Public-data File 86-88

COAL, PEAT, AND GEOTHERMAL POTENTIAL OF KUSKOKWIM AREA PLAN

By

T.K. Bundtzen and J.T. Kline

Alaska Division of Mining and Geology

October 1986

THIS REPORT HAS NOT BEEN REVIEWED FOR TECHNICAL CONTENT (EXCEPT AS NOTED IN TEXT) OR FOR CONFORMITY TO THE EDITORIAL STANDARDS OF DGGS.

794 University Avenue, Basement
Fairbanks, Alaska 99709

CONTENTS

FIGURES

TABLES

SUMMARY

In 1986 the Alaska Division of Geological and Geophysical Surveys assessed the coal, peat and geothermal potential of the Kuskokwim Area Plan, a 38,000 mi^2 region in southwestern Alaska being studied by DNR. Although the region includes part of four historic mining districts (see Bundtzen and others, 1986), utilization of energy resources has been limited to 1) coal for local home heating/black smithing, 2) minor testing of peat for horticultural and fuel potential, and 3) occasional recreational use of a single geothermal spring.

Coal potential is confined mainly to portions of 34 townships comprising, a foothills/lowland, complex immediately north of the Alaska Range which are underlain by a series of fault-controlled Tertiary non-marine sedimentary basins. In addition, thin, lignite bearing sediments of Cretaceous age occur discontinuously in the Flat, Dishna River, and Fossil Mountain areas of the Kuskokwim Mountains province; however, this latter 13 township area is considered to have relatively poor potential.

DGGS sampling data and limited drilling programs by private firms show that the Kuskokwim Area Plan contains over 100 million tons of coal resources--virtually all confined to the Alaska Range and Foothills lowland province. Based on present knowledge 1,024 townships or 96 percent of the Kuskokwim Area Plan is poorly known and does not contain a definable coal potential.

Horticultural and fuel-quality peat resources are abundant throughout the poorly drained lowlands of the KAP, but have only been documented in a 2,400 acre bog and fen complex near McGrath. More field investigations are needed to document this resource and assess potential for economic utilization.

Geothermal resources are confined to poorly known thermal springs south of Selatna Hills and possibly near Granite Mountain in the Kuskokwim Mountains. Much more work is needed to document and assess these potential recreational resources.

It is emphasized that the coal, peat, and geothermal assessment is dependent on the quality of information available. Relatively good reconnaissance data is available for coal in the northern portion of KAP but virtually absent for much of the southern KAP. Only rudimentary information is available for peat and geothermal resources.

GEOLOGIC SKETCH OF COAL-BEARING STRATA

Coal potential is confined to two distinct sedimentary rock sections in the northern portion of the Kuskokwim Area Plan (fig. 1). Coal bearing, nonmarine, river derived sandstone, shale, and conglomerate of Eocene to Oligocene (Tertiary) age crop out along the foothills and lowlands, primarily along flood plain exposures immediately north of the southern Alaska Range. Detailed stratigraphic sections have been examined and measured by the Alaska Division of Geological and Geophysical Surveys (Solie and Dickey, 1982), by

