert S., W. S. Landers, and Charles C. Boley. Sampling and Coking Studies of Coal From the Kukpowruk River Area, Arctic Northwestern Alaska. BuMines Rept. of Inv. 6767, 1966, 59 pp.

ACKNOWLEDGMENTS

J. A. Herdlick (retired), formerly Bureau of Mines Area Director for Alaska, gave helpful suggestions and advice both during field work and manuscript preparation. W. S. Landers (retired), formerly Chief of the Denver Coal Research Laboratory, and J. L. Elder, Chief of the Grand Forks Coal Research Laboratory, provided advice and guidance during the studies. The Kaiser Steel Corp. kindly provided the blending coals used in the coking studies.

PREVIOUS INVESTIGATIONS

The existence of coal in Arctic Northwestern Alaska was first reported by A. Collie who accompanied Captain Beechey of the Beechey expedition to the Arctic Ocean in 1826-27.[4] The earliest reported use of these coals was during the late 1800's and early 1900's to replenish the fuel supply of whaling ships and to supply local needs. About 1,000 tons were mined, shipped, and sold at Nome in 1900-1901. This coal was produced from several different beds in the Corwin Bluff area east of Cape Lisburne. No coal is mined now in the region except for very small amounts used locally by Eskimos from coastal villages.

In 1904, A. J. Collier of the U.S. Geological Survey (USGS) headed a party that made a detailed geologic examination that included the coastal area of the Utukok-Corwin region between Cape Beaufort and Cape Lisburne.[5] Following establishment of Naval Petroleum Reserve No. 4 in 1923, USGS field parties investigated parts of the Utukok-Corwin region by rapid geologic reconnaissance during the field seasons of 1923-26.[6] This included ascending the Kukpowruk, Kokolik, and Utukok Rivers for distances of 20 to 40 airline miles from the coast and, after reaching the upper Kokolik River via an overland journey by dog team from Kivalina, descending by canoe to the coast.

Reconnaissance of a number of Arctic coal deposits was made in the summer of 1946 by Bureau of Mines engineers[7] to obtain onsite information about coal deposits known to exist near some Eskimo villages. The information was used to plan and suggest methods of small-scale coal mine development; the coal was to be used locally for space heating in lieu of coal and oil being imported, generally from the State of Washington. One deposit investigated and sampled was a 19- to 20-ft coalbed outcropping along the Kukpowruk River. This site

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[4] Brooks, Alfred H., and others. Report on Progress of Investigations of Mineral Resources of Alaska in 1904. U.S. Geol. Survey Bull. 259, 1905, pp. 172-185.

[5] Collier, Arthur J. Geology and Coal Resources of the Cape Lisburne Region, Alaska. U.S. Geol. Survey Bull. 278, 1906, 54 pp.

[6] Paige, Sidney, W. T. Foran, and James Gilluly. A Reconnaissance of the Point Barrow Region, Alaska. U.S. Geol. Survey Bull. 772, 1925, 33 pp.

Smith, P. S., and J. B. Mertie, Jr. Geology and Mineral Resources of Northwestern Alaska. U.S. Geol. Survey Bull. 815, 1930, 351 pp.

[7] Toenges, Albert L., and Theodore R. Jolley. Investigation of Coal Deposits for Local Use in the Arctic Regions of Alaska and Proposed Mine Development. BuMines Rept. of Inv. 4150, 1947, 19 pp.

and coalbed later became the subject of detailed investigations by both the Bureau of Mines and private interests.

Additional field studies of the Utukok-Corwin region were undertaken in 1947 and 1949-53 as part of the USGS program of mapping and studying stratigraphy and structure, in order to evaluate the petroleum possibilities in and near Naval Petroleum Reserve No. 4.[8] Incidentally to this work, which included traversing all the major rivers and much of the coastline, outcrop samples of many coalbeds were collected.

Along the Kukpowruk River in 1954, J. S. Robbins and Associates, Inc., of Seattle, Wash., for Morgan Coal Co. of Indianapolis, Ind., drove a 70-ft S 18° E adit angling across dip to the floor of the 19- to 20-ft coal seam, thence an inclined raise to within about 2 ft of the roof of the seam. A fairly large sample was taken from the raise at that time, but results of test work on the sample are unknown.

In 1961 and again in 1963, Union Carbide Ore Co. of New York obtained large samples of the 19- to 20-ft Kukpowruk coalbed from the previously driven inclined raise and also from freshened outcrops. The results of carbonization tests made on these samples are held confidential.

During the field seasons of 1962-63, the Bureau of Mines attempted to obtain completely fresh samples for coking studies from the bituminous coalbeds that outcrop along the Kukpowruk River. Eight samples from five locations were taken; most of the samples represented the same 19- to 20-ft coalbed mentioned above that had been of principal interest to previous investigators. Rather extensive carbonization studies were made on the samples by the Bureau of Mines Denver Coal Research Laboratory. The 19- to 20-ft coalbed was weakly coking by itself, but produced coke of or very near metallurgical quality when blended with as little as 15 pct of selected medium- and/or low-volatile strongly coking coals.[9]

LOCATION AND ACCESSIBILITY

The part of the northern Alaska coalfield of interest here lies within a 7,500-square-mile area that has been termed the Utukok-Corwin region.[10] This region lies north of the DeLong Mountains, the westernmost extension of the Brooks Range, in the extreme western part of Northern Alaska, and is bounded on the west by the Chukchi Sea (fig. 1).

The Utukok-Corwin region can be reached by air or water (during the ice-free summer months) from Kotzebue or Barrow, which are about 150 miles south and northeast, respectively. Small aircraft can be landed on a short airstrip at Point Lay, an Eskimo village of about a dozen people, located on the bar that forms Kasegaluk Lagoon. With special permission from the U.S. Air Force,

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[8] Chapman, Robert M., and Edward G. Sable. Geology of the Utukok-Corwin Region, Northwestern Alaska. U.S. Geol. Survey Prof. Paper 303-C, 1960, 167 pp.

[9] Work cited in footnote 3.

[10] Work cited in footnote 8.

FIGURE 1. - Index and Location Map, Arctic Northwestern Alaska. (Modified from U.S. Geological Survey Alaska Map B.)

relatively large aircraft may be landed at DEW (Distant Early Warning) sites located at Cape Lisburne and Point Lay (Liz 2). In addition, a former DEW site near Cape Beaufort, now deactivated and unmanned, may be used with permission of the U.S. Navy; ownership of the Cape Beaufort physical plant and airstrip was transferred from the U.S. Air Force to the U.S. Navy Arctic Research Laboratory. During periods of low water, some gravel bars adjacent to main rivers are sufficiently large for landings by small aircraft; in the foothills section of the region, some ridges also are smooth and level enough for this purpose. Numerous lakes on the coastal plain, a few in the foothills, and some stretches of main rivers (especially during periods of high water) will permit landings by pontoon-equipped light aircraft. During winter months, landings with ski-equipped aircraft are possible almost anywhere. Helicopters are ideal transportation for reconnaissance work.

Water transportation to the region is possible during the ice-free months (July through September), but there is no regularly scheduled common carrier ship service further north than Kotzebue. The Bureau of Indian Affairs ship North Star III visits the Eskimo coastal villages annually, and the northern DEW sites receive staple supplies, heavy equipment, and fuel by chartered tug and barges.

None of the major rivers of the region can be classed as navigable, but some river travel is possible. During high water periods, the major rivers can be ascended considerable distances in a shallow-draft boat powered by an outboard motor, and nonpowered downstream travel is possible even during low water stages.

Various types of tracked vehicles can be used for all-season transportation throughout most of the region, but successful operation on swampy parts of the coastal plain during late summer is dependent on the depth of the seasonable thaw and the characteristics of the particular vehicle used, such as track-ground pressure and ability to cross rivers.

Bureau of Mines overland travel equipment used in the Utukok-Corwin region consisted of a crawler tractor bulldozer, equipped with relatively wide grouser shoes, and a wide-tracked weasel-type vehicle. In addition, each powered vehicle pulled a trailer and/or trailers--the bulldozer pulled a heavy-duty, single-axle, dual-wheeled trailer, and during 1966 in train fashion, a second heavy-duty, single-axle trailer equipped with large aircraft tires and on which the core drill was mounted; the weasel-type vehicle pulled a wide-tracked trailer. This equipment, together with fuel, hand tools, camp equipment, drill rods, casing, pump, dynamite, and other material was airlifted in multiple flights from Anchorage and Fairbanks to the Cape Beaufort former DEW site. From here, travel was overland to campsites along the Kokolik and Kukpowruk Rivers. The drilling site along the Kukpowruk River is about 38 miles northeast of Cape Beaufort, in the immediate vicinity of the most eastern meander of the river. Because the Kukpowruk River flows almost parallel to the Chukchi Sea coast over part of its course, this location is only about 15 miles inland. The area from which samples were obtained along the Kokolik River is about 70 miles northeasterly of Cape Beaufort and is a part of the most eastern reaches of the Kokolik. This location is about 44 miles due east of the Chukchi Sea coast, measured along the protracted Umiat Base Line.

Construction of a railroad or highway to the Chukchi Sea coast and dredging of a harbor at a seaward terminal to enable mass movement of coal from the region is considered feasible from an engineering standpoint. The difficulty and cost of construction to a great extent would be dependent on location and ease of excavation of perennially frozen, suitable borrow material. Materials dredged from a harbor very conceivably could aid in road construction; a firm road base for heavy hauling would probably result by placing borrow materials directly on undisturbed tundra.

OWNERSHIP

The area investigated along the Kukpowruk River is (1968) public domain land held under Coal Prospecting Permits issued to an officer of Morgan Coal Co. of Indianapolis, Ind. The area along the Kokolik River is within Naval Petroleum Reserve No. 4, and the Cape Beaufort area, with the exception of a 431-acre withdrawal for the former Cape Beaufort DEW site, is public domain land open under the mineral leasing laws.

Lands subject to the mineral leasing laws are Government-owned lands to which no title can be acquired. However, Coal Prospecting Permits are granted by the Department of the Interior for a 2-year period to qualified applicants to prospect unclaimed, undeveloped lands where prospecting or exploratory work is necessary to determine the existence or workability of coal deposits. An application for a permit must be filed, in duplicate, in the appropriate land office. Each application must be accompanied by a filing fee of $10 which is not returnable and by full payment of the first year's rental at the rate of 25 cents per acre. In addition, the applicant must furnish a corporate surety bond or a personal bond conditional upon compliance with all the terms of the prospecting permit.

Each permit covers a maximum of 2,560 acres, and no permit holder may have more than four permits (16 square miles). The recipients of a permit may remove only as much coal as is necessary to determine the commercial value of the deposit. If coal is mined commercially, a Coal Lease must be obtained. Leases are subject to the 25 cents per acre rental fee and to a royalty payment on a minimum annual production, the payments beginning with the sixth year of the lease.

The above is a very brief summary of pertinent parts of the regulations. Bureau of Land Management Circular No. 2154[11] is a reprint of the regulations in entirety, current as of August 3, 1964.

Petroleum Reserve No. 4 is comprised of about 37,000 square miles with its western boundary at approximately 161°53' W longitude; it therefore includes the area along the Kokolik River from which the 1964 series of samples was taken. The Reserve is closed to entry under the mineral leasing laws (petroleum, natural gas, coal, phosphate), but open to entry under the

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[11] Regulations Pertaining to Coal Leases, Permits, and Licenses on the Public Land (as contained in Title 43 of the Code of Federal Regulations). Bureau of Land Management Circular No. 2154, 1964, 11 pp.

mining laws, subject to Bureau of Land Management and Navy Department concurrence.

PHYSICAL FEATURES AND CLIMATE

The Utukok-Corwin region contains two physiographic provinces, the Arctic coastal plain and the Arctic foothills.[12] The two provinces merge along an irregular boundary extending northwestward from Cape Beaufort. Coal deposits herein described are in the foothills province but only a short distance from the boundary of the coastal plain.

The coastal plain is characterized by relief of less than 300 ft, many lakes and marshes, poor drainage, and poorly defined, meandering streams, with the few existing outcrops present only in the cutbanks of major streams. The foothills section is an eastward-trending belt of rolling terrain 40 to 50 miles wide within which relief and altitude increase southward; the belt is marked by prominent cuesta ridges and mesas that reflect the underlying structural features and that are commonly separated by wide lowland areas. Outcrops are numerous in river bluffs, along tributary streams, and on the ridges where vegetal cover is thin or absent. Relief is as much as 2,200 ft and averages about 600 ft.

The only treelike growth within the region is willows, immediately adjacent to streams. Mainly, the vegetation consists of cotton grass tussock, sedges, lichens, mosses, dwarfed berry bushes, glandular and dwarfed birch, mountain heather, and many wild flowers. The plants and a layer of humus and soil, extending down to perennially frozen ground, comprise the tundra of this treeless Arctic region and cover a high percentage of the entire area. The cotton grass tussock is the most prevalent plant life, and because of its closely spaced, clumplike distribution and springlike resilience, travel on foot is slow and arduous.

Permafrost[13] is believed to underlie nearly all of northern Alaska, but may be at considerable depth or absent beneath large rivers and deep lakes. The permafrost, except for the shallow surface zone that is subject to summer thawing, is known to extend to depths of 1,000 feet or more.

The climate of Arctic Northwestern Alaska is semiarid with precipitation probably averaging less than 15 in per year; in 1965, total precipitation at Kotzebue was 12.1 in; at Wainwright, 16.2; and at Point Barrow, 5.9 in. Average yearly temperatures are well below freezing, with Kotzebue during 1965 having an average temperature of 20.2° F; Wainwright, 10.0° F; and Point Barrow, 9.1° F. During summer months, temperatures in the 50° and 60° F range are fairly common, but freezing temperatures may occur during

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[12] Work cited in footnote 8.

[13] Permafrost or perennially frozen ground is defined by Chapman and Sable (in work cited in footnote 8) as, "...a thickness of soil or other superficial deposit, or even bedrock, at a variable depth beneath the surface of the earth, in which a temperature below freezing has existed continually for a long time (two to tens of thousands of years)."

every month of the year. During winter months minimum temperatures in the -40° F range are common. Strong windstorms are common with many reaching gale velocities.

GEOLOGY

The geology of the Utukok-Corwin region has been studied extensively on a regional basis by the USGS; the most recent published work was undertaken as a part of the program of investigation for the U.S. Navy Department in and near Naval Petroleum Reserve No. 4. The results of this and earlier work are incorporated into an excellent comprehensive report entitled "Geology of the Utukok-Corwin Region, Northwestern Alaska;"[14] only that geology believed pertinent to coal deposits of the region is herein briefly summarized.

During the summer field season of 1966 the USGS Branch of Mineral Classification began a detailed mapping program of about 250 square miles. The area covered included the 20-ft coalbed outcropping along the Kukpowruk River discussed herein.

Coalbeds of potential economic significance are confined almost entirely to the Corwin formation, which is believed to be partly of middle or late Lower Cretaceous age and may be partly of Upper Cretaceous age. The formation consists predominantly of nonmarine rocks that intertongue with and overlie the Kukpowruk formation of late Lower Cretaceous age. Shale, siltstone, claystone, sandstone, coal, conglomerate, ironstone, clay, and bentonitic clay constitute most of the rock types of the Corwin formation. These sediments are believed to have been deposited everywhere in the region; only at a very few localities has erosion apparently completely removed the formation.

The region has been divided into the eastern and western structural provinces which are approximately separated by the lower Pitmegea River. In the eastern structural province, the major folds in the northern foothills and coastal plain trend mainly west and northwest, the results of northward-directed forces from the Brooks Range. These folds include prominent simple synclines and basins separated by complex anticlines which may, in part, be the expression of major thrust faults. Surface rocks are folded to progressively greater depths westward. The western structural province is characterized by northwest-striking thrust faults which alternate with southwestward-dipping sections or partial limbs of synclines. This structural pattern is the result of eastward-directed forces from the Tigara uplift west of the area.

The western structural province includes the numerous coal outcrops of the Cape Beaufort-Corwin Bluff coastal area where more than 80 coalbeds that exceed 1 ft in thickness are known. At least 17 of these beds are between 2.5 and 9 ft thick. The structural geology of these coalbeds, however, appears relatively more complex than that of beds of the eastern structural province. Some coalbeds outcropping along the Corwin-Cape Beaufort coastal bluffs have measured dips of as much as 45°, whereas beds of the eastern structural province, at least in the synclines, are generally more gently folded.

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[14]Work cited in footnote 8.

Samples taken from the Cape Beaufort area were from within the eastern structural province. The geology of the sample area appeared fairly simple, with strike continuity probable for several miles but with dips progressively steepening from a measured 14° to 30° as stratigraphic depth of the various sample cuts increased.

The major rivers of the region, the Kukpowruk, Kokolik, and Utukok, are also within the eastern structural province. Each of these rivers exposes considerable thicknesses of the Corwin formation along its cutbanks, and thus many coalbeds have been exposed.

SURFACE SAMPLES, 1964 SERIES

Surface samples from Kokolik River and Cape Beaufort areas were taken from coalbeds that occur at varying intervals in stratigraphic sections of several thousand feet thickness and thus represent a fairly large geologic age span.

Each sample face was "freshened" to the greatest degree practicable. Methods of excavating the permanently frozen ground included blasting, bulldozing, and hand digging. Blast holes, 1-5/8 in in diameter, were drilled by augering. The drill consisted of a gasoline-powered 2-cycle chain saw engine equipped with a roller-chain-driven power takeoff mounted in place of the cutting bar. The drill powered continuous-flight augers of about 3-ft length each that could be quickly coupled into various multiples of 3 ft. Bits were tungsten carbide tipped and of a design normally used for drilling roof bolt holes. The drill performed well in all sediments encountered except competent abrasive sandstones which were very difficult, if not impossible, to penetrate with this type of equipment.

Individual samples were cut by either channeling or collection of cuttings from multiple auger holes. The samples were shipped in airtight polyethylene-lined bags to the Denver Coal Research Laboratory.

