Clough, Roe, Eakins, Callahan, and Charlie—COAL RESOURCES OF NORTHWEST ALASKA—Division of Geological & Geophysical Surveys Report of Investigations 93-3

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Tony Knowles, *Governor*

John T. Shively, *Commissioner*

Milton A. Wiltse, *Acting Director and State Geologist*

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COAL RESOURCES OF NORTHWEST ALASKA

by

J.G. Clough,[1] J.T. Roe,[2] G.R. Eakins,[3] J.E. Callahan,[4] and K.M. Charlie[5]

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INTRODUCTION

In 1988, DGGS entered into Cooperative Agreement No. 14-08-0001-A0668 with the U.S. Geological Survey to enter point-source coal data from northwestern Alaska into the National Coal Resource Data System (NCRDS), a nationwide network linked to computing facilities in Reston, Virginia. The NCRDS provides a convenient means for archiving, retrieving, and analyzing coal information for resource estimates and basin studies. DGGS provided encoded and formatted coal data on floppy diskette media for inclusion into NCRDS within the USTRAT (stratigraphic) and USALYT (analytical) point-data files. Because the data files are continually updated, the process is ongoing. DGGS entered 125 point identifications (point Id's) that represent all data from 13 sites in northwestern Alaska and additional data from other sources into the NCRDS (table 1). This summary report of the history, geology, and coal resources of northwestern Alaska supplements the information entered into the National Coal Resource Data System.

Coal in northwest Alaska occurs within Lower Mississippian, Cretaceous, and Tertiary rocks. Coal quality and extent depend largely on geologic age and tectonic setting. The oldest and highest rank coals (bituminous to semianthracite) in the Lower Mississippian rocks exposed on Cape Lisburne are in a structurally complex setting that makes resource estimates unreliable. The thickest individual coal beds (≤100 ft thick) are also the youngest and lowest in rank (lignite); they occur in numerous isolated Tertiary basins scattered across the Seward Peninsula, St. Lawrence Island, and Norton Sound to Kobuk River areas. Many basins are subsiding, and their relationship to one another is poorly understood. The high-quality (subbituminous to high-volatile C, B, and A) and extensive coal resources occur in Cretaceous rocks located north of the Brooks Range.

From 1980 to 1985, the DGGS Northwest Alaska Coal Project examined lignite to bituminous coal occurrences in northwestern Alaska to evaluate the practicality of coal as an alternative energy source for 28 regional villages. The 13 most promising sites (fig. 1) were investigated by geologists from DGGS and U.S. Bureau of Land Management (BLM). The sites from north to south are Cape

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Beaufort-Deadfall Syncline; Cape Lisburne; Kallarichuk River; Hockley Hills; Singauruk River; Chicago Creek; Turner Creek; Sinuk River; Wilson Creek; Grouse Creek; Koyuk; Unalakleet; and St. Lawrence Island. Beginning in 1981, Requests for Proposals (RFPs) to conduct test drilling at six sites (Cape Beaufort, Chicago Creek, Sinuk River, Koyuk, Unalakleet, and St. Lawrence Island) were solicited from drilling companies and consulting geologists. Drill-site and coal-occurrence studies included drill-hole coring and lithologic and geophysical logging; field examinations and trenching of coal outcrops; and measurement of stratigraphic sections where feasible. Coal-quality analyses (proximate and some ultimate) were performed on samples collected from outcrops and on drill-hole cores and cuttings. Data from these analyses, along with stratigraphic thickness of coal beds, cross-sections, and detailed

Table 1. *Number of point identifications and coal-quality analyses entered by DGGS into the National Coal Resource Data System by number and locality*

Locality	**Number of coal-quality analyses**	**Number of point identifications**
Cape Beaufort-Deadfall Syncline	88	50
Cape Lisburne	19	19
Kallarichuk River	2	2
Hockley Hills	2	2
Singauruk River	4	3
Chicago Creek	85	18
Turner Creek	1	1
Sinuk River	1	1
Wilson Creek	1	1
Grouse Creek	2	2
Koyuk	17	17
Unalakleet	3	3
St. Lawrence Island	6	6
TOTAL	**231**	**125**

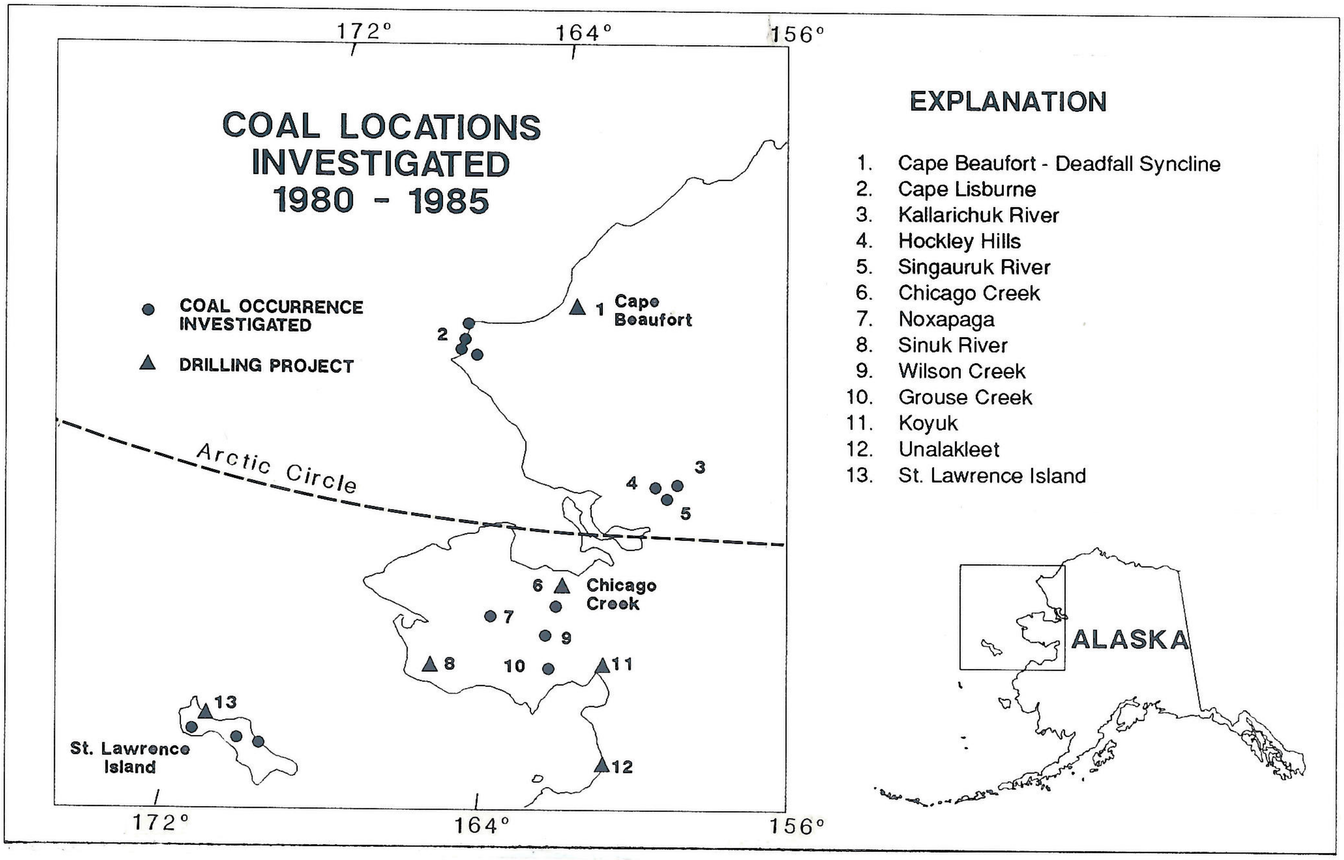


Figure 1. *Locations investigated during Resources of Northwest Alaska Project.*

maps, were entered into the NCRDS. The distribution of coal-bearing rocks and the locations of coal mines, DGGS field investigations, and subcontracted drill holes are shown on sheet 1.

Reports on the Northwest Alaska Coal Project written by DGGS geologists and its subcontractors and BLM geologists are listed below: Alaska Division of Geological & Geophysical Surveys, unpub. data, 1982; Callahan and Eakins (1986); C.C. Hawley and Associates (1983, 1986); Clough and others (1982a, b); Dames and Moore (1980); Eakins G.R. and Clough J.G., unpub. data, 1982; Haga, H., unpub. data, 1984; Ramsey and others (1986); and Mannings and Stevens (1982). Additional State of Alaska funded products on northwest Alaska coal used in this summary report are Arctic Slope Consulting Engineers (1984, 1986); Denton and others (1986); and Grinage and Gillen (1986).

Other sources of information on the geology, coalbed thickness, and coal-quality were obtained Barnes (1967a, b); Barnes and Hudson (1977); C.C. Hawley and Associates (1977a, b, c); Callahan and Sloan (1978); Cass (1959); Collins (1958); Martin and Callahan (1978); Miller and others (1972); Patton (1967); Patton and Csejtey (1980); Patton and Miller (1968); Patton and others (1968); Rao (1980); Rao and Smith (1983); Sainsbury (1974, 1975); Sainsbury and Hudson (1972); Tailleur (1965); Tailleur and Brosgé (1976); and U.S. Bureau of Mines (1979).

METHODS

Stratigraphic and coal-quality data were compiled from unpublished results of the 1980-85 DGGS Northwest Alaska Coal Project and entered into *Keypunch*, a NCRDS utility software program, on a dedicated microcomputer. Data from cross-sections of coal deposits, drill-hole locations, lithologic and geophysical logs, and measured stratigraphic sections were reviewed, and additional information was obtained from published and unpublished reports of DGGS, U.S. Geological Survey, U.S. Bureau of Mines, and Mineral Industry Research Laboratory (Fairbanks).

The latitude and longitude of drill-holes and outcrops were digitized using the U.S. Geological Surveys public domain *GSDIG* software. Stratigraphic and coal-quality information were assigned a location data-point identification number (point Id) that corresponds to its drill-hole number or outcrop sample number. Generally, the point Id consists of a number and letter combination (for example, *82CCDH4* or *82GE7*) that represents the year the hole was drilled or sample was collected (for example, *82* for 1982); the coal deposit drilled (for example, *CCDH*; where *CC* represents Chicago Creek and *DH* represents drill hole) or the geologist who collected the sample (for instance, *GE* represents Gil Eakins); and the drill-hole number (for example, *4*) or geologist's sample number (for example, *7*). These data were submitted on 1.2 mb floppy diskette media to NCRDS staff in Reston, Virginia, where they were converted to USTRAT (stratigraphic) and USALYT (analytical) files within the NCRDS database and storage retrieval system (*PACER*). The Alaska stratigraphic data appear in the AKSTRAT files within NCRDS.

U.S. Geological Survey staff in Reston, Virginia, generated lithologic logs of drill holes using the NCRDS Stratigraphic Analysis Techniques System (STRATS) program described by Boger (1986) and DGGS data entered into the USTRAT file system. The seven *STRATS* lithologic log plots that were prepared appear as figures in the locality summaries described in this report. A table of northwestern Alaska coal data (app., p. 30) was generated from NCRDS *PACER* files. This table includes point Ids, latitude and longitude, unit number, BTUs, moisture percent, volatile-matter percent, carbon percent, ash percent, and percentages of hydrogen, carbon, nitrogen, oxygen, sulfur, and total sulfur.

Coal samples collected during the Northwest Alaska Coal Project were submitted to the Mineral Industry Research Laboratory (MIRL), University of Alaska (Fairbanks), for proximate and ultimate analyses by ASTM standards.

COAL LOCALITY SUMMARIES

CAPE BEAUFORT-DEADFALL SYNCLINE

HISTORY AND INVESTIGATIONS

Coal in Arctic northwest Alaska was first officially reported by A.J. Collier, a member of the Beechey expedition to the Arctic Ocean in 1826-27 (Collier, 1906, 1908). Coal beds exposed in the coastal sea cliffs at Corwin Bluff, east of Cape Lisburne, were exploited during the late 1800s and early 1900s to replenish the fuel supplies of whaling ships. A total of 1,000 tons of coal was mined and shipped for use in Nome in 1900-01. Historic coal prospecting and mining occurred at Cape Beaufort, Cape Sabine, Thetis Mine, Corwin Bluff, and Corwin Mine (mine nos. 9, 10, 11, 12, and 13; sheet 1).

In 1983, DGGS and BLM explored the Cape Beaufort-Deadfall Syncline region for information on the thickness, continuity, and quality of selected coal beds. This program included auger and core drilling of 21 holes, and downhole geophysics in the Pt. Lay A-2, A-3, A-4, B-1, B-2, and B-3 Quadrangles and De Long Mountains D-4 Quadrangle. The general geology and drill-hole locations are shown on sheets 2, 3, and 4 and point Id data are shown in the appendix (p. 30).

In 1984, Arctic Slope Consulting Engineers drilled 47 holes in the Deadfall Syncline area (Arctic Slope Consulting Engineers, 1984). Based on this drilling program and other data, an assessment of local coal use was prepared

(Arctic Slope Consulting Engineers, 1986). Arctic Slope Consulting Engineers also tested open-pit and underground mining methods for the Deadfall Syncline coal.

GEOLOGY

Of the four Cretaceous-age formations that occur in the region, the Fortress Mountain, Torok, and Kukpowruk Formations are primarily marine and largely barren of coal. The Corwin Formation is a clastic sedimentary assemblage of interbedded claystone, siltstone, sandstone, ironstone, conglomerate, and minor bentonite that contains at least 146 coal beds, 28 of which are potentially minable (Chapman and Sable, 1960). Estimated cumulative thickness of the coal-bearing Corwin Formation rocks is between 11,353 and 15,494 ft (Chapman and Sable, 1960). The Corwin Formation underlies most of the western North Slope of Alaska and is locally buried beneath Pleistocene and younger surficial deposits. The formation is folded and faulted along east-west axes that generally parallel the northern front of the Brooks Range. Deformation intensity decreases northward from tight, asymmetric folds with steep dips and many faults in the southern part of the foothills belt to broad, open folds with flat dips and few faults under the coastal plain (Barnes, 1967a). Data from seismic work and three deep exploratory wells suggest that the unit is roughly divided into three zones (Callahan and Martin, 1980). Lower zone coal is normally thin and laterally continuous up to 12 mi while upper zone coal is generally thicker, but thins and splits over short distances. Coal beds in the middle transitional zone are 6 to 10 ft thick and laterally persistent for 65 mi (Callahan and Eakins, 1986).

Coal crops out in the sea cliffs at Corwin Bluff (De Long Mountains Quadrangle, sheet 4) and in the banks of the Kukpowruk and Kokolik Rivers (Pt. Lay Quadrangle, sheets 2 and 3). Deadfall Syncline, east of Cape Beaufort (De Long Mountains Quadrangle, sheet 2), is one of many broad, east-west-oriented structural basins that are separated by complex faulted and Torok Formation-cored anticlines (Callahan and Eakins, 1986). Other prominent synclinal structures include the Kukpowruk, Beaufort, and Howard synclines (sheets 2 and 3), and Liz-A and Thetis synclines.

In the Liz-A syncline area, 26 coal beds ≥1 ft thick have been identified. Most are relatively thin or limited in extent. The thickest beds, no. 7 (15-17 ft), no. 8 (12-13 ft), no. 10 (8 ft), and no. 15 (9 ft), contain most reserves for the Cape Beaufort area (Dames and Moore, 1980). Dips of 14° to 20° were determined from drill holes.

At Corwin Bluff, 80 coal beds >1 ft thick and 17 coal beds from 2.5 to 9 ft thick were measured from outcrops (Chapman and Sable, 1960). A sample *STRATS* lithologic log of five drill-holes (DH3, DH4, DH5, DH6, and DH11) at Corwin Bluff is shown in figure 2. Known coal beds in the Thetis syncline dip from 45° to 52°S. (near Corwin Bluff) to 16° to 24°S. (Thetis Mine).

Another major coal occurrence is located at Coke basin, a structural depression along the Kukpowruk River where 10,000 ft of Corwin Formation is exposed (Chapman and Sable, 1960). Beds dip steeply on the flanks of this elliptical basin and flatten abruptly near the center. Six coal beds range from 1 to 3 ft thick, and coal from the thickest beds exhibits good coking qualities.

COAL QUALITY

The Deadfall syncline contains eight high-volatile bituminous C, B, and A coal beds that range from 4.3 to 13.1 ft thick, with heating values between 10,675 and 13,209 Btu/lb. The coal is low in moisture, ash, and sulfur, with less than 0.03 percent pyritic sulfur. The average *as-received* values for the Cape Beaufort data set are 9,976 Btu/lb, 9.38 percent moisture, 28.87 percent volatile matter, 44.55 percent fixed carbon, 16.73 percent ash, and 0.27 percent total sulfur (app., p. 30). This average includes coal beds with numerous partings, which results in high ash percentages and low Btu/lb values. The higher quality coal, excluding ash percentages of >20 percent, yields average heating values of 10,598 Btu/lb.

Coke basin coal has an extremely low *as-received* moisture value of 0.8 percent and heating value of 15,300 Btu/lb (Warfield and Lauders, 1966; Warfield and Boley, 1969). This coal appears to have been upgraded in rank by tectonic deformation or nearby igneous intrusion.

COAL RESOURCES

Onshore combined coal resources for the Cape Beaufort and Deadfall/Liz-A synclines area are 35 million tons measured, 312 million tons indicated, and 186 million tons inferred (Callahan, 1976). Measured reserves for the Deadfall syncline, at a 10:1 stripping ratio, total about 15,810,000 tons, with additional reserves of about 59 million tons inferred (Arctic Slope Consulting Engineers, 1984). Coal resources for the Corwin Bluff area show no actual measured tonnages, but Barnes (1967b) estimated 48,700,000 tons indicated and 848,400,000 tons inferred.

Drill-hole data indicate that Corwin Formation coals are laterally continuous and that resource estimates are reliable where there is no structural complication by faulting. With coal-bed dips of 14° to 20° and a projected stripping ratio of 10:1, strip mining of the Cape Beaufort-Deadfall Syncline resources is favored. Steeper dips of 45° to 52° at Corwin Bluff and thrust faulting in the Thetis Mine area suggest that underground mining may be the best coal-extraction method. The mining potential of Cape Beaufort coal is enhanced by its location at or near tidewater. Several Coal Prospecting and Preference Right Coal Lease Applications are held (sheet 3), and Arctic Slope Regional Corporation is applying for a Mining Permit in the Deadfall syncline area.

