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INTRODUCTION

From 1992 through 1993 the Alaska Division of Geological and Geophysical Surveys, in a cooperative effort with the U.S. Geological Survey, examined the potential for coal resources in the Colville Mining District (CMD), located in northern Alaska (fig. 1). This project was funded by the U.S. Bureau of Mines ongoing Mineral Land Assessment mining district studies which is designed to provide reliable and comprehensive mineral resource information to support policy and land use decisions made by Congress and Federal land management agencies (Meyer and others, in press). This report is the coal resource potential assessment of the CMD (Clough and Stricker, in press) which is included in the comprehensive mineral resource potential for the CMD of Meyer and others (in press).

LOCATION AND LAND STATUS

The CMD is situated in the west-central part of the northern slope of the Brooks Range and is geographically defined by the drainage divides of the Colville and Itkillik Rivers and their tributaries (fig. 1). The CMD is part of the sixty-seven mining districts within Alaska defined by Ransom and Kerns (1954). This area is within the Arctic Coastal Plain, the Arctic Foothills, and the Central and Eastern Brooks Range physiographic provinces of Wahrhaftig (1956). The area of the CMD is approximately 16.5 million acres (6.7 million hectares) and occurs within twelve 1:250,000-scale quadrangles, the Teshekpuk River, Harrison Bay, Utukok River, Lookout Ridge, Ikpikpuk River, Umiat, Misheguk Mt., Howard Pass, Killik River, Chandler Lake, Philip Smith Mts., and Survey Pass quadrangles (locations shown in fig. 1).

Land ownership within the CMD includes lands managed by the State of Alaska, Native regional and village corporations, the U.S. Bureau of Land Management (BLM), and the National Park Service. The area north and west of the Colville River is within the National Petroleum Reserve in Alaska (NPRA) managed by the BLM. Meyer and others (in press) indicate the presence of small parcels of private inholdings within the CMD.

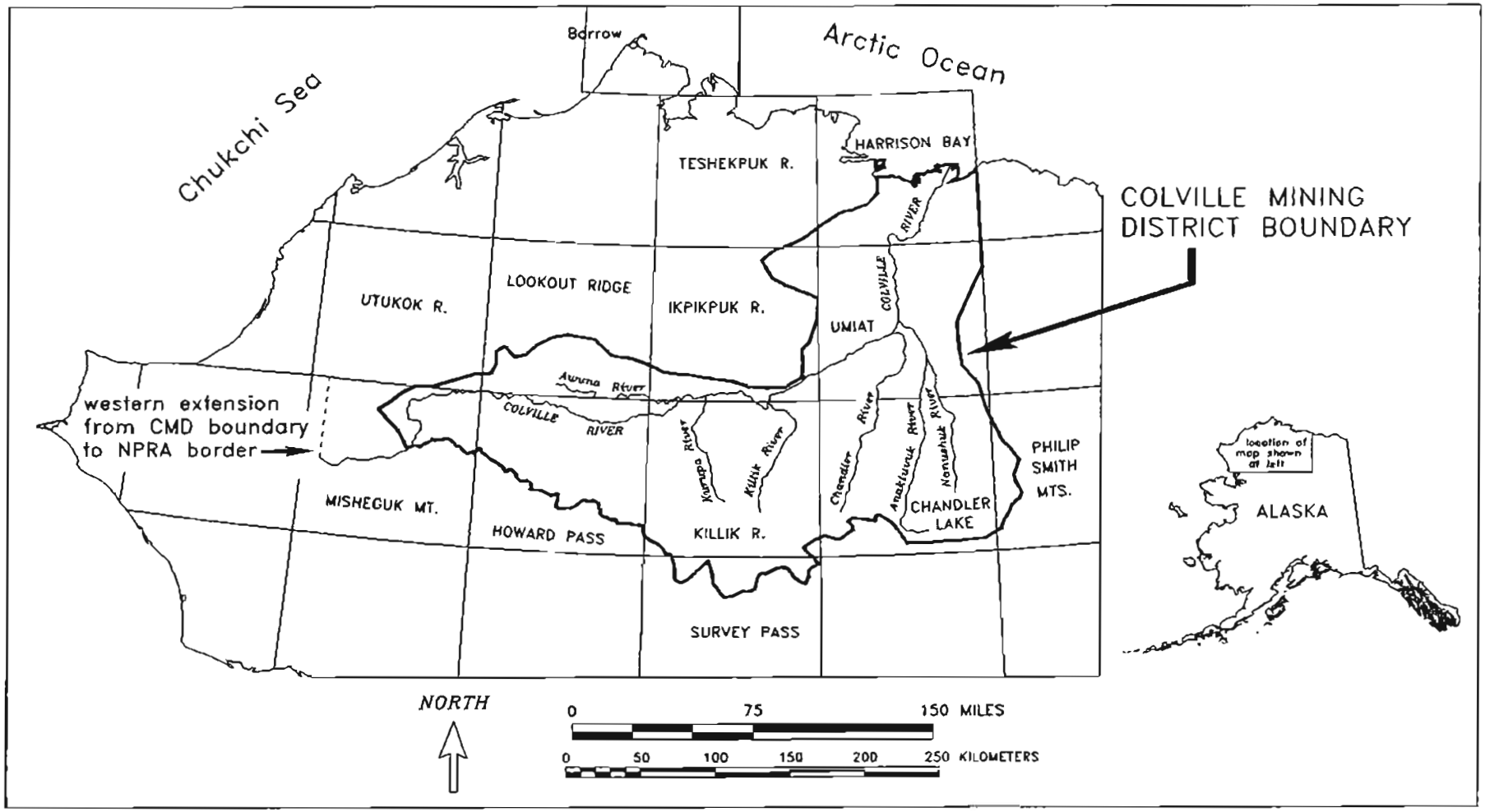

Figure 1. Location of the Colville Mining District (CMD) in northern Alaska. Major rivers within the CMD and quadrangles which contain the CMD are identified.