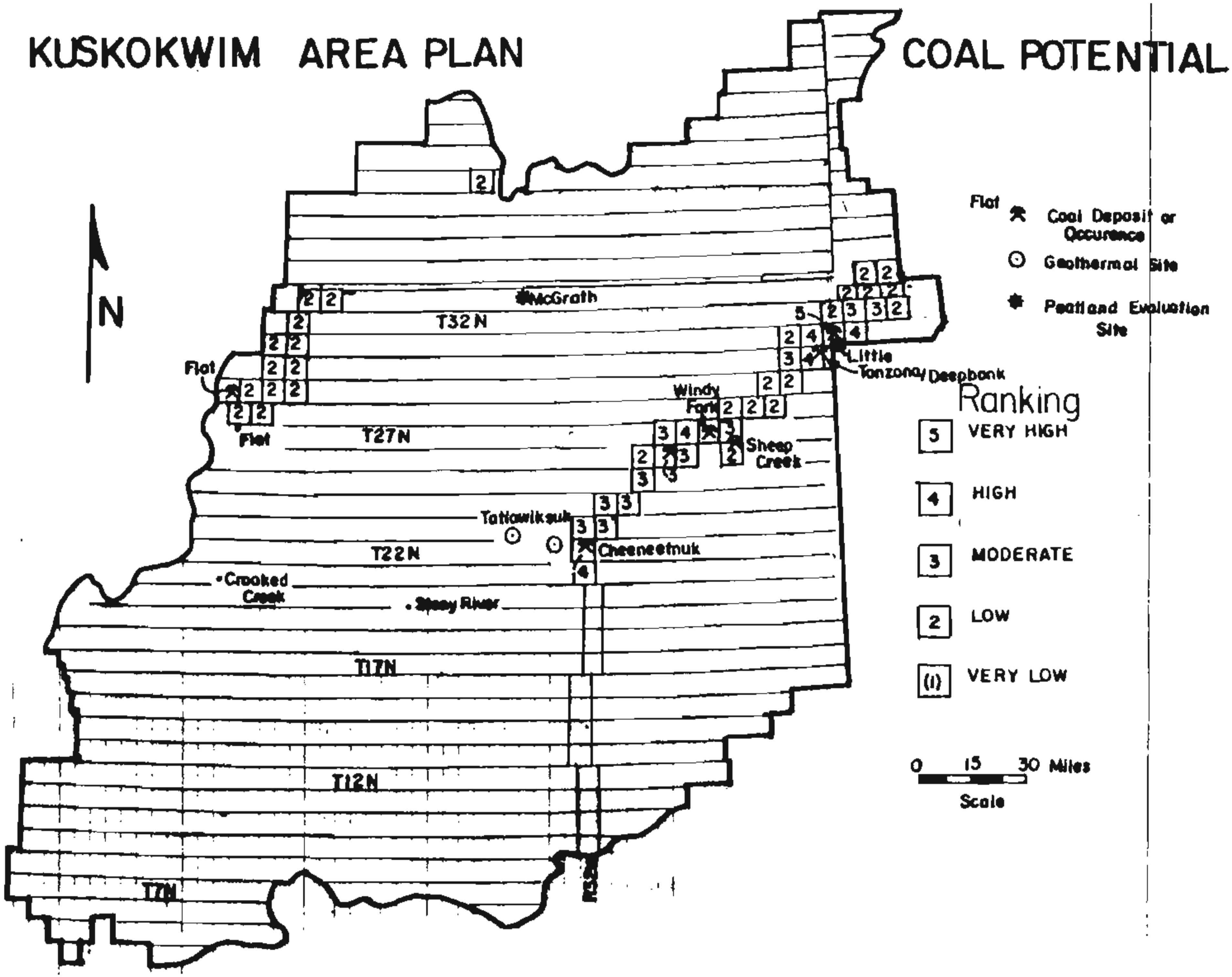

Figure 1. Coal, peat, and geothermal potential of Kuskokwim

the U.S. Geological Survey (Sainsbury and MacKevett, 1965; Barnes, 1967; Sloan and others, 1979), and by the private sector (Thorpe, 1980, 1981, 1982).

According to Dickey (1984) the Tertiary coal bearing rocks flanking the Alaska Range probably formed in a series of small, fault-bounded sedimentary basins (grabens) inbetween strands of the Denali-Farewell fault system. Quartz and argillite clasts from the lowest units were derived from a metamorphic terrane to the northeast; carbonate/shale clasts in the uppermost part of the section were probably derived from the Dillinger Group in the Alaska Range (Bundtzen and Gilbert, 1983). Lithologies and overall depositional history is quite similar to the Nenana coal field exposed approximately 200 miles to the northeast (Wahrhaftig and others, 1969). In the Nenana field Usibelli Coal Mines, Inc., currently mines coal for domestic and export markets.

The Cretaceous lignite-bearing rocks in the Western portion of the Kuskokwim area plan are part of shallowing upward succession of sedimentary rocks along the margin of the Kuskokwim flysch basin. (Bundtzen and others, 1985). The succession consists mainly of quartz rich sandstone, conglomerate, plant rich shale, and cochina beds rich in mollusk shells---lithologies indicative of a shallow water environment and which are in marked contrast to lithic sandstone (graywacke) and shale that form the bulk of the deeper water, turbidite dominated basin of the Kuskokwim Group to the east. The environment of coal bearing units is one of subtidal, supratidal, and fluvial deposition along and adjacent to a shoreline.