CAPE LISBURNE

HISTORY AND INVESTIGATIONS

Coal exposed along the coast south of Cape Lewis to south of Cape Dyer was first noted in 1831 (Collier, 1906). For many years, whaling ships and revenue cutters replenished their fuel supplies from the readily accessible coal beds visible in the sea cliffs. In 1900, A.G. Maddren first recognized that the coals exposed south of Cape Lewis are much older than those elsewhere in Alaska (Tailleur, 1965). Historic coal prospecting and mining occurred at two mines on the Kukpuk River (mine no. 14, sheet 1) and at Cape Thompson (mine nos. 14 and 15, sheet 1). Prior to western contact, local Inupiat Eskimos collected coal from the beaches to burn with driftwood.

In 1983, DGGS investigated the Cape Lisburne coals. Due to observed structural complications, the lateral continuity of bedding is highly suspect, and it was decided not to drill in this area. Outcrop samples were collected from coal beds for analyses, and a panoramic sketch of the bluff south of Kapaloak Creek was prepared from photos taken of the sea-cliff exposures (fig. 3).

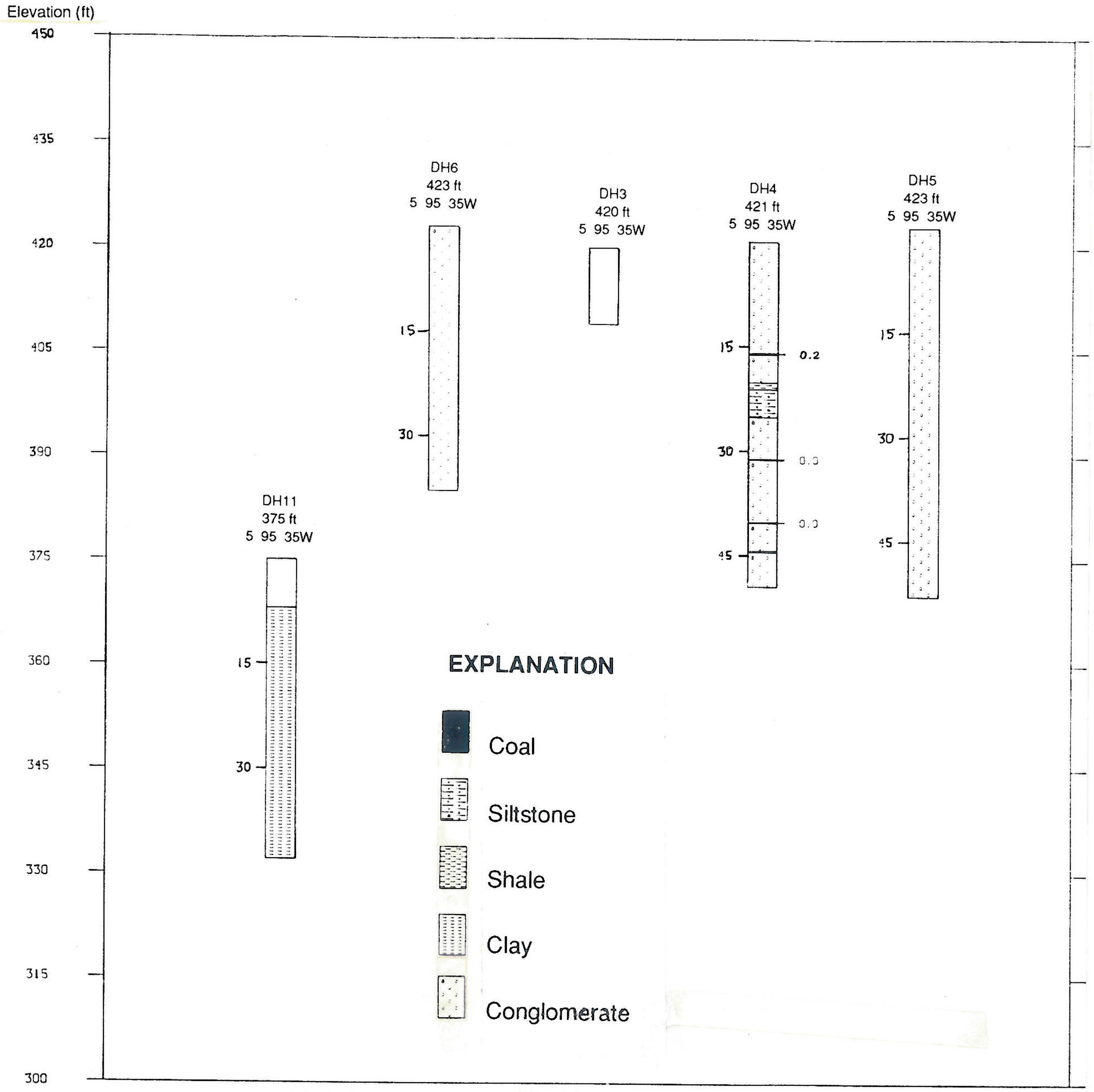


Figure 2. *Stratigraphic Analysis Techniques Systems (STRATS) log for 1983 drill holes (DH) 3, 4, 5, 6, and 11 at Corwin Bluff. Locations of drill holes shown on figure 10 and sheet 2.*

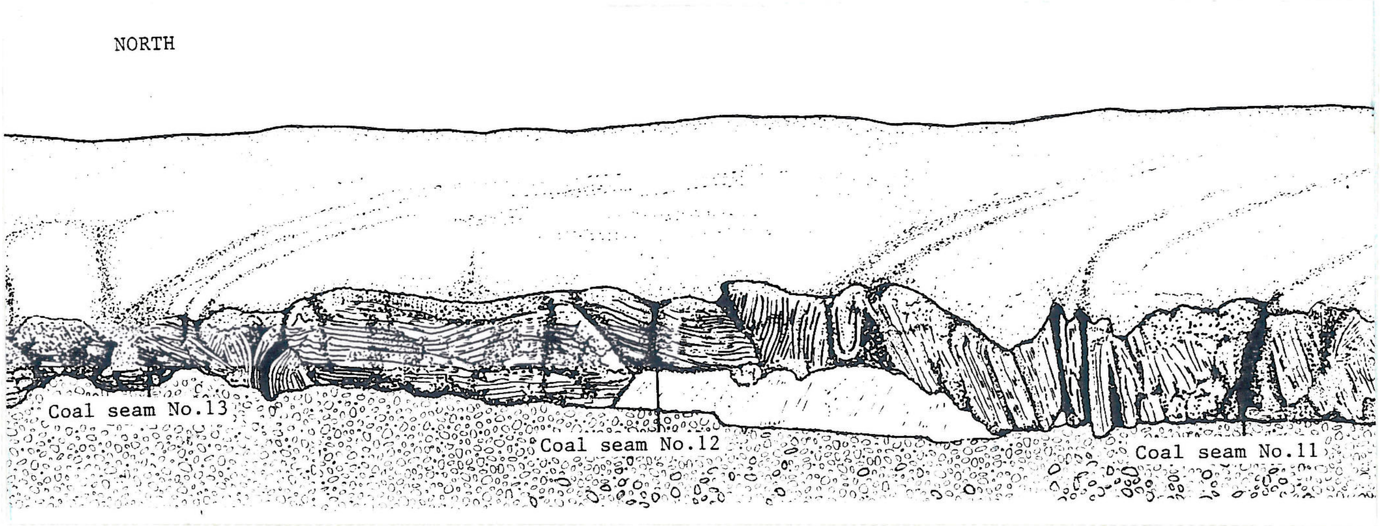


Figure 3. *Panoramic drawing of Lisburne Peninsula Cape Dyer coal beds.*

GEOLOGY

Cape Lisburne coal occurs in the Kapaloak Formation named by Tailleur (1965). This formation consists of Early Mississippian-age nonmarine sandstone, mudstone, shale, and coal, with minor conglomerate and marine limestone. It lies directly below the base of the Lisburne Group, a sequence of Carboniferous-age marine limestone and dolomite. The structure of the Kapaloak Formation is complex due to extensive faulting, shearing, contorted folding, and crumpling along east-trending fold axes, which results in erratic dip angles that range from horizontal to vertical. Deformation of the coal-bearing rocks, which tend to weather and erode rapidly, has resulted in coal beds that are difficult to locate or trace.

The largest outcrops of Mississippian coal-bearing strata occur in the sea cliffs 1.5 mi south of Cape Lewis and along Kapaloak Creek south of Cape Dyer. Several small beds and a 4-ft-thick sheared coal bed south of Cape Lewis strike N.75°E. and dip 40°N. (Collier, 1906). In the sea cliffs south of Kapaloak Creek, Tailleur (1965) documented 13 coal beds that range from 2.5 to 11 ft thick, within 2,200 ft of section. To the north, the upper 1,900 ft is coal-bearing, but the lower 300 ft is barren marine strata. The coal-bearing type section of the Kapaloak Formation at Kapaloak Creek has an overall dip to the south, with moderate to steep attitudes.

Reported isolated occurrences of Mississippian-age coal occur at three additional places: Niak Creek, 5 mi south of Cape Lisburne, where a 4- to 5-ft-thick coal bed dips 60°N. (Collier, 1906); on the Kukpuk River, 0.25 mi west of the mouth of Iglupak Creek, a 6-ft-thick coal bed strikes east and dips 23°S. (Conwell and Triplehorn, 1976); and at Cape Thompson, 25 mi southeast of Point Hope, where Conwell and Triplehorn (1976) observed two near-vertical coal beds, each about 1 ft thick.

COAL QUALITY

DGGS collected samples for proximate analysis from the thickest accessible coal beds exposed in the sea cliffs at Cape Dyer. Additional samples were collected from the Kupuk River area (app., p. 32). The samples range in *as received* heating values of 11,457 to 14,731 Btu/lb with low total sulfur and an apparent rank of low-volatile bituminous coal.

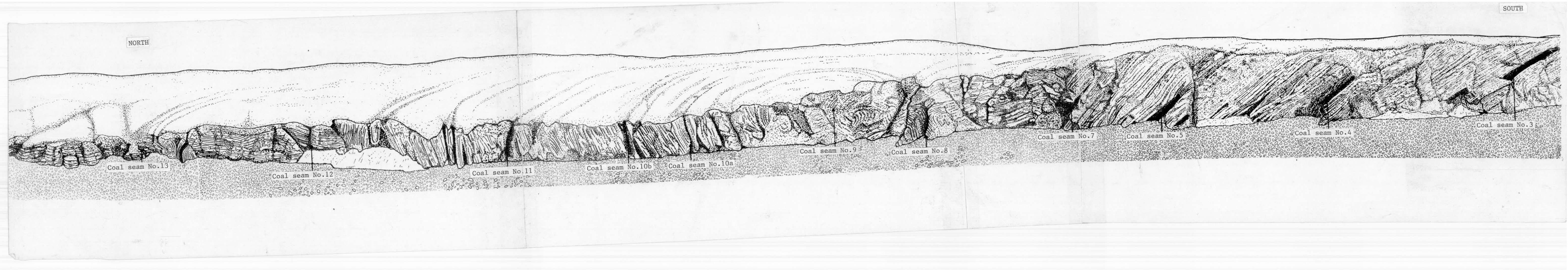
COAL RESOURCES

Structural deformation of the Kapaloak Formation in the Cape Lisburne region makes lateral continuity of the coal beds unpredictable. The absence of subsurface drill-hole data inland from the coastal bluff exposures precludes making accurate reserve estimates of Mississippian-age coal resources in this region.

KALLARICHUK RIVER

HISTORY AND INVESTIGATIONS

Coal was first discovered in the Kobuk River area in 1884 by Lt. G.M. Stoney during exploration work for the U.S. Navy Department (Smith, 1913). Stoney reported using bituminous coal from a 2- to 3-ft-thick bed for the furnace of his steam launch (Smith, 1913). Lt. J.C. Cantwell visited the area later in 1884, but found the coal unsatisfactory for his launch. Mendenhall (1902) also noted that the coal burned slowly and yielded abundant ash and disagreeable gases. In 1908, a mine on the Kobuk River (at its confluence with the Kallarichuk River) was opened by Captain Theilen to fuel-placer gold operations on nearby Squirrel River. Reed (1931) reported that 150 tons of coal were mined at this and several smaller nearby mines


NORTH
SOUTH
Coal seam No.13
Coal seam No.12
Coal seam No.11
Coal seam No.10b
Coal seam No.10a
Coal seam No.9
Coal seam No.8
Coal seam No.7
Coal seam No.5
Coal seam No.4
Coal seam No.3

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during 1918. In 1929, Alexander Haralan reopened the main mine, which became known as the Haralan Mine (mine no. 16, sheet 1), and apparently produced 35 tons of coal during the peak production year in 1932. According to Reed (1931), the Kobuk River Mine (mine no. 17, sheet 1), about 5 mi downstream from the Haralan, also operated during the Squirrel River gold stampede, producing 100 tons of coal that was lost during spring breakup. Reed (unpub. data, 1931) believed that Stoney and Cantwell obtained coal for their launches from this mine. In 1960, R.H. Chadwick revisited the area and found a number of shallow pits, now caved in, at the Haralan Mine and piles of coal on the riverbank at the Kobuk River Mine (Chadwick, 1960). Patton and Miller (1968) determined the extent of the coal-bearing strata in the Kobuk River region. From 1979 to 1982, DGGS explored the Kallarichuk and Kobuk River areas in an effort to relocate the mine sites and to explore for new, significant coal occurrences.

GEOLOGY

Coal in the Kallarichuk River region is interbedded with nonmarine Cretaceous-age conglomerate, sandstone, and mudstone (Patton and Miller, 1968). A K-Ar age of 83.4 ± 2.2 m.y. (from an ash-fall tuff) agrees with well-preserved plant fossils that verify a Late Cretaceous age for these rocks (Patton and Miller, 1968). The unnamed Cretaceous nonmarine rocks are found as isolated exposures along the Kobuk River in the Baird Mountains and Selawik Quadrangles, with the best exposure at Hotham Peak in the Selawik Quadrangle.

The regional structure is a broadly folded, northeast-trending marginal trough (the Kobuk/Koyukuk Basin) dissected by numerous high-angle faults (Patton, 1973). Isolated pockets of Cretaceous coal-bearing strata occur in the neighboring Noatak and Ambler River Quadrangles.

Primary coal occurrences on the Kobuk River are located at the confluence of the Kallarichuk River and 2 mi and 5 mi downriver from the confluence of the Kallarichuk and Kobuk Rivers. At the confluence of the Kallarichuk River, numerous coal beds are ≤3 ft thick, but most seams are much thinner (Dames and Moore, 1980). G.R. Eakins (written commun., 1979) reported that the beds strike N.60°E. and dip 50°S. Two miles down the Kobuk River and 1 mi past the Haralan Mine, Eakins (written commun., 1979) described five or six coal beds that range from a few inches to 18 inches thick in bedding that strikes N.60°E. and dips 25°S. Five miles further down the Kobuk River, a number of poorly exposed, thin coal seams have a similar strike and dip (Eakins, written commun., 1979). Chadwick (1960) reports piles of coal, presumably from the old Kobuk River Mine, but Eakins (written commun., 1979) and Sanders (1984a, b) found no evidence of the mines. Minor coal occurs on both forks of the Kallarichuk River. Patton and Miller (1968) report bituminous coal float on the south fork of the Kallarichuk, but no coal beds. Clough and others (1982b) describe blocky and relatively unweathered coal float in cutbanks on the south fork of the Kallarichuk and on a nearby creek. Although coal seams reportedly occur in the creek bed, they were covered by high water at the time of the visit (Clough and others, 1982b). Other small occurrences were noted 1 mi upstream from the confluence of the two forks of the Kallarichuk River, where two exposed coal beds 1 ft and 2 ft thick strike N.45°E., dip 45°N., and are of poor quality with high ash content.

COAL QUALITY

Coal-quality analyses of two samples from the Kallarichuk River field yield average *as-received* heating values of 7,450 Btu, 15.18 percent moisture, 27.73 percent volatile matter, 35.03 percent fixed carbon, 22.21 percent ash, and 0.72 percent total sulfur (app., p. 32). Sample 82GE1, which has a heating value of 9,292 Btu and an apparent rank of high-volatile bituminous C, is similar in quality to the Cretaceous coal at Corwin Bluff and Cape Beaufort.

COAL RESOURCES

The absence of drill-hole subsurface stratigraphic information and the sparse coal outcrops preclude making accurate reserve estimates. Additionally, the coal-bearing strata are within and adjacent to the western part of the Kobuk Valley National Park, which prevents an extensive exploratory drilling program to determine the local structure and lateral continuity of coal. If considerable coal resources exist, their location near the Kobuk and Kallarichuk Rivers makes them readily accessible for development as a local fuel source.

HOCKLEY HILLS AND SINGAURUK RIVER

HISTORY AND INVESTIGATIONS

In 1959, Burand (1959) sampled a coal occurrence 16 mi northwest of Selawik on the Singauruk River, which local natives had for some time been using in their stoves without much success. Chadwick (1960) examined coal on the Singauruk River near the southwest edge of the Waring Mountains and on the northern flank of the Hockley Hills. Patton and Miller (1968) mapped the coal-bearing sequences as volcanic rocks, calcareous greywacke, and mudstone. In 1982, DGGS geologists located and sampled the occurrences north of the Hockley Hills and on the Singauruk River (Clough and others, 1982a).

In 1907 and 1908, L.S. Quakenbush (1909), on an expedition to collect mammoth fossils for the American Museum of Natural History, discovered minor amounts of coal and peat along Eschscholtz Bay (near Elephant Point) and on the south side of Hotham Inlet. This area was investigated in 1983 by DGGS and it was determined that exploratory drilling was not feasible due to logistical constraints and the lack of visible evidence of substantial coal resources.

GEOLOGY

Cretaceous-age coals in the Hockley Hills and Singauruk River areas (Selawik Quadrangle) are interbedded with nonmarine conglomerate, sandstone, and mudstone. These rocks are best exposed at Hotham Peak, where the 3,000-ft-thick section lacks significant coal beds (Patton and Miller, 1968). The structure of the area is interpreted as a broadly folded, northeast-trending trough (the Kobuk/Koyukuk Basin) dissected by numerous high-angle faults (Patton, 1973). Attitude measurements show that the coal-bearing strata may be near the nose of a regional syncline that plunges 40° northwest (Burand, 1959). Isolated pockets of similar Cretaceous-age coal-bearing strata occur in the neighboring Ambler River and Baird Mountains Quadrangles, but correlation is uncertain. North of the Hockley Hills, beds containing very thin coal layers can be traced across several north-flowing creeks (Dames and Moore, 1980). Clough and others (1982a) describe numerous 1-in.-thick coal streaks in bedding that strikes N.20°E. and dips 40°W. No coal of potential commercial value was found, but Chadwick (1960) speculated that the coal on the Singauruk River is probably in the same stratigraphic position as the thin streaks at Hockley Hills. Burand (1959) reported that four coal seams at the Singauruk River occurrence range from 2 to 3.5 ft thick, separated by zones of shale, mudstone, and poorly consolidated sandstone. Clough and others (1982a) collected a channel sample from the four main beds and reported coal thicknesses ranging from 3 to 6 ft, with many thin shale partings. Bedding of the coal-bearing strata at this locality strikes N.40°E. and dips 30°W. Coal may occur in the 3,000-ft-thick sedimentary section on Hotham Peak, in the extreme western part of the Hockley Hills, but none has been reported.