COAL RESOURCES

Coal geology

The CMD lies within the Northern Alaska Coal Province which includes the Arctic Foothills and Arctic Coastal Plain coal subprovinces (Merritt and Hawley, 1986) (fig. 2). Coal is found in nonmarine rocks of the Kekiktuk Conglomerate, Fortress Mountain Formation, Nanushuk Group, Colville Group, and the Sagavanirktok Formation (fig. 3). The bulk of the high quality coal is found in the Nanushuk Group which has two principal coal-bearing formations; the Corwin Formation (western CMD) and the Chandler Formation (central and eastern CMD) (fig. 4). The major structural elements in the CMD which control outcrop pattern, thickness of the coal-bearing interval, and minability of the coals, are a series of east-west trending anticlinal-synclinal pairs in the Arctic Foothills Subprovince. These anticlines and synclines were folded by north-vergent thrusting occurring during the Brooks Range orogenic event. Maximum bedding dip of the coal-bearing sedimentary rocks in the foothills fold belt are greater than 15°, whereas in the coastal plain, bedding is less than 15° (fig. 2).

The Mississippian-age Kekiktuk Conglomerate occurs at considerable depth within the CMD. Although known to contain coal beds up to 5 feet thick (1.5 m) in the subsurface at several test well sites on the North Slope (Sable and Stricker, 1987), it is not considered to contain any significant coal resources. Assessment of Kekiktuk Conglomerate coal resources in the CMD is not possible due to uncertainty of lateral continuity, great depth below the surface, and paucity of data. The Lower Cretaceous Fortress Mountain Formation crops out in the Arctic foothills of the Brooks Range and contains minor occurrences of thin, discontinuous seams of coal associated with fluvial sandstone (Crowder, 1989). This unit does not contain economic quantities of coal.

The Nanushuk Group is comprised of six marine to nonmarine rock units (fig. 3) which were deposited in the Cretaceous-age Colville basin situated north of the Brooks Range. During Early to Late Cretaceous time the Colville basin was the site of two river delta systems, the Corwin delta (western North Slope) and the Umiat delta (central North Slope) (Ahlbrandt and others, 1979). These deltas may have merged during Albian time (Molenaar, 1981; 1985). The Corwin Formation represents deposition in the southwest-sourced Corwin delta plain to alluvial plain depositional environments. On shore, this formation is thickest (11,000 ft, 3350 m) at Corwin Bluff on the Chukchi Sea coast west of the CMD. It thins eastward to zero in the subsurface near the Colville River (Stricker, 1991). Northwest of the CMD coal beds up to 20 feet (6 m) thick occur in Corwin Formation outcrop along the Kukpowruk River (Warfield and Boley, 1969). Known surface and subsurface Corwin Formation in the CMD is limited to the far western end of the district. Coal-bearing Nanushuk Group rocks in the central and eastern CMD consist of the Chandler Formation (fig. 3) which was deposited in the Umiat middle delta plain environment (Stricker, 1991). The Chandler Formation is as thick as 3,575 feet (1090 m) and intertongues with marginal marine to marine rocks. Chandler Formation outcrops along the Colville River contain coal beds as thick as 5.5 feet (1.7 m) thick.