Noncoal constituents excluded from samples were assumed to be materials that normally are separable from mined coal by such cleaning systems as washing and heavy media.

Kokolik River Area

Samples 9 through 14 were taken during 1964 from coalbeds outcropping along the Kokolik River bluffs in T 1 N, R 39 W; T 1 S, R 39 W; and T 1 S, R 40 W; Umiat meridian. The location of each sample is shown in figure 2; the geographic relationship of the sample area to the region as a whole is shown in figure 1. Sections through the opencut of each sample location are shown in figure 3. The sample logs and sites are described in appendix A.

Cape Beaufort Area

Samples 16 through 21 were obtained from along Kahkatak Creek and Tulugak Creek in the Cape Beaufort area; these locations are in T 5 S, R 50 W, Umiat

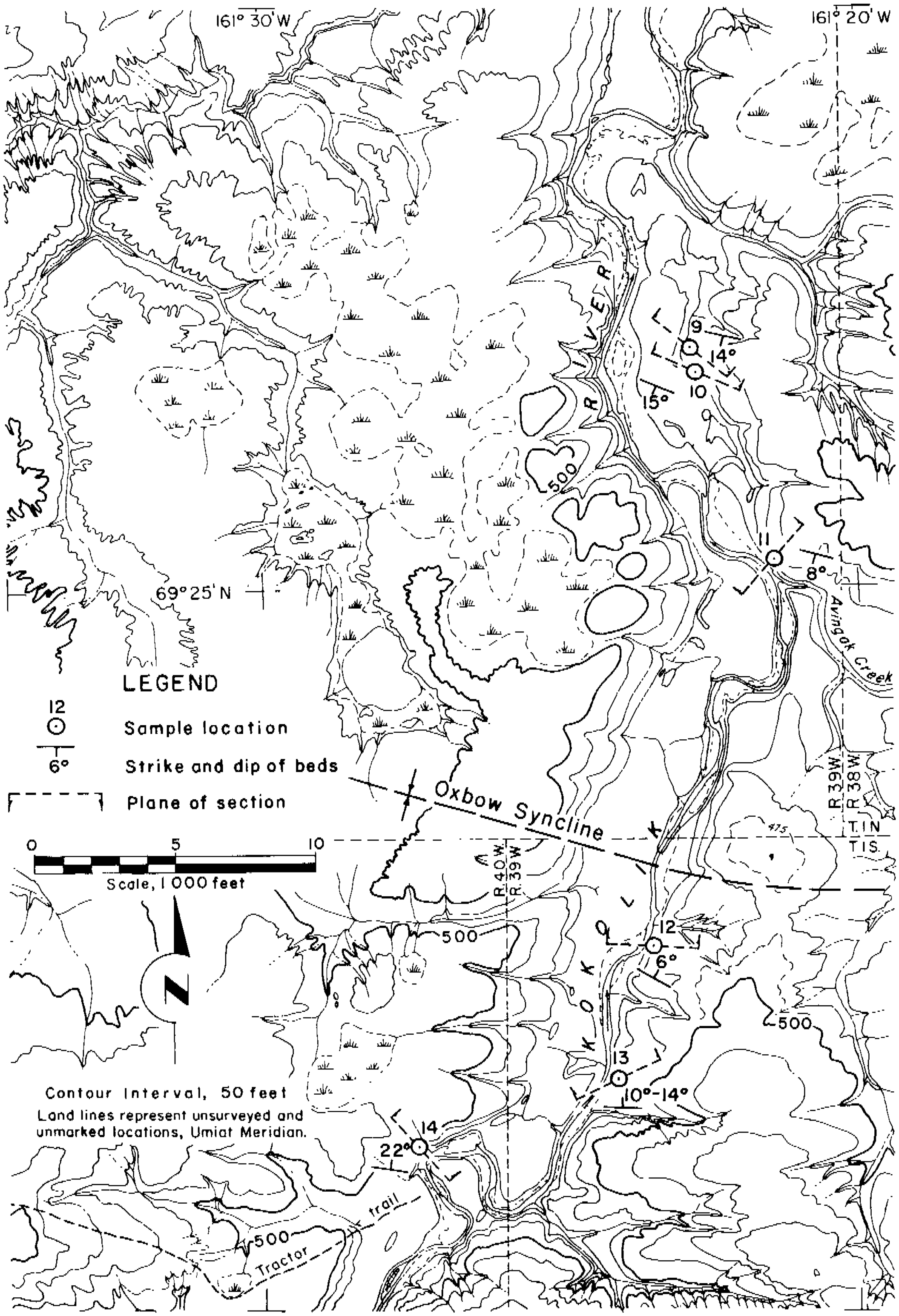

FIGURE 2. - Location Map, Kokolik River Area Samples. (Modified from U. S. Army Map Service Preliminary Map Sheets 1459 I and 1559 IV.)

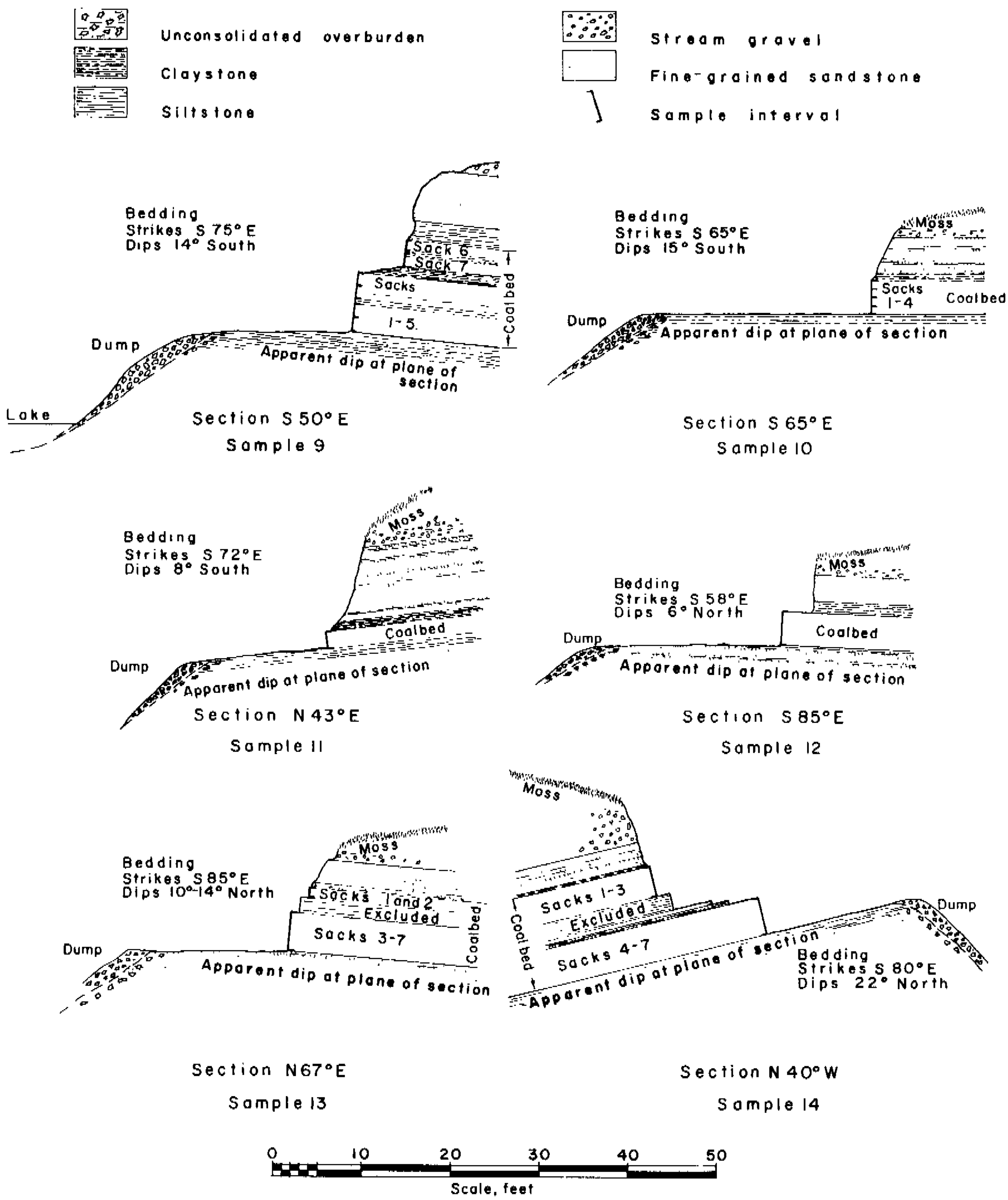

FIGURE 3. - Sections, Kokolik River Area Samples 9 Through 14.

meridian. The airstrip for Liz A, a former DEW site, parallels the Chukchi Sea coast between Kahkatak Creek and Tulugak Creek.

Kahkatak Creek flows northwesterly entering the Chukchi Sea about 3.5 miles southwest of Cape Beaufort, and Tulugak Creek enters the sea about 0.8

mile further southwest. Samples 16 through 21 were taken at intervals over a 2.6-mile distance along a line that nearly parallels the northwesterly flow of Kahkatak Creek (fig. 4). Since Kahkatak Creek cuts the strike of the Corwin formation at a high angle and since the dip of the beds sampled progressively steepens inland from a measured 14° to 30°, a fairly large stratigraphic age sequence of Corwin formation coalbeds is represented by the samples.

Dependent on the location of outcrop with respect to topography and the difficulty of excavation, some samples were taken by collecting cuttings from auger drill holes, and others were channel cut. Plan and section drawings of individual samples are shown in figures 5 and 6. The sample logs and sites are described in appendix A.

CORE DRILLING AND SAMPLES, 1966 SERIES

Core drill samples were taken along the Kukpowruk River and in the Cape Beaufort area, as a followup of previous reconnaissance-type surface sampling,[15] to determine if the coals' oxygen content decreased at subsurface depths, and, if so, to determine the resulting degree of improvement in coking quality.

The core sample site along the Kukpowruk River nearly coincides with the river's most eastern meander. Here the strata strike almost east-west, dip 8° to 17° northerly, and represent the south limb of a shallow syncline. This structure has been named the Howard syncline and extends at least from the Kukpowruk River to the Utukok River, a distance of 65 miles. Plan and section drawings of the drill hole area are shown in figures 7 and 8.

Because the 1966 core drilling along the Kukpowruk River closely ties in with the 1962-63 near-surface sampling, a brief description of the earlier work is presented as follows: Six samples (1 through 6) from four locations were taken during the 1962 field season, and two samples, 7 and 8, were taken from a single location during the 1963 field season. All samples except one were taken from excavations into outcrops; the exception, S6 (sample 6) was taken underground at the face of the previously driven 70-ft adit and raise. A fault, alined about as shown in figure 7, cuts the sample area. Figure 9, a westward view into the river bluff, shows the fault; a massive sandstone member vertically abuts silty shale beds. If this fault has a vertical displacement of about 300 ft, it is probable that all samples except S1 were from the same coalbed. Sample 1 was cut from a 4.5-ft seam, whereas S2 through S8 represented a seam almost 20 ft thick.

In the 1966 field season, four vertical holes were spaced along a N 14° E line at horizontal intervals of about 200 ft. Hole 1 was located about 160 ft N 13° W from the surface outcrop from which surface samples 7 and 8 were taken in 1963 (fig. 7). The horizontal spacing was designed to intercept the 19- to 20-ft coalbed at vertical intervals of about 50 ft and thus determine whether coking quality increased with depth of overburden. The 19- to 20-ft coalbed, as determined by the core drilling, has an average dip of about 14°.

[15]Work cited in footnote 3.

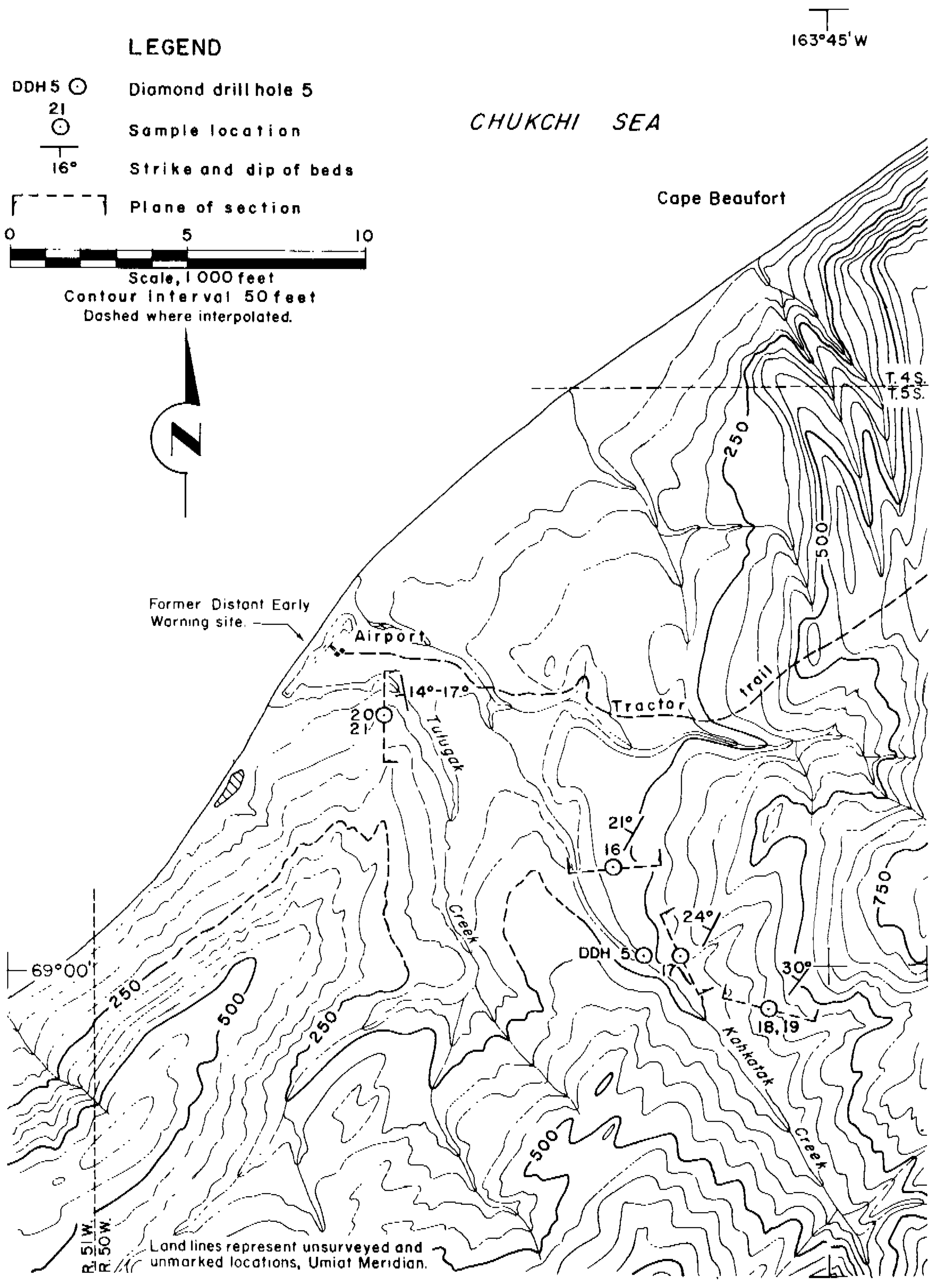

FIGURE 4. - Location Map, Cape Beaufort Area Samples. (Modified from U.S. Army Map Service Preliminary Map Sheets 1259 II and 1359 III.)

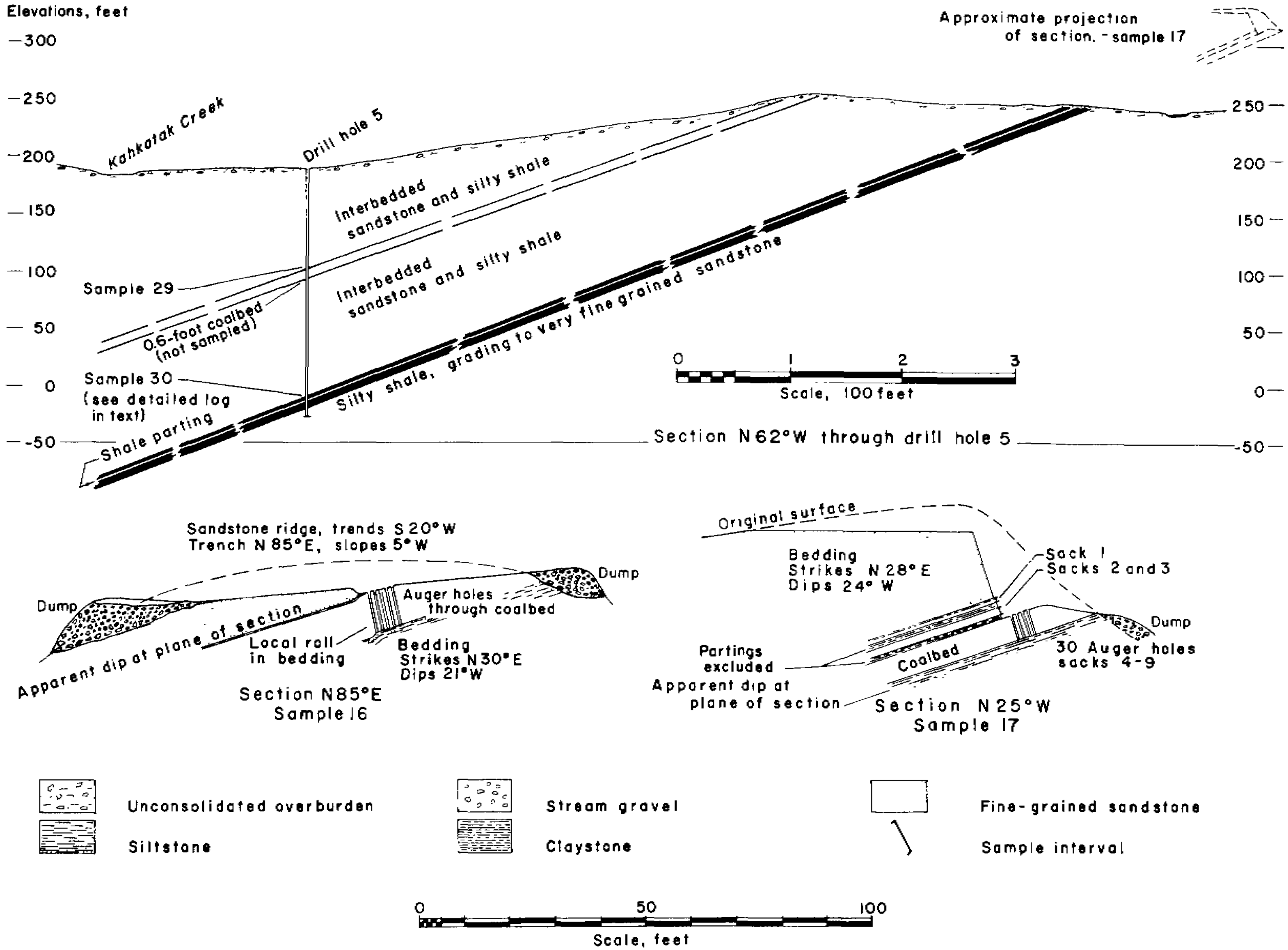

FIGURE 5. - Sections, Cape Beaufort Area Samples 16 and 17, and Drill Hole 5.