Coal in the Elephant Point area (Selawik Quadrangle) is interbedded with up to 500 ft of poorly consolidated conglomerate, sandstone, siltstone, and clay. The Tertiary age of the unit is based on pollen identifications (Patton, 1973). Deposits are confined to small structural or topographic basins, which may be part of a larger 6-mi-wide graben located south of the main Selawik basin. On the beach bluffs 2 mi south of Elephant Point (Eschscholtz Bay), a 2-ft-thick coal bed was reported by Quakenbush (1909), but more recently Dames and Moore (1980) reported that only 4 in. of coal is exposed at low tide. The coal-bearing sequence is generally flat lying, with a total onshore extent of probably only several square miles (Dames and Moore, 1980). About 31 mi south of Selawik, up to 500 ft of Tertiary coal-bearing sedimentary rocks are exposed along the east fork of the Mangoak River (Selawik Quadrangle). These strata generally strike northeasterly with shallow dips up to 15° to the northwest (Dames and Moore, 1980). Patton and Miller (1968) measured rocks striking northwest and dipping 30° southwest in the same area. Coal float has been found in this area, but up to 10,000 ft of Cretaceous to Tertiary coal-bearing section is predicted to occur throughout the Selawik basin (Patton, 1973).

COAL QUALITY

Clough and others (1982a) assign the coals a rank of high-volatile bituminous C based on analyses shown in the appendix. Both Burand (1959) and Chadwick (1960) rank the coals as subbituminous. However, the coals have moderate-moisture, low-sulfur, and high-ash content due to numerous shale partings. High-ash coal is known to give an apparent rank—when determined from heating values—that is lower than actual rank. The use of a float-sink technique to decrease the ash content, or the measurement of vitrinite reflectance will yield a more accurate coal rank. Generally, the low-ash coal resembles coal beds along the Kobuk River in the Baird Mountains Quadrangle, and compares in quality to Cretaceous coal found farther north at Corwin Bluff and Cape Beaufort. No analysis of the Tertiary coal in the Elephant Point area was performed because samples were not collected by DGGS. However, this coal is apparently lignite as described by Quakenbush (1909) and Patton (1973) and appears similar to Tertiary coal found elsewhere on Seward Peninsula.

COAL RESOURCES

The location of the coal along the Singauruk River, at an average distance of 16 mi from the villages of Selawik and Kiana, makes future development as a local fuel source possible if useful reserves are found. Reserves of Singauruk River coal are difficult to determine due to lack of subsurface information and should be considered uneconomical until a drilling program confirms substantial lateral continuity of the coal beds.

CHICAGO CREEK

HISTORY AND INVESTIGATIONS

Coal at Chicago Creek, a tributary to the Kugruk River (mine no. 18, sheet 1) was discovered by gold prospectors in 1902 (Moffit, 1906), staked in 1905, and mined between

1907 and 1911. During that time, the Wallin and Superior coal mines, 6 mi to the south along the Kugruk River (mine no. 19, sheet 1), worked what is probably a continuation of the same bed. Coal does not crop out in the area, but coal float occurs in the Kugruk River and Chicago Creek. The early gold prospectors located the Chicago Creek coal deposit by looking for traces of coal in the creek bed upstream from its confluence with the Kugruk River. At the point where coal fragments became absent in the creek bed, they dug a south-facing adit into the bank to mine the coal. The Chicago Creek mine was operated during the winter months and sealed to prevent thawing of permafrost around the adit in summer (Ramsey and others, 1986). Total coal production of the three mines (Wallin, Superior, and Chicago Creek), approximately 110,000 tons (Toenges and Jolley, 1947), was used by local placer miners at Candle Creek as a source of heat for steam-thaw mining methods.

From the summer of 1982 through the summer of 1985, subcontractors for DGGS conducted extensive investigations of the Chicago Creek coal deposit that included field mapping, core and auger drilling, and down-hole and surface geophysics. More than 60 holes were drilled to a maximum depth of 300 ft (sheet 5) from which 85 core samples were analyzed (app., p. 33).

GEOLOGY

The Chicago Creek coal field is in a north-south-trending linear trough that may be as much as 2 mi wide. Bedding strikes approximately north-south and dips from 50° to 70° W. The coal occurs in one main bed up to 100 ft thick with intermittent partings of sandy or silty clay. The coal rests unconformably on weathered metamorphic schist and is overlain by shale, siltstone, and unconsolidated surficial deposits of ice and frozen silt (Ramsey and others, 1986; sheet 6). Fossil pollen samples obtained from drill-hole cores indicate a late Tertiary or younger age of the coal-bearing strata (H. Haga, unpub. data, 1984). Drilling has traced coal along strike for 8,000 ft, both north and south of the original mine site, and the bed probably continues to the north (Mannings and Stevens, 1982; C.C. Hawley and Associates, 1983, 1986; Ramsey and others, 1986). The main bed is truncated by a fault 50 ft south of the old mine adit on the south side of Chicago Creek, but continues with an offset beyond the fault. The irregular thickness implies plastic deformation, which causes pinching out and thickening of the unit at irregular intervals north and south of Chicago Creek. The structural elements at Chicago Creek trend north-south as a result of east-directed compressional forces that were regionally active during Tertiary time (Ramsey and others, 1986). Ramsey and others (1986) suggest this compression warped the strata into anticlinal/synclinal folds that were eventually thrust faulted and subsequently eroded to the present configuration (fig. 4).

Downhole stratigraphic data from 15 Chicago Creek drill holes were processed into four separate *STRATS* lithologic logs (figs. 5, 6, 7, and 8). Each *STRATS* log represents an east-west transect across the coal deposit and demonstrates the high-angle, westerly dip of the main coal bed.

The coal bed mined at the Wallin site is up to 66 ft thick, with several partings of sandy clay and shale; strike is N.15°E., with an average dip of 62°W. (Reed, 1933). Coal at the Superior mine has a similar strike and dip, and is reported to be at least 53 ft thick (Reed, 1933). The Superior mining venture was discontinued because the coal bed is truncated by a fault offset on the south side of the mine (Reed, 1933: Dames and Moore, 1980).

Tertiary coal-bearing rocks and coal float have been mapped in the vicinity of French Creek, Goose Creek, Independence Creek, and Mina Creek, all tributaries of the Kugruk River. Although little is known of these coal-bearing rocks, they may be part of the same sequence as those at Chicago Creek (Moffit, 1905; Roehm, 1941; Sainsbury, 1975). Another occurrence of lignite, unrelated to Chicago Creek and the Kugruk River, is located on Perry Creek 15 mi west of Chicago Creek. Here, a 2- to 4-ft-thick bed of lignite is overlain by Tertiary to Holocene basalt flows (J.T. Kline, DGGS, oral commun., 1980). Tertiary coal-bearing rocks may also underlie the Quaternary flats in the upper Pinnell River and Burnt River area (Dames and Moore, 1980).

COAL QUALITY

Proximate analyses of Chicago Creek coal yields an average *as-received* heating value of 6,602 Btu/lb and dry mineral matter free fixed carbon content of 29.22 percent (app., p. 33). Because this lignite contains a significant amount of moisture, fluid-bed-reactor technology is recommended for its combustion (Ramsey and others, 1986).

COAL RESOURCES

Demonstrated (measured and indicated) coal resources at Chicago Creek total 3.4 million short tons (Ramsey and others, 1986; table 2). These calculations assume an average lignite density of 80 lb/ft^3. Inferred coal resources, based on the reasonable lateral continuity of coal beds extending to the north, could add an additional 1 million tons (Ramsey and others, 1986).

Retherford and others (1986) developed a preliminary mine plan and feasibility study of the Chicago Creek coal deposit that assumes an average of 50,000 short tons of coal mined per year for 30 yr to supply a power plant in Kotzebue. Their study proposes an open-pit mine with transportation by truck to Willow Bay and shallow draft barging across Kotzebue Sound to Kotzebue during the short, open-water season. The future of coal mining at

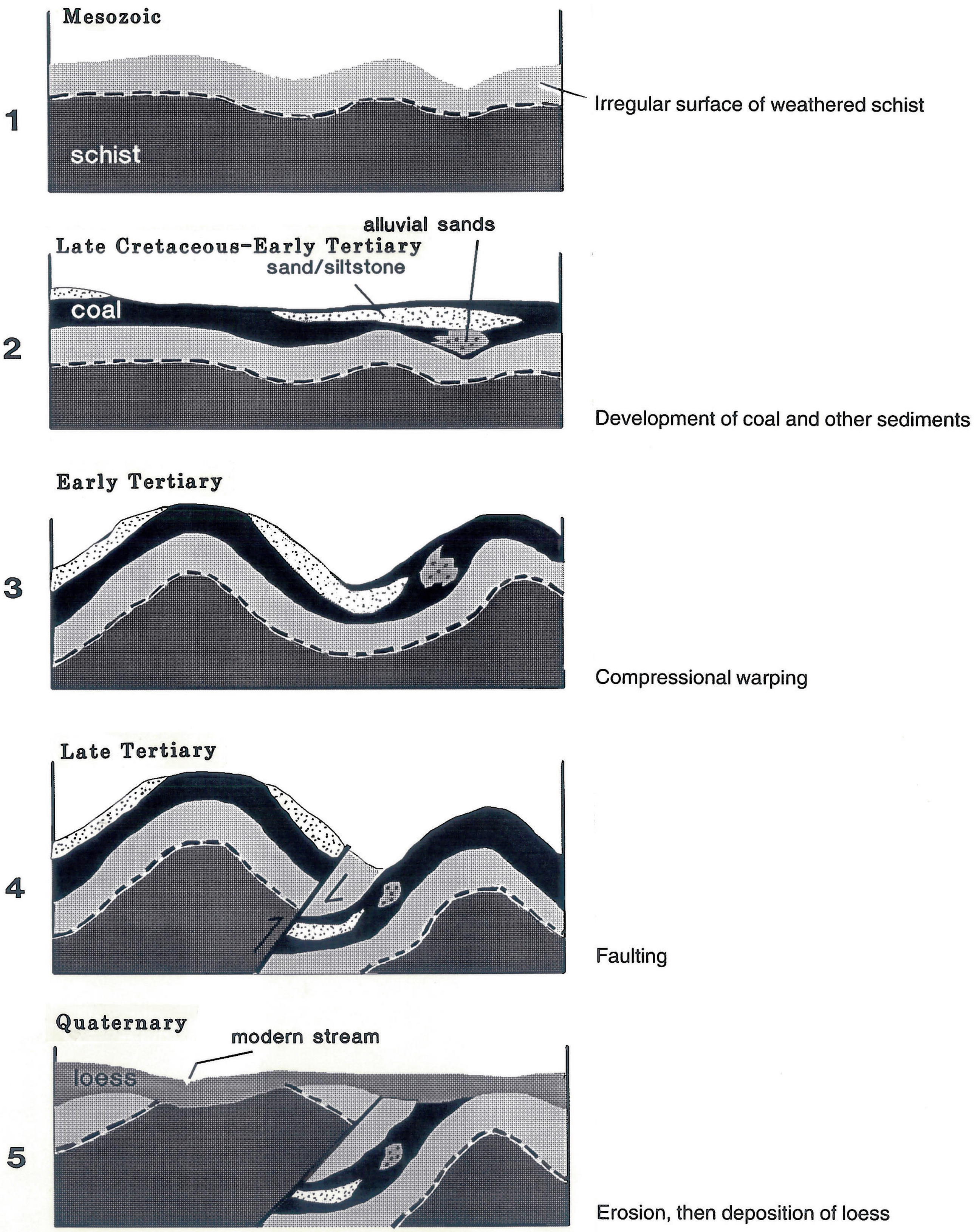


Figure 4. *Proposed structural history of Chicago Creek coal. From Ramsey and others (1986).*

Chicago Creek is largely dependent on fuel oil prices; as fuel-oil becomes more expensive, the use of Chicago Creek lignite may become feasible.

TURNER CREEK

HISTORY AND INVESTIGATIONS

During the early 1900s, lignite was mined from a 1-to 12-ft-thick bed in a pingo located near Turner Creek, west of the Noxapaga River in the Bendeleben Quadrangle (Hopkins, 1963). In 1982, DGGS and BLM geologists excavated this bed and collected a sample for analysis (Alaska Division of Geological & Geophysical Surveys, unpub. data, 1982).

GEOLOGY

Northwest of McCarthy's Marsh along the upper Kuzitrin River drainage, the 250-mi^2 Kuzitrin basin contains Tertiary-age coal-bearing rocks of the Noxapaga

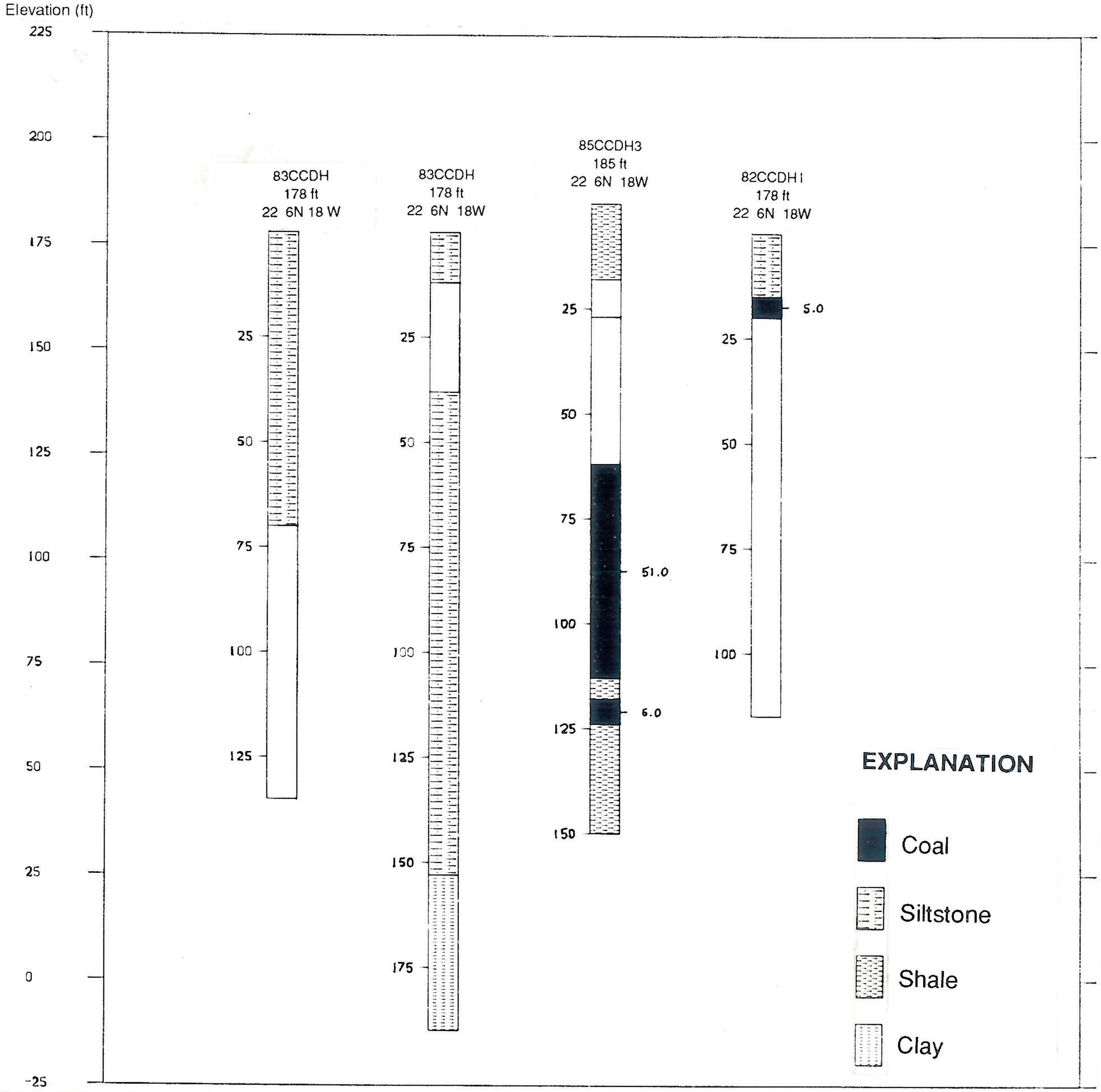


Figure 5. *Stratigraphic Analysis Techniques Systems (STRATS) log for 1982, 1983, and 1985 Chicago Creek drillholes 82CCDH10, 83CCDH10, 83CCDH3, and 85CCDH35.*

Formation that include claystone, sandstone, minor conglomerate, and coal (Dames and Moore, 1980). Outcrops of this formation are found on the northeast bank of Turner Creek and in a pingo west of the Noxapaga River, a major tributary of the Kuzitrin River (Sainsbury, 1975; Dames and Moore, 1980). A gravity anomaly associated with the Kuzitrin basin suggests that the coal-bearing sedimentary rocks may continue to the northeast for considerable distance under Tertiary basalt flows (Barnes and Hudson, 1977; Dames and Moore, 1980).

COAL QUALITY

Analysis of coal sample 82GE8 collected from the Turner Creek pingo locality indicates it is lignite, with *as-received* heating value of 6,653 Btu/lb and 33.56 percent moisture content (app., p. 34). This very low ash (3.46 percent) lignite is also very low in sulfur (0.16 percent), but is otherwise similar to Tertiary coal found elsewhere on Seward Peninsula.