Coal 'rank' discussed in the following text is based on American Society for Testing Materials (ASTM) standards established by Lukens, 1981. 'Lignite' has a calorific value ranges from 6,300 to 8,300 Btu; 'subbituminous C' ranges from 8,300 to 9,500; 'subbituminous B' ranges from 9,500 to 10,500; 'subbituminous A' ranges from 10,500 to 11,500; 'bituminous' coals range from 11,500 to 14,000; anthracitic coals have similar values to high quality bituminous coals. Moisture content and ash contents are also important in ranking coals. Ash content of 0-to-10 percent is considered low; 10 to 20 percent-moderate and >20 percent-high. The amount of 'clinker' that needs to be removed is an important economic factor so that low ash content is desired. Sulfur content ranges from low (0.0 to 0.3 percent), moderate (0.3 to 0.7 percent), and high (>0.7 percent) in coal classifications. Environmental laws require low sulfur emissions so that low sulfur contents in coal is a strongly desired physical characteristic. For an Alaskan example, the Usibelli Coal at Healy is ranked subbituminous C - - not very high in terms of calorific value; however, it has moderate moisture/ash value and very low sulfur values and these are distinct advantages over coals of the eastern U.S. or Australia where coals have high Btu values but an environmentally deleterious sulfur content.

COAL MINING/EXPLORATION HISTORY

Coal was found by Brooks (1911) in 1902 while traversing the north flank of the Alaska Range from the south fork of Kuskokwim River to Little Tonzona River and Pingston Creek. Brooks (1925) also reported coal in Big River

Valley; however, detailed investigations by Gilbert (1981) and other DGGS personnel have not been able to locate the Big River occurrence and its existance is questioned. Gilbert (1981) and Solie and Dickey (1982) describe various coal occurrences near Sheep Creek, Windy Fork, and Cheeneetnuk River. Player (1970) conducted a survey of the Farewell and Little Tonzona River area and reported that the latter locality contained a 180 foot thick section of coal bearing rocks, nearly 100 feet of which consisted of coal seams and coal rich shale. He also identified thick sections of coal at Deepbank Creek. Sloan and others (1979) examined samples and measured sections of coal outcrops from Little Tonzona River to Deepbank Creek but concentrated on the former locality.

Doyon Regional Corporation, who selected lands in the Little Tonzona River under ANILCA Legislation, contracted mining companies including Canadian Superior Exploration Ltd. and McIntyre Mines Ltd. to conduct exploration of the Little Tonzona River. Drill holes over a 3 mile long transect each intersected 119-to-173 feet of coal. Their investigation suggested an enormous resource (a minimum of 100 million metric tons) of sub-bituminous coal similar in quality to seams at Healy (Thorpe, 1981, 1982). However, the beds dip steeply to near vertical and the amount that can be mined by open cast methods is unknown. Open cast mining is the most economically viable mining method for coal extracting; underground methods are considered less desirable for safety and economic considerations.

No other specific coal exploration efforts along the Alaska front are known. According to local McGrath residents modest amounts of coal has been utilized along Windy Fork (fig. 4) over the years by trappers, prospectors, and big game guides for local home-heating applications.

Thin (≤ 18 inches) lignitic to sub-anthracitic coal seams were discovered on a low ridgeline three miles west of Flat prior to World War I (fig. 1). Mertie (1936) reports that an inclined shaft approximately 40 feet deep and an undisclosed amount of drifting developed the deposit. The seams were found to be discontinuous along a strike length of several hundred feet; however, some coal was mined and utilized for home heating and blacksmithing at Flat until well into the 1930's (John Miscovich, personal commun., 1985). During recent DGGS/USGS investigation, a large 300 ft by 300 ft heavily vegetated open cut near the shaft was discovered suggesting that open cut exploration and mining also took place many years ago in the coal deposit area.

COAL RESOURCES

Table 1 summarizes present knowledge of the coal resources in the region; coal quality is summarized briefly in the following text. A coal resource for the Little Tonzona River is based on examination of records including drilling results provided by the private sector.