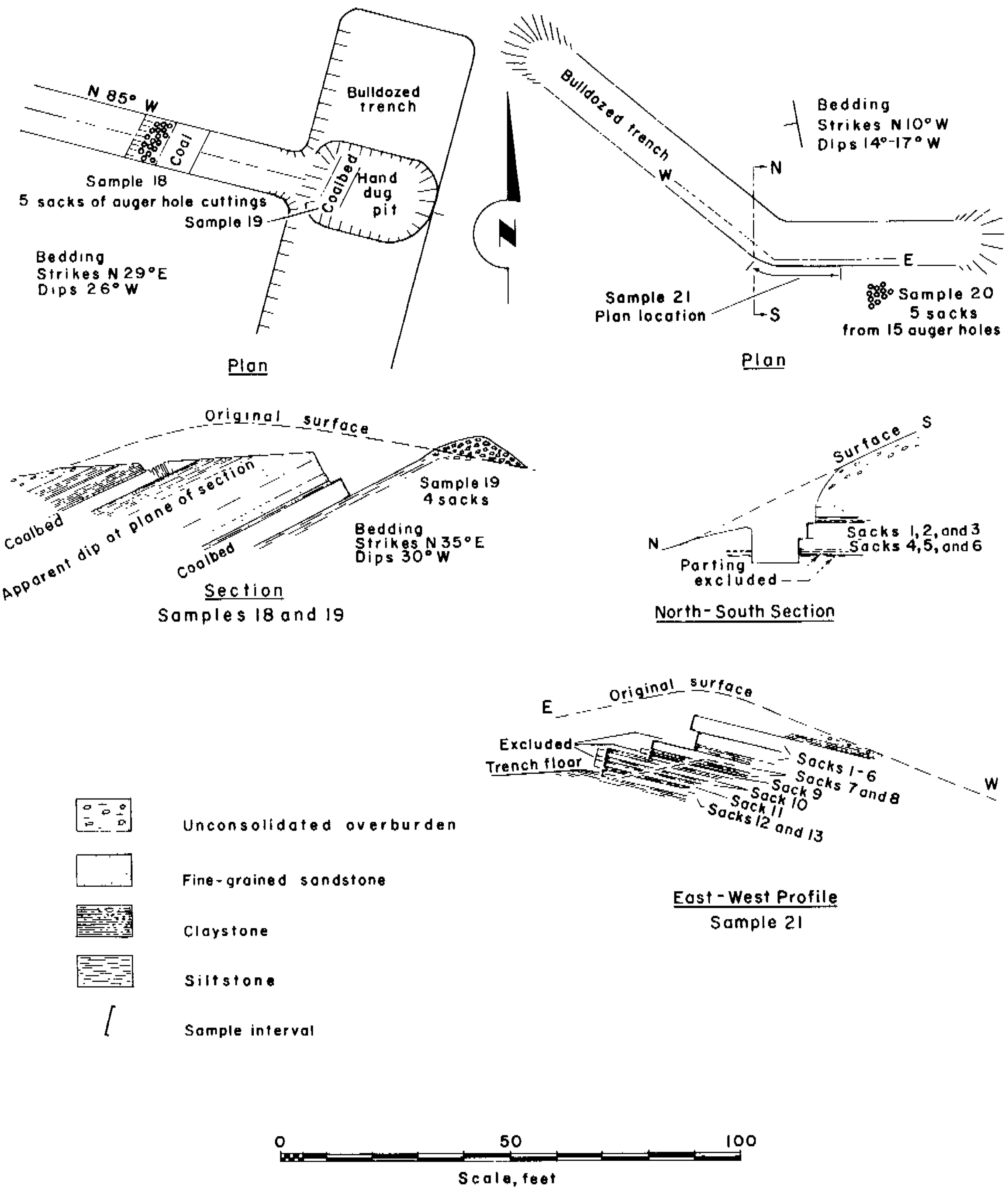

FIGURE 6. - Plans and Sections, Cape Beaufort Area Samples 18 Through 21.

Figure 10 is a northeastward view of the Kukpowruk River valley with the core drill operating in the foreground.

Samples 22, 24, 26, and 28, from drill holes 1 through 4, represent penetrations of the 19- to 20-ft coal seam; samples 23, 25, and 27, from drill holes 2, 3, and 4, represent an approximately 2.5-ft seam that overlies by

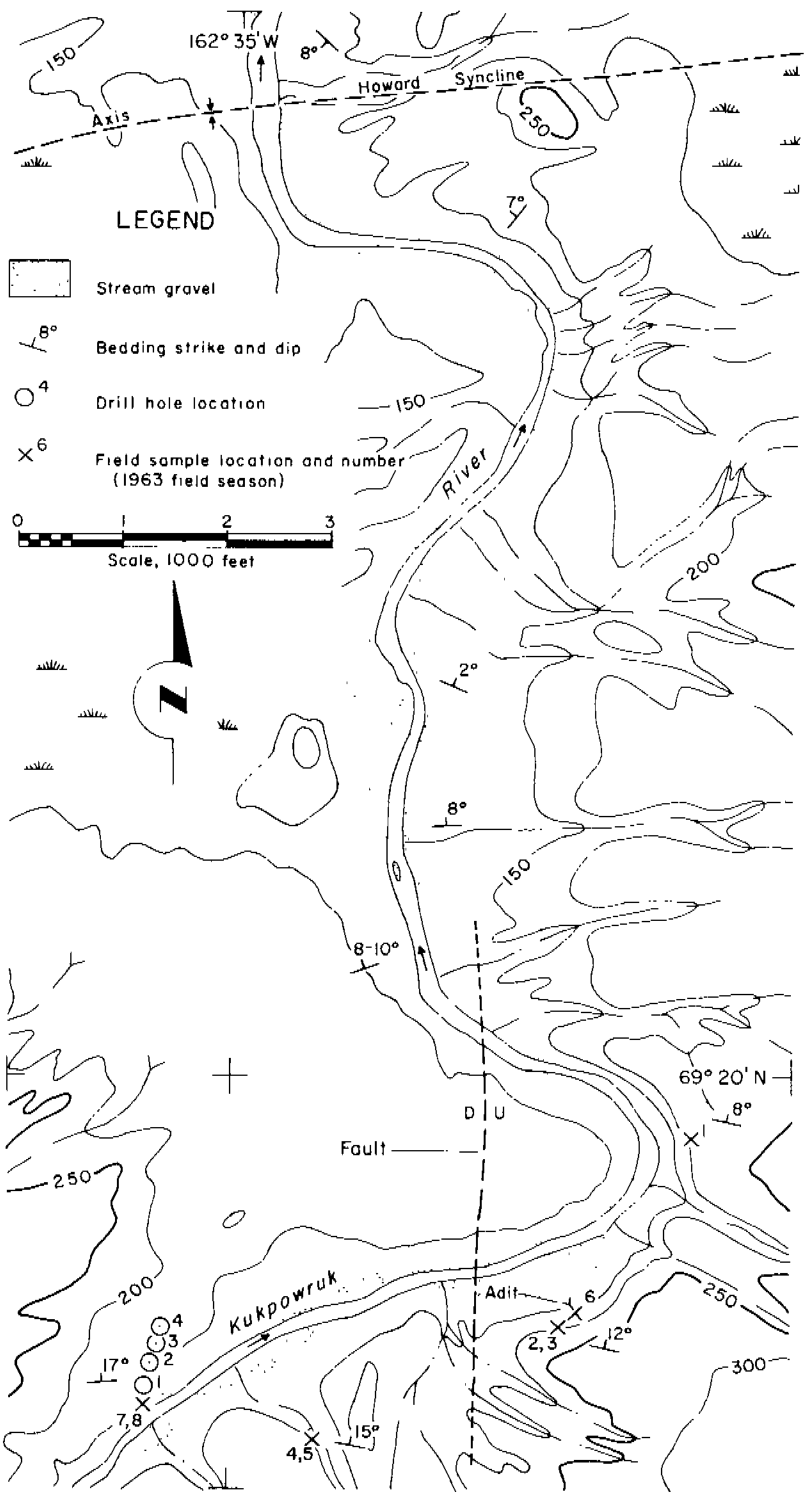

FIGURE 7. - Plan, Kukpowruk River Area Drill Hole Samples. (Modified from U.S. Geological Survey Point Lay (B-1), Alaska quadrangle map and Plate 9 of Geological Survey Professional Paper 303-C.)

about 80 ft the 19- to 20-ft seam. One other coalbed about 1 ft thick was intersected in holes 3 and 4. This bed overlies the 2.5-ft bed about 27 ft, and, because of its thinness, was not sampled. All coal samples, except S24 from hole 2, had good core recovery and were considered excellent. Sample 24 apparently cored well, but when the core barrel was pulled from the hole, the core lifter failed to function properly, and 2.6 ft of coal core were lost. Drill-hole logs showing sample data and core recovery are in table B-1. Detailed sample analyses and coking studies data are in the section of this report entitled "Coking Studies, 1966 Series."

Hole 5 was drilled in the Cape Beaufort area along Kahkatak Creek about 2.6 miles upstream from the Chukchi Sea coast (fig. 4). This hole was designed to intersect at depth the coal seam represented by the 1964 surface S17. The coalbed intersection depth was from 197.8 to 209.3 ft, represented by S30 (fig. 5). One other approximately 1.7-ft-thick overlying seam was intersected in hole 5; this bed is represented by S29.

The bedrock overburden encountered in drill holes along the Kukpowruk River was predominately a silty shale which spalled and caved into the drill hole when thawed by the

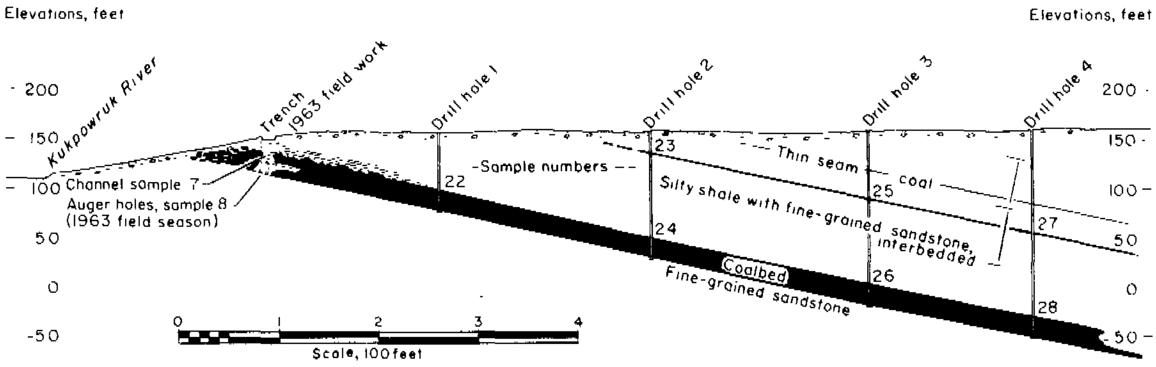

FIGURE 8. - Section, Kukpowruk River Area Drill Hole Samples.

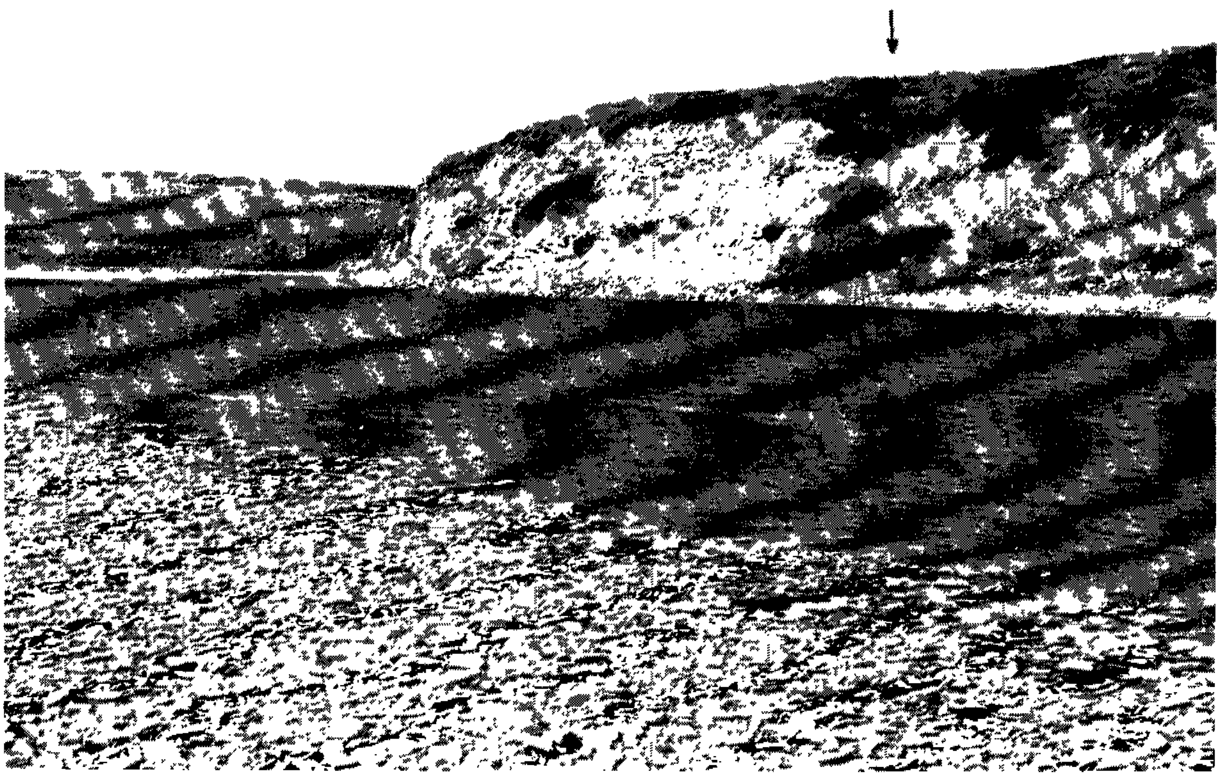

FIGURE 9. - View of Faulted Area in Kukpowruk River Bluff.

circulating drilling water. Some of this caved material usually entered the core barrel each time the drilling tools were replaced in the hole; this together with a tendency for the silty shale core to fracture along joint planes into wedgelike segments, caused short blocking of the core barrel and made numerous short runs necessary. Drill hole 5 along Kahkatak Creek contained some silty shale material but also some rather massive sandstone beds which drilled excellently.

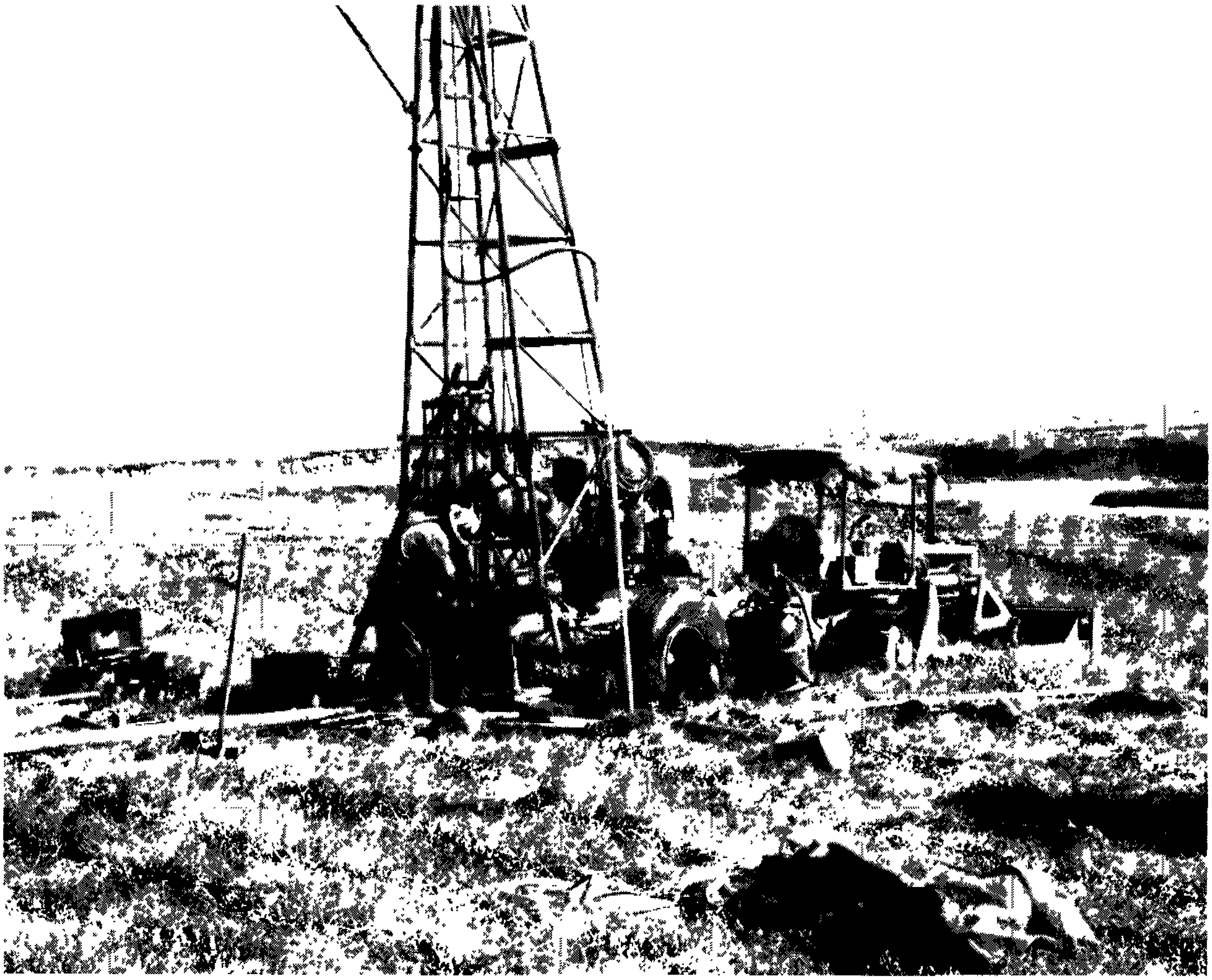

FIGURE 10. - Drilling Equipment, Northeastward View of Kukpowruk River Valley.