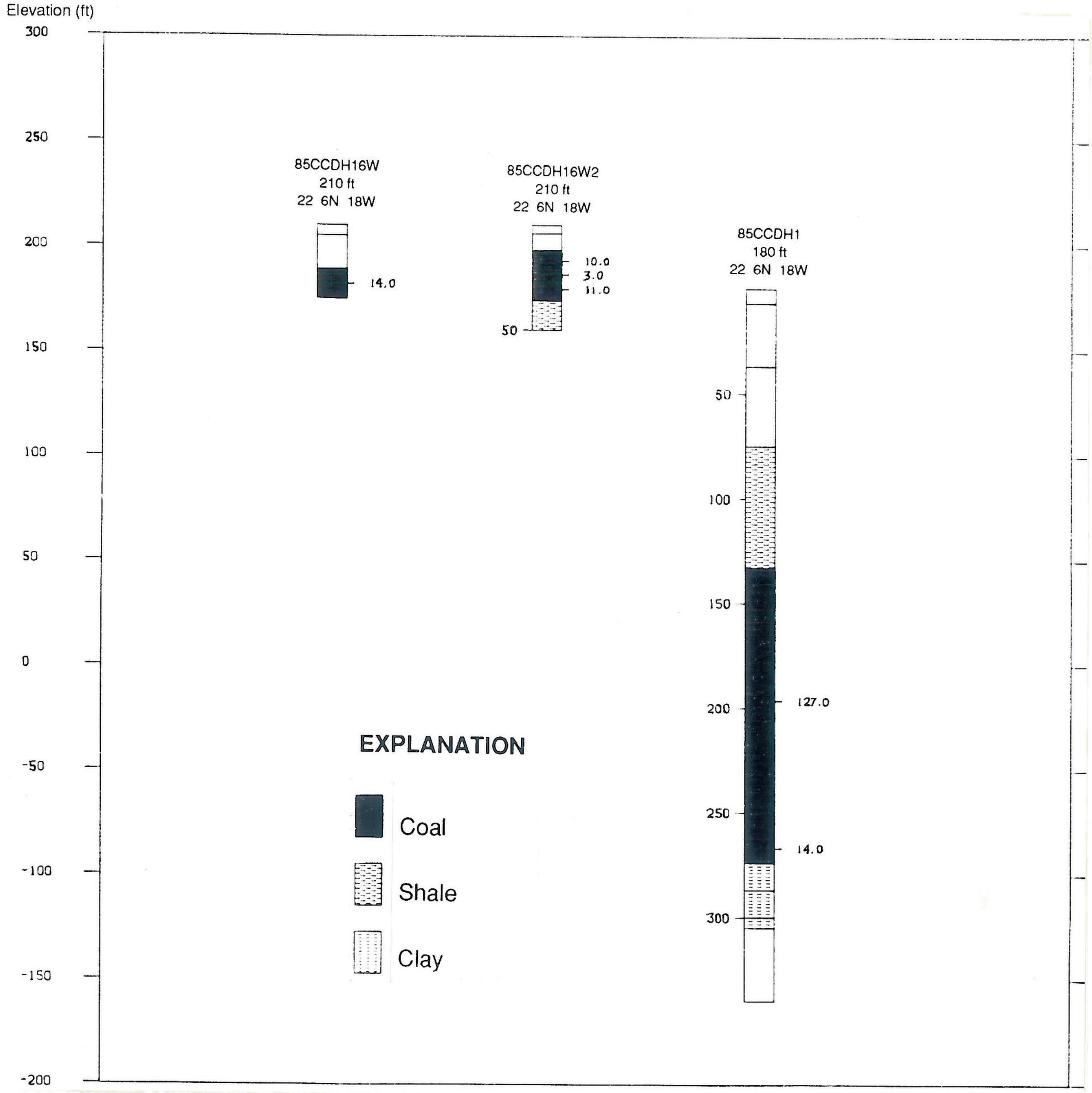


Figure 6. *Stratigraphic Analysis Techniques Systems (STRATS) log for 1985 Chicago Creek drill-holes 85CCDH1, 85CCDH16W2, and 85CCDH16W1.*

COAL RESOURCES

Coal resources for the Turner Creek area are difficult to determine from two poorly exposed and slumped outcrops because the lateral continuity of coal beds is uncertain. The best coal exposure is the result of ice-wedge growth and subsequent pingo formation that lifted the coal bed above the surrounding swamp. Any remaining coal resources lie beneath tundra and swamp and would be difficult to extract without major alterations to the drainage system.

SINUK RIVER

HISTORY AND INVESTIGATIONS

Coal-bearing strata in the Nome Quadrangle occur on Coal Creek, a small tributary to the Sinuk River about 32 mi west of Nome. Natives from the village at the mouth of the Sinuk River first brought the coal to the attention of prospectors in 1902. Systematic development of this deposit (mine no. 20, sheet 1) was first

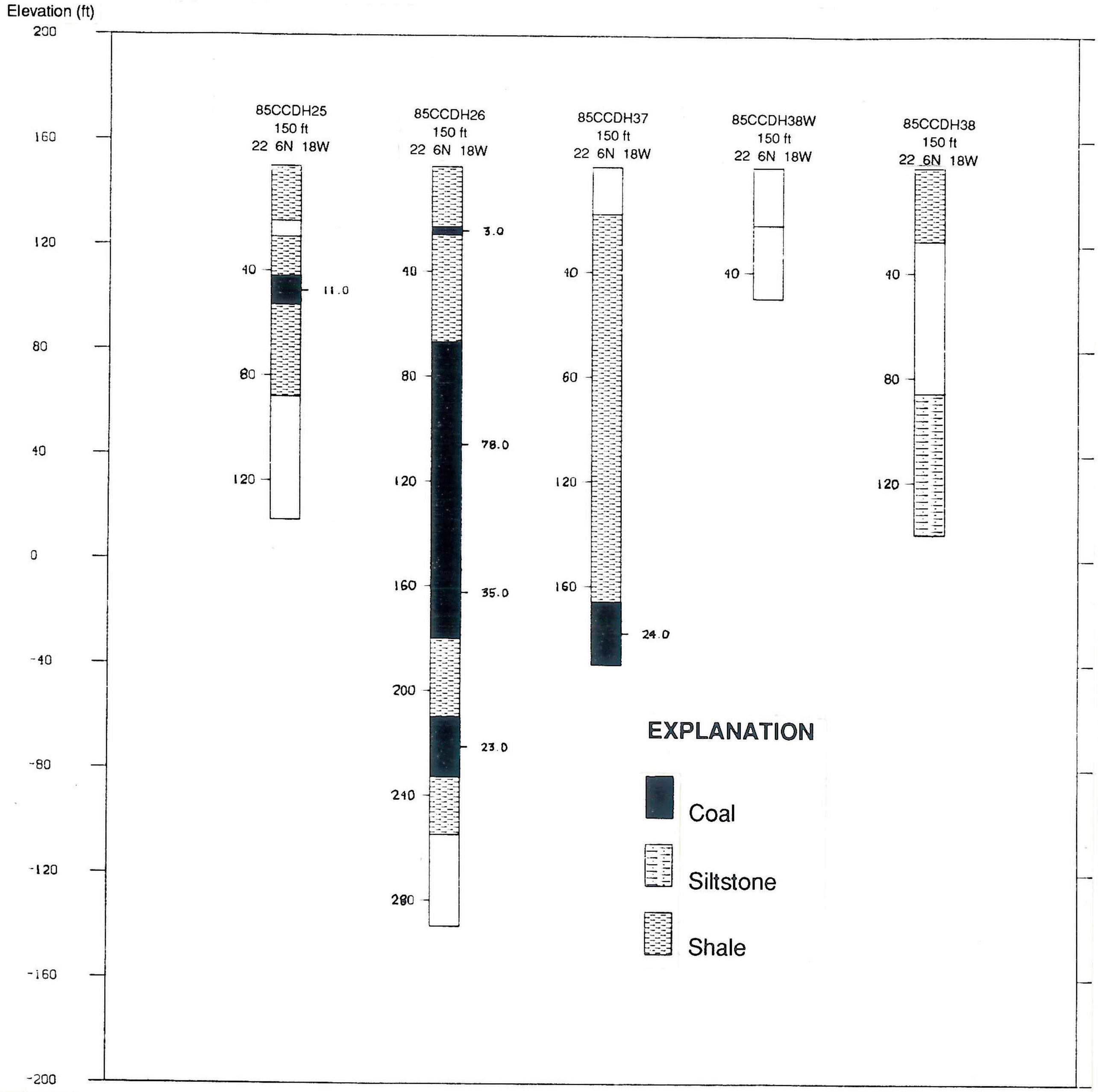


Figure 7. *Stratigraphic Analysis Techniques Systems (STRATS) log for 1985 Chicago Creek drill-holes 85CCDH25, 85CCDH26, 85CCDH37, 85CCDH38W, and 85CCDH38.*

attempted in the same year, but no production records remain (Collier and others, 1908). Today the mine site has small-gauge rails leading from a collapsed adit, and rail carts, a boiler, remains of a small cabin, and miscellaneous mining items. The first detailed geologic map of the Sinuk River was compiled by Herreid (1970). In fall 1982, DGGS drilled 16 exploratory holes at this site (sheet 7) with a tracked, vehicle-mounted air drill.

GEOLOGY

The Sinuk River area coals are interbedded with well-indurated conglomerate composed of schist, vein quartz, and a few large, well rounded, slightly sheared greenstone boulders (Dames and Moore, 1980). In addition to the conglomerates, the coal-bearing rocks contain finer sediments that consist of decomposed schist pebbles and thin seams of fire clay and coal (Collier, 1906). These clastic units

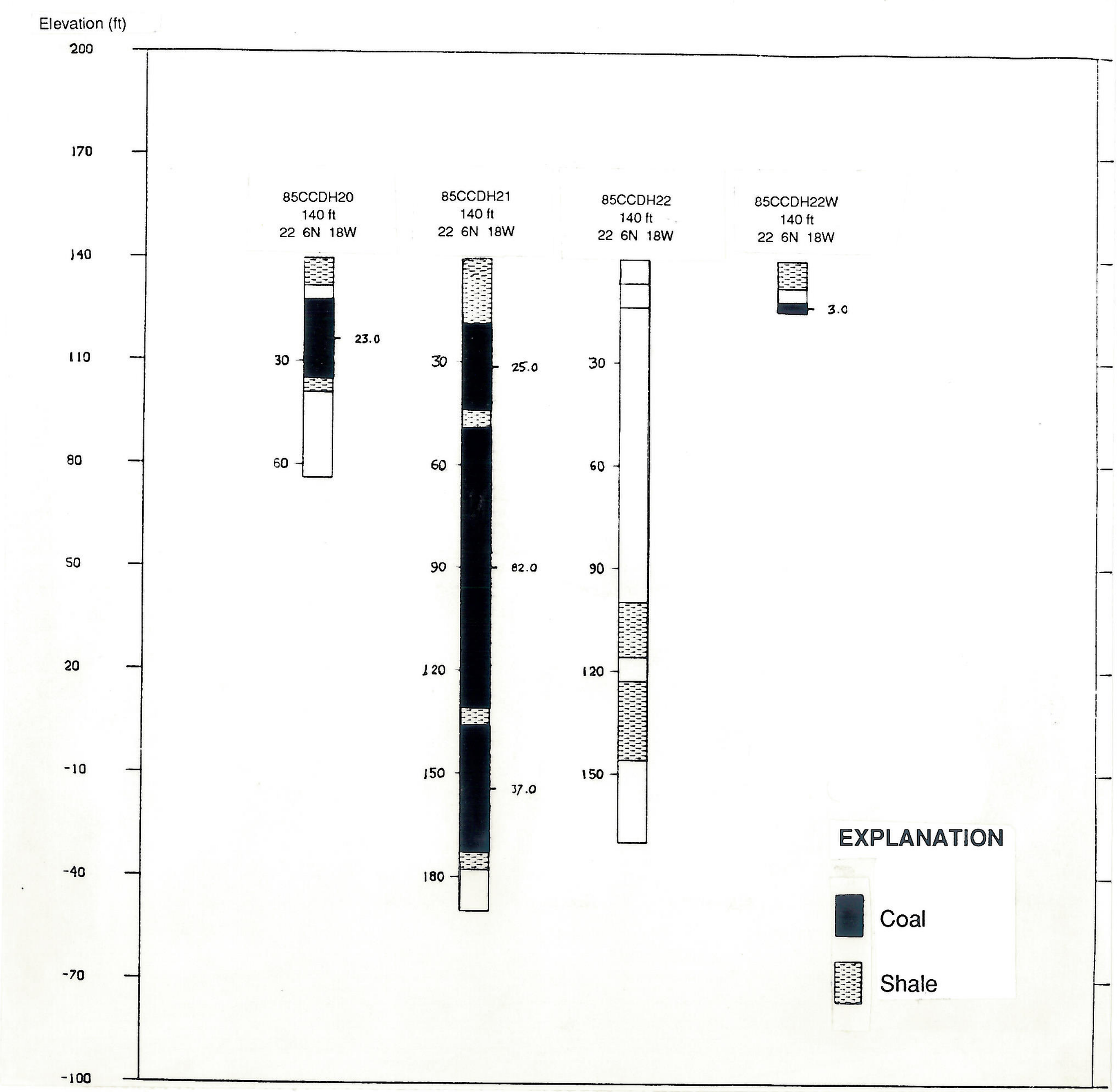


Figure 8. *Stratigraphic Analysis Techniques Systems (STRATS) log for 1985 Chicago Creek drill-holes 85CCDH20, 85CCDH21, 85CCDH22, and 85CCDH22W.*

unconformably overlie Paleozoic crystalline limestone and schist (Dames and Moore, 1980). However, because the beds are slightly crushed and sheared, they are difficult to distinguish from the underlying schist bedrock (Collier and others, 1908). Exposures along Coal Creek are limited by vegetation and deep surficial cover making coal-bearing strata difficult to trace. Collier and others (1908) and Smith (1908) estimate that the coal-bearing strata only extend for about 0.5 mi along the creek and underlie less than 1 mi^2. Bedding strikes N.50°W. and dips 18°-30° SW. (G.R. Eakins and J.G. Clough, unpub. data, 1982). These coal-bearing units are inferred to be Late Cretaceous or Tertiary in age by Collier (1908), whereas Sainsbury (1975) postulates a strictly Cretaceous age due to their highly deformed character and lack of conglomeratic granite clasts from Middle to Late Cretaceous intrusive rocks in the area. Herreid (1970) considers the sedimentary rocks to be Tertiary in age, and related in origin to the present drainage system. G.R. Eakins and J.G. Clough (unpub. data, 1982) concur with Herreid and describe the deposit as an alluvial fan derived from the regional metamorphic quartz mica schist. A few thin (<1 in. thick) seams of carbonaceous shale are visible in outcrop.

The 16 exploratory holes drilled in 1982 by DGGS (sheet 7) reached depths of 40 to 77 ft. Very thin beds of carbonaceous shale and possibly coal were encountered in only seven of the 16 holes drilled in an approximately 0.06 mi^2 near the mine. DH 1, located on tundra near the old mine site, encountered carbonaceous shale and coal stringers (≤1 in. thick) at depths of 38 ft, 56 ft, and 65 ft. This hole was terminated in very hard metamorphic schist at 77 ft. The rotary-air-drill cuttings were insufficient for coal-quality analysis because they were often only a brief puff of black dust. Downhole stratigraphic data from six Sinuk River drill holes were processed into a *STRATS* lithologic log shown in figure 9.

COAL QUALITY

No samples large enough for laboratory analysis were recovered by drilling, but a weathered coal sample collected by DGGS near the old adit gave an *as-received* ash content of 16.85 percent and a heating value of 11,311 Btu/lb (app., p. 34). These values correspond to an apparent rank of subbituminous A or B, but they are considered unreliable due to the weathered condition of the sample, which resulted in low-volatile-matter (24.51 percent) and very low moisture (4.07 percent) contents. No other laboratory proximate analyses have been performed on the Sinuk River area coal. According to Collier (1908), the coal is bituminous in appearance, and was used by a Nome blacksmith for welding, which suggests a higher rank than lignite.

Table 2. *Coal resource estimates for Chicago Creek* (from Ramsey and others, 1986, table 2, p. 31)

Mineable strike length (ft)	Mining depth (ft)	Dip length (ft)	Demonstrated coal resource (short tons)
	100	141	1,140,000
6,300	200	283	2,288,900
	424	424	3,429,000

COAL RESOURCES

Coal in this area is very thin and limited in extent, and it appears that the small resource was mined out. Detailed geologic studies of the coal-bearing strata and additional exploratory drilling may indicate thick and minable coal beds, but results of the 1982 DGGS drilling program are not encouraging. The similar quartz mica schist conglomerate-hosted coal that occurs as float on Washington and Aurora Creeks (Herreid, 1970) needs further investigation. In 1982, DGGS was unable to locate the source beds of this float. Coal resources in these areas are probably also limited.

WILSON CREEK

HISTORY AND INVESTIGATIONS

Coal in the Wilson Creek area (Candle Quadrangle) was discovered in early 1900 by gold prospectors, and first reported by Harrington (1919). In 1980, subcontractors for the Alaska Power Authority compiled a comprehensive report on the coal resources of northwest Alaska, which includes previously unpublished locations of Tertiary outcrops and coal float discovered in 1978-79 during uranium and precious-metals exploration of the area (Dames and Moore, 1980). In 1982, DGGS geologists investigated Wilson Creek, a tributary to the Kiwalik River, to ascertain its coal potential.

GEOLOGY

Unnamed coal-bearing strata in the Wilson Creek area consist of sandstone, conglomerate, claystone (often containing coalified wood and plant detritus), and coal. The typically flat-lying sediments at Wilson Creek occur at the southeast extremity of the Tertiary Kiwalik basin. Extensive areas of the Kiwalik and adjacent Buckland and Koyuk basins are covered by basalt flows that mask the suspected coal-bearing rocks below. The thickness of the Tertiary rocks within these basins is not known, but all three are believed to be relatively shallow (Dames and Moore, 1980). Aeromagnetic data collected by DGGS (Alaska Division of Geological & Geophysical Surveys, 1973) and Bouguer gravity measurements published by the U.S. Geological Survey (Barnes and Hudson, 1977) help define the Kiwalik and Buckland basins. The linear shape of the basins suggests that they are fault controlled, while the structure of the Koyuk basin is unknown (Dames and Moore, 1980). In the Kiwalik basin, coal-bearing sedimentary rocks are thickest near the Kiwalik River, which probably marks the axis of the basin. Basalts that cover much of this basin are thickest in the north and south, and thin to absent near the center (Barnes and Hudson, 1977; Dames and Moore, 1980). The eastern and western boundaries of the Kiwalik basin are defined by contacts with older metamorphic and igneous rocks and overlain by a basalt flow. Coal-bearing units in the Wilson Creek area closely resemble Miocene rocks in the adjacent Bendeleben Quadrangle and are tentatively assumed to be of the same Tertiary age or younger (Harrington, 1919; Dames and Moore, 1980).