For the calculation a maximum overburden coa ratio of 3:1 and maximum mined depth of roughly 200 feet are used. For the remaining deposit-prospects for which resource estimates are provided, the half square resource estimate is used (McKinstry, 1948; Harding, 1923) which predicts that an 'ore body' will probably extend down dip at least half the measured horizontal shoot as exposed on the surface. For coal bearing strata, this assumption is particularly valid and probably represents a minimum estimate.

Table 1. Coal resources of the Kuskokwim Area Plan.[1]

Locality	Inferred reserves (metric tons)	Resources (metric tons)
Little Tonzona	23,000,000	100,000,000
Deepbank Creek		2,000,000
Windy Fork		4,000,000
Cheeneetnuk		500,000
TOTAL	23,000,000	106,500,000

[1] Data derived from Thorpe (1981, 1982) and unpublished DGGS estimates. 'Reserves' are proven with definitive drilling and other subsurface techniques. 'Resources' are based partly on geologic inference.

Little Tonzona River Prospect

According to Sloan and others (1979, p. 3-4) "Tertiary nonmarine sedimentary rocks crop out along the southwest bank of the Little Tonzona River in sec. 27, T. 31 N., R. 20 W., Seward Meridian. The Tertiary strata strike N. 73° E., and dip 47-63° NW. Three minor bedding plane faults with associated drag folds occur in the section.

Seven seams of coal each at least 1 meter thick are exposed in this outcrop. Areas of disturbed bedding are not included in the calculations, although they probably represent additional coal beds. Coal samples were taken from shallow trenches and analyzed by the Department of Energy, Coal Laboratory in Pittsburgh, Pennsylvania (table 1). Heating values for the coal ranged from 8,466 to 9,517 Btu per pound on a moisture-ash free basis and from 7,848 to 8,295 Btu per pound on an as-received basis. Sulfur content varies considerably from bed to bed ranging from 0.7 to 1.7 percent." The sulfur content is considered moderate-to-high by ASTM classifications.

Thorpe (1981, 1982) gave numerous detailed data on the drilling programs conducted in the Little Tonzona field.

Deepbank Creek

Coal beds in sec. 13, T. 30 N., R. 20 W., Seward Meridian occur in sandstone and shale similar to those at Little Tonzona River. Outcrops are generally weathered and burned coal seams are common in this area. Analyses reported by Sloan and others (1979) range from 11,240 to 11,386 Btu (moisture/ash free), contain low ash, and moderate (0.7 percent) sulfur contents.

Windy Fork Prospect

A measured section of Tertiary nonmarine sedimentary rocks includes a 190-m-thick section of carbonaceous shale and coal. Five coal samples analyzed by Solie and Dickey (1982) including sections ranging from 7 to 20 m are exposed along a steep bluff of Windy Fork in sec. 19, 20, 21, T. 27 N., R. 26 W., Seward Meridian. Most beds strike to the northeast and dip northwest; however, the upper coal-bearing zone is in a broad synclinal fold. The section includes conglomerate, sandstone, siltstone, shale, and coal.

Sandstone petrography indicates the clastic rocks were derived from a low-grade metamorphic terrane. The section fines upward in cycles, and rock types indicate that periods of very slow deposition alternated with periods of rapid deposition. Rapid deposition is represented by thick, cross-bedded, coarse channel conglomerate. Shale, siltstone, and mudstone represent interchannel deposits. Some conglomerates and sandstones include substantial quantities of woody material, now coalified. The paleoenvironment probably consisted of fluvial systems draining highlands to the north during the Oligocene and Miocene Epochs (37-7 million years ago).

The Windy Fork coals rank in grade from subbituminous A to high volatile C bituminous according to the ASTM classification; they are low rank bituminous on the basis of reflectance of vitrinite. Sulfur content is fairly low, and ash content is high (20.27 percent) in proximate analysis reported by Solie and Dickey (1982).

Cheeneetnuk River Prospect

Southwest of White Mountain at T. 22.N., R. 32 W. township of Seward Meridian, the Cheeneetnuk River drains an area transected by the Farewell fault zone. Coal-bearing Tertiary rocks overlie Devonian limestone in a graben bounded by strands of the Farewell fault. These medium- to thin-bedded, laminated, moderately sorted, friable, micaceous sandstones and siltstones (with carbonaceous partings) contain fossil flora suggestive of a Late Miocene age. Outcrops of this unit along the Cheeneetnuk River contain brittle coal beds up to 0.5 m known thickness.