Drill holes 1 through 4 were cored with a 2-3/4-in by 3-7/8-in large-series core barrel to obtain enough sample of the 19- to 20-ft coal seam for 50-lb coking tests. Assuming 100 pct core recovery, 20 ft of coal core, and 25 cu ft per ton of coal in place, each sample should have weighed 63 lb. Drill hole 5 was cored NX, 2-1/8-in core, for faster drilling and because the anticipated coal intersection was not thick enough to provide a 50-lb sample.

The core drill was gasoline-engine driven and had a rated capacity of 1,000 ft of NX drill hole; it was equipped with a cathead for driving pipe through overburden. The drill and tower were mounted on a heavy-duty two-wheel trailer equipped with large aircraft tires for flotation permitting cross-country travel on tundra (fig. 8).

The drilling procedure was to set 4-in flush-joint drive casing through the overburden into bedrock by a combination of driving, drag bit drilling, chopping, and water circulation. Along the Kukpowruk River, core drilling followed with the 2-3/4-in by 3-7/8-in core barrel except in drill hole 4 where the section between the 2.5-ft and the 19- to 20-ft coalbeds was drilled with a tricone roller bit. Another core section of the silty shale material between the two coalbeds was not needed, and the tricone bit drilled much faster eliminating the numerous trips required with the core barrel. In the hole drilled along Kahkatak Creek, NX casing equipped with a casing-shoe diamond bit to permit reaming was installed inside the 4-in casing, and NX core drilling then followed. Both the NX and large-series core barrels were of the swivel-high-core-recovery type.

All drilling was done on a single shift, 6 days per week basis. Water alone was used as a drilling fluid, and all holes were in permafrost ground their entire length except for the active surface zone that seasonally thaws and freezes. Therefore, some difficulty was experienced with ice forming in the drill holes overnight. This was particularly true of drill hole 5 along the Kahkatak Creek, where, at least in part, more rapid ice formation was attributed to the relative lack of heat introduced into this hole by the water circulated to remove drill cuttings. Kahkatak Creek water was several degrees cooler than the Kukpowruk River and also, because of faster drilling, less volume of water was introduced. The formation of ice was successfully overcome to some extent by the introduction of calcium chloride into the hole at the end of each drilling shift. But because of the many variables--temperature of permanently frozen ground, volume of water introduced, volume of drill hole because of spalling and caving of some materials upon thawing, temperature of circulating water--it was very difficult to judge the amount of calcium chloride necessary to prevent freezing. Upon occasion, as much as 2 hr were consumed drilling out ice.

Complete logs of all five core-drill holes are given in appendix B.

COKING STUDIES

Coking studies on the 12 surface samples obtained during the 1964 field season were conducted by the Denver Coal Research Laboratory. In 1965, functions of the Denver Coal Research Laboratory were transferred to the Grand Forks Coal Research Laboratory (Grand Forks, N. Dak.), where coking studies were made on the 1966 samples.

Coking Studies, 1964 Series

The 1964-series coking studies were made on 12 samples from six locations in the Kokolik River area and six locations in the Cape Beaufort area (see "Surface Samples, 1964 Series"). The samples were received at the laboratory in 32 parts, representing separate, logged portions of the coal seams as sampled at the 12 locations.

Proximate and ultimate analyses and heating values for each of the 32 sample parts are presented in appendix C (tables C-1 and C-2). Table C-3 summarizes selected chemical properties that are of special interest in coking studies--heating value, volatile matter, and oxygen content--all on a

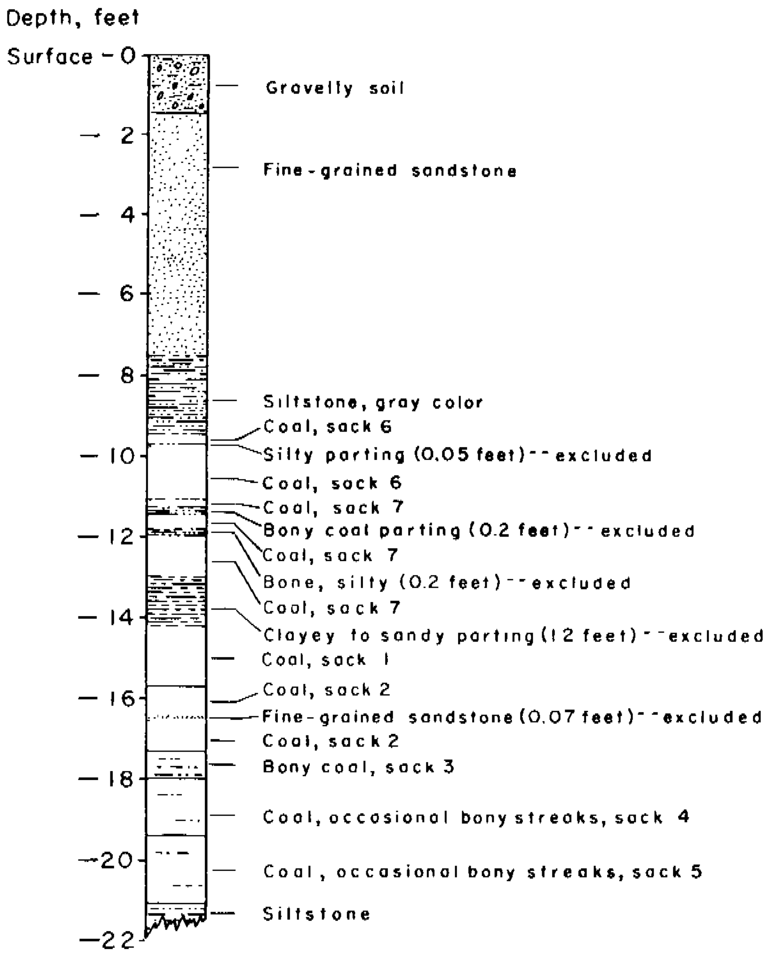

FIGURE 11. - Graphic Log of Sample 9, Kokolik River Area.

moisture- and ash-free (maf) basis. Table C-3 also includes free swelling index.[16] All samples, with one exception, were high-volatile bituminous or sub-bituminous in rank, as indicated in table C-3. The exception was S17: 2 and 3, Cape Beaufort area, which is indicated to be medium-volatile bituminous.[17]

Only S9, a channel sample from the Kokolik River area, had coking properties. Five of the seven parts of this sample showed some agglomeration (free swelling indexes ranging from 1-1/2 to 5); two parts were nonagglomerating. Test work on the 11 nonagglomerating samples (10 through 14 and 16 through 21) was considered complete following proximate and ultimate analyses and free swelling index determinations.

The seven parts of S9 extended over a total seam thickness of 11.6 ft, siltstone roof to siltstone floor, within which was a total of 9.88 ft of sampled coal and 1.72 ft of excluded partings. The channel log is shown graphically in figure 11.

Although the top 1.55 ft and the bottom 1.65 ft of the coal seam were nonagglomerating, they represent a substantial part of the seam and might be considered for inclusion in possible future mining if they do not reduce the coking strength of the rest of the seam too much. The coking properties of six composites prepared from S9 coal were studied at bench scale:

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[16] ASTM Test Designation D720-57.
[17] See footnote 22 in a later section of this report.

Sample 9 composites	Recoverable coal, ft
1, full-seam mining	9.9
2, omitting top 1.55 ft (sack 6)	8.3
3, omitting bottom 1.65 ft (sack 5)	8.2
4, omitting both top 1.55 ft and bottom 1.65 ft (sacks 5 and 6)	6.7
5, omitting bottom 3.8 ft (sacks 3, 4, and 5)	6.1
6, omitting both bottom 3.8 ft and top 1.55 ft (sacks 3, 4, 5, and 6)	4.5

To prepare the foregoing six composites, the seven parts of S9 were combined in proportion to the thicknesses they represent in the channel log. Proximate and ultimate analyses, heating values, and plasticity data (free swelling indexes and Gieseler plastometer[18] results) for the six composites are given in table C-4, together with ash fusion temperatures for two of the six composites. To learn more about the behavior of the coal, carbonization assays at 500° C were run on composites 1 and 4; assay results appear in table C-5.

Available coal quantities permitted three 50-lb coking tests. The tests were conducted in a 50-lb, 10-in, circular, gas-fired retort. Byproducts were not collected but were burned in a combustion chamber during tests. The furnace and auxiliary equipment are illustrated in figure 12.

In each coking test, a 50-lb charge of 1/4-in by 0 coal was carbonized with 900° C maintained at the outer surface of the charge. Carbonization was considered complete when the charge's center reached,nearly or fully,900° C, which normally required 3 to 4 hr.

After the charge was coked, the retort was withdrawn from the furnace, cooled, and opened. Coke yields were determined by weighing all coke produced. The coke was then "stabilized" by one 6-ft drop in standard ASTM drop-shatter apparatus, and screen analyses were made.

Coke strength was evaluated by use of the Columbia tumbler, a tumbler that produces less degradation than the standard ASTM coke tumbler and is better suited to studies of the less strongly coking coals typical of Western United States. An important further consideration is that the amount of coke ordinarily produced in the 50-lb retort is adequate for the Columbia tumbler but inadequate for the standard ASTM tumbler. The Columbia tumbler is 18 in in diameter, with four internal lifters. For each test, 10 lb of plus 1-in pieces, selected to match the observed size analysis, was tumbled 720 revolutions at 24 rpm, and the resultant was screened for size. Average resultant particle size was computed and expressed as a percentage of average particle size of the 10-lb charge to the tumbler. This percentage is designated as "size stability." (Size stability as determined by the Columbia tumbler test is not the same as ASTM "stability factor.")

[18]ASTM Test Designation D1812-66.

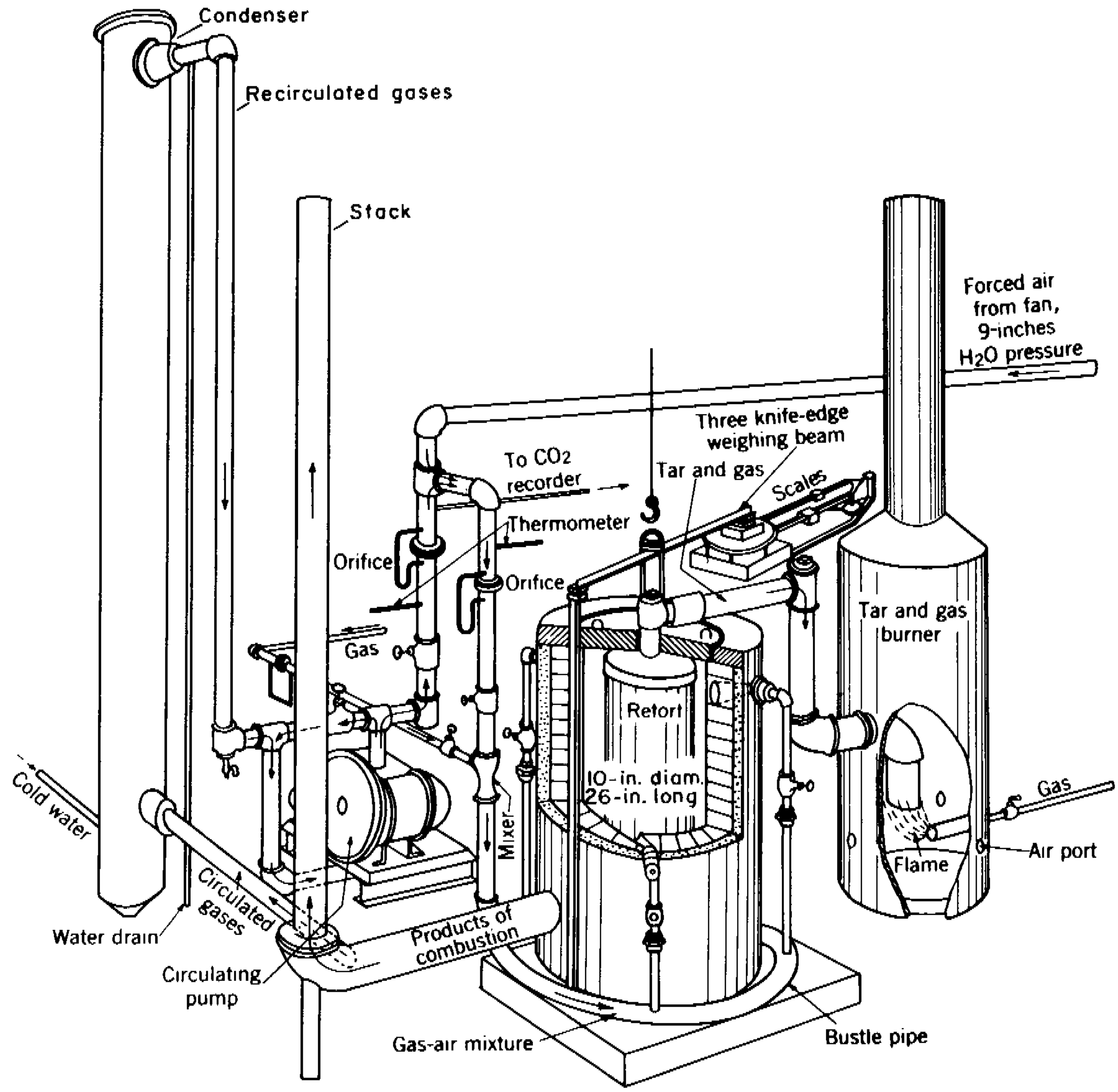

FIGURE 12. - Gas-Heated 50-Pound Carbonizing Unit, With a 10-Inch Circular Retort.

Since some of the earlier coking studies on samples from the Kukpowruk River area, less than 40 miles to the west,[19] had been done with two medium-volatile bituminous blending coals (Coal Basin, Pitkin County, Colo., and Red Indian, Wyoming County, W. Va.), these blending coals were used in the three 50-lb coking tests. The blends consisted of:

[19]Work cited in footnote 3.

50-lb test number	Blend
CP-149	85 pct composite 1, plus 7.5 pct of each of the two blending coals
CP-150	70 pct composite 1, plus 15 pct of each of the two blending coals
CP-148	85 pct composite 4, plus 7.5 pct of each of the two blending coals

Salient data on the chemical and plastic properties of these blends and of the chemical and physical properties of the resultant cokes are given in table C-6, which also summarizes selected quality measures for these cokes together with corresponding measures for coke produced under the same conditions from a blend of 85 pct Sunnyside (Utah) coal with 15 pct of the same two blending coals. This blend has been used by Kaiser Steel Corp. to produce commercially acceptable coke at its Fontana, Calif., plant.

The summarized data in table C-6 indicate that the CP-149 coke was heavy and blocky but weak. Both CP-148 and CP-150 cokes were also heavy and blocky, but significantly stronger (see data for size stability, tumbler resultant on 0.25-in screen, and modified coke strength index); they approached the Fontana blend coke in overall quality. It is indicated that cokes that would probably be only slightly less acceptable than Fontana blend coke could be produced by using either (1) 70 pct full-seam S9 plus 30 pct blending coals, or (2) 85 pct coking-portion-only S9 plus 15 pct blending coals. The use of 85 pct full-seam S9 does not appear to be favorable.

Coking Studies, 1966 Series

The 1966-series coking studies were made on nine drill-core samples from four locations along the Kukpowruk River and one location in the Cape Beaufort area (see "Core Drilling and Samples, 1966 Series"). The samples were received at Grand Forks Coal Research Laboratory in 14 parts, representing separate, logged portions of the coal seams sampled.

A primary objective of the testing program for the Kukpowruk River area samples was to determine the possible effect, if any, of varying thicknesses of permanently frozen overburden on the coking characteristics of the Kukpowruk River 19- to 20-ft coal seam. Therefore, upper and lower portions of this major seam, plus composites and blends, were studied. Tests of coking properties included the free swelling index, the Gieseler plastometer, the 100-gram coking test,[20] and a special 50-lb coking test. The same tests, with one exception, were made on the overlying 2.5- to 3.0-ft Kukpowruk River seam and the two coal seams intersected in the Cape Beaufort area drill hole; not enough coal was available in these samples for the 50-lb coking tests.

[20] The 100-gram coking test is a rapid and useful bench-scale indicator of coking quality, although it has not been standardized industrially. It is described on p. 36 of BuMines Rept. of Inv. 6767.