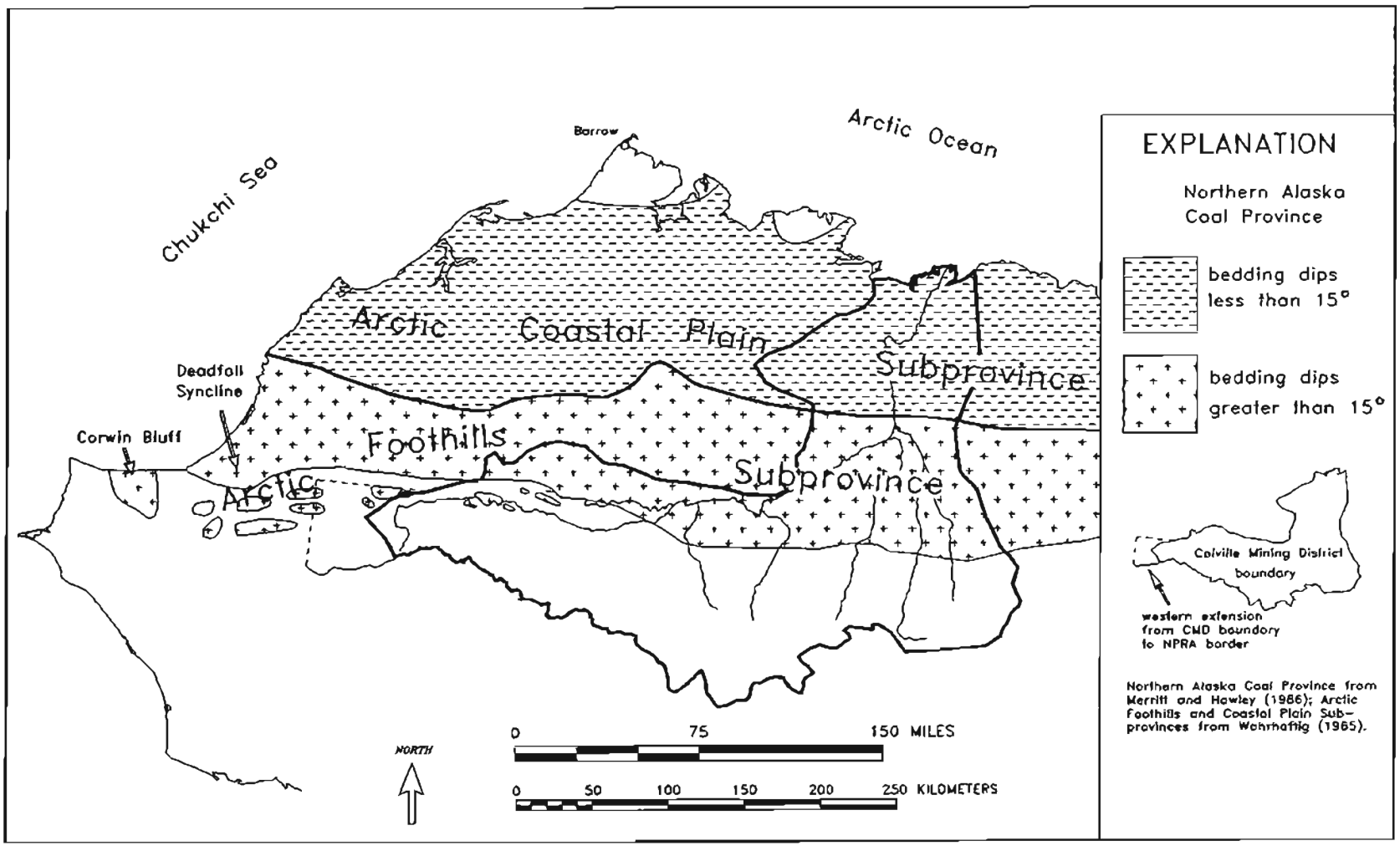

Figure 2. Location of Northern Alaska Coal Province and Arctic Foothills and Coastal Plain subprovinces.