According to Solie and Dickey (1982), analyses of the Cheeneetnuk River coal samples show rank determinations ranging from subbituminous B to high volatile C bituminous. The average of four analyses yields a mineral-matter-free Btu value of 11,124. Reflectance of vitrinite measurements indicate rank in the same range, between subbituminous and low grade bituminous. Ash content as measured in the float-sink separation is low to moderate.

Sulfur content in two samples is high with a moisture and ash-free total sulfur content of 8.19 percent. Ferruginous laminae, probably pyritic in origin, were noted in the field description, and laboratory analysts report some framboidal pyrite which indicates a strongly-reducing, organic-rich environment of deposition.

The Cheeneetnuk River coals are relatively high in grade (subbituminous to bituminous), but the generally thin seams, variable attitudes of beds, and fault-bounded nature of the coal-bearing unit limit their extent. Their ultimate extent is poorly known due to poor exposure as well.

Flat Coal Prospect

Thin coal seams 3 miles west of Flat were examined by the senior author in 1985. The coal bearing unit crops out in a poorly exposed, vegetated hillslope near a 7 mile long aerial tram connecting Iditarod to Flat. Thin coal beds 6 inches to 2 feet thick were sampled and analyzed; which show rank determination of lignite to subanthracite with ASTM moisture/mineral matter free Btu values ranging from 6,600 to 13,500. Sulfur content ranges from 0.3 to 1.1 and ash content is generally low; hence these coals are of good quality. The extent of the coal bearing beds is very poorly known but believed to be quite limited based on geologic inference.

SUMMARY OF SCORING FOR COAL POTENTIAL

Table 2 summarizes criteria used in ranking the coal potential at the township level. Each criterian can have scores ranging from 1 to 10. An algorithim was multiplied into each score that reflects the various uncertainties and importance of each criteria. Scores ranged from 0 to 35. The raw scores are equated to a 1 (low) to 5 (highest) ranking system, in order to standardize the method with those of the KAP minerals element and the minerals/energy elements of the Northwest Area Plan. Table 3 is the ranking system used and displayed on Figure 1.

Coal potential is confined to 34 townships underlying foothills and lowlands adjacent to the Alaska Range and 14 townships in the Kuskokwim Mountains, less than 5 percent of the aerial extent of the Kuskokwim Area Plan. Of these, only 18 townships (1.8 percent of total KAP area) contain a moderate (3) rank, four contain a high (4) rank, and a single township, the Little Tonzona River block, received the highest possible score (5).

Table 2. Generalized criteria used for assessing coal potential, Kuskokwim Area Plan.

		Algorithim
1.	Presence or absence of nonmarine rocks of Cretaceous or Tertiary age and their aerial extent.	1.6
2.	Coal occurrences and prospects including density size, thickness, etc.	1.0
3.	Reserve/resources (incremental scoring on the basis of volume, tonnage, etc.	1.8
4.	Production (if any).	1.8
5.	Coal quality.	1.0
6.	Potential for mine extraction; i.e. overburden, coal ratio, open cast vs. underground possibilities, etc.	0.8
7.	Industry interest nominations.	1.0

Table 3. Coal potential, Kuskokwim Area Plan.

1) Very Low - Geologic environment considered unfavorable; nonmarine sedimentary rocks of Cretaceous or Tertiary age are not known or are deeply buried by younger sedimentary strata. No coal occurrences are known.

2) Low - Geologic environment may be favorable but existance of significant coal prospects unknown. Cretaceous-Tertiary nonmarine rocks do exist within township and define a portion of a known coal bearing province. Some thin coal seams may exist but physical characteristics may be unknown or unfavorable.

3) Moderate - Coal bearing nonmarine sedimentary strata underly major part of township and significant coal occurrences or prospects may be present. Published coal analyses may be available which classify and rank coal according to standard ASTM/Btu classifications. However, not enough known to classify occurrences or prospects as resources or reserves.

4) High - Geologic environment always favorable; i.e. most if not all of township is underlain by significant coal bearing basin. Significant coal deposits recognized and measured physical characteristics show favorable Btu/ASTM classifications. In study area, they are mainly subbituminous to bituminous rank. Some resources are known and coal thicknesses are significant.