Proximate and ultimate analyses, heating values, and ash fusion temperatures for each of the 14 sample parts are presented in table C-7 (Kukpowruk River area) and C-8 (Cape Beaufort area). Shown for comparison are, in table C-7, analyses of parts of 1963 surface samples 7 and 8,[21] obtained directly up dip from the 1966-series Kukpowruk River drill holes, and, in table C-8, analyses of parts of 1964 surface sample 17, obtained up dip from drill hole 5 in the Cape Beaufort area (fig. 5) and described earlier in this report.

All seams sampled in 1966 are high-volatile bituminous in rank except one, S30-1 (Cape Beaufort area), which is indicated to be medium-volatile bituminous.[22]

The comparisons of the drill hole samples with correlating surface samples are interesting. In the excellent, low-ash, Kukpowruk thick (19- to 20-ft) seam, almost no difference was observed between the samples obtained at depth and the 1963 surface samples. However, in the Cape Beaufort area, drill hole S30, obtained at a depth of about 200 ft, is much higher in heating value and lower in oxygen content than correlating surface S17.

Analyses of several commercial coking coals are shown in table C-9 for comparison with the Alaskan coals.

Coking properties of each Alaskan sample part were studied on bench scale by conducting Gieseler plastometer tests, free swelling tests, and 100-gram coking tests. An improved design of the Gieseler plastometer, by which constant torque is maintained on the stirrer shaft, was used in the plastometric tests. Where possible, sample parts were combined to represent a full seam (the 19- to 20-ft seam in the Kukpowruk River area, and the 10.7-ft seam in the Cape Beaufort area), and these composites were also tested. All sample parts and composites of the drill hole samples were found to be agglomerating to some extent.

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[21]Work cited in footnote 3.

[22]See footnote 17 earlier in this report. Reference to figure 5 is also recommended. It is very unusual to find a coal seam that is of high-volatile bituminous rank in its lower half, with a 1.5-ft portion in its upper half that is apparently medium-volatile bituminous. This anomaly in rank appears to be real, since it is exhibited twice, in samples taken 2 years apart in time and about 1,000 ft apart in the coal seam itself (S17 in 1964 and S30 in 1966).

There is evidence, however, that the 1.5-ft portion of the seam, classified medium-volatile bituminous by ASTM Specifications for Classification of Coals by Rank (D388-66), is not typical. The ASTM specification is based solely upon volatile matter content, but other chemical-analysis data for the 1.5-ft portion are not consistent with normal medium-volatile bituminous coals. In both samples, maf heating value and carbon content are lower, and maf oxygen content is higher than normal.

Results of the Gieseler plasticity and free swelling tests are given in tables C-10 (for Alaska samples) and C-11 (for commercial coking coals), together with the results of a 1963-series surface sample of the 19- to 20-ft seam. Table C-12 gives the averaged results of duplicate 100-gram coking tests run on each sample part and composite.

No progressive effect of depth of cover on coking properties is evident from the foregoing laboratory-scale tests of the 19- to 20-ft Kukpowruk River coal seam; this corresponds to the conclusion later reached in the 50-lb coking test. However, in line with the observation made on the chemical analyses shown in table C-8 for Cape Beaufort samples, drill hole S30 was much superior to surface S17. The latter gave no indication whatsoever of coking qualities in the free swelling test (see table C-3), whereas both parts of S30--especially the lower 5.2-ft portion--showed good free swelling indexes and Gieseler fluidities.

The overlying 2.5- to 3.0-ft seam in the Kukpowruk River area and the overlying 1.7-ft seam in the Cape Beaufort area also show coking properties.

In the Kukpowruk River area, the overlying seam is about the same quality as the 19- to 20-ft seam. In the Cape Beaufort area, the thin overlying seam is high in ash content (12 pct, as received).

For the 1966 series of samples, a 50-lb coking test was used that was somewhat different from the earlier 50-lb coking test. In the newer test, stainless-steel cylinders 8-1/4 in in inside diameter by 38 in high are used. The retorts are each charged with 50 lb of coal, vibrated to a charge density of 50 lb per cubic foot, and placed into an oven preheated to and maintained at 900° C (1,652° F). Under these conditions the center of the charge reaches 90 pct of absolute oven temperature in about 5 hr. Carbonization is considered to be complete in 6 hr, at which time the hot retorts are removed and allowed to cool; their bases are cut off, and the coke is removed and tested. Testing procedures are the same as used for the earlier 50-lb coking test.

An examination of possible effects of permafrost cover on the 19- to 20-ft seam was of prime importance to the testing program. As these effects, if any, would be likely to be best exhibited in the extremes of permafrost cover (minimum, 59 ft in drill hole 1; maximum, 191 ft in drill hole 4), the samples obtained at these extremes--S22 and S28--were chosen for 50-lb test work. By this test, no differences in coke quality ascribable to depth of cover were found. Four measures of coke quality as derived from the 50-lb coking tests are presented in table C-13.

Because, as judged by the tests on S22 and S28, depth of cover is not a factor in the quality of coke producible from the 19- to 20-ft seam, it was decided to use the two remaining samples, obtained from intermediate depths of cover, to further test these Alaskan coals as a base coal in blends to produce metallurgical-quality coke. The coal selected for blending was that from Coal Basin mine, Pitkin County, Colo.--a medium-volatile bituminous coal that had been used with the 1964-series samples. To provide comparative data, high-volatile A bituminous coals from the York Canyon mine, Colfax County, N. Mex.;

the Arkwright mine, Monongalia County, W. Va.; and the Sunnyside mines, Carbon County, Utah, were used. (Analyses of all four coals appear in table C-9.)

Data on the blends and qualitative results of their 50-lb coking tests appear in table C-13. The Sunnyside-York Canyon-Coal Basin blend has been used by Kaiser Steel Corp. at Fontana for production of blast furnace coke. When Alaskan coal was substituted for Sunnyside and York Canyon, increases were noted in coke yield, tumbler size stability, and apparent specific gravity; average coke size was slightly reduced, but this was regarded as less important.

Chemical analyses of cokes produced in the 50-lb tests are presented in table C-13.

Conclusions From the Coking Studies

On the basis of laboratory and pilot-plant studies of 12 samples (32 sample parts) obtained in 1964 in the Kokolik River and Cape Beaufort areas and of nine samples (14 sample parts) obtained in 1966 in the Kukpowruk River and Cape Beaufort areas, several coal deposits in Arctic Northwestern Alaska have been established to be of good quality and of possible use for coke production.

Earlier work was confirmed that had identified a high-volatile bituminous coal seam in the Kukpowruk River area, 19-to 20-ft thick, as being a potentially satisfactory base coking coal. The coal has low moisture and ash contents, and its sulfur content is within proposed air pollution limits of the Department of Health, Education, and Welfare. An overlying 2.5- to 3.0-ft seam in the same area also possesses good coking properties. The seams pitch at an average angle of 12° to 13°. Drill hole samples obtained at several depths up to 191 ft show no significant change in coking or chemical properties with increased depth of overlying permafrost.

In the Kokolik River area, one of the six surface samples had distinct coking properties, possibly high enough to produce commercially acceptable coke if 15 to 30 pct lower volatile blending coals are added. The deposit of potential coking coal is nearly 10 ft thick (excluding 1.72 ft of partings) and pitches at 14°. It is the lowermost of at least three coal seams sampled in the area.

In the Cape Beaufort area, none of six surface samples showed coking properties. However, when a drill hole was sunk to intersect one of the better coal seams at a depth of about 200 ft, the seam's lower 5.2 ft was much less oxidized than the surface sample and had significantly higher heating value and pronounced coking characteristics.

APPENDIX A.--SURFACE SAMPLE LOGS

Kokolik River

Kokolik River area sample logs are shown in table A-1; the sample sites are described in table A-2.

Sample 9 was taken from a hand dug opencut into the eastern bluff of the Kokolik River near the south end of a long lake; frozen coal and overburden were broken by blasting.

Sample 10 was taken from a coalbed that outcrops in the eastern Kokolik River bluff about 640 ft S 20° E of the S9[1] site. The S10 opencut was initially excavated by blasting and bulldozing; then an additional cut almost on the strike of the bed was blasted and hand dug further into the outcrop. The sample seemed to contain an abnormal amount of ice.

Sample 11 was cut from a 2-ft coalbed that outcrops in the eastern bluff of the Kokolik River 1-1/2 miles to the south of S9 and S10, or just north of the confluence of Avingak Creek and the Kokolik River. The opencut for this sample was excavated by hand digging aided by blasting.

Sample 12 was taken from a 4-ft coalbed that outcrops in the eastern bluff of the Kokolik River about 2-1/2 miles to the south of S11. This location is just south of the axis of the Oxbow syncline.[2] The opencut for S12 was excavated by blasting and hand digging. There seemed to be an abnormal amount of ice contained in the coalbed at sample face depth, even though the roof consisted of claystone that appeared impermeable.

Sample 13 was cut from a coalbed that outcrops in the eastern bluff of the Kokolik River about 3-1/2 miles to the south of the confluence of Avingak Creek and the Kokolik River. The opencut for S13 was excavated entirely by hand digging aided by blasting. Sample 13 appeared to contain an unusual amount of resinous material.

Sample 14 was obtained from a coalbed that outcrops in the western bluff of the Kokolik River 4-1/2 miles to the south of the confluence of Avingak Creek and the Kokolik River. This location is along the northern stretch of a prominent oxbow meander of the Kokolik River. The opencut for S14 was excavated entirely by hand digging and blasting. Sample 14 contained an abnormal amount of ice, which probably indirectly indicates considerable coal oxidation at sample depth, even though the sample was cut entirely within the permafrost zone.

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[1]Sample 9.
[2]Work cited in text footnote 8.

TABLE A-1. - Kokolik River area sample logs

Depth, ft From	Depth, ft To	Material
		SAMPLE 9
Surface	1.5	Gravelly soil.
1.5	7.5	Fine-grained sandstone.
7.5	9.5	Siltstone, gray color.
9.5	9.7	Coal, sack 6.
9.7	9.75	Silty parting--excluded.
9.75	11.1	Coal, sack 6.
11.1	11.3	Coal, sack 7.
11.3	11.5	Bony coal parting--excluded.
11.5	11.85	Coal, sack 7.
11.85	12.05	Bone, silty--excluded.
12.05	13.0	Coal, sack 7.
13.0	14.2	Clayey to sandy parting--excluded.
14.2	15.7	Coal, sack 1.
15.7	16.5	Coal, sack 2.
16.5	16.57	Fine-grained sandstone--excluded.
16.57	17.3	Coal, sack 2.
17.3	17.9	Bony coal, sack 3.
17.9	19.45	Coal, occasional bony streaks, sack 4.
19.45	21.1	Coal, occasional bony streaks, sack 5.
21.1	?	Siltstone.
		SAMPLE 10
Surface	1.0	Tundra.
1.0	2.0	Gravel and clayey overburden.
2.0	6.0	Interbedded fine-grained sandstone and siltstone.
6.0	7.0	Soft, mushy (when thawed) gray clay.
7.0	7.1	Coal--not sampled to prevent roof contamination of sample.
7.1	8.1	Coal, sack 1.
8.1	9.05	Coal, sack 2.
9.05	9.85	Coal, sack 3.
9.85	10.8	Coal, sack 4.
10.8	?	Claystone.
		SAMPLE 11[1]
Surface	1.0	Tundra.
1.0	2.0	Gravelly overburden.
2.0	10.1	Interbedded siltstone and very fine-grained sandstone, occasional coaly streaks.
10.1	10.3	Bony coal--not sampled.
10.3	11.0	Claystone, coaly lower 0.2 ft.
11.0	13.0	Coal, S11, 5 sacks.
13.0	14.0	Coaly siltstone grading to fine-grained sandstone.
14.0	?	Fine-grained sandstone.
		SAMPLE 12[1]
Surface	1.0	Tundra.
1.0	2.0	Gravelly overburden.
2.0	5.0	Fine-grained sandstone.
5.0	6.3	Claystone.
6.3	10.3	Coal, S12, 5 sacks.
10.3	?	Siltstone with coal streaks grading to fine-grained sandstone within a short distance.
		SAMPLE 13
Surface	1.0	Tundra.
1.0	2.0	Gravel and soil overburden.
2.0	4.5	Fine- to medium-grained sandstone.
4.5	5.1	Fine-grained sandstone grading through siltstone with coal streaks to coaly claystone.
5.1	5.2	Powdery ice saturated coal--not sampled.
5.2	6.7	Coal, S13: 1-2.[2]
6.7	8.1	Siltstone parting, occasional coal streaks and bands, lower 0.1 ft coal except 1/4-in ice band--excluded.
8.1	12.45	Coal, S13: 3-7.
12.45	?	Very fine-grained sandstone with coal streaks grading to fine- to medium-grained sandstone within a short distance.
		SAMPLE 14[1]
Surface	1.0	Tundra.
1.0	5.0	Gravelly overburden.
5.0	7.8	Interbedded, fine-grained sandstone and siltstone.
7.8	8.0	Claystone.
8.0	11.7	Coal, S14: 1-3; 1/4-in parting included in sack 2.
11.7	13.5	Thinly bedded clayey bone and coal parting--excluded from sample.
13.5	13.95	Coal, sack 4.
13.95	14.35	Siltstone parting--excluded.
14.35	18.8	Coal, sacks 4-7.
18.8	?	Siltstone grading to fine- and medium-grained sandstone within a few feet.

[1]The log interval represents true thickness of the coalbed.
[2]Sample 13, sacks 1 and 2.

TABLE A-2. - Kokolik River area sample sites, by samples

Site conditions	9	10	11	12	13	14
Channel cut, width by depth, in.	12 by 4	12 by 6	12 by 12	12 by 6	12 by 6	12 by 4
Coalbed:						
Strikes	S 75° E	S 65° E	S 72° E	S 58° E	S 85° E	S 80° E
Dips	14° S	15° S	8° S	6° N	10°-14° N	22° N
Thickness, ft:						
Total seam	11.6	3.8	2	4	7.35	10.8
As-sampled	9.88	3.7	2	4	5.85	8.6
Excluded	1.72	-	-	-	1.5	2.2

Cape Beaufort Area

Cape Beaufort area sample logs are shown in table A-3; sample sites are described in table A-4. Sample 16 was obtained on the northeast side of Kahkatak Creek about 2 miles inland. The opencut was made by bulldozing a trench in the weathered sandstone and coal to as great a downdip depth as possible without the aid of blasting and then handpicking the frozen silty claystone immediate roof off the top of the coal. The sample was obtained by collecting cuttings from multiple 1-5/8-in auger holes. Sacks 1 through 4 represent 8.5 ft, the entire coalbed. Observation of cuttings indicated that the upper portion of the seam contained high ash material. Therefore, the upper 0.6 ft of the bed was removed and sacks 5 through 7 representing 7.9 ft of the seam were collected. As nearly as possible, all auger holes were drilled normal to the dip.

Sample 17 was taken on the northeast side of Kahkatak Creek about 2.6 miles inland. The opencut for this sample was made with the bulldozer aided by blasting; considerable hand digging was necessary in preparation for sampling. The sample was cut by a combination of channel sampling and collection of auger drill hole cuttings. (This coalbed was sampled at depth by core drilling in 1966.) Several concretions were noted up dip from the auger holes in an excavated section of the coalbed; their stratigraphic position would be about equivalent to 28.0 ft of the log. A specimen was identified as predominately ankerite. The channel-cut portions of the sample represent true thickness; the auger holes as nearly as possible were drilled normal to the dip.

Samples 18 and 19 were taken from a single location on the northeast side of Kahkatak Creek, about 3.2 miles inland. The opencut for these samples was excavated by bulldozing and by hand digging aided by blasting. The coalbed from which S18 was taken overlies the S19 coalbed about 25 ft. Sample 18 was taken by collecting cuttings from multiple 1-5/8-in auger holes. Sample 19 was a channel cut; excluded partings were separated out to the best of the samplers' ability, but parts of some partings were undoubtedly included in the sample which consisted of four sacks.

Samples 20 and 21 were taken from a single location on the south side of Tulugak Creek about 0.5 mile inland. Sample 20 represents the upper 9.6 ft of the coalbed that is represented in its entirety by S21. Sample 20 was taken with the auger previous to opencutting the coalbed for S21 and was intended as a check against channel S21. Observation of auger cuttings indicated that S20 cut at least one parting of fair thickness at 8 to 8.5 ft below the top of the coal (see log of S21 for comparison). The opencut for S21 was excavated with the bulldozer aided by blasting. Minute films of ice were noted on some cleat faces at the sample site.

TABLE A-3. - Cape Beaufort area sample logs

Depth, ft From	To	Material
		SAMPLE 16
Surface	5.5	Medium-grained sandstone.
5.5	6.0	Silty claystone.
6.0 and 6.6	14.5	Coal, S16: 1-4 (6.0 to 14.5) and 5-7 (6.6 to 14.5).
14.5	?	Siltstone.
		SAMPLE 17
Surface	21.0	Medium- to fine-grained buff sandstone with occasional coal or coaly bands.
21.0	21.1	Bony coal--not sampled.
21.1	21.8	Coal, sack 1, channel cut 12 in wide by 6 in deep.
21.8	22.9	Coaly claystone and bony coal--excluded.
22.9	24.45	Coal, sacks 2 and 3, channel cut 12 in wide by 6 in deep.
24.45	25.70	Siltstone parting--excluded.
25.70	31.20	Coal, sacks 4-9, 30 1-5/8-in × 5.5-ft auger holes.
31.20	?	Claystone grading to fine-grained sandstone.
		SAMPLE 18
Surface	1.0	Medium- to fine-grained buff sandstone.
1.0	6.5	Interbedded coaly claystone, coal bands (to 0.3-ft thick), occasional fine-grained sandstone bands, occasional siltstone bands.
6.5	7.0	Very fine-grained sandstone.
7.0	9.5	Coal, S18, 5 sacks from approximately 75 1-5/8-in auger holes.
9.5	?	Siltstone.
		SAMPLE 19[1]
Surface	3.0	Soil and sandstone gravel overburden.
3.0	11.5	Medium- to fine-grained sandstone with occasional silty and coaly bands.
11.5	12.5	Coaly siltstone.
12.5	13.9	Coal, S19 (1/4-in silty parting at 13.4 ft included in sample).
13.9	14.0	Silty parting--excluded.
14.0	14.6	Coal, S19.
14.6	14.8	Silty parting--excluded.
14.8	15.15	Coal, S19.
15.15	15.3	Silty parting--excluded.
15.3	15.9	Coal, S19 (1/4-in silty parting at 15.4 ft excluded).
15.9	15.95	Silty parting--excluded.
15.95	16.65	Coal, S19.
16.65	?	Siltstone grading to fine-grained sandstone.