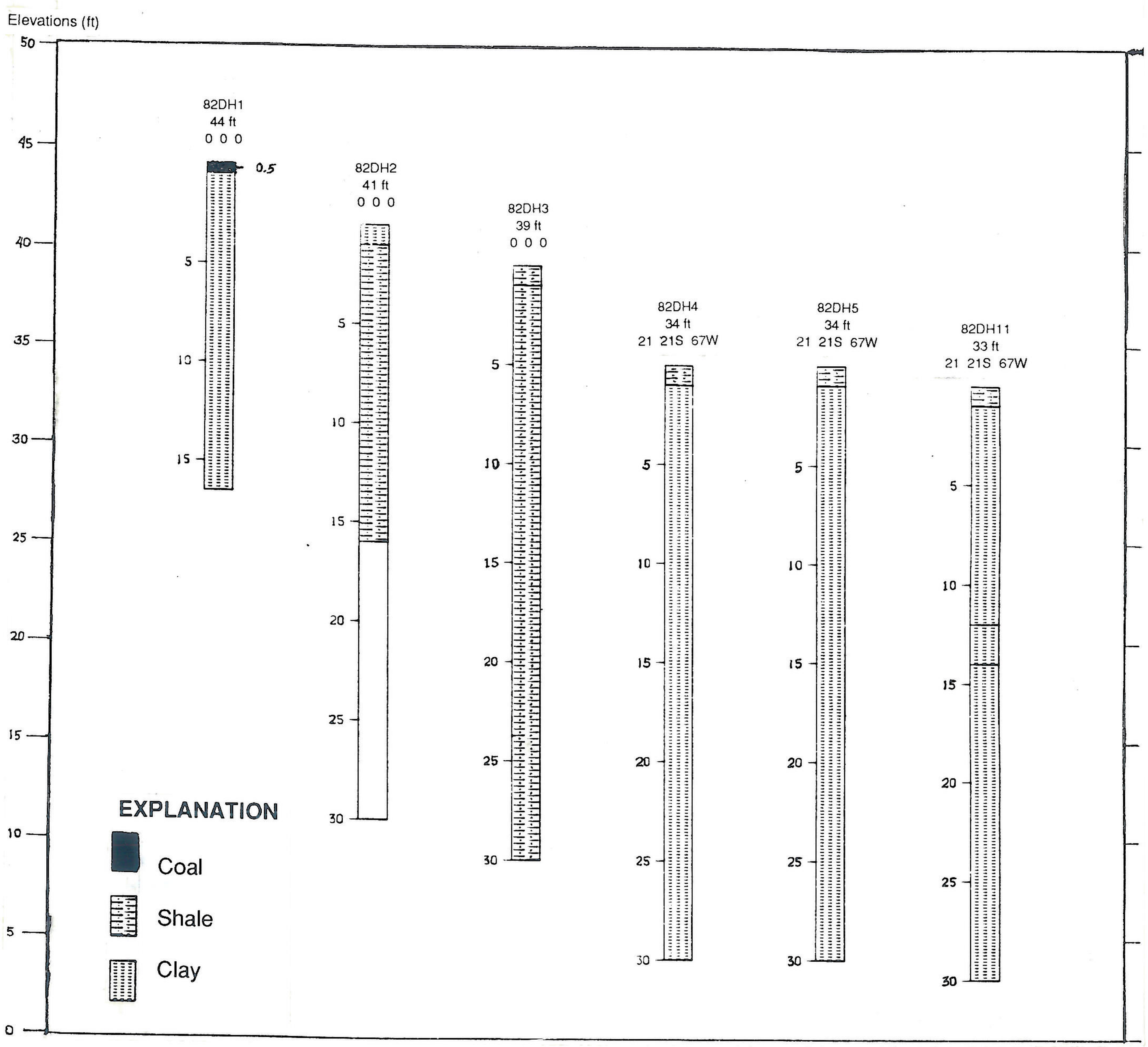


Figure 9. *Stratigraphic Analysis Techniques Systems (STRATS) log for 1982 Sinuk River drill-holes 82DH1, 82DH2, 82DH3, 82DH4, 82DH5, and 82DH11.*

The coal and clay at Wilson Creek are highly slumped but partly exposed for 20 to 30 ft along the creek bank where it is overlain by basalt. When examined by Resource Associates of Alaska in 1978, only 3 ft of the coal bed were visible, but the total thickness could be as much as 10 ft (Fankhauser and others, 1978). Coal rubble along the creek indicates that the coal may extend under the surface for an additional 600 ft or more downstream from the outcrop. Additional coal float and outcrops of Tertiary sedimentary rocks are found on Coal Creek, Connolly Creek, Hunter Creek, and Lava Creek, all tributaries of the Kiwalik River on the eastern perimeter of the basin (Dames and Moore, 1980).

COAL QUALITY

A sample of lignite (82GE7A) collected as float from along Wilson Creek (the coal bed was not exposed in 1982 due to creek-bank slumping and a thick snow cover) yielded an *as-received* heating value of 6,445 Btu (app., p. 34). This heating value is the same as the average heating value obtained for the Grouse Creek weathered coal sample (app., p. 35).

COAL RESOURCES

The quantity of coal in the Wilson Creek area is unknown, but this locale may hold considerable tonnage of Tertiary lignite (Dames and Moore, 1980). The association of coal with a basalt flow suggests that it may have been deposited in a similar setting to the Grouse Creek area coal described below. Further evaluation will require drilling and trenching. The locality is a considerable distance from tidewater (>30 mi) and potential local users.

GROUSE CREEK

HISTORY AND INVESTIGATIONS

In the Death Valley area of Seward Peninsula, coal as float along the Tubutulik River was first recognized by Mendenhall (1902). The presence of a Tertiary-age coal outcrop on Grouse Creek (sheet 1) was first described by West (1953). Additional geologic reports on the area include Miller and others (1972) and Sainsbury (1974).

In 1980, a sedimentary uranium drilling program conducted by Houston International Minerals Corporation revealed a significant coal deposit in Death Valley (Dickinson and others, 1987). Fifty-two holes drilled along a 3,500-ft-long northwest-trending mineralized zone indicate the presence of a 175-ft-thick coal bed. This property was conveyed to Greatland Exploration, Ltd., in 1982, and the data were published in part by Dickinson and others (1987) and Dickinson (1988).

GEOLOGY

East of the Darby Mountains in the Death Valley Basin (Bendeleben A-1 Quadrangle), quartz monzonite plutonic rocks occur with Tertiary volcanic and sedimentary rocks. Coal occurs as float along the Tubutulik River, as coal fragments in the sands that underlie the basalt flows, and in Tertiary outcrops along the eastern margin of the basin (Resource Associates of Alaska, 1978). Exposure of sedimentary rocks is poor because Eocene to Holocene black aphanitic basalt flows cover much of the southern extension of the basin. This southern extension was named the Boulder Creek basin by industry geologists (Dickinson and others, 1987). The Boulder Creek basin sediments and volcanic rocks were deposited in a graben formed in the north-south Kugruk fault zone, described by Till and others (1986). The development of this basin is probably analogous to the tectonic origin of the Chicago Creek deposit.

An approximately 35-ft-thick coal outcrop on Grouse Creek (fig. 10) is highly weathered and slumped, with bedding attitude indiscernible. We believe this coal is coeval with and probably the same bed as the thick subsurface coal discovered by Houston Industrial Minerals Corporation in 1980. According to their drill logs, the 175-ft-thick lignite lens encountered in drill hole DV-30 contains minor partings and is overlain successively by an Eocene basalt flow, coal, lacustrine sideritic mudstone, sandstone, and a Quaternary basalt flow (figs. 11 and 12) (Dickinson and others, 1987). Depth to the thickest coal bed is 300 ft, with other coal intercepts as shallow as 70 ft (David Hederley-Smith, oral commun., 1985). The coal and uranium are hosted in Paleocene nonmarine sandstone with average uranium grade of 0.27 percent U_3O_8 (Dickinson and Cunningham, 1984). The coal and related sedimentary rocks were deposited in the area of ancestral Lake Tubutulik, created when early Eocene basaltic lava dammed the ancestral Tubutulik River and flooded the valley (Dickinson, 1988).

West of Death Valley is McCarthy's Marsh, a present-day topographic depression that contains 3,000 to 10,000 ft of Tertiary sedimentary fill (based on gravity measurements by Barnes and Hudson, 1977). This basin is fault-bounded to the north and east by the Bendeleben and Darby Mountains. Coal float with a woody, lignitic appearance, and sedimentary rocks typical of the Tertiary coal-bearing strata in Death Valley, have been found on Omilak, Windy, and Telephone Creeks (Resource Associates of Alaska, 1978).

COAL QUALITY

The average of two proximate analyses of Death Valley coal samples recovered from the sedimentary uranium-drilling program yielded an *as-received* ash content of 3.3 percent, 0.52 percent total sulfur content, and a heating value of 7,680 Btu/lb (G.D. Stricker, oral commun., 1986). The two highly weathered samples (82GE6A and 82GE6B) collected from the outcrop on Grouse Creek are lignite in apparent rank, with an average *as-received* heating value of 6444 Btu/lb (app., p. 35).

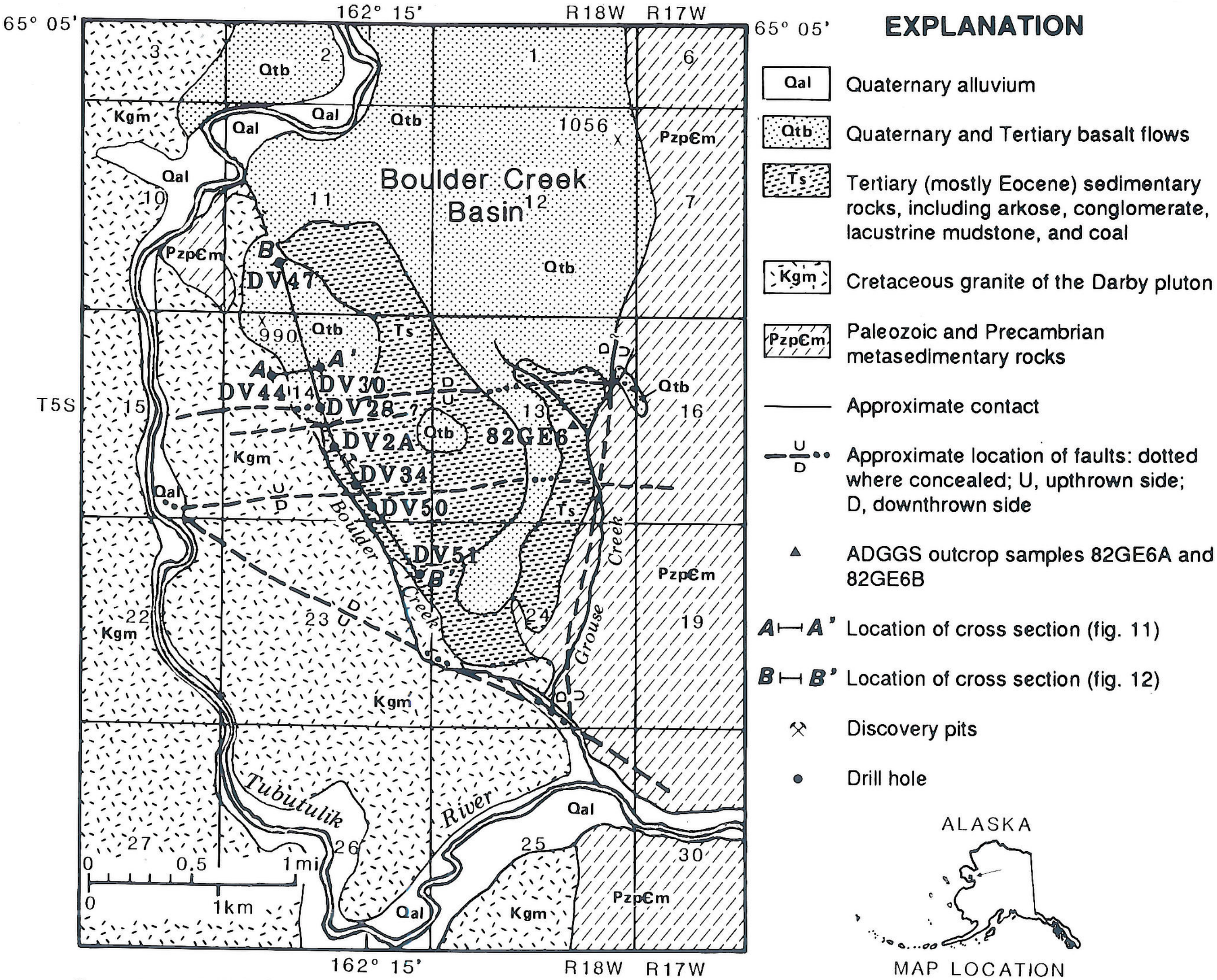
COAL RESOURCES

The 175-ft-thick coal bed indicates that considerable coal resources are present in Death Valley. The lateral extent of the Grouse Creek coal exposure is unclear due to overburden slumping, and reserve estimates based on this outcrop would be unreliable. The basalt overburden, considerable depth to subsurface coal beds (up to 300 ft), and distance from tidewater (>25 mi) are not favorable for development of Death Valley coal. The deep sedimentary basin beneath McCarthy's Marsh may also contain quantities of coal comparable to the Death Valley deposit (Resource Associates of Alaska, 1978).

KOYUK

HISTORY AND INVESTIGATIONS

For many years, residents of the Koyuk area have picked up coal on the Norton Bay beach for fuel, and barges have hauled pieces of coal up from the bottom of the bay



Base from U.S.G.S. Bendeleben A-1
Quadrangle, Alaska, 1950.

Figure 10. *Geologic map of the Death Valley uranium and coal deposit. Lithologic section for A-A' shown in figure 11; bor B-B' see figure 12. Lithologic logs for drill-holes (DV) shown in figures 11 and 12. Data for outcrop samples 82GE6A ad 82GE6B provided in Appendix A, p. 35.*

when weighing anchor (Mannings and Stevens, 1982; C.C. Hawley and Associates, 1983). Coal was first prospected in the Koyuk area sometime before 1909. Coal claims were located on a creek locally called 'Coal Creek,' (mine no. 21, sheet 1) a tributary of the Koyuk, and Harrington (1919) reports that a coal mining permit was issued in 1919 for an unspecified location on the Koyuk River. The vicinity was visited by geologists P.S. Smith and H.M. Eakin in 1909. Their examination of the abandoned prospect sites failed to reveal any coal beds. Harrington (1919) recorded secondhand reports of a 2- to 4-ft-thick coal bed and some thin coal seams exposed at sea level near the mouth of the Koyuk River.

In 1982-83, DGGS explored for coal in the Koyuk area by rotary drilling. A DGGS subcontractor drilled 22 holes along the Koyuk River in 1982, and in 1983 a second subcontractor undertook a program of surface mapping, drilling, and geophysics on approximately 230 acres near the mouth of the Koyuk River.

GEOLOGY

The unnamed coal-bearing sequence in the lower Koyuk River area may be either Late Cretaceous in age, possibly related to the Shaktolik Group (including the Kaltag and Nulato Formations) or to the Ungalik Conglomerate (Cass, 1959; Patton, 1973), or Tertiary in age, contemporary with the Koyuk basin coal-bearing group to the north in the Candle Quadrangle (Mannings and Stevens, 1982; C.C. Hawley and Associates, Inc., 1983). East of the Koyuk area, the coal-bearing rocks may continue north along the Koyuk River for as much as 30 mi (Harrington, 1919; Hudson, 1977; Dames and Moore, 1980). The coal-bearing strata are bounded on the west by older metamorphic rocks, and on the north by mostly volcanic rocks. Regional mapping by Cass (1959), Patton (1973), and Hudson (1977) has not clearly identified the age and extent of the coal-bearing strata. The sedimentary rocks exposed in old prospect shafts were reportedly much less

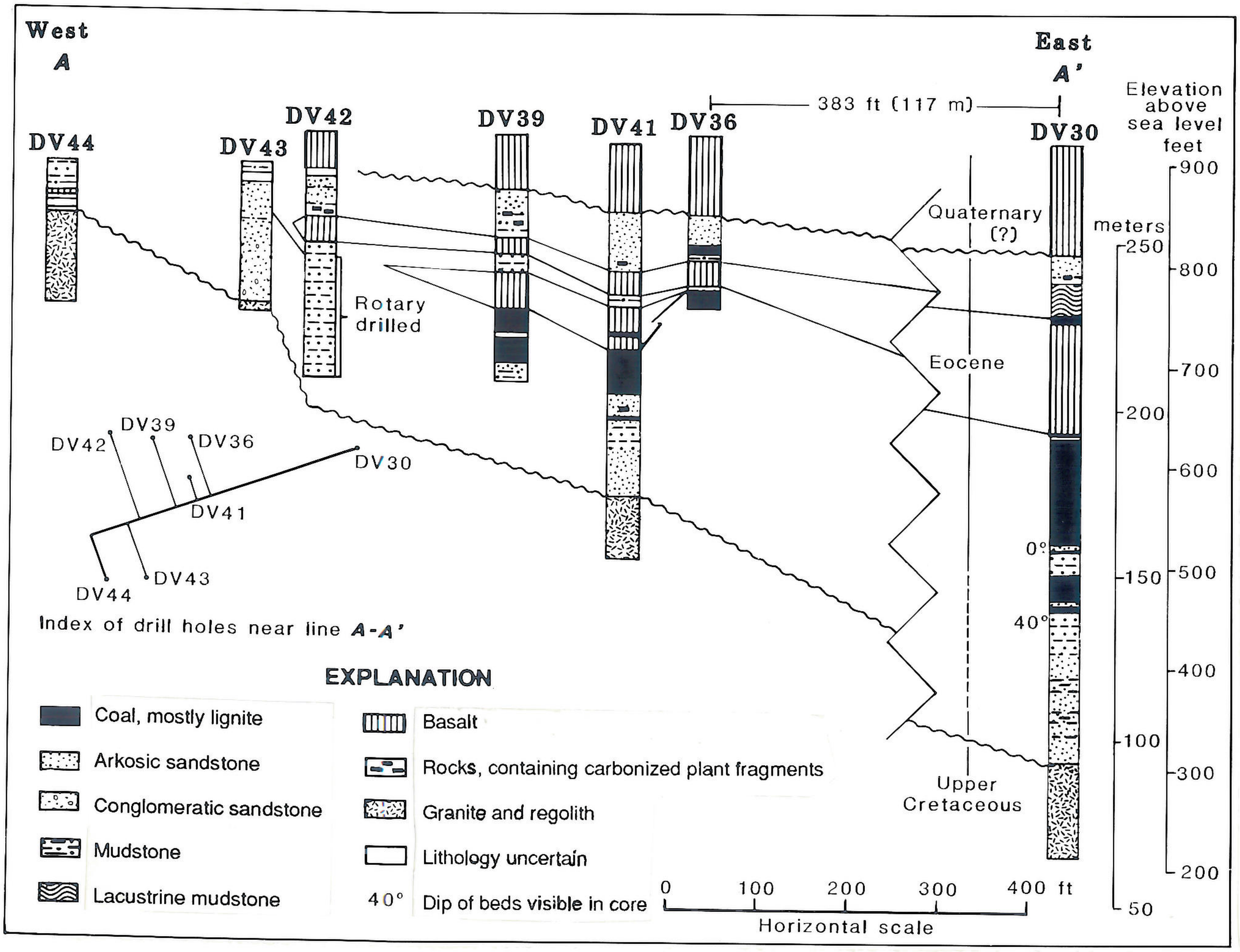


Figure 11. *Line of drill-hole-based lithologic section (A-A', fig. 10) in Death Valley uranium and coal deposit. Modified from Dickinson and others (1987, p. 1563).*