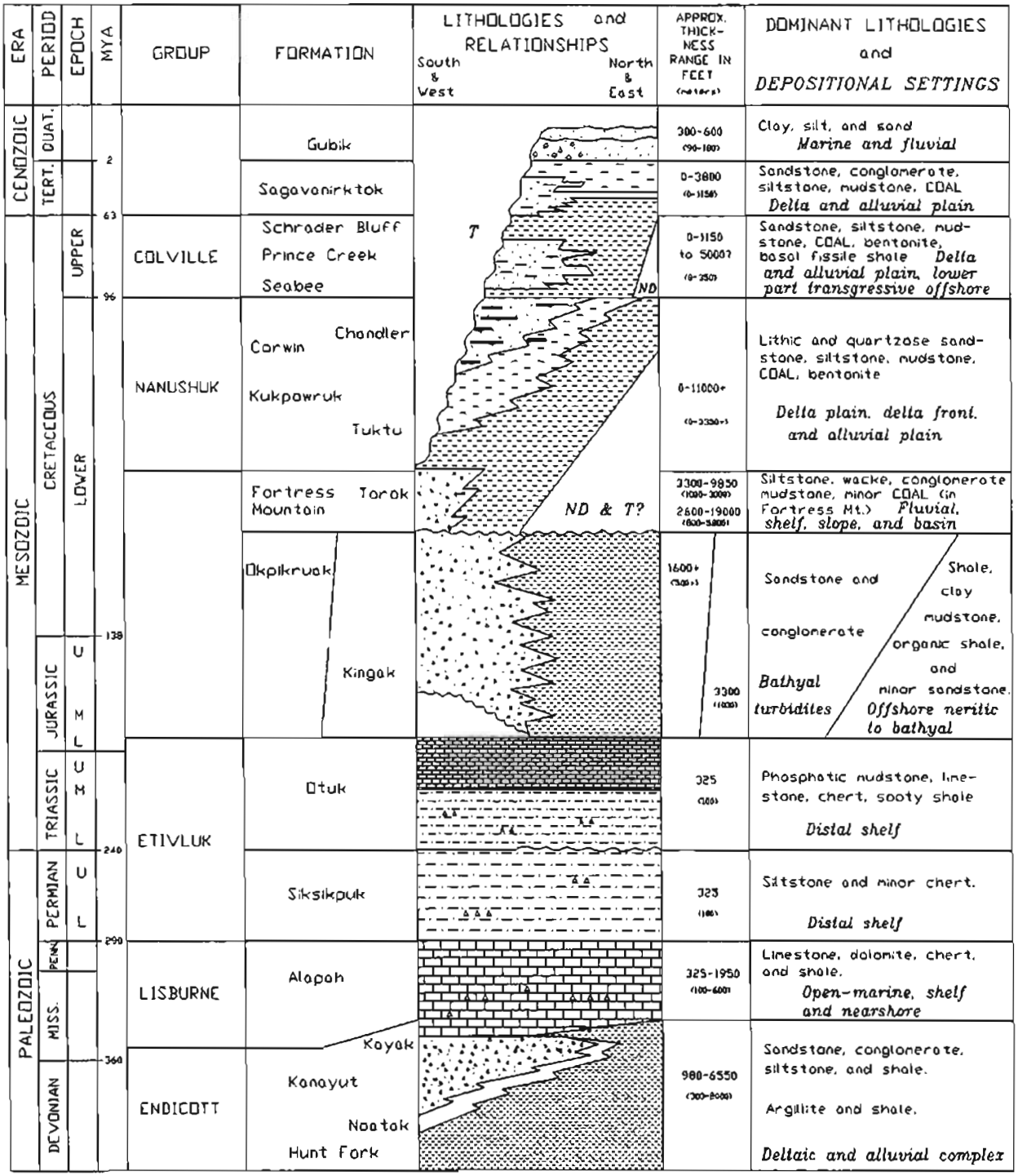

Figure 3. Generalized columnar section of Mesozoic to Paleozoic strata in the CMD; *T*– tectonic and erosional unconformity, *ND*– mostly nondeposition (modified from Sable and Stricker 1987, with assistance from C.G. Mull).

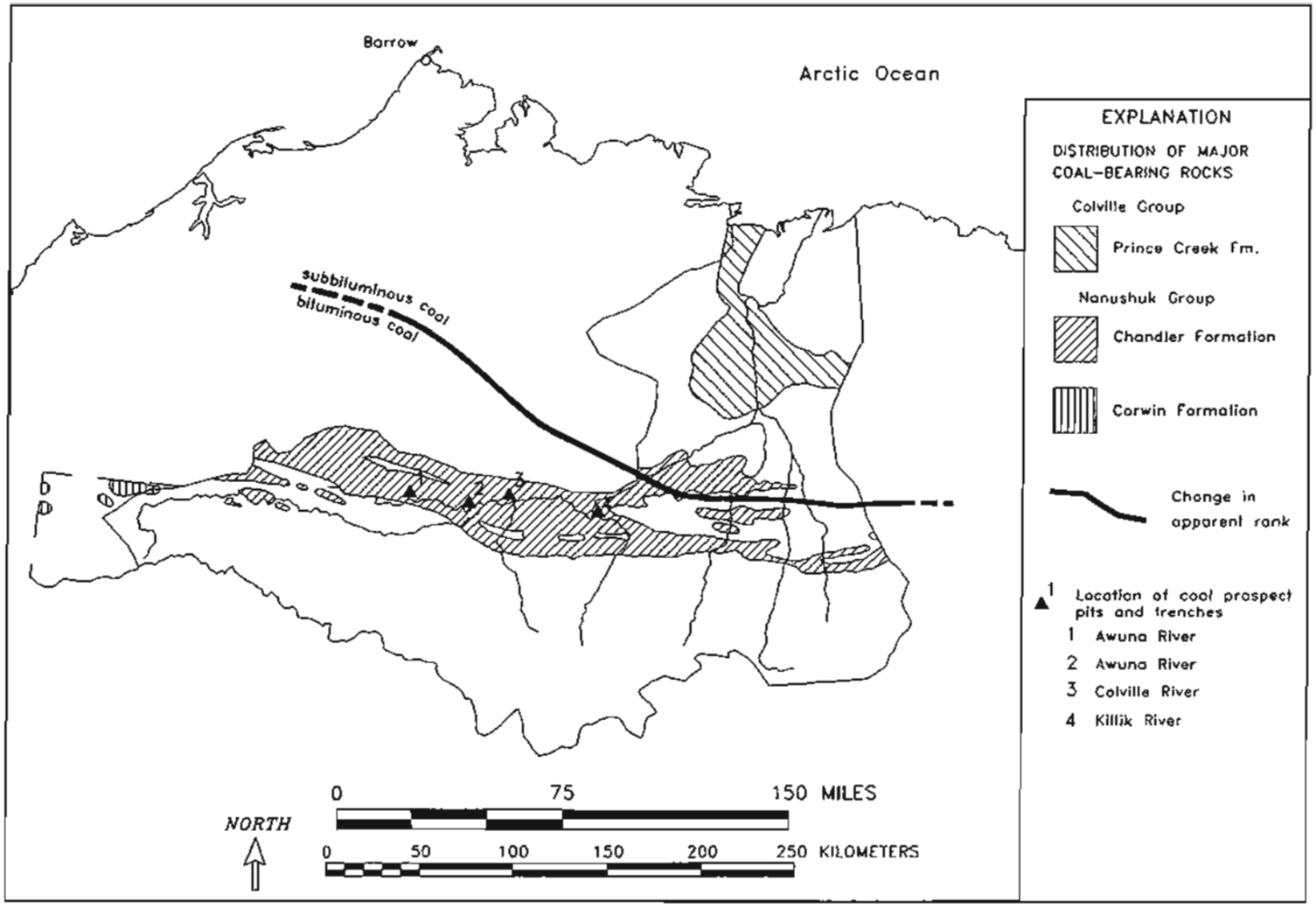

Figure 4. Distribution of major coal-bearing rocks (Nanushuk Group and Colville Group) in surface and subsurface within the Colville Mining District and western extension to NPRA border. Lines indicating change in apparent rank (bituminous-subbituminous coal) from Sable and Stricker (1987).