Depth, ft From	To	Material
		SAMPLES 20 AND 21
Surface	2.0	Loose, gravelly sandstone.
2.0	6.0	Loose, weathered and broken medium-grained sandstone.
6.0	8.0	Medium- to fine-grained buff sandstone.
8.0	9.5	Silty to clayey roof.
9.5	26.5	Coalbed, S21, see separate log.
26.5	?	Siltstone.
		SAMPLE 21 COALBED LOG[1]
Top of coal	3.35	Coal, sacks 1-3.
3.35	6.45	Coal, sacks 4-6.
6.45	6.7	Silty parting--excluded, sacks 4-6.
6.7	7.05	Coal, sacks 4-6.
7.05	7.25	Silty parting--excluded.
7.25	9.25	Coal, very occasional thin (1/8-in) partings--included, sacks 7 and 8.
9.25	9.75	Silty partings (3) and coal bands (2)--excluded, sacks 7 and 8.
9.75	10.1	Coal, sacks 7 and 8.
10.1	10.2	Silty parting--excluded.
10.2	11.15	Coal, sack 9.
11.15	11.75	Silty parting--excluded.
11.75	11.95	Coal, not sampled.
11.95	12.05	Silty parting--excluded.
12.05	12.85	Coal, sack 10.
12.85	13.05	Silty parting--excluded.
13.05	13.5	Coal, 1/8-in parting included, sack 10.
13.5	13.55	Silty parting--excluded.
13.55	13.65	Coal, not sampled.
13.65	14.1	Silty parting--excluded.
14.1	14.9	Coal, 1/4-in parting included, sack 11.
14.9	15.35	Silty parting--excluded.
15.35	17.0	Coal, sacks 12 and 13.
17.0	?	Siltstone.

[1]Log intervals represent true thickness.

TABLE A-4. - Cape Beaufort area sample sites, by samples

Site conditions	16	17	18	19	[1]20	21
Channel cut, width by depth, in.	-	12 by 6	-	12 by 4 (4.15 ft long)	-	12 by 4
Auger holes.....	Multiple 1-5/8 in	Multiple 1-5/8 in	Multiple 1-5/8 in	-	Multiple 1-5/8 in	-
Coalbed:						
Strikes.......	N 30° E	S 28° W	S 29° W	S 35° W	-	N 10° W
Dips..........	21° W	24° W	26° W	30° W	-	14°-17° W
Thickness, ft:						
Total seam....	8.5	10.1	2.5	4.15	17.0	17.0
As-sampled....	8.5 and 7.9	7.75	2.5	3.65	9.6	13.8
Excluded......	-	2.35	-	.5	-	3.2

[1]Combined with sample 21, see log.

APPENDIX B.--CORE DRILL LOGS

TABLE B-1. - Logs of core-drill holes, Kukpowruk River and Cape Beaufort areas

Location : 160 ft N 13° W of outcrop S7 and S8 (1963), Kukpowruk River
Elevation of collar: 158 ft (approx.)
Dip of hole : Vertical
Dates drilled : June 29-July 7, 1966

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
		HOLE 1		
0.0	4.0	Tundra and soil overburden.	0.0	Drilled with a noncoring drag bit.
4.0	16.0	Gravel overburden, gravel pebbles, mostly sandstone.	.0	Do.
16.0	20.5	Light gray, silty shale with occasional bands of fine-grained sandstone.	.0	Do.
20.5	24.6	Light gray, silty shale, 0.2-ft very fine-grained sandstone bands at 22 ft and 24.2 ft.	4.1	Silty shale material--weathers very readily.
24.6	30.0	Light gray, silty shale.	2.8	-
30.0	30.3	Very fine-grained sandstone.	.3	-
30.3	33.5	Light gray, silty shale.	3.0	-
33.5	33.7	Very fine-grained sandstone.	.2	-
33.7	38.7	Light gray, silty shale, 0.2-ft very fine-grained sandstone band at 37.7 ft.	3.7	-
38.7	59.3	Light gray, silty shale, occasional thin, very fine-grained sandstone bands.	19.5	Bedding angle 14°.
59.3	63.4	Coal.	4.0	S22: 1.[1]
63.4	68.8	Coal, very occasional thin, bony partings.	5.4	S22: 1. Bedding angle 12° at 64.4 ft.
68.8	71.0	do.	2.2	S22: 1.
71.0	71.5	Coal.	.2	S22: 2. (Lost core assumed to be coal.)
71.5	78.3	Coal, very occasional thin, bony partings.	6.8	S22: 2.
78.3	81.0	Very fine-grained sandstone, occasional carbonaceous streaks and inclusions.	2.4	-

[1]Sample 22, sack 1.

TABLE B-1. - Logs of core-drill holes, Kukpowruk River and Cape Beaufort areas--Continued

Location : 213 ft N 14° E of hole 1, Kukpowruk River
Elevation of collar: 160 ft (approx.)
Dip of hole : Vertical
Dates drilled : July 8-14, 1966

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
HOLE 2				
0.0	2.0	Tundra and soil overburden.	0.0	Drilled with a noncoring drag bit.
2.0	16.0	Gravel unconsolidated overburden, pebbles, mostly sandstone.	.0	Do.
16.0	22.0	Light gray, clayey shale.	.0	Do.
22.0	22.5	Coal.	.0	Do.
22.5	24.5	do.	2.0	S23, core badly broken.
24.5	28.1	Silty shale, numerous coal streaks and and bands, up to 1/8 in.	3.0	Bedding angle 9°.
28.1	36.3	Silty shale, light gray color, occasional coal streaks.	1.0	-
36.3	59.0	Silty shale.	.0	Drilled with a noncoring drag bit.
59.0	67.0	Silty shale, occasional very fine-grained sandstone bands.	7.0	-
67.0	91.7	Silty shale, occasional thin, very fine-grained sandstone bands, up to 0.4 ft thick.	23.8	Silty shale--weathers readily upon thawing and exposure to air.
91.7	106.6	Silty shale, numerous fine-grained sandstone bands and streaks up to 0.2 ft thick.	11.6	Bedding angles 11° and 12°.
106.6	109.2	Silty shale, occasional carbonaceous streaks.	1.8	Do.

TABLE B-1. - Logs of core-drill holes, Kukpowruk River and Cape Beaufort areas--Continued

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
		HOLE 2--Continued		
109.2	116.4	Coal, 1/4-in bony parting at 111.4 ft. Included in sample.	4.6	S24: 1. Apparently cored well, but lost all except 2.5 ft of coal core upon pulling--recovered some but not all core upon reentering hole.
116.4	118.4	Coal, very occasional thin, bony partings.	2.0	S24: 1.
118.4	127.7	Coal, very occasional very thin, bony streaks.	9.3	S24: 2. Bedding angle 12° to 13°.
127.7	131.9	Silty shale grading to very fine-grained sandstone, light gray color, occasional coal streaks.	3.7	Bedding angle 10° to 11°.

Location : 218 ft N 14° E of hole 2, Kukpowruk River
Elevation of collar: 159 ft (approx.)
Dip of hole : Vertical
Dates drilled : July 15-23, 1966

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
		HOLE 3		
0.0	2.0	Tundra and soil overburden.	0.0	Drilled with a noncoring drag bit.
2.0	18.0	Gravel unconsolidated overburden, pebbles mostly sandstone.	.0	Do.
18.0	42.5	Silty shale, occasional very fine-grained sandstone bands.	.0	Do.
42.5	43.0	Coal.	.0	-
43.0	43.5	do.	.5	Not sampled.
43.5	44.5	Silty shale, occasional coal streaks and bands.	1.0	-
44.5	67.6	Silty shale, light gray color, occasional very fine-grained sandstone bands--up to 0.2 ft.	22.7	-

TABLE B-1. - Logs of core-drill holes, Kukpowruk River and Cape Beaufort areas--Continued

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
		HOLE 3--Continued		
67.6	69.5	Very fine-grained sandstone.	1.7	-
69.5	70.3	Silty shale.	.8	-
70.3	70.5	Bony coal.	.2	-
70.5	73.1	Coal.	2.6	S25.
73.1	73.7	Bony coal.	.6	Bedding angle 20°.
73.7	75.8	Silty shale, occasional coal streaks and bands, one 0.2-ft fine-grained sandstone band at 73.7 ft.	2.0	-
75.8	88.4	Silty shale, occasional coal streaks and bands to 80.5 ft, 0.4-ft fine-grained sandstone bands at 78.0 ft and 85.8 ft.	12.0	Bedding angle 11°.
88.4	95.4	Silty shale, light gray color, 0.2-ft, 0.3-ft, and 0.2-ft fine-grained sandstone bands at 88.4 ft, 93.0 ft, and 93.6 ft--calcite veinlets in lower two bands, sandstone light tan color.	6.9	-
95.4	96.9	Very fine-grained sandstone.	1.5	-
96.9	154.2	Silty shale, light gray color, occasional fine-grained sandstone bands, up to 0.2 ft.	55.6	Bedding angle at 142 ft, 18°, bedding angle at 148 ft, 11°.
154.2	158.7	Silty shale, occasional very thin coaly streaks, 1/4-in band of coal at 158.6 ft.	4.2	-
158.7	168.4	Coal, bright, very occasional thin, bony partings, 1/16 in to 1/8 in.	9.7	S26: 1.
168.4	178.1	Coal, bright, very occasional very thin, bony partings.	9.7	S26: 2. Bedding angles 10° and 14°.
178.1	179.4	Fine-grained sandstone, light gray color.	1.3	-

TABLE B-1. - Logs of core-drill holes, Kukpowruk River and Cape Beaufort areas--Continued

Location : 162 ft N 14° E of hole 3, Kukpowruk River
Elevation of collar: 160 ft (approx.)
Dip of hole : Vertical
Dates drilled : July 27-August 6, 1966

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
		HOLE 4		
0.0	5.0	Tundra and soil overburden.	0.0	Drilled with a noncoring drag bit.
5.0	18.0	Gravel unconsolidated overburden, pebbles mostly sandstone.	.0	Do.
18.0	21.0	Silty shale.	.0	Do.
21.0	22.7	do.	.8	-
22.7	24.3	do.	.0	Drilled with a noncoring drag bit.
24.3	28.7	Fine-grained sandstone.	4.2	-
28.7	29.5	Silty shale with interbedded thin beds of fine-grained sandstone.	.8	-
29.5	33.7	do.	3.7	-
33.7	39.5	Silty shale, fine-grained sandstone bands, occasional to numerous coal streaks and bands.	4.5	-
39.5	59.5	Silty shale with interbedded thin beds of fine-grained sandstone.	19.4	Bedding angle 10° at 46 ft.
59.5	74.9	Silty shale with interbedded thin beds of fine-grained sandstone. Some slightly carbonaceous.	14.4	-
74.9	75.2	Claystone with occasional coal streaks.	.3	-
75.2	75.8	Coal.	.5	Not sampled; apparently correlates with bed at 43 ft, hole 3.
75.8	78.3	Silty shale, occasional coal streaks and bands.	2.5	-
78.3	82.6	Fine-grained sandstone.	4.3	-
82.6	85.2	Silty shale with interbedded thin beds of fine-grained sandstone.	2.6	-
85.2	88.9	Fine-grained sandstone, banded, light gray color.	3.6	Bedding angle 11°.
88.9	102.3	Silty shale with interbedded thin beds of fine-grained sandstone.	12.5	-
102.3	104.6	Silty shale with occasional streaks and bands of coal.	2.3	-

TABLE B-1. - Logs of core-drill holes, Kukpowruk River and Cape Beaufort areas--Continued

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
		HOLE 4--Continued		
104.6	104.8	Coal, mostly dull.	0.2	S27.
104.8	107.6	Coal, bright.	2.8	Do.
107.6	108.6	Silty shale with occasional streaks and inclusions of coal.	1.0	-
108.6	109.4	Coal, several bone inclusions.	.8	Not sampled.
109.4	115.4	Silty shale with interbedded thin fine-grained sandstone beds, occasional streaks and inclusions of coal to 113.5 ft.	4.5	-
115.4	156.0	Silty shale with interbedded thin beds of fine-grained sandstone.	.0	Drilled with a noncoring tricone rock bit.
156.0	156.4	Silty shale.	.3	-
156.4	189.2	Silty shale with interbedded thin beds of fine-grained sandstone.	.0	Drilled with a noncoring tricone rock bit.
189.2	189.5	Silty shale.	.0	-
189.5	191.2	Silty shale, occasional thin coaly streaks and bands.	1.7	-
191.2	200.7	Coal, mostly bright, occasional very thin, bony streaks and partings, 1/4-in bony parting at 193.9 ft, included in sample.	9.5	S28: 1. Bedding angle 7°.
200.7	210.2	Coal, bright, occasional very thin, bony partings and streaks.	9.5	S28: 2.
210.2	212.5	Fine-grained sandstone, small amount of bony coal upper part.	1.5	-

Location : Cape Beaufort area, see figure 4
Elevation of collar: 197 ft (approx.)
Dip of hole : Vertical
Dates drilled : August 13-20, 1966

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
		HOLE 5		
0.0	1.0	Soil and tundra overburden.	0.0	Drilled with a noncoring drag bit.
1.0	6.0	Gravel overburden, pebbles and cobbles mostly sandstone.	.0	Do.

TABLE B-1. - Logs of core-drill holes, Kukpowruk River and Cape Beaufort areas--Continued

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
		HOLE 5--Continued		
6.0	12.0	Sandstone, medium-grained.	0.0	Drilled with a noncoring drag bit.
12.0	20.5	Medium-grained sandstone--granitic appearing, occasional coaly streaks and thin bands.	6.2	Appears weathered.
20.5	23.7	Silty shale, occasional coal streaks and thin bands, occasional medium-grained sandstone bands.	2.5	Bedding angle 25°.
23.7	25.7	Fine-grained sandstone, carbonaceous streaks.	2.0	-
25.7	44.5	Silty shale with occasional interbedded fine-grained sandstone bands--light gray color.	17.7	Silty shale--weathers rapidly to small pieces.
44.5	45.0	Fine-grained sandstone, buff color.	.5	-
45.0	61.9	Silty shale, interbedded with fine-grained sandstone--silty shale predominant, two 1/2-in coal bands near 48.1 ft, light gray color.	16.7	Silty shale--weathers rapidly to small pieces.
61.9	76.0	Fine-grained sandstone interbedded with silty shale--fine-grained sandstone predominates, light gray color.	13.3	Bedding angle 19°.
76.0	82.5	Silty shale interbedded with fine-grained sandstone--some slightly carbonaceous, occasional coal streaks and thin bands.	6.5	Silty shale weathers rapidly to small pieces. Bedding angle 16°.
82.5	84.5	Shale--light gray color, one small coal inclusion.	2.0	-
84.5	94.7	Silty shale interbedded with fine-grained sandstone, some at lower 2 ft not silty, but instead a straight clay, occasional thin bands coal lower 0.5 ft.	9.8	-
94.7	96.5	Coal--some appears slightly bony.	1.8	S29.
96.5	96.7	Bony coal.	.2	-
96.7	102.9	Fine-grained sandstone, very light gray color, occasional coal streaks and inclusions--grades to carbonaceous silty shale lower 0.6 ft.	6.2	-
102.9	103.5	Coal, bright.	.6	Not sampled.
103.5	103.8	Bony coal.	.3	-

TABLE B-1. - Logs of core-drill holes, Kukpowruk River and Cape Beaufort areas--Continued

Depth, ft		Material	Core recovery, ft	Remarks
From	To			
HOLE 5--Continued				
103.8	105.9	Carbonaceous shale.	2.1	-
105.9	118.1	Silty shale interbedded with fine-grained sandstone, occasional coal streaks and bands.	11.8	-
118.1	170.1	Fine-grained sandstone--light gray color, occasional coaly streaks and banding.	51.8	Bedding angles 20° at 136 ft, 30° at 147 ft, 23° at 163 ft.
170.1	177.5	Fine-grained sandstone--coaly streaks banding and inclusions, clay inclusions.	7.4	-
177.5	182.7	Silty shale interbedded with very fine-grained sandstone--light gray color.	5.2	-
182.7	197.8	Fine- to medium-grained sandstone--coal streaks, bands, and inclusions, one large silty shale inclusion at 187.2 ft.	15.0	-
197.8	198.6	Coal.	.2	Core loss assumed to be coal--not sampled; see S17 for correlation.
198.6	198.8	Interbedded coal and bony coal.	.2	-
198.8	199.3	Carbonaceous shale.	.5	-
199.3	199.4	Bony coal.	.1	-
199.4	200.9	Coal--appeared slightly high ash.	1.5	S30: 1.
200.9	201.2	Bony coal grading to carbonaceous shale.	.3	Bedding angle 21°.
201.2	203.4	Shale, occasional thin coal bands (1/16 in), and inclusions.	2.0	-
203.4	203.7	Bony coal.	.3	-
203.7	209.3	Coal--some appeared slightly high ash, occasional graphitic appearance.	5.6	S30: 2.
209.3	209.4	Bony coal.	.1	-
209.4	217.5	Shale and silty shale grading to very fine-grained sandstone lower 1.5 ft, upper 0.5 ft slightly carbonaceous.	7.5	-