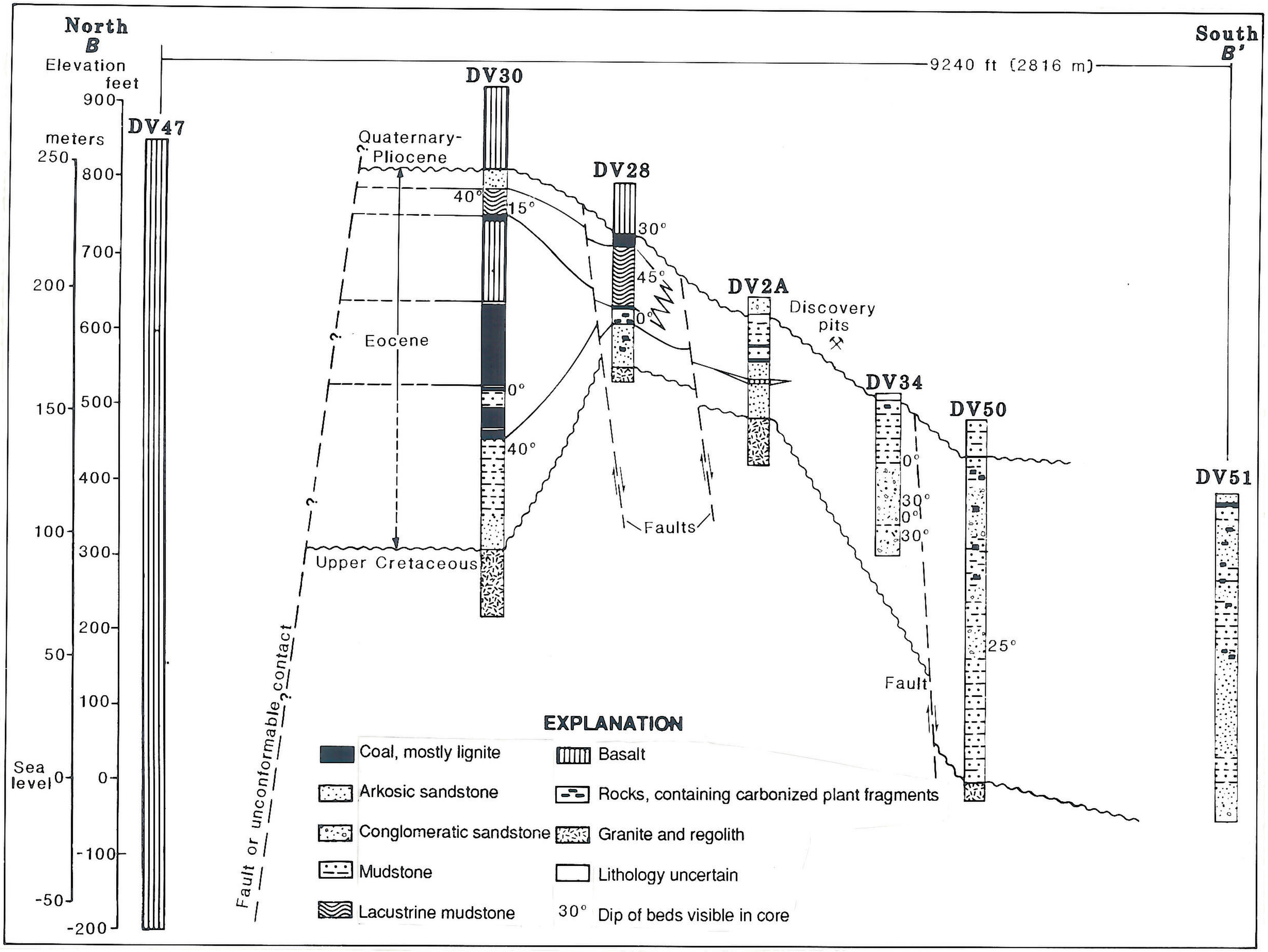


Figure 12. *Line of drill-hole-based lithologic section (B-B', fig. 10) in Death Valley uranium and coal deposit. Modified from Dickinson and others (1987, p. 1564).*

indurated than those of the Kaltag and Nulato Formations that crop out to the east (Smith and Eakin, 1910). This suggests that the coal-bearing rocks are of Tertiary rather than Cretaceous age.

The coal-bearing succession near Koyuk dips 10° to 20°S., with a strike of N.70°-85°E. Typical coal-bearing strata are thin, low-angle, cross-bedded, unconsolidated silts and sands that contain clay laminae and scattered coaly material. The coal occurs in irregularly shaped lenses rather than continuous beds (Mannings and Stevens, 1982; C.C. Hawley and Associates, 1983).

The 1982 DGGS drill holes reached an average depth of 20 ft; 10 holes penetrated coal beds up to 3.5 ft thick. Thirteen holes drilled in 1983 logged a cumulative total of 1,442 ft and intercepted thin and discontinuous coal (sheet 8). Of 10 coal intercepts, all at different horizons, the thickest was 3.5 ft, and most were <1.5 ft thick (C.C. Hawley and Associates, 1983).

COAL QUALITY

Average *as-received* values of the Koyuk coals are 8,365 Btu/lb, 21.77 percent moisture, 29.42 percent volatile matter, 39.78 percent fixed carbon, 9.22 percent ash, and 0.38 percent total sulfur (app., p. 35). This includes average analyses of samples from 16 drill holes combined with a weathered sample from a beach-level outcrop (82GE7B). There is no apparent difference in the values from drill-hole and outcrop samples as shown in the appendix. The coals rank as subbituminous C to subbituminous B, and are typical of Tertiary-age subbituminous coals found elsewhere in northwestern Alaska.

COAL RESOURCES

The discontinuous nature of the coal discovered during the 1982 and 1983 drilling programs makes quantitative coal-resource calculations unrealistic (Mannings and Stevens, 1982; C.C. Hawley and Associates, 1983). The coal was probably deposited in a river-delta distributary system, an environment of deposition that does not promote thick, continuous coal-bed formation. Judged solely on drilling results, the coal-resource potential in the Koyuk area is not high. However, abundant, widespread coal float and other indirect indications of coal in the Koyuk region suggest the presence of undiscovered coal resources beneath the surficial sedimentary cover (Mannings and Stevens, 1982; C.C. Hawley and Associates, 1983).

UNALAKLEET

HISTORY AND INVESTIGATIONS

Coal was mined in the early 1900s from a timber-supported adit dug at beach level into the bluff south of Unalakleet (Cathcart, 1920). Cathcart (1920) reports that 300 tons of weathered coal from this Norton Sound beach mine (mine no. 26, sheet 1) was sent to Nome and St. Michael in 1918 for steamship use. A nearby creek is now named Coal Mine Creek.

Early geologic studies in the region include reports by Smith and Eakin (1911) and Harrington (1919), and the first comprehensive geologic map was published by Cass (1959). In 1982, DGGS, BLM, and Mannings and Stevens conducted a brief reconnaissance of the Unalakleet coal occurrences. In 1983, C.C. Hawley and Associates drilled 12 rotary boreholes along the coast at the top of the bluff adjacent to exposed coal (Ramsey and others, 1986).

GEOLOGY

The eastern coast of Norton Sound is characterized by a thick, extensive sequence of nonmarine and volcanogenic Cretaceous to Tertiary age sedimentary rocks (Ramsey and others, 1986). These rocks (mainly greywacke, mudstone, sandstone, and coal) are probably equivalent to the Kaltag and Nulato Formations and the Ungalik Conglomerate exposed to the east (Patton, 1973) and probably underlie a large part of Norton Sound (Scholl and Hopkins, 1969). The sedimentary package is bordered to the south by Quaternary basalt flows, to the east by Mesozoic granitic and andesitic rocks juxtaposed by the Chirosky fault, and to the north by the Kaltag Fault, which crosscuts and deforms the Cretaceous strata (Ramsey and others, 1986). Patton (1973) reports an early Tertiary age for the Unalakleet coal, based on pollen, and Ramsey and others (1986) speculate this coal is part of a nearly continuous Late Cretaceous to early Tertiary depositional sequence.

The Quaternary and Tertiary to Cretaceous sedimentary section that crops out on the beach bluff south of Unalakleet is complicated by large slump blocks (sheet 9) resulting from partial thawing of exposed permafrost and subsequent slope failure. Elsewhere, these rocks are exposed in the banks of deeply incised streams. Ramsey and others (1986, p. 65) characterize the coal-bearing portion of the exposed beach section as

> "a complex assemblage of unconsolidated silt, clay, coal, and ash lenses intercalated with indurated sandstones and shales. Lateral facies changes are frequent and abrupt; and few beds have a lateral extension of more than 50 ft. Low angle crossbeds (<10°) are the most common sedimentary structures".

Subsurface stratigraphy, determined by drilling, reveals a section dominated by silt and clay with discontinuous coal lenses, and unconformably overlain by 20 to 50 ft of Holocene and Quaternary unconsolidated sediments. The Quaternary sediments, deposited in alluvial fans shed from the local highlands, contain ice as accretionary wedges and interstitial void fillings up to 80 percent by volume in places (Ramsey and others, 1986). Coal lenses were intercepted by seven of the drill holes (sheet 9), with the thickest coal (2-ft) in DH-U1-83 (Ramsey and others, 1986).

COAL QUALITY

The quality of Unalakleet coal is variable, with an average *as-received* heating value of 8206 Btu/lb, 23.61 percent moisture content, 31.77 percent fixed carbon content, 8.86 percent ash content, and 0.15 percent total sulfur content (app., p. 35). The thicker exposed lenses are lignite in apparent rank, while many thinner coal horizons and streaks (not analyzed) have an apparent higher rank. Coal chips recovered from the 2-ft-thick-coal lens in DH-U1-83 contain vitrain and plant fragments (Ramsey and others, 1986).

COAL RESOURCES

The largest lens of exposed coal occurs at the mouth of Coal Mine Creek, where a 6-ft-wide pod of clayey lignite pinches out laterally within 20 ft. This coal is probably the bed mined in 1918; it now contains very limited reserves. Drilling results indicate the coal-bearing strata south of Unalakleet dip 40° to 45°E. (Ramsey and others, 1986), suggesting that coal exposed in the bluffs, if continuous, lies at considerable depth onshore. The depositional environment of the Tertiary to Cretaceous section at Unalakleet is interpreted as a marginal marine distributary system of a lower delta plain, an unlikely setting for thick and continuous coal formation (Ramsey and others, 1986).

ST. LAWRENCE ISLAND

HISTORY AND INVESTIGATIONS

Coal on St. Lawrence Island was first used by the local Siberian Yup'ik Eskimos, who burned it with driftwood in their campfires and communal houses. Early geologic investigations of St. Lawrence Island were primarily coastal surveys (Dawson, 1894; Emerson, 1904; Collier, 1906) or associated with archaeological excavations (Geist and Rainey, 1936). Little was known about the geology of the Island's interior until later work by Patton and Csejtey (1971a, b, 1980), Jones and Forbes (1976), and C.C. Hawley and Associates (1978).

In 1981, DGGS and Dan Renshaw explored the western part of St. Lawrence Island for coal occurrences. An apparently promising site near Naskak on the western shore of Niyrakpak Lagoon was recommended for further exploration and trenching (Renshaw, 1981). A limited drilling program was conducted at the site in 1982 with disappointing results (Renshaw, 1982), and the remaining parts of the island were explored by helicopter and on foot for coal resources in 1983 (Renshaw, 1983). Coal localities reported in the literature and by local inhabitants were visited, and a few samples were collected for analysis.

GEOLOGY

St. Lawrence Island contains a thick section of Paleozoic and Mesozoic sedimentary rocks similar to coeval rocks exposed in Chukostk Peninsula, Russia, and in the Brooks Range of northern Alaska (Patton and Dutro, 1969). Various Cretaceous to Tertiary plutonic and volcanic rocks also occur on the island (Patton and Csejtey, 1971b). The Kookooligit Mountains, south of the village of Savoonga, were formed by extensive Pleistocene basalt flows that overlie thin, coal-bearing Tertiary sediments. Several cinder cones related to the Kookooligit volcanic extrusive rocks still remain.

The coal-bearing sediments consist of poorly consolidated sandstone, grit, and conglomerate, carbonaceous mudstone, ashy tuff, volcanic breccia, and lenses of lignitic coal ó18 in. thick. The low-grade lignite, Oligocene in age (Patton and Csejtey, 1980), occurs along St. Lawrence Island drainages and lagoon shores (sheet 1). Several previously reported coal localities are vitrified, bedded volcanic rocks with a coal-like appearance, while others are eroded lignite float along river drainages (Renshaw, 1983). Coal fragments were recovered from a water-well drill hole at Savoonga, where the coal-bearing strata are overlain by the Kookooligit volcanic rocks.

A minor, 6-in.-thick occurrence of lignite is exposed on the southwest bank of Fossil River, 7 mi from its mouth (sheet 1). The seam walls consist of silty clays that are adjacent to volcanic rocks. The attitude of the lignite seam is indiscernible due to soil frost heaving and subsequent slumping. Lignite and coalified wood fragments also occur along the east side of Koozata River (sheet 1) where volcanic rocks predominate. A 4-in.-thick seam of lignite is exposed within about 30 ft of unconsolidated sediments.

The thickest lignite beds are exposed on the west shore of Niyrakpak Lagoon and at the south end of Aghnaghak Lagoon (sheet 1). Four shallow trenches dug into the bluff at Niyrakpak Lagoon (trench locations shown on sheet 10) show coal lenses up to 18 in. thick within carbonaceous shale, clay, and sand (Renshaw, 1981). In 1982, 12 auger holes were drilled into the tundra west of the trench sites to determine the lateral continuity of the coal. A cumulative total of 353.5 ft of drilling intercepted very little coal and mostly dark-gray clay with gravel, carbonaceous clay, and silt. Permafrost was encountered between 3 ft and 12 ft depth and discontinuous ice lenses to 30 ft depth (sheet 10) (Renshaw, 1982). The most abundant coal beds were encountered in DH10 adjacent to 1982 trench no. 1.

COAL QUALITY

The quality of St. Lawrence Island coal is highly variable, with an average *as-received* heating value of 8267 Btu/lb, 28.13 percent moisture content, 32.40 percent volatile matter content, 34.31 percent fixed carbon content, and 0.98 percent total sulfur content (app., p. 35). Heat and pressure from coeval volcanic processes appear to have assisted in the coalification of available organic material (Renshaw, 1983).

COAL RESOURCES

Based on the drilling results, Renshaw (1982) concluded that the coal exposed on the bluff and in trenches at Niyrakpak Lagoon has little lateral continuity and suggested that the high rate of bluff erosion will probably remove the remaining coal in a few years. The results of the 1981-83 St. Lawrence Island field investigations indicate that coal resources on the island are very limited. Many coal beds are associated with volcanic-derived sediments and apparently formed in small basins between episodes of volcanic eruptions (Renshaw, 1983).

CONCLUSIONS

The diverse quantity and quality of coal in northwestern Alaska (figs. 13 and 14) is directly related to disparate depositional settings and ages. The most abundant high-quality coal resources are the Cretaceous-age coals that occur in the Arctic foothills region, extending east from Cape Beaufort along the northern flank of the Brooks Range. The likelihood that these resources will be mined by both surface and underground techniques is high. A mining plan developed by Arctic Slope Regional Corporation for the Deadfall Syncline proposes mining 300,000 tons of coal per year for local use and export. More than 300 workers would be employed.