5) Very High - Contains virtually all favorable characteristics of coal potential including significant coal basin, significant occurrences and deposits, favorable physical characteristics, and significant resources. Subsurface and surface data allow for some reserve estimates.

PEAT RESOURCES

Introduction

Many thousands of acres within and adjacent to flood plains and lowland areas of the Kuskokwim Area Plan contain peat bogs and fens. Although systematic surveys have not been made, it is probable that substantial resources of horticultural or fuel grade peat exist in the KAP. Peat utilized for firing small power plants or local home heating require certain specific physical characteristics. Factors relevant to harvestability include bog thickness, presence of and depth to permafrost, texture, density, the water table and relative moisture content. According to the American Society for Testing and Materials standards for fuel grade peat, a minimum thickness of 5 feet, an energy value of 8,300 Btu/lb, and an ash content of less than 25 percent is required (Lukens, 1981).

Other important criteria are location and access. It is doubtful that peat can be economically hauled any notable distance and it is probably best to view as significant only those resources immediately adjacent to existing village sites or proposed developments in need of energy sources.

McGrath Peat Study

A reconnaissance peat study was undertaken by Kline (1983, unpublished report) in an initial attempt to identify potential peat resources immediately adjacent to McGrath (fig. 2). Some 29 peat samples were analyzed from 10 sample sites from a mixed, ribbed 2,400 acre peatland approximately 1 mile west of the McGrath airport across the river (fig. 2). The mixed peatland is composed of both a sedge dominated, ribbed or string fens with abundant standing water between vegetated areas and a peat plateau type characterized by spruce covered sphagnum peat islands, raised bogs, and palsa. Peat was sampled with a hand operated core drill McCauley peat sampler modified by Kornelia Cameron of the U.S. Geological Survey. The sampling program shows that the peat is approximately 8 to 10 feet in thickness, and characterized by a fibrous sedge dominated basal zone about 4 feet thick and a spagnum rich hemic upper zone; both zones contain various percentages of interlaced silt; however such impurities were much less abundant than expected, and peat quality appeared high.

The samples were analyzed for ash, moisture, and other physical characteristics (table 4). When plotted on an ash/Btu graph, they generally fall within the range of acceptable fuel quality peat standards previously described (fig. 3). However, it is emphasized that the reconnaissance sampling effort does not define an economically extractable peat reserve. More systematic sampling as well as engineering, and feasibility studies will be required to determine whether or not such a resource can be economically utilized.

GEOTHERMAL RESOURCES

There is no published information of geothermal prospects in the Kuskokwim Area Plan (Motyka and Liss, 1983). However, several undocumented springs are known and shown on Figure 1. All appear to be relatively low temperature geothermal spring systems---in contrast to superheated systems currently producing electric power in other parts of the world.

A geothermal spring is located in the western portion of McGrath A-6 Quadrangle south of Selatna Hills (fig. 1). Another is located near the canyon breakout of Cheeneetnuk River where the river flood plain intersects the Nushagak-Big River Hills. Both are aligned along a remarkable E-W trending 70 mile long linear feature best observed on an infra red ERTS satellite image. The lineament extends from Cheeneetnuk River to Devils Elbow on Kuskokwim River and possibly beyond. Neither spring has been measured for flow rate, temperature, chemistry, or other physical data. According to local residents, the Selatna Hills spring has been used as a hot springs bathing area intermittently by local residents. According to several residents a third prospect may exist on the north slope of Granite Mt. in the Iditarod B-2 Quadrangle; however the senior author has searched for but not found the possible hot springs and its existance is questionable.