APPENDIX C.--COKING STUDIES

TABLE C-1. - Analyses of coal samples from Kokolik River area, 1964 series

Sample No.	9					
Sack No.	1		2		3	
Basis	As-received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	4.4	-	5.3	-	5.7	-
Volatile matter	38.9	42.1	33.9	38.9	32.6	40.2
Fixed carbon	53.4	57.9	53.2	61.1	48.4	59.8
Ash	3.3	-	7.6	-	13.3	-
Ultimate analysis, pct:						
Hydrogen	5.7	5.6	5.3	5.4	5.2	5.6
Carbon	76.9	83.3	73.1	83.9	67.7	83.6
Nitrogen	1.9	2.1	1.7	2.0	1.7	2.1
Oxygen	11.9	8.7	12.1	8.4	11.9	8.4
Sulfur	.3	.3	.2	.3	.2	.3
Ash	3.3	-	7.6	-	13.3	-
Heating value....Btu/lb..	13,750	14,900	12,870	14,780	12,010	14,830
Sample No.	9					
Sack No.	4		5		6	
Basis	As-received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	7.0	-	8.0	-	12.1	-
Volatile matter	31.4	35.8	31.5	35.1	28.5	34.2
Fixed carbon	56.3	64.2	58.2	64.9	54.7	65.8
Ash	5.3	-	2.3	-	4.7	-
Ultimate analysis, pct:						
Hydrogen	5.3	5.1	5.3	4.9	5.2	4.6
Carbon	73.8	84.2	73.7	82.2	63.6	76.4
Nitrogen	1.8	2.0	1.7	1.9	1.6	2.0
Oxygen	13.5	8.3	16.5	10.5	24.5	16.6
Sulfur	.3	.4	.5	.5	.4	.4
Ash	5.3	-	2.3	-	4.7	-
Heating value....Btu/lb..	12,730	14,520	12,760	14,220	11,010	13,230

TABLE C-1. - Analyses of coal samples from Kokolik River area, 1964 series--Continued

Sample No.	9		10			
Sack No.	7		1		2	
Basis	As-received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	7.3	-	12.6	-	17.8	-
Volatile matter	34.6	39.8	28.7	35.2	30.2	38.2
Fixed carbon	52.3	60.2	52.9	64.8	48.8	61.8
Ash	5.8	-	5.8	-	3.2	-
Ultimate analysis, pct:						
Hydrogen	5.5	5.4	5.1	4.6	5.6	4.5
Carbon	72.0	82.9	63.4	77.7	59.4	75.2
Nitrogen	1.7	2.0	2.0	2.4	1.7	2.2
Oxygen	14.7	9.4	23.3	14.8	29.9	17.8
Sulfur	.3	.3	.4	.5	.2	.3
Ash	5.8	-	5.8	-	3.2	-
Heating value....Btu/lb..	12,650	14,560	10,740	13,160	10,030	12,690

Sample No.	10				11	
Sack No.	3		4		1-5	
Basis	As-received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	16.3	-	15.0	-	14.3	-
Volatile matter	30.3	37.0	30.7	36.9	30.6	38.5
Fixed carbon	51.7	63.0	52.4	63.1	48.8	61.5
Ash	1.7	-	1.9	-	6.3	-
Ultimate analysis, pct:						
Hydrogen	5.5	4.5	5.4	4.5	5.0	4.4
Carbon	61.8	75.3	62.8	75.6	59.2	74.5
Nitrogen	1.8	2.2	1.8	2.1	2.1	2.6
Oxygen	29.0	17.7	27.8	17.4	26.8	17.8
Sulfur	.2	.3	.3	.4	.6	.7
Ash	1.7	-	1.9	-	6.3	-
Heating value....Btu/lb..	10,430	12,720	10,460	12,590	9,850	12,400

TABLE C-1. - Analyses of coal samples from Kokolik River area, 1964 series--Continued

Sample No	12		13			
Sack No	1-5		1-2		3-7	
Basis	As-Received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	22.6	-	22.1	-	14.2	-
Volatile matter	29.5	41.0	30.4	41.3	30.5	36.8
Fixed carbon	42.5	59.0	43.1	58.7	52.4	63.2
Ash	5.4	-	4.4	-	2.9	-
Ultimate analysis, pct:						
Hydrogen	5.6	4.3	5.5	4.1	5.2	4.4
Carbon	52.3	72.7	52.0	70.8	62.6	75.5
Nitrogen	1.8	2.5	1.8	2.5	2.1	2.5
Oxygen	34.6	20.1	35.7	21.8	26.9	17.2
Sulfur	.3	.4	.6	.8	.3	.4
Ash	5.4	-	4.4	-	2.9	-
Heating value....Btu/lb..	8,600	11,950	8,500	11,560	10,460	12,620

Sample No	14			
Sack No	1-3		4-7	
Basis	As-received	Maf	As-received	Maf
Proximate analysis, pct:				
Moisture	21.5	-	16.7	-
Volatile matter	25.8	34.9	27.0	34.5
Fixed carbon	48.2	65.1	51.4	65.5
Ash	4.5	-	4.9	-
Ultimate analysis, pct:				
Hydrogen	5.6	4.3	5.5	4.7
Carbon	57.3	77.5	62.2	79.3
Nitrogen	1.6	2.1	1.6	2.0
Oxygen	30.7	15.7	25.6	13.8
Sulfur	.3	.4	.2	.2
Ash	4.5	-	4.9	-
Heating value....Btu/lb..	9,560	12,920	10,570	13,480

TABLE C-2. - Analyses of coal samples from Cape Beaufort area, 1964 series

Sample No.	16				17	
Sack No.	1-4		5-7		1	
Basis	As-received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	10.9	-	11.1	-	12.8	-
Volatile matter	29.1	38.5	29.6	38.1	25.4	32.1
Fixed carbon	46.4	61.5	48.2	61.9	53.8	67.9
Ash	13.6	-	11.1	-	8.0	-
Ultimate analysis, pct:						
Hydrogen	5.1	5.1	5.1	4.9	4.9	4.4
Carbon	58.7	77.7	60.1	77.3	63.4	80.1
Nitrogen	1.8	2.4	1.9	2.4	1.7	2.1
Oxygen	20.6	14.5	21.6	15.1	21.4	12.7
Sulfur	.2	.3	.2	.3	.6	.7
Ash	13.6	-	11.1	-	8.0	-
Heating value....Btu/lb..	10,000	13,250	10,210	13,120	10,550	13,320
Sample No.	17				18	
Sack No.	2-3		4-9		1-5	
Basis	As-received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	7.3	-	8.8	-	19.8	-
Volatile matter	21.9	27.7	31.0	35.5	26.2	34.9
Fixed carbon	57.1	72.3	56.2	64.5	48.9	65.1
Ash	13.7	-	4.0	-	5.1	-
Ultimate analysis, pct:						
Hydrogen	3.8	3.8	5.1	4.7	5.8	4.8
Carbon	64.8	82.0	67.9	77.9	58.6	78.0
Nitrogen	1.5	1.9	2.0	2.3	1.9	2.6
Oxygen	16.0	12.0	20.8	14.9	28.3	14.2
Sulfur	.2	.3	.2	.2	.3	.4
Ash	13.7	-	4.0	-	5.1	-
Heating value....Btu/lb..	10,520	13,320	11,600	13,300	10,120	13,480

TABLE C-2. - Analyses of coal samples from Cape Beaufort area, 1964 series--Continued

Sample No.	19		20		21	
Sack No.	1-4		1-5		1-3	
Basis	As-received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	6.3	-	17.3	-	11.9	-
Volatile matter	31.3	37.6	24.5	37.2	22.0	31.6
Fixed carbon	51.9	62.4	41.4	62.8	47.5	68.4
Ash	10.5	-	16.8	-	18.6	-
Ultimate analysis,pct:						
Hydrogen	5.0	5.1	4.4	3.7	3.8	3.6
Carbon	66.5	79.9	50.0	75.8	53.5	77.0
Nitrogen	2.2	2.7	1.3	2.0	1.3	1.8
Oxygen	15.5	11.9	27.4	18.3	22.7	17.4
Sulfur	.3	.4	.1	.2	.1	.2
Ash	10.5	-	16.8	-	18.6	-
Heating value....Btu/lb.	11,510	13,830	7,970	12,100	8,530	12,270

Sample No.	21					
Sack No.	4-6		7-8		9	
Basis	As-received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	15.8	-	15.6	-	17.0	-
Volatile matter	29.0	38.3	28.5	39.8	29.3	39.5
Fixed carbon	46.6	61.7	43.2	60.2	45.0	60.5
Ash	8.6	-	12.7	-	8.7	-
Ultimate analysis, pct:						
Hydrogen	4.9	4.1	4.8	4.3	5.2	4.4
Carbon	56.4	74.6	53.9	75.1	56.0	75.4
Nitrogen	1.4	1.9	1.4	2.0	1.6	2.1
Oxygen	28.6	19.2	27.0	18.3	28.3	17.8
Sulfur	.1	.2	.2	.3	.2	.3
Ash	8.6	-	12.7	-	8.7	-
Heating value....Btu/lb.	9,280	12,270	8,890	12,400	9,280	12,490

TABLE C-2. - Analyses of coal samples from Cape Beaufort area, 1964 series--Continued

Sample No.	21					
Sack No.	10		11		12-13	
Basis	As-received	Maf	As-received	Maf	As-received	Maf
Proximate analysis, pct:						
Moisture	16.2	-	16.3	-	17.9	-
Volatile matter	27.6	39.9	27.2	42.6	30.9	40.3
Fixed carbon	41.5	60.1	36.7	57.4	45.8	59.7
Ash	14.7	-	19.8	-	5.4	-
Ultimate analysis, pct:						
Hydrogen	4.8	4.4	4.8	4.7	5.4	4.4
Carbon	52.6	76.1	47.3	74.0	57.0	74.3
Nitrogen	1.4	2.0	1.4	2.2	1.6	2.1
Oxygen	26.4	17.3	26.5	18.8	30.4	18.9
Sulfur	.1	.2	.2	.3	.2	.3
Ash	14.7	-	19.8	-	5.4	-
Heating value....Btu/lb..	8,720	12,620	7,930	12,410	9,410	12,270

TABLE C-3. - Selected properties of samples obtained in 1964 field season

(Moisture and ash free)

Sample and sack	Heating value, Btu/lb	Volatile matter, pct	Oxygen content, pct	Free swelling index	Rank[1]
KOKOLIK RIVER AREA SAMPLES					
S9:					
1...............	14,900	42.1	8.7	5	High-volatile bituminous.
2...............	14,780	38.9	8.4	5	Do.
3...............	14,830	40.2	8.4	2	Do.
4...............	14,520	35.8	8.3	1½	Do.
5...............	14,220	35.1	10.5	NA	Do.
6...............	13,230	34.2	16.6	NA	Do.
7...............	14,560	39.8	9.4	2½	Do.
S10:					
1...............	13,160	35.2	14.8	NA	Subbituminous.
2...............	12,690	38.2	17.8	NA	Do.
3...............	12,720	37.0	17.7	NA	Do.
4...............	12,590	36.9	17.4	NA	Do.
S11: 1-5.........	12,400	38.5	17.8	NA	Do.
S12: 1-5.........	11,950	41.0	20.1	NA	Do.
S13:					
1-2.............	11,560	41.3	21.8	NA	Do.
3-7.............	12,620	36.8	17.2	NA	Do.
S14:					
1-3.............	12,920	34.9	15.7	NA	Do.
4-7.............	13,480	34.5	13.8	NA	Do.
CAPE BEAUFORT AREA SAMPLES					
S16:					
1-4.............	13,250	38.5	14.5	NA	High-volatile bituminous.
5-7.............	13,120	38.1	15.1	NA	Do.
S17:					
1...............	13,320	32.1	12.7	NA	Do.
2-3.............	13,320	[2]27.7	12.0	NA	Do.
4-9.............	13,300	35.5	14.9	NA	Do.
S18: 1-5.........	13,480	34.9	14.2	NA	Subbituminous.
S19: 1-4.........	13,830	37.6	11.9	NA	High-volatile bituminous.
S20: 1-5.........	12,100	37.2	18.3	NA	Subbituminous.
S21:					
1-3.............	12,270	31.6	17.4	NA	Do.
4-6.............	12,270	38.3	19.2	NA	Do.
7-8.............	12,400	39.8	18.3	NA	Do.
9...............	12,490	39.5	17.8	NA	Do.
10..............	12,620	39.9	17.3	NA	Do.
11..............	12,410	42.6	18.8	NA	Do.
12-13...........	12,270	40.3	18.9	NA	Do.

NA: Nonagglomerating--indicative of no caking properties.

[1] Rank determinations were made as prescribed by the American Society for Testing and Materials and are shown here for comparative purposes, though ASTM Desgination D388-66 states in part: "Analyses of samples from outcrops or from weathered or oxidized coal shall not be used for classification by rank."

[2] See text footnotes 17 and 22.

TABLE C-4. - Chemical analyses and plasticity data for composites prepared from parts of sample 9, Kokolik River area

Items	Composites					
	1, sacks 1-7	2, sacks 1-5, and 7	3, sacks 1-4, 6, and 7	4, sacks 1-4, and 7	5, sacks 1, 2, 6, and 7	6, sacks 1, 2, and 7
As received:						
Proximate analysis, pct:						
Moisture	6.0	4.9	5.7	4.4	6.0	4.4
Volatile matter	34.0	34.3	34.2	35.0	34.6	36.4
Fixed carbon	54.8	55.3	54.1	54.5	54.5	53.9
Ash	5.2	5.5	6.0	6.1	4.9	5.3
Ultimate analysis, pct:						
Hydrogen	5.2	5.3	5.2	5.3	5.4	5.5
Carbon	73.8	74.7	73.2	74.5	73.3	75.3
Nitrogen	1.3	1.3	1.3	1.3	1.3	1.4
Oxygen	14.1	12.8	14.0	12.5	14.8	12.2
Sulfur	.4	.4	.3	.3	.3	.3
Ash	5.2	5.5	6.0	6.1	4.9	5.3
Heating value Btu/lb.	12,830	13,120	12,770	13,230	12,870	13,370
Moisture and ash free:						
Proximate analysis, pct:						
Volatile matter	38.3	38.4	38.7	39.1	38.8	40.2
Fixed carbon	61.7	61.6	61.3	60.9	61.2	59.8
Ultimate analysis, pct:						
Hydrogen	5.2	5.3	5.2	5.4	5.3	5.5
Carbon	83.1	83.4	82.9	83.3	82.1	83.4
Nitrogen	1.4	1.4	1.4	1.5	1.5	1.5
Oxygen	9.9	9.5	10.1	9.5	10.8	9.3
Sulfur	.4	.4	.4	.3	.3	.3
Heating value Btu/lb.	14,440	14,650	14,460	14,780	14,430	14,800
Fusibility of ash, ° F:						
Initial deformation temperature	2,310	-	-	2,260	-	-
Softening temperature	2,360	-	-	2,310	-	-
Fluid temperature	2,520	-	-	2,390	-	-
Plasticity data:						
Free swelling index	2	2	1½	3	2	4
Gieseler plastometer results:						
Maximum fluidity ddpm[1]	1.70	1.80	2.55	4.60	2.30	13.80
Temperature, ° C, at:						
Initial movement[2]	384	387	387	384	387	378
Rate of 5.0 ddpm rising	-	-	-	-	-	427
Maximum fluidity	429	426	433	441	436	441
Rate of 5.0 ddpm falling	-	-	-	-	-	450
Solidification	463	466	462	468	463	469
Plastic range[3] ° C.	79	79	75	84	76	91
Fusion range[4] ° C.	-	-	-	-	-	23

[1] Dial divisions per minute.
[2] Continuous movement of 0.1 ddpm.
[3] Initial movement to solidification.
[4] 5.0 ddpm rising to 5.0 ddpm falling.

TABLE C-5. - Carbonization assays at 500° C: Composites from sample 9, Kokolik River area

Assays	Composite 1, blend of sacks 1-7	Composite 4, blend of sacks 1-4, 7
Carbonization yields, maf, pct:		
Char	77.3	76.8
Water formed	4.9	3.7
Tar, dry	10.1	12.4
Light oil	1.2	1.5
Gas	6.2	5.7
Hydrogen sulfide	.2	.1
Total	99.9	100.2
Gas composition (O_2- and N_2-free), pct:		
CO_2	13.6	9.5
Illuminants	2.3	2.7
CO	9.1	8.1
H_2	15.0	14.9
CH_4	50.2	54.0
C_2H_6	9.8	10.8
Net gas yield...scf/lb of maf coal	1.119	1.101
Heat in gas...Btu/lb of maf coal	911	964
Heating value of gas, calculated...Btu/scf	814	876
Specific gravity of gas, calculated (air = 1)	.717	.683
Analysis of coal, maf:		
Proximate analysis, pct:		
Volatile matter	38.3	39.1
Fixed carbon	61.7	60.9
Ultimate analysis, pct:		
Hydrogen	5.2	5.4
Carbon	83.1	83.3
Nitrogen	1.4	1.5
Oxygen	9.9	9.5
Sulfur	.4	.3
Heating value...Btu/lb	14,440	14,780
Analysis of assay char, mf:[1]		
Proximate analysis, pct:		
Volatile matter	13.4	12.7
Fixed carbon	79.0	79.3
Ash	7.6	8.0
Heating value...Btu/lb	13,650	13,580

[1]Moisture-free.