The second most abundant coal resource exists in the Tertiary-age basins on Seward Peninsula, where very thick coal and lignite beds of limited areal extent occur. A mining plan developed by C.C. Hawley and Associates for Chicago Creek proposes the open-pit mining of

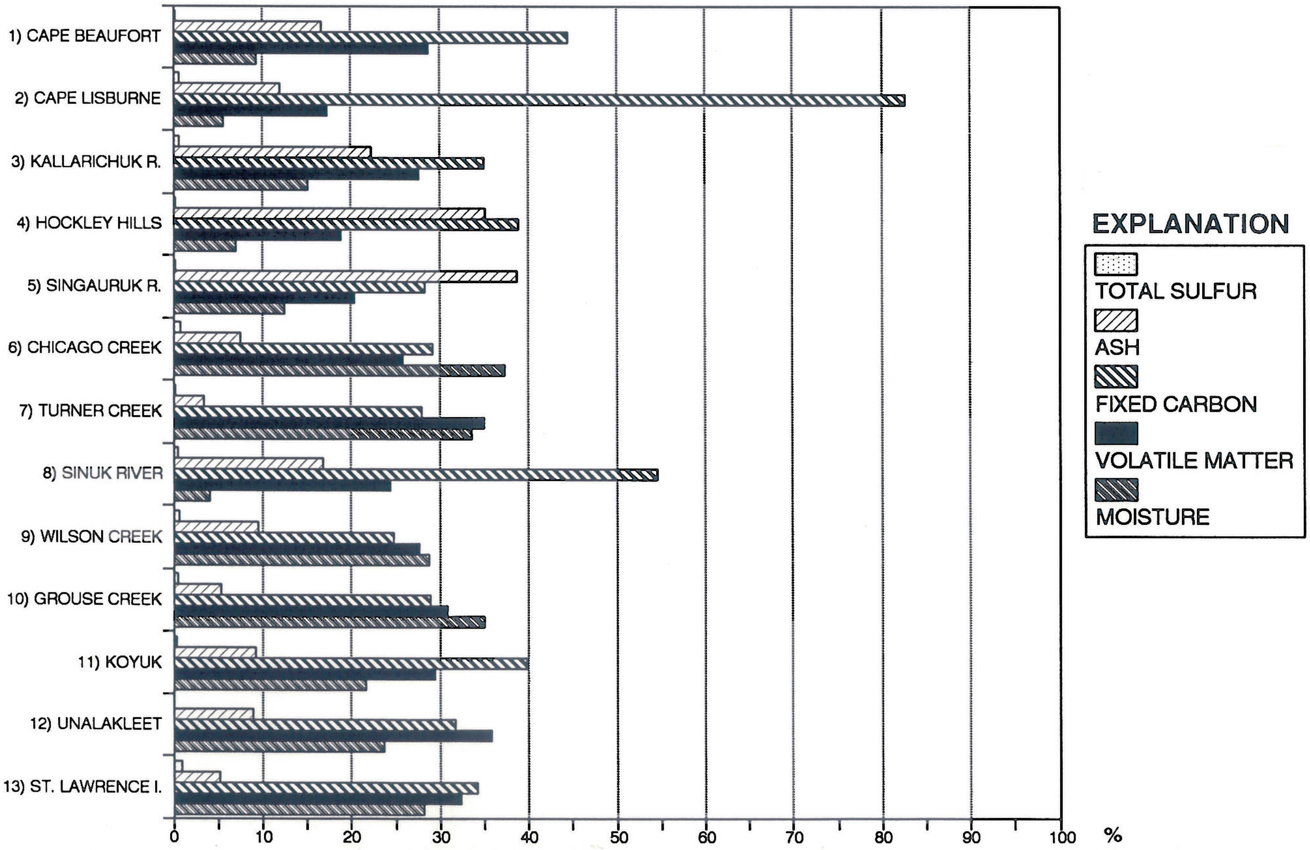


Figure 13. *Bar graph of average as-received percentages of moisture, volatile matter, fixed-carbon, ash, and total sulfur for 13 northwestern Alaska areas. Average values from data entered in NCRDS USALYT files and shown in appendix.*

50,000 short tons of coal per year for 30 yr from demonstrated resources of 3,429,000 short tons. This coal would supply a power plant in Kotzebue. Other Tertiary coal deposits that have limited potential under current market conditions include those in the Death Valley-Boulder Creek basin, where a 175-ft-thick bed of subsurface coal and a 35-ft-thick-bed in outcrop at Grouse Creek are known. Undiscovered Tertiary coal deposits on Seward Peninsula may be considerable.

The highest quality coal in the region, but also the most difficult to extract, is the Mississippian-age deposit at Cape Dyer on the Lisburne Peninsula. This coal is as high as semianthracite in apparent rank, but is structurally complicated by local and regional tectonics. The high rank and near tidewater location may be incentives for further exploration by industry and government.

Coal in northwestern Alaska is low in total sulfur content and generally low in pyritic sulfur content. To comply with strict coal-burning regulations, the demand for high-quality, low-sulfur coal is expected to rise in the United States and worldwide. Northwest Alaska contains significant known resources of high-quality, compliance coal and lignite that can supplement this demand.

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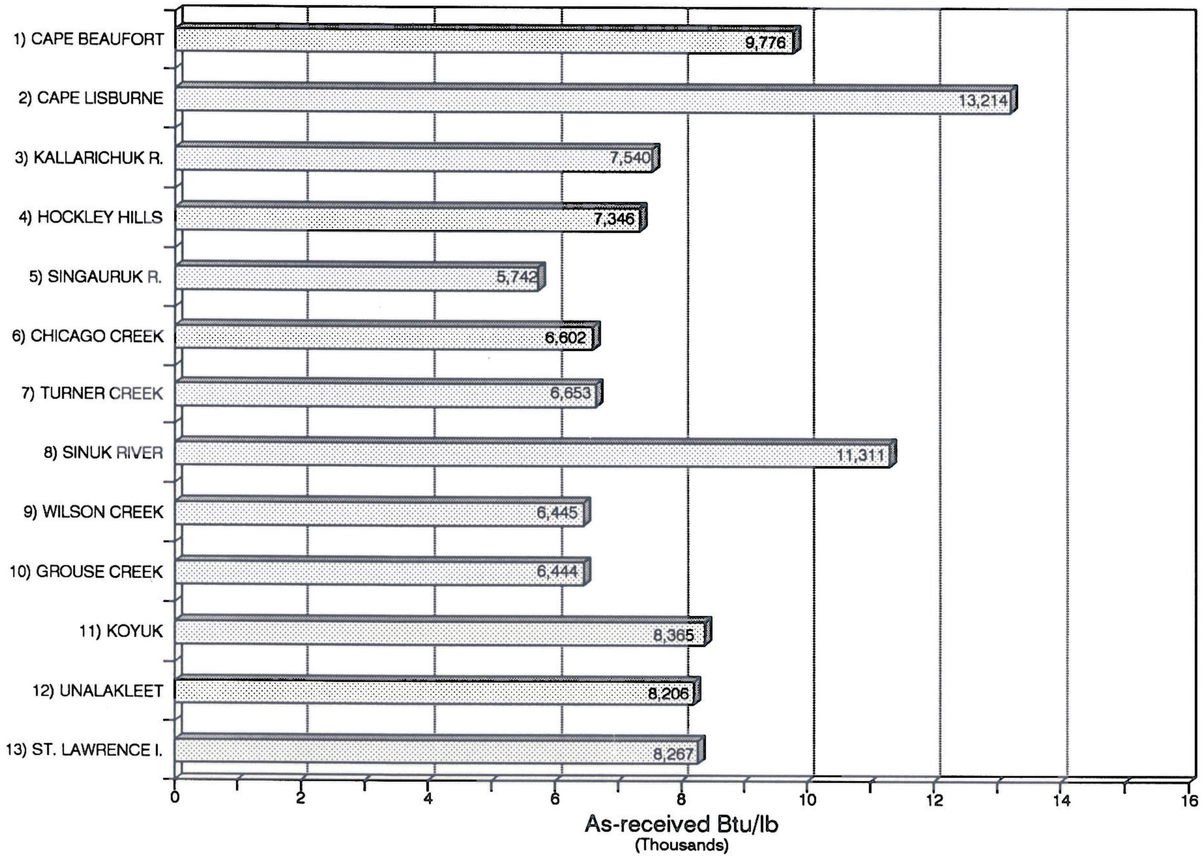

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APPENDIX A

Listing of PointIds and coal quality data entered into NCRDS for thirteen northwestern Alaska coal localities

CAPE BEAUFORT/DEADFALL SYNCLINE (Pt. Lay, De Long Mountains, and Pt. Hope Quadrangles)

Point ID	Latitude	Longitude	Unit no.	Depth in feet	Btu/lb	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	H %	C %	N %	O %	Sulfur (pyritic) %	Sulfur (total) %
SS70-11W	685425 N	1642002 W	*	**	11570	3.9	36.4	45.7	14.0	5.2	65.6	1.9	12.8	***	0.5
SS70-17W	685412 N	1644150 W	*	**	9900	10.0	30.4	46.4	13.2	5.0	57.9	1.8	21.7	***	0.4
SS70-19W	685408 N	1644120 W	*	**	6010	6.0	18.5	27.2	48.3	3.2	34.9	1.1	12.3	***	0.2
SS70-27W	685355 N	1644525 W	*	**	9710	14.2	30.0	48.6	7.2	4.9	58.0	1.6	29.9	***	0.4
SS70-28W	685353 N	1644607 W	*	**	8400	12.9	32.5	41.0	13.6	4.7	51.4	1.5	28.4	***	0.4
SS70-29W	685353 N	1644639 W	*	**	8460	12.9	33.4	40.6	13.1	4.8	51.8	1.5	28.69	***	0.2
SS70-30W	685340 N	1644938 W	*	**	6480	12.6	24.9	31.4	31.1	4.0	39.9	0.9	23.7	***	0.4
			*	**	8970	12.9	34.0	42.1	11.0	4.9	54.8	1.3	27.6	***	0.4
			*	**	9040	13.2	32.7	44.2	9.9	4.9	54.6	1.5	28.8	***	0.3
			*	**	9770	12.3	34.1	47.8	5.8	5.1	58.9	1.5	28.3	***	0.4
			*	**	6060	12.1	25.9	30.4	31.6	3.9	37.9	1.2	25.2	***	0.2
SS70-30WA	685340 N	1644938 W	*	**	6480	12.6	24.9	31.4	31.1	4.0	39.9	0.9	23.7	***	0.4
			*	**	8970	12.9	34.0	42.1	11.0	4.9	54.8	1.3	27.6	***	0.4
			*	**	9040	13.2	32.7	44.2	9.9	4.9	54.6	1.5	28.8	***	0.3
			*	**	9770	12.3	34.1	47.8	5.8	5.1	58.6	1.5	28.8	***	0.3
			*	**	6060	12.1	25.9	30.4	31.6	3.9	37.9	1.2	25.2	***	0.2
SS70-31W	685344 N	1644736 W	*	**	9670	15.7	32.4	49.0	2.9	5.0	59.2	1.3	31.3	***	0.3
SS70-32W	685344 N	1644829 W	*	**	104000	12.6	28.8	53.2	5.4	4.9	62.3	1.2	25.8	***	0.4
			*	**	9510	15.0	31.7	58.0	6.3	5.2	48.0	1.1	29.2	***	0.2
			*	**	11690	8.0	30.4	56.3	5.3	5.1	68.5	1.3	19.6	***	0.2
			*	**	8200	17.3	31.6	40.3	10.8	4.9	50.8	1.1	32.1	***	0.3
SS70-33W	685339 N	1644907 W	*	**	110800	9.1	27.6	57.4	5.9	4.5	66.9	1.1	21.4	***	0.2
			*	**	12450	5.6	39.4	48.7	6.5	5.3	69.3	1.37	17.3	***	0.3
			*	**	12030	5.3	39.5	48.7	6.5	5.3	69.3	1.3	17.3	***	0.3
SS70-73W	685225 N	1650701 W	*	**	12030	4.4	37.4	48.8	9.4	5.1	68.8	1.6	14.9	***	0.2
SS70-74W	685211 N	1650815 W	*	**	9160	13.2	35.4	44.3	7.1	5.1	56.1	1.4	30.1	***	0.2
SS70-80W	685222 N	1650726 W	*	**	10400	9.1	34.3	48.8	7.8	4.9	61.9	1.3	23.9	***	0.2
SS70-82W	685203 N	1650947 W	*	**	9080	12.7	34.0	42.4	10.9	5.1	54.6	1.3	27.7	***	0.4
SS70-83W	685205 N	1650923 W	*	**	8190	11.1	32.6	36.6	19.7	4.7	49.5	1.1	24.6	***	0.4
SS70-88W	685233 N	1650413 W	*	**	9740	11.7	32.7	47.4	8.2	4.9	58.6	1.2	26.7	***	0.4
73DSAH1	690639 N	1632313 W	2	4.5	8620	6.3	23.5	43.3	26.9	3.7	51.5	0.9	16.8	***	0.2
73DSAH2	690812 N	1632248 W	2	2.7	***	17.9	25.9	37.9	18.3	***	***	***	***	***	***
73DSAH3	690828 N	1632363 W	*	3	9000	14.1	27.9	45.7	12.3	***	***	***	***	***	0.2
73DSAH4	691107 N	1631117 W	*	3	10390	13.4	29.9	51.3	5.4	5.3	61.9	1.4	25.8	***	0.2
73DSAH5	691047 N	1631128 W	*	4	9380	12.7	25.9	48.4	13.0	4.5	57.0	1.1	24.3	***	0.1
73DSAH6	691056 N	1631332 W	*	4	9430	14.3	28.4	47.8	9.5	4.9	57.2	1.0	27.2	***	0.2
73DSAH8	691007 N	1630848 W	*	4.5	9370	13.7	28.5	47.6	10.2	4.8	56.7	1.0	27.1	***	0.2
73DSAH10	691025 N	1631028 W	*	5	10400	12.5	28.5	53.5	5.5	4.8	62.7	1.3	25.4	***	0.3
73DSAH23	690935 N	1630829 W	*	4.5	9300	13.7	29.8	46.2	10.3	4.9	56.5	1.1	19.7	***	0.2
			*	7	***	11.7	29.6	43.6	15.1	***	***	***	***	***	***

73DSAH24	691006 N	1630854 W	*	3	9070	16.0	28.3	45.6	10.1	5.0	54.7	1.0	29.0	***	0.2
73DSAH25	691006 N	1630854 W	*	4	8160	13.7	25.6	41.4	19.3	4.5	49.9	0.9	29.0	***	0.2
73DSAH27	691051 N	1631727 W	*	4	10100	15.6	29.2	51.1	4.1	5.3	60.5	1.3	28.6	***	0.2
83-1	691045 N	1632349 W	5	5	11256	2.29	29.67	49.09	18.94	***	***	***	***	***	0.24
	691100 N	1632332 W	4	61	11966	5.41	26.51	56.75	11.33	***	***	***	***	***	0.40
			4	69	13206	4.78	32.31	57.69	5.22	***	***	***	***	***	0.28
			4	69	11450	4.79	30.26	48.41	16.54	***	***	***	***	***	0.27
83-3	691047 N	1631535 W	4	88	13001	3.95	32.40	56.97	6.68	***	***	***	***	***	0.25
			4	94	12543	3.45	32.59	53.20	10.77	***	***	***	***	***	0.3
83-4	691039 N	1631533 W	3	51	11470	4.67	28.73	52.01	14.60	***	***	***	***	***	0.21
			3	58	11133	3.83	30.84	47.13	18.19	***	***	***	***	***	0.28
83-5	691030 N	1631520 W	3	82	11967	4.21	30.27	53.17	11.81	***	***	***	***	***	0.27
			3	84	11228	4.62	30.35	47.84	15.02	***	***	***	***	***	0.24
83-6	691024 N	1631459 W	3	66	11647	4.38	31.00	49.60	15.57	***	***	***	***	***	0.26
83-8	690932 N	1630751 W	2	25	11358	5.51	29.61	49.32	15.57	***	***	***	***	***	0.26
			2	28	11165	11.47	30.03	47.12	11.39	***	***	***	***	***	0.20
83-8-C	690932 N	1630751 W	5	51	12593	5.30	33.08	53.15	8.47	***	***	***	***	***	0.22
			4	55	9509	2.16	26.21	41.16	30.47	***	***	***	***	***	0.27
83-9	690912 N	1630821 W	4	55	9509	2.16	26.21	41.16	30.47	***	***	***	***	***	0.27
83-10	690803 N	1630759 W	3	69	11513	3.43	30.89	50.17	15.51	***	***	***	***	***	0.24
			3	74	13266	3.25	34.82	56.25	5.68	***	***	***	***	***	0.20
			5	125	12484	2.86	33.45	52.32	11.37	***	***	***	***	***	0.27
83-11	690722 N	1631021 W	3	47	10438	3.46	27.93	45.33	23.28	***	***	***	***	***	0.29
			3	50	11448	3.42	31.76	48.97	15.85	***	***	***	***	***	0.21
			3	55	11989	3.45	33.23	49.60	13.73	***	***	***	***	***	0.20
			3	60	12722	3.57	34.29	52.99	9.15	***	***	***	***	***	0.20
			3	03	11777	3.53	32.50	48.77	15.20	***	***	***	***	***	0.22
83-12	690753 N	1632303 W	5	67	9454	3.66	24.57	45.78	25.99	***	***	***	***	***	0.15
83-16	690414 N	1633441 W	5	96	9401	7.22	28.14	37.62	29.02	***	***	***	***	***	0.26
			5	100	9831	6.02	32.03	36.71	25.25	***	***	***	***	***	0.24
			5	102	11163	6.72	32.16	45.14	15.98	***	***	***	***	***	0.22
83-17	690453 N	1633957 W	4	63	9327	23.25	25.03	35.16	16.56	***	***	***	***	***	0.35
			4	68	8466	21.50	26.33	34.65	17.52	***	***	***	***	***	0.40
83-19	690014 N	1633041 W	1	1	5976	28.46	23.21	27.90	20.43	***	***	***	***	***	0.21
83-20	690608 N	1631721 W	1	4	6276	23.68	21.12	27.81	27.39	***	***	***	***	***	0.32
83-21	690638 N	1631312 W	3	78	12507	5.02	35.12	50.81	9.05	***	***	***	***	***	0.22
			3	83	12780	6.05	35.37	51.12	7.46	***	***	***	***	***	0.19
83-22	690453 N	1633818 W	3	49	10093	5.82	29.28	41.94	22.95	***	***	***	***	***	0.35
83-201	693344 N	1623752 W	3	33	10923	6.53	29.03	46.71	17.73	***	***	***	***	***	0.50
			5	89	9544	6.36	25.96	41.32	26.36	***	***	***	***	***	0.33
			7	112	9097	5.40	28.11	36.16	30.33	***	***	***	***	***	0.22
83-203	691922 N	1624109 W	5	86	9448	11.75	27.65	48.19	12.41	***	***	***	***	***	0.21
			5	91	10077	9.96	29.09	48.99	11.96	***	***	***	***	***	0.18
			5	96	11549	8.12	31.34	54.55	5.9	***	***	***	***	***	0.28
			5	101	9980	8.32	28.00	46.03	17.65	***	***	***	***	***	0.45
83-206	691553 N	1625548 W	3	137	6495	7.35	19.31	26.78	46.56	***	***	***	***	***	0.35
			3	42	10850	5.57	29.28	46.05	19.10	***	***	***	***	***	0.32
			5	87	2530	17.82	13.05	8.51	60.62	***	***	***	***	***	0.21
AVERAGE					**9976**	**9.38**	**28.87**	**44.55**	**16.73**	**6.00**	**71.74**	**1.64**	**32.24**	***	**0.27**