The Upper Cretaceous Colville Group (fig. 3), is a younger sequence than the Nanushuk Group, and is best exposed along the lower part of the Colville River and its tributaries in the eastern part of the CMD. Coals of the Colville Group have been studied less than those of the Nanushuk Group because they have shown less economic potential. The Colville Group contains coal, but outcrop descriptions of Colville Group coals indicate that most beds are thinner and of lower rank than those in the Nanushuk Group. Many of these coals are described as "lignites and bony coals." We consider the Colville Group to contain insignificant coal resource in the CMD.

The Tertiary Sagavanirktok Formation (fig. 3) appears to have little or no coal potential in the CMD, but does contain some thick coal beds farther east (Roberts, 1991). Published descriptions indicate that these coals are lignitic and subbituminous in apparent rank (Roberts and others, 1990). Detterman and others (1975) reported that coaly beds more than 20 feet (6 m) thick crop out in the lowest member of the formation (Sagwon Member), but they are described as lignite and coaly shale of a slightly lower grade than those in the subjacent Colville Group.

Coal resource estimate

The U.S. Geological Survey divided coal resources into two categories, identified and hypothetical, which are based on available coal data (Wood and others, 1983). Identified coal are resources whose location, rank, quality, and quantity are known or can be estimated from geologic evidence. Identified resources includes measured, indicated, and inferred and includes economic, marginal economic, or subeconomic coals (Wood and others, 1983). By convention, identified coal resources includes all the coal within a distance of 3 miles (4.8 km) from points of control or reliability. Points of control include outcrop, trench, or drill hole.

Hypothetical coal resources assume a low degree of geologic assurance. Estimates of thickness, extent, rank, and quality are based on an assumption of continuity beyond the identified resource classification (Wood and others, 1983). By convention, estimates are made by projecting coal data beyond 3 miles (4.8 km) from points of control, which include outcrop, trench, or drill hole.

Although identified coal resources could be estimated for the CMD, they were not made. The paucity of data available would produce an insignificantly small tonnage of identified coal resource. For this study, only hypothetical coal resources were assessed for the coal-bearing Corwin and Chandler Formations of the Nanushuk Group. The other coal-bearing units were determined to contain very minor to unknown quantities of coal (Kekiktuk Conglomerate and Fortress Mountain Formation), poor quality coal (Colville Group), or possess limited areal extent within the CMD boundary (Sagavanirktok Formation) to constitute significant coal resources.

Hypothetical coal resources of the CMD were determined using the following formula given in Sable and Stricker (1987):

$$R = A \times T \times C$$

where:

R = hypothetical coal resources for the Nanushuk Group in the CMD;
A = areas of coal-bearing rocks determined by this study;
T = thickness of coals present in drill holes and measured sections;
C = conversion from volume to short tons based on coal density by rank.

Areas of coal-bearing rocks (**A**) considered economic for this study (Corwin and Chandler Formations of the Nanushuk Group) were determined from available geologic maps and also are published in Sable and Stricker (1987). Thickness of coal-bearing intervals and percentage of coal in stratigraphic section (**T**) were determined from available outcrop and drill hole data. These are summarized in Figures 5 and 6. Coal density by rank (C) is given in Wood and others (1983). Boundaries of each "sub-area" used to determine **A** are defined by:

1.) quadrangle boundaries
2.) isopach thickness contour lines and percentage of coal lines (fig. 5)
3.) line delimiting the change in coal rank from bituminous to subbituminous coal (figs. 4 and 6)
4.) line defining the northern limit of the foldbelt (fig. 6); subdivides rocks into two classes based on structural deformation: (a) >15° dip, foldbelt disturbed rocks of the Arctic foothills and (b)<15° dip- undisturbed rocks of the coastal plain province

Area in acres (and hectares) of sub-areas were determined by digitizing their boundaries (defined by the above criteria) on a microcomputer system (PC DOS-based) and multiplying by a conversion factor. Figure 6 summarizes the data-set used in this study.

Total hypothetical coal resources for the CMD are estimated to be 278 billion short tons (253 billion metric tons) of bituminous coal and 51 billion short tons (47 billion metric tons) of subbituminous coal. Table 1 shows the distribution of hypothetical coal resources in thickness of overburden categories (0-500 ft, 500-1000 ft, 1000-2000 ft, and > 2000 ft) and total resources. Table 2 gives the tonnage for coal in beds dipping >15° (Arctic foothills subprovince) and in beds dipping <15° (coastal plain subprovince). Table 3 provides hypothetical coal resource estimates for the CMD by quadrangle. Of the twelve quadrangles containing the CMD, only the Survey Pass quadrangle does not contain hypothetical coal resources. Hypothetical coal resources of Nanushuk Group rocks in the NPRA were previously estimated by Sable and Stricker (1987) to be as much as 2.7 trillion short tons (2.5 trillion metric tons).