TABLE C-6. - Coking test data for sample 9 (Kokolik River area) blended with two medium-volatile coals, and Fontana blend, at 900° C in a 50-lb retort

Test data	Sample 9 blends: Full seam, with: 15 pct blending coals[1]	Sample 9 blends: Full seam, with: 30 pct blending coals[1]	Sample 9 blends: Coking portion of seam only, with 15 pct blending coals[1]	Fontana blend[2]
50-lb test No.	CP-149	CP-150	CP-148	CP-136
Coal blend data:				
Free swelling index	2½	3½	4	-
Gieseler plastometer:				
Maximum fluidity ... ddpm..	1.7	2.3	7.1	-
Temperature at, ° C:				
Initial movement (0.1 ddpm)	373	384	378	-
Maximum fluidity	433	442	438	-
Solidification	469	472	468	-
Oxygen, maf ... pct..	9.4	8.2	8.6	-
Heating value, moist, ash-free..Btu/lb..	13,790	14,140	14,190	-
Calculated coking index[3]	1.17	1.30	1.24	-
Coke data:				
Yield, pct:				
As-carbonized	66.6	68.8	67.2	-
Moisture-free	70.8	72.3	70.5	68.0
Moisture- and ash-free	68.7	70.1	67.9	-
Average size ... in..	1.87	1.88	1.76	1.64
Apparent specific gravity	.77	.81	.79	.66
True specific gravity	1.91	1.91	1.90	-
Cell space ... pct..	59.5	57.8	58.7	-
Columbia tumbler test:				
Retained on ¼-in screen (¼-in index) ... pct..	74.5	80.5	82.4	88.7
Tumbler size stability[4] ... pct..	42.1	47.7	49.8	56.8
Modified coke strength index[5]	111.4	119.2	118.3	112.4
Net resultant coke factor[6]	0.51	0.60	0.57	-

[1] Blending coals were equal parts of Coal Basin (Pitkin County, Colo.) and Red Indian (Wyoming County, W. Va.) coals.

[2] Eighty-five percent of Sunnyside seam (Sunnyside No. 1 mine, Dragerton, Carbon County, Utah--high-volatile A bituminous rank) plus 7.5 pct each of blending coals indicated in footnote 1.

[3] Calculated coking index of coal is defined as: $(22/O_2$, maf basis) + $(2H_2/O_2$, maf basis) + (0.769 FC/VM) + (Heating value, Btu/lb on moist, ash-free basis)/13,600, all divided by 5.

[4] Tumbler size stability is calculated from tumbler data and is defined as:

$$\frac{100 \times \text{Average size of tumbler resultant}}{\text{Average size of tumbler charge}}.$$

(Tumbler size stability is not identical with ASTM tumbler stability factor.)

[5] Modified coke strength index is calculated as follows:

0.284 × (cumulative coke percentage retained on 1.50-in screen)
+ .202 × (cumulative coke percentage retained on 1.00-in screen)
+ .902 × (cumulative tumbler resultant percentage on 1.00-in screen)
+ .259 × (cumulative tumbler resultant percentage on 0.25-in screen)
+ .269 × (tumbler size stability).

[6] Net resultant coke factor is defined as: (Percent coke yield, ash-free) × (average size of coke, in) × (tumbler size stability, pct) × 10^{-4}.

TABLE C-7. - Analyses of drill hole and surface samples: Kukpowruk River area

Test data	19- to 20-ft seam		2.5- to 3-ft seam (over-lying), full	19- to 20-ft seam		2.5- to 3-ft seam (over-lying), full
	Upper half	Lower half		Upper half	Lower half	
Drill hole No	1	1	2	2	2	3
Sample No	22: 1	22: 2	23	24: 1	24: 2	25
As received:						
Proximate analysis, pct:						
Moisture	4.4	3.8	3.9	4.4	3.2	3.5
Volatile matter	32.3	38.6	39.1	32.0	39.1	38.4
Fixed carbon	58.4	54.6	50.0	58.6	55.3	54.4
Ash	4.9	3.0	7.0	5.0	2.4	3.7
Ultimate analysis, pct:						
Hydrogen	5.0	5.6	5.6	5.1	5.6	5.6
Carbon	75.4	77.0	73.4	75.8	78.6	77.2
Nitrogen	1.2	1.4	1.4	1.3	1.4	1.4
Oxygen	13.3	12.8	12.3	12.6	11.8	11.7
Sulfur	.2	.2	.3	.2	.2	.4
Ash	4.9	3.0	7.0	5.0	2.4	3.7
Heating value...Btu/lb	13,140	13,570	13,100	13,120	13,830	13,590
Moisture and ash free:						
Proximate analysis, pct:						
Volatile matter	35.6	41.5	43.9	35.3	41.4	41.3
Fixed carbon	64.4	58.5	56.1	64.7	58.6	58.7
Ultimate analysis, pct:						
Hydrogen	5.0	5.6	5.8	5.1	5.6	5.6
Carbon	83.1	82.6	82.4	83.7	83.2	83.3
Nitrogen	1.4	1.5	1.6	1.4	1.5	1.5
Oxygen	10.3	10.1	9.9	9.6	9.5	9.2
Sulfur	.2	.2	.3	.2	.2	.4
Heating value...Btu/lb	14,500	14,560	14,710	14,480	14,660	14,660
Fusibility of ash, ° F:						
Initial deformation	2,200	2,300	2,460	2,300	2,080	2,300
Softening	2,290	2,350	2,620	2,350	2,140	2,400
Fluid	2,680	2,570	2,840	2,640	2,800	2,860

TABLE C-7. - Analyses of drill hole and surface samples: Kukpowruk River area--Continued

Test data	19- to 20-ft seam		
	Upper half	Lower half	Full seam
SURFACE SAMPLES--1963 SERIES[1]			
Sample No........................	7 and 8[2]	7 and 8	7 and 8
As carburized:			
Proximate analysis, pct:			
Moisture......................	7.4	8.3	7.9
Volatile matter...............	37.5	31.9	34.5
Fixed carbon..................	52.7	55.6	54.2
Ash...........................	2.4	4.2	3.4
Ultimate analysis, pct:			
Hydrogen......................	5.8	5.3	5.5
Carbon........................	75.3	73.3	74.2
Nitrogen......................	1.4	1.1	1.3
Oxygen........................	14.8	15.8	15.3
Sulfur........................	.3	.3	.3
Ash...........................	2.4	4.2	3.4
Heating value...........Btu/lb..	13,310	12,720	13,010
Moisture and ash free:			
Proximate analysis, pct:			
Volatile matter...............	41.6	36.5	39.0
Fixed carbon..................	58.4	63.5	61.0
Ultimate analysis, pct:			
Hydrogen......................	5.5	5.0	5.2
Carbon........................	83.6	83.8	83.8
Nitrogen......................	1.6	1.3	1.4
Oxygen........................	9.0	9.6	9.3
Sulfur........................	.3	.3	.3
Heating value...........Btu/lb..	14,760	14,540	14,650
Fusibility of ash, ° F:			
Initial deformation............	([3])	([3])	([3])
Softening......................	([3])	([3])	([3])
Fluid..........................	([3])	([3])	([3])

[1] See BuMines Rept. of Inv. 6767.

[2] See figure 13, p. 51, of BuMines Rept. of Inv. 6767. Parts 1-5 of S7 are considered to correlate with "upper half;" remainder to correlate with "lower half."

[3] Cannot be composited.

TABLE C-7. - Analyses of drill hole and surface samples: Kukpowruk River area--Continued

Test data	19- to 20-ft seam		2.5- to 3-ft seam (overlying), full	19- to 20-ft seam	
	Upper	Lower		Upper	Lower
Drill hole No	3	3	4	4	4
Sample No	26: 1	26: 2	27	28: 1	28: 2
As received:					
Proximate analysis, pct:					
Moisture	3.5	3.3	2.9	4.2	2.9
Volatile matter	33.0	39.6	39.3	32.1	39.4
Fixed carbon	58.5	54.7	53.2	58.7	54.8
Ash	5.0	2.4	4.6	5.0	2.9
Ultimate analysis, pct:					
Hydrogen	5.0	5.6	5.6	5.0	5.6
Carbon	76.3	78.6	76.8	76.0	78.3
Nitrogen	1.3	1.4	1.4	1.3	1.4
Oxygen	12.2	11.8	11.3	12.5	11.6
Sulfur	.2	.2	.3	.2	.2
Ash	5.0	2.4	4.6	5.0	2.9
Heating value.........Btu/lb..	13,230	13,810	13,650	13,130	13,820
Moisture and ash free:					
Proximate analysis, pct:					
Volatile matter	36.0	42.0	42.5	35.3	41.9
Fixed carbon	64.0	58.0	57.5	64.7	58.1
Ultimate analysis, pct:					
Hydrogen	5.0	5.6	5.7	5.0	5.6
Carbon	83.4	83.3	83.0	83.7	83.1
Nitrogen	1.4	1.5	1.6	1.4	1.5
Oxygen	10.0	9.4	9.4	9.7	9.6
Sulfur	.2	.2	.3	.2	.2
Heating value.........Btu/lb..	14,450	14,640	14,760	14,460	14,670
Fusibility of ash, ° F:					
Initial deformation	2,210	2,180	2,390	2,140	2,080
Softening	2,360	2,270	2,440	2,190	2,130
Fluid	2,910+	2,350	2,640	2,460	2,400

TABLE C-8. - Analyses of drill hole and surface samples: Cape Beaufort area

Test data	1.7-ft seam (overlying)	10.7-ft seam Upper 1.4 ft	10.7-ft seam Lower 5.2 ft	Correlates with S30:1	Correlates with S30:2
Sample source	Drill hole 5	Drill hole 5	Drill hole 5	Surface	Surface
Sample No	29	30: 1	30: 2	17: 2, 3[1]	17: 4-9[1]
As received:					
Proximate analysis, pct:					
Moisture	2.0	2.6	2.7	7.3	8.8
Volatile matter	33.1	27.5	37.2	21.9	31.0
Fixed carbon	52.9	53.2	55.4	57.1	56.2
Ash	12.0	6.7	4.7	13.7	4.0
Ultimate analysis, pct:					
Hydrogen	4.8	4.4	5.3	3.8	5.1
Carbon	71.9	76.8	77.7	64.8	67.9
Nitrogen	1.3	1.3	1.6	1.5	2.0
Oxygen	9.7	10.5	10.5	16.0	20.8
Sulfur	.3	.3	.2	.2	.2
Ash	12.0	6.7	4.7	13.7	4.0
Heating value......Btu/lb..	12,570	13,100	13,590	10,520	11,600
Moisture and ash free:					
Proximate analysis, pct:					
Volatile matter	38.5	30.4	40.2	27.7	35.5
Fixed carbon	61.5	69.6	59.8	72.3	64.5
Ultimate analysis, pct:					
Hydrogen	5.4	4.5	5.4	3.8	4.7
Carbon	83.6	84.8	84.0	82.0	77.9
Nitrogen	1.5	1.4	1.7	1.9	2.3
Oxygen	9.2	9.0	8.7	12.0	14.9
Sulfur	.3	.3	.2	.3	.2
Heating value......Btu/lb..	14,610	14,450	14,680	13,320	13,300
Fusibility of ash, ° F:					
Initial deformation	2,400	2,080	2,280	-	-
Softening	2,430	2,130	2,450	-	-
Fluid	2,460	2,210	2,720	-	-

[1] See figure 5 and table C-2.

TABLE C-9. - Analyses of several U.S. commercial coking coals

Analyses	Sunnyside, Carbon County, Utah	Coal Basin, Pitkin County, Colo.	Red Indian, Wyoming County, W. Va.	York Canyon, Colfax County, N. Mex.	Arkwright, Monongalia County, W. Va.
As received:					
Proximate analysis, pct:					
Moisture	6.0	0.6	3.8	2.9	1.6
Volatile matter	37.1	22.8	22.1	36.0	38.3
Fixed carbon	51.2	69.2	71.0	53.6	52.7
Ash	5.7	7.4	3.1	7.5	7.4
Ultimate analysis, pct:					
Hydrogen	5.7	4.9	5.4	5.4	5.2
Carbon	72.9	81.7	83.7	75.9	75.4
Nitrogen	1.6	2.0	1.4	1.7	1.5
Oxygen	13.4	3.4	6.3	9.1	8.3
Sulfur	.7	.6	.5	.4	2.2
Ash	5.7	7.4	7.5	7.5	7.4
Heating value...Btu/lb	13,110	14,450	14,620	13,620	13,600
Moisture and ash free:					
Proximate analysis, pct:					
Volatile matter	42.0	24.8	23.7	40.1	42.1
Fixed carbon	58.0	75.2	76.3	59.9	57.9
Ultimate analysis, pct:					
Hydrogen	5.7	5.2	5.0	5.7	5.5
Carbon	82.5	88.9	89.8	84.6	82.9
Nitrogen	1.8	2.1	1.6	1.9	1.6
Oxygen	9.2	3.2	3.1	7.3	7.6
Sulfur	.8	.6	.5	.5	2.4
Heating value...Btu/lb	14,840	15,700	15,690	15,190	14,930
Rank	hvab	mvb	mvb	hvab	hvab
Free swelling index	4	9½	9	7½	8½

TABLE C-10. - Free-swelling and Gieseler plasticity tests for Kukpowruk River and Cape Beaufort area samples, 1966 series

Test data	19- to 20-ft seam			2.5- to 3.0-ft seam (overlying), full seam	19- to 20-ft seam			2.5- to 3.0-ft seam (overlying), full seam	19- to 20-ft seam		
	Upper half	Lower half	Full seam		Upper half	Lower half	Full seam		Upper half	Lower half	Full seam
	KUKPOWRUK RIVER AREA SAMPLES										
Drill hole No................	1	1	1	2	2	2	2	3	3	3	3
Sample No.....................	22: 1	22: 2	22	23	24: 1	24: 2	24	25	26: 1	26: 2	26
Free swelling index...........	2½	4½	3	4	2½	4½	3½	3½	2½	4	3½
Gieseler plastometer results:											
Maximum fluidity......ddpm..	0.7	7.0	2.4	11.7	0.8	10.6	2.8	7.2	0.8	19.7	4.0
Temperature, ° C, at:											
Initial movement..........	402	376	384	374	400	372	385	378	399	371	382
Rate of 5.0 ddpm, rising..	-	423	-	420	-	418	-	425	-	414	-
Maximum fluidity..........	431	428	428	432	428	429	428	432	428	428	430
Rate of 5.0 ddpm, falling.	-	436	-	441	-	438	-	438	-	441	-
Solidification............	452	456	453	462	451	456	458	461	450	458	456
Plastic range..........° C..	50	80	69	88	52	84	73	83	51	87	74
Fusion range...........° C..	-	13	-	21	-	20	-	13	-	27	-

Test data	2.5- to 3.0-ft seam (overlying), full seam	19- to 20-ft seam			19- to 20-ft seam, composite	1.7-ft seam (overlying), full seam	10.7-ft seam	
		Upper half	Lower half	Full seam			Upper 1.4 ft	Lower 5.2 ft
	KUKPOWRUK RIVER AREA SAMPLES					CAPE BEAUFORT AREA SAMPLES		
Drill hole No................	4	4	4	4	Surface samples	5	5	5
Sample No.....................	27	28: 1	28: 2	28	7 and 8 (1963 series)	29	30: 1	30: 2
Free swelling index...........	4	2	4½	3½	5	2	1½	4½
Gieseler plastometer results:								
Maximum fluidity......ddpm..	10.0	0.8	14.9	3.4	14	4.7	0.2	11.0
Temperature, ° C, at:								
Initial movement..........	376	400	370	386	378	392	424	378
Rate of 5.0 ddpm, rising..	422	-	416	-	426	-	-	420
Maximum fluidity..........	432	427	430	430	435	434	434	431
Rate of 5.0 ddpm, falling.	440	-	440	-	444	-	-	442
Solidification............	458	452	456	454	462	464	452	461
Plastic range..........° C..	82	52	86	68	84	72	28	83
Fusion range...........° C..	18	-	24	-	18	-	-	22

TABLE C-11. - Free-swelling and Gieseler plasticity tests for selected commercial coking coals, 1966 series

Test data	Sunnyside, Carbon County, Utah	Coal Basin, Pitkin County, Colo.	York Canyon, Colfax County, N. Mex.	Arkwright, Monongalia County, W. Va.
Free swelling index..............	4	9½	7½	8½
Gieseler plastometer results:				
Maximum fluidity..........ddpm..	41	1,160	3,700	16,900
Temperature, ° C, at:				
Initial movement.............	364	388	350	329
Rate of 5.0 ddpm, rising......	414	422	401	391
Maximum fluidity.............	432	463	434	419
Rate of 5.0 ddpm, falling.....	448	493	463	474
Solidification...............	462	505	474	485
Plastic range.............° C..	98	117	124	156
Fusion range..............° C..	34	71	62	83

TABLE C-12. - 100-gram coking tests, Kukpowruk River and Cape Beaufort samples and composites

Sample No.	Coke yield, pct	Plus ¼-inch material after 15 drops		
		Number of pieces	Average weight per piece, grams	Percentage retention[1]
KUKPOWRUK RIVER AREA				
22: 1[2]............	68.1	39	1.69	96.2
22: 2[3]............	61.0	71	.85	97.1
24: 1[2]............	67.7	45	1.48	96.5
24: 2[3]............	61.2	64	.93	96.3
26: 1[2]............	67.5	41	1.59	96.7
26: 2[3]............	62.1	72	.81	95.9
28: 1[2]............	67.4	46	1.40	95.5
28: 2[3]............	61.2	67	.89	96.2
Composite 22[4].....	64.6	58	1.09	98.0
Composite 24[4].....	64.8	50	1.25	95.8
Composite 26[4].....	64.7	55	1.14	96.7
Composite 28[4].....	64.4	64	1.00	95.8
23[5]...............	60.3	75	.78	96.1
25[5]...............	61.4	76	.79	96.1
27[5]...............	60.9	71	.84	96.8
CAPE BEAUFORT AREA				
29[6]...............	67.7	49	1.35	96.0
30: 1[7]............	70.5	54	.86	66.6
30: 2[8]............	63.2	46	1.32	96.8

[1] As referred to coke yield.
[2] Upper half of 19- to 20-ft seam.
[3] Lower half of 19- to 20-ft seam.
[4] Entire 19- to 20-ft seam, composited.
[5] Overlying 2.5- to 3.0-ft seam.
[6] Overlying 1.7-ft seam.
[7] Upper part (1.4 ft) of 10.7-ft seam.
[8] Lower part (5.2 ft) of 10.7-ft seam.