Point ID	Latitude	Longitude	Unit no.	Depth in feet	Btu/lb	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	H %	C %	N %	O %	Sulfur (pyritic) %	Sulfur (total) %
CAPE LISBURNE															
83CD-3	683825 N	1661249 W	*	**	13060	7.13	10.96	75.52	6.39	4.02	77.71	1.13	10.22	***	0.53
			*	**	14150	4.47	11.98	81.80	1.75	***	***	***	***	***	0.49
83CD-5	683828 N	1661250 W	*	**	12439	13.28	11.58	72.10	3.04	***	***	***	***	***	0.81
83CD-6	683829 N	1661249 W	*	**	13029	10.69	11.25	75.33	2.73	***	***	***	***	***	0.52
83CD-7	683820 N	1661250 W	*	**	11457	5.39	10.82	66.56	17.24	***	***	***	***	***	0.54
83CD-8	683815 N	1661258 W	*	**	12796	5.60	13.62	71.00	9.77	***	***	***	***	***	0.48
83CD-9	683801 N	1661301 W	*	**	14731	2.06	13.10	83.24	1.60	***	***	***	***	***	0.60
83CD-10	682328 N	1655725 W	*	**	11879	12.81	9.56	70.21	7.42	***	***	***	***	***	0.50
83CD-11	682423 N	1655912 W	*	**	***	0.36	5.99	1.92	91.73	***	***	***	***	***	0.06
82GE7C	682422 N	1655912 W	*	**	13208	6.17	43.44	47.28	3.11	***	***	***	***	***	0.060
H24240	683828 N	1661250 W	*	**	11800	3.0	12.8	68.2	16.0	***	***	***	***	***	0.90
H24241	683828 N	1661249 W	*	**	14010	3.0	14.1	80.0	2.9	***	***	***	***	***	0.60
H24242	683829 N	1661250 W	*	**	14280	2.0	15.0	79.0	4.0	***	***	***	***	***	0.50
H24243	683829 N	1661250 W	*	**	14140	2.0	15.40	79.4	3.2	***	***	***	***	***	0.80
H24244	683830 N	1661250 W	*	**	13150	2.1	12.50	75.7	9.70	***	***	***	***	***	0.60
H24245	683830 N	1661250 W	*	**	13760	2.9	13.5	80.1	3.5	***	***	***	***	***	0.80
H24246	683830 N	1661250 W	*	**	12860	2.3	15.9	71.6	10.2	***	***	***	***	***	0.50
Niak Creek	684031 N	1661251 W	*	**	13887	3.77	15.64	77.65	2.94	***	***	***	***	***	***
Kikiktukgot	683224 N	1661251 W	*	**	***	5.51	21.16	70.33	3.0	***	***	***	***	***	0.96
Kapaloak	683022 N	1661251 W	*	**		1.71	15.62	79.86	2.8	***	***	***	***	***	***
AVERAGE					**13214**	**5.66**	**17.29**	**82.75**	**11.95**	***	***	***	***	***	**0.63**
KALLARICHUK RIVER															
82GE1	671201 N	1594532 W	*	**	9292	13.20	32.15	41.68	12.97	5.34	52.68	0.82	27.13	0.41	1.06
82GE2	671301 N	1594530 W	*	**	5788	17.15	23.30	28.38	31.17	***	***	***	***	***	0.38
AVERAGE					**7540**	**15.18**	**27.73**	**35.03**	**22.21**	***	***	***	***	***	**0.72**
HOCKLEY HILLS															
82JC3	664656 N	1601959 W	*	**	9496	12.77	26.52	48.90	11.81	4.88	57.24	0.96	24.65	0.14	0.46
82JC1	665418 N	1602630 W	*	**	5196	1.46	11.11	28.76	58.67	***	***	***	***	***	0.25
AVERAGE					**7346**	**7.12**	**18.82**	**38.83**	**35.24**	***	***	***	***	***	**0.36**
SINGAURUK RIVER															
82GE3	664656 N	1601959 W	*	**	6948	15.23	22.18	34.97	27.62	***	***	***	***	***	0.35
82GE4	664656 N	1601959 W	*	**	4125	9.91	16.51	21.07	52.51	3.10	26.59	0.46	17.08	0.01	0.26
			*	**	5937	15.86	21.46	30.11	32.57	***	***	***	***	***	0.28
82JC2	664656 N	1601959 W	*	**	5959	9.13	21.27	27.39	42.21	***	***	***	***	***	0.24
AVERAGE					**5742**	**12.53**	**20.36**	**28.39**	**38.73**	***	***	***	***	***	**0.28**

CHICAGO CREEK

82CCDH1	655421 N	1622549 W	4	112.6	6377	36.44	24.39	28.26	10.91	6.66	38.03	0.69	42.71	0.44	0.99
			4	123.0	6416	38.73	23.97	28.32	8.98	6.83	37.43	0.76	45.37	0.03	0.63
			4	132.0	6692	36.03	25.74	28.51	9.72	6.74	38.37	0.04	43.72	0.47	1.41
			4	141.0	6949	38.97	25.57	30.77	4.69	7.04	40.22	0.74	46.51	0.06	0.81
			4	150.0	6493	37.09	24.17	28.16	10.58	6.87	37.65	0.59	42.81	0.40	1.50
			4	160.0	5607	36.83	21.05	25.38	16.73	6.41	33.28	0.70	42.12	0.08	0.75
			4	180.0	7042	37.06	26.22	30.64	6.09	6.83	40.10	0.71	44.36	0.65	1.91
			4	190.0	6592	40.71	24.72	28.28	6.29	7.18	38.02	0.70	46.82	0.10	1.00
			4	202.5	6940	40.10	26.49	28.59	4.82	7.22	39.37	0.70	45.92	0.83	1.98
			4	212.5	6446	43.69	24.93	26.65	4.73	7.40	36.76	0.63	48.47	0.93	2.02
82CCDH4	655418 N	1622547 W	2	40.0	7109	37.10	27.26	31.73	3.91	***	***	***	***	***	0.49
			2	47.5	6987	39.45	26.88	31.15	2.52	***	***	***	***	***	0.64
			2	51.5	6269	36.31	28.58	24.83	10.29	***	***	***	***	***	0.59
			2	57.5	6880	41.41	25.39	30.37	2.84	***	***	***	***	***	0.62
			2	62.0	7017	40.76	25.93	30.34	2.97	***	***	***	***	***	0.55
			2	68.0	7750	34.19	28.43	34.26	3.12	***	***	***	***	***	0.73
			2	73.5	7992	30.53	29.94	35.66	3.87	***	***	***	***	***	0.67
			2	80.0	8007	31.23	30.66	34.74	3.37	***	***	***	***	***	0.65
			2	87.0	7799	30.87	29.47	34.43	5.23	***	***	***	***	***	0.71
			2	94.5	7958	28.99	29.68	35.42	5.91	***	***	***	***	***	0.56
			2	101.5	8209	29.61	30.14	37.11	3.14	***	***	***	***	***	0.66
			2	112.0	7959	32.08	29.80	34.56	3.56	***	***	***	***	***	0.98
			2	118.0	8099	29.04	29.07	37.75	4.13	***	***	***	***	***	0.67
			2	130.0	8226	28.23	30.29	37.62	3.86	***	***	***	***	***	0.61
			2	138.0	7887	30.82	29.12	36.39	3.67	***	***	***	***	***	0.63
82CCDH8	655504 N	1622538 W	2	47.0	7411	35.32	27.74	32.52	4.42	***	***	***	***	***	1.15
			2	54.0	7049	38.07	26.73	30.46	4.75	***	***	***	***	***	1.34
			2	61.0	7412	34.85	27.67	32.71	4.77	***	***	***	***	***	1.07
			2	67.0	7037	35.30	27.07	29.94	7.69	***	***	***	***	***	1.07
			2	72.0	6175	36.59	24.16	26.53	12.71	***	***	***	***	***	0.74
			2	77.0	6471	34.28	25.55	27.70	12.47	***	***	***	***	***	0.85
82CCDH11	655441 N	1622554 W	2	31.5	6527	38.02	23.18	30.63	8.17	***	***	***	***	***	0.77
			2	31.5	6527	38.02	23.18	30.63	8.17	***	***	***	***	***	0.77
			2	40.0	6326	39.01	24.38	28.06	8.55	***	***	***	***	***	1.15
			2	42.5	7156	36.93	25.44	33.18	4.45	***	***	***	***	***	0.82
			2	48.0	6482	33.69	24.73	29.21	12.37	***	***	***	***	***	0.79
			2	53.0	6930	37.97	24.99	31.21	5.82	***	***	***	***	***	0.74
			2	58.0	6961	35.24	25.49	31.66	7.61	***	***	***	***	***	0.71
			2	63.0	6621	36.00	24.44	30.37	9.20	***	***	***	***	***	0.78
			2	68.0	6805	33.91	26.06	29.78	10.24	***	***	***	***	***	0.73
			2	73.0	6670	30.46	25.22	29.95	14.37	***	***	***	***	***	1.04
85CCDH1	654162 N	1622549 W	5	83.0	7499	35.67	29.46	30.59	4.28	***	***	***	***	***	0.56
85CCDH2	655413 N	1622548 W	4	221.0	7179	37.94	26.36	32.67	3.03	***	***	***	***	***	0.65
			4	222.0	5819	36.62	24.61	25.69	13.08	***	***	***	***	***	0.55
			4	232.0	6385	43.95	24.39	27.85	3.81	***	***	***	***	***	0.59
			4	236.0	7164	38.55	27.34	31.09	3.02	***	***	***	***	***	0.72
			4	263.0	6653	40.05	26.59	28.62	4.74	***	***	***	***	***	0.53
			4	264.0	7244	28.53	26.98	32.01	2.48	***	***	***	***	***	0.53
			4	269.0	6877	40.57	25.79	29.04	4.60	***	***	***	***	***	0.50

Point ID	Latitude	Longitude	Unit no.	Depth in feet	Btu/lb	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	H %	C %	N %	O %	Sulfur (pyritic) %	Sulfur (total) %
85CCDH3	655414 N	1622544 W	6	45.0	7011	37.17	26.37	31.40	5.06	***	***	***	***	***	0.54
85CCDH5	655411N	1622541 W	4	84.0	5648	34.88	29.64	18.72	16.76	***	***	***	***	***	0.42
			4	86.0	6712	41.63	25.69	29.52	3.16	***	***	***	***	***	0.53
85CCDH6	655411 N	1622540 W	5	83.0	5586	44.24	22.59	24.59	8.58	***	***	***	***	***	0.49
85CCDH6	655411 N	1622540 W	3	68.0	7138	36.66	28.16	30.50	4.68	***	***	***	***	***	0.68
			3	95.0	5245	37.94	26.01	18.99	17.06	***	***	***	***	***	0.68
			3	82.0	6872	40.63	26.08	29.90	3.39	***	***	***	***	***	0.64
			3	87.0	6269	39.35	25.39	26.73	8.53	***	***	***	***	***	0.72
			3	93.0	6474	40.05	25.81	27.15	6.99	***	***	***	***	***	0.95
			3	95.0	7022	37.52	27.57	30.15	4.76	***	***	***	***	***	1.11
			3	97.0	4863	32.96	24.48	20.45	22.11	***	***	***	***	***	5.28
85CCDH17	655418 N	1622542 W	*	**	6372	43.05	23.95	27.86	5.13	***	***	***	***	***	0.64
85CCDH17	655418 N	1622542 W	6	38.0	6944	38.54	27.06	30.67	3.73	***	***	***	***	***	0.48
			6	48.0	7066	38.50	27.46	31.21	2.84	***	***	***	***	***	0.32
			10	130.0	6812	40.41	25.16	30.71	3.71	***	***	***	***	***	0.44
85CCDH21	655425 N	1622550 W	2	25.0	6905	39.30	24.70	32.11	3.88	***	***	***	***	***	0.52
			4	70.0	6659	42.19	24.85	29.26	3.70	***	***	***	***	***	0.85
			4	75.0	5175	40.72	20.13	23.19	15.96	***	***	***	***	***	0.70
			4	90.0	6414	41.86	23.50	28.00	6.64	***	***	***	***	***	1.23
85CCDH23	655430 N	1622553 W	3	60.0	6914	40.17	26.55	29.56	3.73	***	***	***	***	***	0.54
			3	65.0	7134	37.97	26.30	31.63	4.10	***	***	***	***	***	0.58
85CCDH23	655430 N	1622553 W	3	68.0	5460	24.70	26.07	21.02	28.21	***	***	***	***	***	1.04
85CCDH30	655436 N	1622559 W	4	47.0	4166	22.90	17.70	15.76	43.63	***	***	***	***	***	0.34
			4	47.0	5648	34.88	29.64	18.72	16.76	***	***	***	***	***	0.42
			4	53.0	6712	41.63	25.69	29.52	3.16	***	***	***	***	***	0.53
			4	100.0	6601	39.86	24.61	29.15	6.38	***	***	***	***	***	0.66
			4	108.0	6682	41.07	24.54	29.93	4.44	***	***	***	***	***	0.60
			4	130.0	6617	40.19	24.54	29.86	4.69	***	***	***	***	***	0.49
85CCDH34	655442 N	1622554 W	2	23.0	6577	39.62	26.13	28.88	5.37	***	***	***	***	***	0.65
			2	32.0	6741	42.48	25.60	29.14	2.78	***	***	***	***	***	0.64
			2	80.0	6135	43.25	22.88	27.16	6.70	***	***	***	***	***	0.99
			2	80.0	4902	46.26	22.88	27.16	6.70	***	***	***	***	***	0.99
			2	95.0	4902	46.65	20.02	21.98	15.35	***	***	***	***	***	1.78
			2	102.0	5414	40.52	21.49	22.46	15.53	***	***	***	***	***	1.25
85CCDH34	655442 N	1622554 W	2	113.0	6741	42.48	25.60	29.14	2.78	***	***	***	***	***	0.64
			2	123.0	6135	43.26	22.88	27.16	6.70	***	***	***	***	***	0.99
AVERAGE					**6602**	**37.36**	**25.81**	**29.22**	**7.58**	**6.92**	**37.92**	**0.63**	**44.88**	**0.40**	**0.85**
TURNER CREEK															
82GE8	653031 N	1641432 W	*	**	6653	33.56	34.98	28.00	3.46	***	***	***	***	***	0.16
SINUK RIVER															
82JC7	644424 N	1655542 W	*	**	11311	4.07	24.51	54.57	16.85	***	***	***	***	***	0.53
WILSON CREEK															
82GE7A	652115 N	1612601 W	*	**	6445	28.82	27.77	24.71	9.62	***	***	***	***	***	0.74

GROUSE CREEK

82GE6A	650255 N	1621647 W	*	**	7577	34.29	30.01	33.37	2.33	6.83	45.04	.34	44.52	0.41	0.94
82GE6B	650255 N	1621647 W	*	**	5310	35.60	31.54	24.55	8.31	***	***	***	***	***	0.78
AVERAGE					**6444**	**34.95**	**30.78**	**28.96**	**5.32**	***	***	***	***	***	**0.86**

KOYUK

85KOYTH18	655252 N	1610625	4	12	8561	21.35	29.41	40.98	8.26	***	***	***	***	***	0.31
82KOY1	655252 N	1610625 W	2	10	8459	22.25	29.25	40.24	8.27	***	***	***	***	***	0.30
82KOY2	655252 N	1610625 W	2	11	8461	21.43	29.55	41.43	7.58	***	***	***	***	***	0.28
82KOY3	655252 N	1610625 W	2	12	8567	20.65	29.22	41.91	9.22	***	***	***	***	***	0.28
82KOY4	655252 N	1610625 W	2	12	7836	23.11	29.25	36.85	10.79	***	***	***	***	***	0.47
82KOY5	655252 N	1610625 W	2	3	8367	20.73	29.19	38.10	11.99	***	***	***	***	***	0.42
82KOY6	655252 N	1610625 W	2	16	8102	21.56	29.95	38.09	10.40	***	***	***	***	***	0.44
82KOY7	655252 N	1610625 W	2	11	8393	21.65	28.37	40.58	9.40	***	***	***	***	***	0.43
82KOY8	655252 N	1610625 W	2	11.5	8502	21.96	29.66	40.39	7.99	50.05	5.75	0.68	35.20	0.03	0.32
82KOY9	655252 N	1610625 W	2	12	8580	21.62	29.80	40.49	8.10	50.03	5.64	0.70	35.23	0.03	0.31
82KOY10	655252 N	1610625 W	4	14	8647	21.18	29.97	40.94	7.91	50.79	5.62	0.66	34.72	0.03	0.31
82KOY11	655252 N	1610625 W	4	12	8561	21.35	29.41	40.98	8.26	***	***	***	***	***	0.31
82KOY12	655252 N	1610625 W	4	19	8017	22.39	28.93	37.95	10.73	***	***	***	***	***	0.40
82KOY13	655252 N	1610625 W	2	22	7775	23.47	29.27	37.77	9.49	***	***	***	***	***	0.31
82KOY14	655252 N	1610625 W	*	**	8497	21.43	28.93	40.70	8.94	50.31	5.59	0.67	34.11	0.02	0.39
82KOY15	655252 N	1610625 W	2	1	8885	21.28	32.23	42.10	5.39	***	***	***	***	***	0.45
82GE7B	652115 N	1612601 W	*	**	7995	21.27	27.77	37.88	13.08		***	***	***	***	0.63
AVERAGE					**8365**	**21.71**	**29.42**	**39.78**	**9.22**	**50.30**	**5.65**	**0.68**	**34.82**	**0.03**	**0.38**

UNALAKLEET

82GE10	634601 N	1604544 W	*	**	7648	24.16	32.39	31.86	11.59	***	***	***	***	***	0.26
82JC	634536 N	1604620 W	*	**	9190	21.39	42.56	30.90	5.15	6.85	51.92	0.65	34.80	0.02	0.55
UA-151	634614 N	1604535 W	*	**	7779	25.29	32.51	32.55	9.85	6.30	45.28	1.13	37.11	0.02	0.33
AVERAGE					**8206**	**23.61**	**35.82**	**31.77**	**8.86**	**6.58**	**48.60**	**0.89**	**35.96**	**0.02**	**0.38**

ST. LAWRENCE ISLAND

82AGH-1	633820 N	1714212 W	1	**	10418	6.10	50.91	39.66	3.33	***	***	***	***	***	1.22
82JC-101	633105 N	1712815 W	1	6	10445	35.18	26.20	33.18	5.43	***	***	***	***	***	0.68
82JC-108	633105 N	1712815 W	3	**	6843	37.63	24.56	32.37	5.45	***	***	***	***	***	0.58
83KR-1	632742 N	1703916 W	*	**	8573	19.71	36.97	38.53	4.79	***	***	***	***	***	0.49
83KR-2	632742 N	1703916 W	6	**	4490	54.03	22.71	20.07	3.19	***	***	***	***	***	2.32
83FR-1	632324 N	1700358 W	1	**	8834	16.14	33.06	42.07	8.73	***	***	***	***	***	0.57
AVERAGE					**8267**	**28.13**	**32.40**	**34.31**	**5.15**	***	***	***	***	***	**0.98**

All values *as-received-basis*.
*No unit number assigned.
**No depth given or denotes surface samples.
***No value given or analsis not run.
#An average of Niak, Kiliktukgot, and Kapaloak Creek.