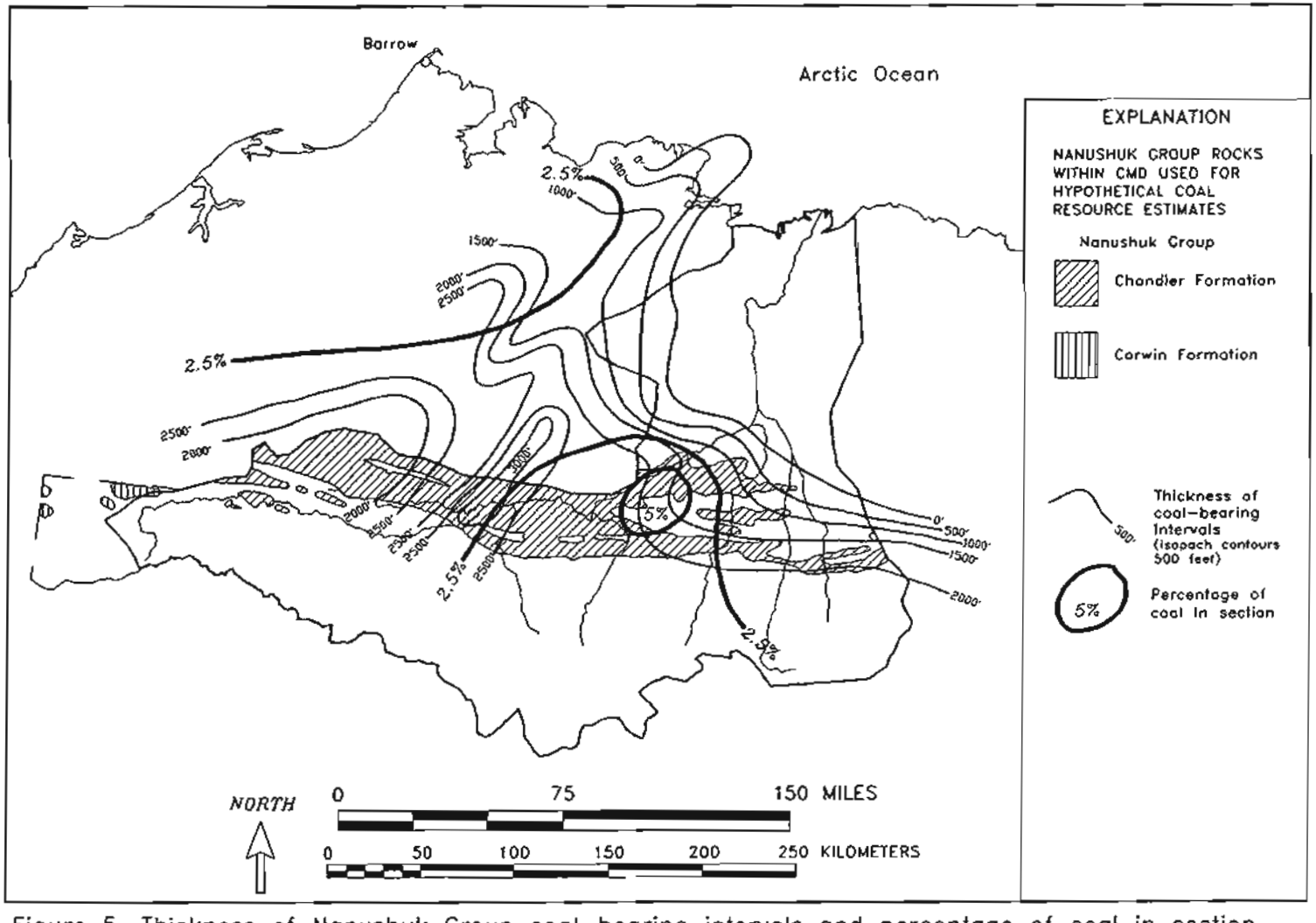

Figure 5. Thickness of Nanushuk Group coal-bearing intervals and percentage of coal in section determined from outcrop and drill hole data; modified from Sable and Stricker (1987).

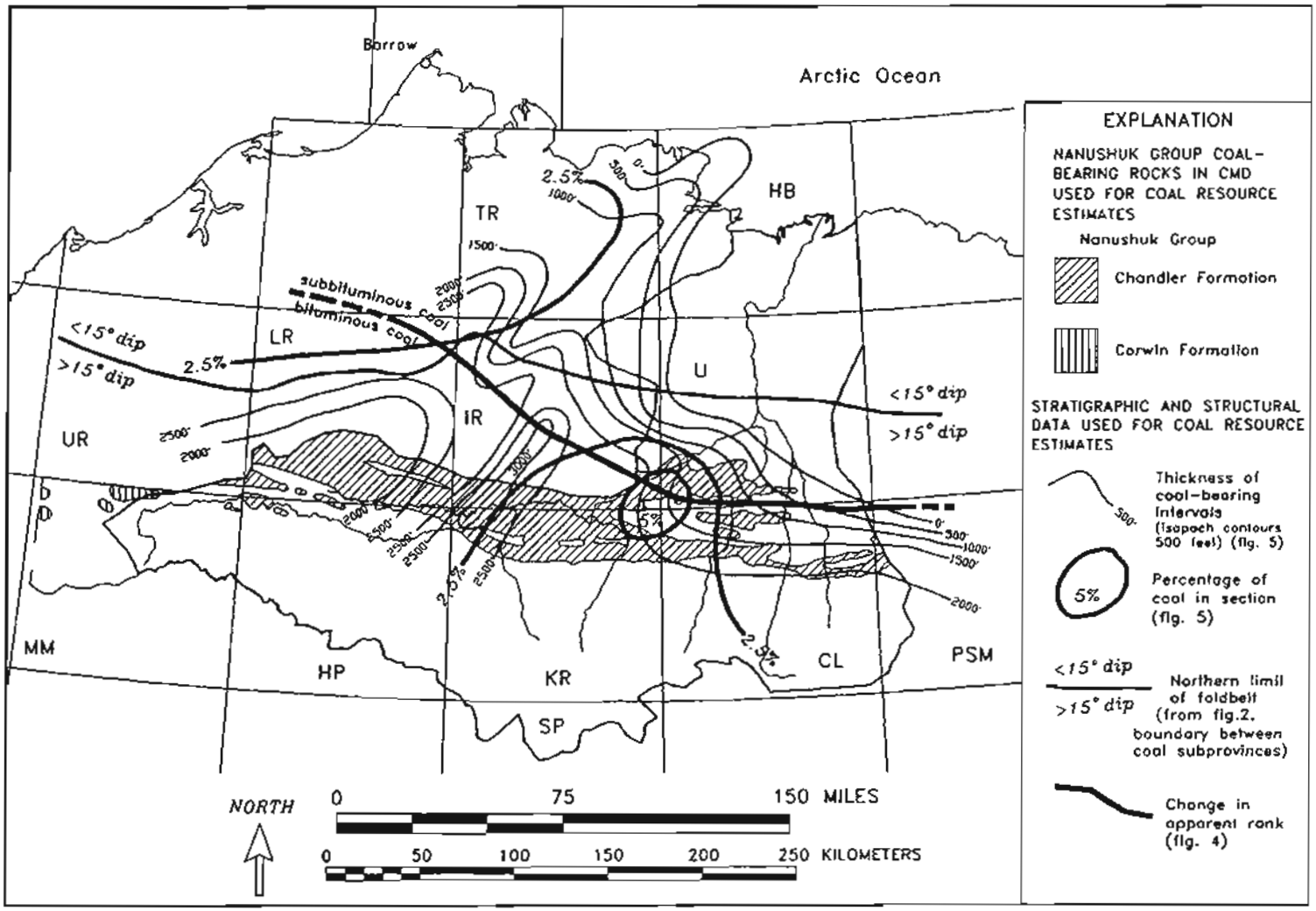

Figure 6. Summary map of Nanushuk Group coal-bearing rock distribution, and stratigraphic and structural data used in hypothetical coal resource estimates for the Colville Mining District. Tonnage estimates are given in Tables 1-3 in text. Data modified from Sable and Stricker (1987). Quadrangle abbreviations are: TR- Teshekpuk River, HB- Harrison Bay, UR- Utukok River, LR- Lookout Ridge, IR- Ikpikpuk River, U- Umiat, MM- Misheguk Mt., HP- Howard Pass, KR- Killik River, CL- Chandler Lake, PSM- Philip Smith Mts., SP- Survey Pass.

Table 1. Coal resources in the Colville Mining District by overburden class.

	SUBBITUMINOUS COAL billions of short tons *(metric tons)*	BITUMINOUS COAL billions of short tons *(metric tons)*
0-500 FT OF OVERBURDEN *(0-150 M)*	41.92 *(38.02)*	261.82 *(237.47)*
500-1000 FT OF OVER-BURDEN *(150-300 M)*	4.70 *(4.26)*	7.75 *(7.03)*
1000-2000 FT OF OVER-BURDEN *(300-600 M)*	2.58 *(2.34)*	7.74 *(7.02)*
>2000 FT OF OVERBURDEN *(>600 M)*	2.62 *(2.38)*	1.53 *(1.38)*
TOTAL COAL RESOURCES IN SHORT TONS (METRIC TONS)	**51.83** *(47)*	**278.85** *(252.92)*

Table 2. Coal resources in the Colville Mining District in beds dipping >15° and in beds dipping <15°.

	SUBBITUMINOUS COAL billions of short tons *(metric tons)*	BITUMINOUS COAL billions of short tons *(metric tons)*
COAL IN BEDS DIPPING >15° (Arctic foothills subprovince)	37.54 *(34.05)*	278.85 *(252.92)*
COAL IN BEDS DIPPING <15° (Arctic coastal plain subprovince)	14.28 *(12.95)*	0

Table 3. Tonnage of hypothetical subbituminous and bituminous coal resources by quadrangle in the Colville Mining District.

QUADRANGLE	SUBBITUMINOUS COAL		BITUMINOUS COAL	
	millions of short tons	*millions of metric tons*	millions of short tons	*millions of metric tons*
Chandler Lake	131.56	*119.33*	57247.69	*51924.28*
Harrison Bay	27.33	*24.79*	0	*0*
Howard Pass	0	*0*	0	*0*
Ikpikpuk River	27272.33	*24736.30*	77971.48	*70720.99*
Killik River	0	*0*	78719.88	*71399.79*
Lookout Ridge	0	*0*	49588.32	*44977.15*
Misheguk Mountain	0	*0*	2733.75	*2479.54*
Umiat	19121.98	*17343.85*	5005.99	*4540.48*
Utukok River	0	*0*	2926.93	*2654.76*
Philip Smith	0	*0*	4659.16	*4225.91*
Teshekpuk	5273.89	*4783.48*	0	*0*
TOTAL	**51827.09**	*47007.75*	**278853.2**	*252922.9*

Coal Quality

Nineteen samples of bituminous coal and fourteen samples of subbituminous coal from the CMD were previously tested for proximate and ultimate analyses (ASTM, 1991) and the minimum, maximum and arithmetic mean values of the analytical results are given in Tables 4 and 5. Nanushuk Group coals range in apparent rank from Lignite A to High volatile A bituminous coal with a mean of high volatile C bituminous coal. Total sulfur content ranges from 0.1 to 2.0 percent (mean value 0.33 percent) and ash content ranges from 2.7 to 27.3 percent (mean value 11.0 percent).

Table 4. Minimum, Maximum and Arithmetic mean values of proximate and ultimate analyses of Colville Mining District bituminous coal.

	Number of Samples[1]	Minimum	Maximum	Arithmetic Mean
Moisture (%)	19	4.19	13.69	9.24
Volatile Matter (%)	19	25.58	33.14	29.73
Fixed carbon (%)	19	43.50	60.20	53.86
Ash[2] (%)	19	2.71	20.20	7.15
Hydrogen (%)	17	4.59	5.93	5.36
Carbon (%)	17	59.48	70.82	66.56
Nitrogen (%)	17	0.97	1.76	1.45
Oxygen (%)	17	16.59	25.58	20.28
Sulfur (%)	19	0.10	0.56	0.33
Heat-of-combustion BTU/lb *(Kcal/Kgram)*[3]	19	10,000 *(5,560)*	12,390 *(6,890)*	11,420 *(6,350)*
Sulfate (%)	17	0.01	0.04	0.01
Pyritic sulfur (%)	17	0.01	0.04	0.01
Organic sulfur (%)	17	0.23	0.55	0.33
MMMFBTU *(MMMFKcal)*[4]	19	11120 *(6,180)*	13140 *(7,310)*	12,390 *(6,890)*

[1]Seventeen samples tested for proximate and ultimate analyses, two samples tested for proximate analyses only.
[2]U.S. Bureau of Mines method for ash analyses.
[3]BTU/lb, British Thermal Units/pound *(Kcal/Kgram, kilocalories/kilogram)*.
[4]Moist, Mineral Matter-Free Heat-of-combustion BTU/lb *(Kcal/Kgram)*.

Mining history

No significant mining of coal within the CMD boundary has ever occurred. West of the CMD coal seams in the Corwin Formation were mined at Corwin Bluff (fig. 2) and Cape Beaufort in the late 1800s and early 1900s to fuel whaling ships. During the summer of 1903, the Colville River region downstream from the mouth of the Killik River, was unsuccessfully prospected for gold. However, thick veins of bituminous coal were discovered and burned in camp fires (Schrader, 1904). Four coal-prospecting sites in the CMD (fig. 4) consisting of exploratory trenches and pits dug into exposures of the Chandler Formation along the Colville River and its tributaries, the Awuna and Killik Rivers (Paige and others, 1925; Smith and Mertie, 1930; and Meyer, 1990), were probably

Table 5. Minimum, Maximum and Arithmetic mean values of proximate and ultimate analyses of Colville Mining District subbituminous coal.

	Number of Samples[1]	Minimum	Maximum	Arithmetic Mean
Moisture (%)	14	6.09	33.00	19.57
Volatile Matter (%)	14	22.10	34.60	27.13
Fixed carbon (%)	14	24.50	45.38	38.93
Ash[2] (%)	14	3.14	27.31	14.31
Hydrogen (%)	10	4.20	6.25	5.41
Carbon (%)	10	43.92	54.89	50.09
Nitrogen (%)	10	0.72	1.26	1.00
Oxygen (%)	10	23.63	39.33	31.80
Sulfur (%)	14	0.13	2.00	0.34
Heat-of-combustion BTU/lb *(Kcal/Kgram)*[3]	14	560 *(3,120)*	9,200 *(5,120)*	7,940 *(4,420)*
Sulfate (%)	10	0.01	0.02	0.01
Pyritic sulfur (%)	10	0.01	0.06	0.03
Organic sulfur (%)	10	0.05	0.26	0.17
MMMFBTU *(MMMFKcal)*[4]	14	7,150 *(3,980)*	10,420 *(5,790)*	9,400 *(5,230)*

[1]Ten samples tested for proximate and ultimate analyses, four samples tested for proximate analyses only.
[2]U.S. Bureau of Mines method for ash analyses.
[3]BTU/lb, British Thermal Units/pound *(Kcal/Kgram, kilocalories/kilogram)*.
[4]Moist, Mineral Matter-Free Heat-of-combustion BTU/lb *(Kcal/Kgram)*.

the results of this early gold prospecting foray. Deadfall Syncline (fig. 2) near the Chukchi Sea coast, approximately 125 miles (~200 km) west of the CMD, is currently being explored by Arctic Slope Regional Corporation and a plan to mine the Corwin Formation coal here is under development.

SUMMARY

For Nanushuk Group coals in the CMD total hypothetical coal resources are estimated to be over 330 billion short tons (300 billion metric tons). More than 80% of this resource is apparent high rank bituminous coal of which greater than 90% is estimated to occur near surface in the 0-500 ft (0-150 m) of overburden class. Although no mining of coal has ever occurred within the CMD, the potential for producing significant tonnage of medium to high rank low sulfur coal exists.

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