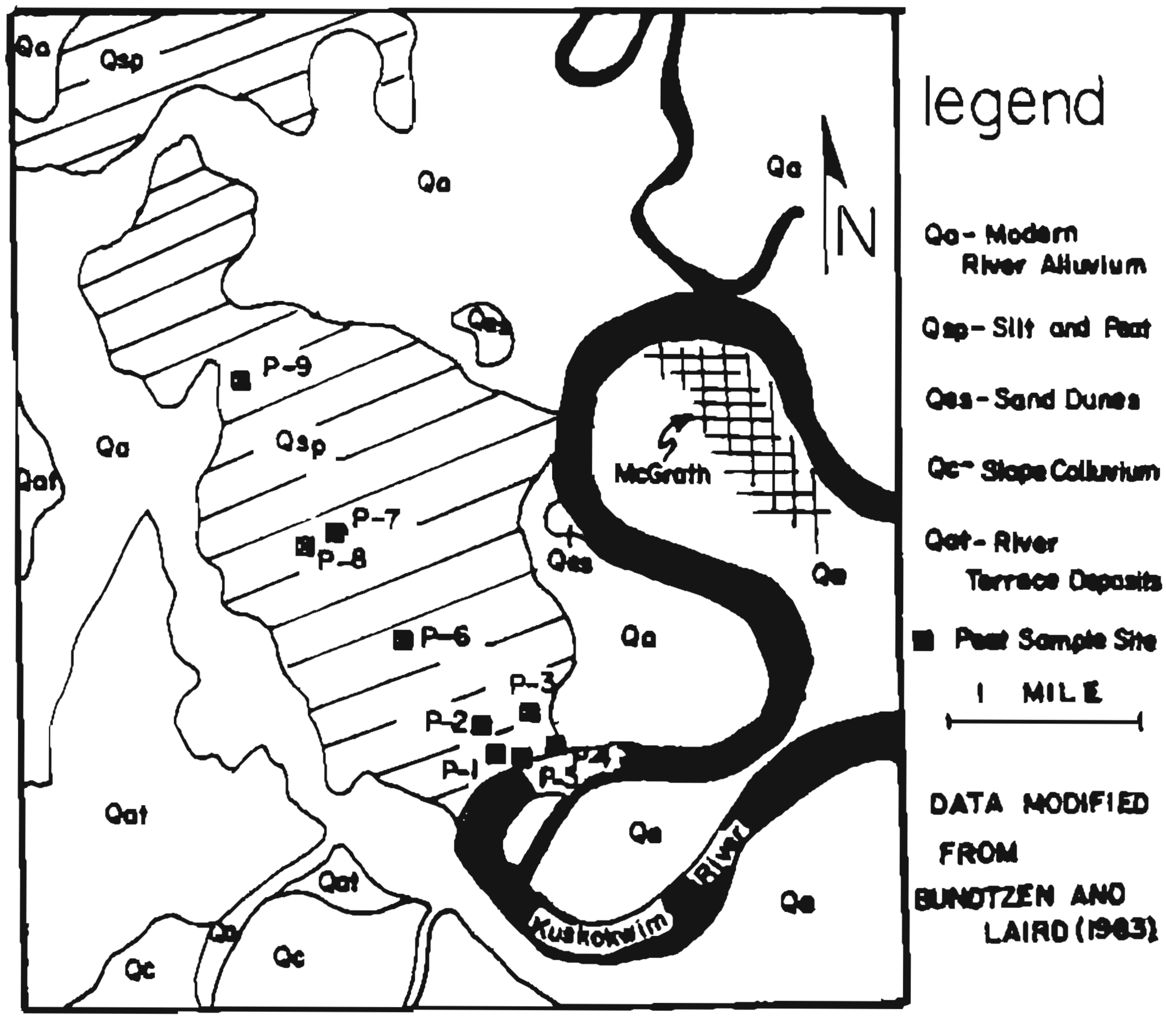

Figure 2. Peat potential of McGrath area, Kuskokwim Area Plan.

Table 4. Analyses of peat samples from McGrath peatland from Kline (1983).

Item	Sample Number	Sample depth interval* (inches below the surface)		Total Wt. (grams)	Dry Wt. (grams)	Ash (%)	Moisture (%)
1.	#1-1	0-16		55.4	8.0	16.3	85.6
2.	#1-2	22-34		61.3	10.9	15.6	82.2
3.	#1-3	54-62	basal peat	51.9	8.7	12.6	83.2
4.	#1-4	62-67	silt below peat	24.0	8.3	55.4	65.4
5.	#2-1	12-24		65.2	12.0	13.3	81.6
6.	#2-2	23-34		64.1	13.0	10.8	79.7
7.	#2-3	36-42	basal peat	42.6	7.8	12.8	81.7
8.	#2-4	42-48	silt below peat	36.5	11.4	57.9	68.8
9.	#3-1	12-24		68.8	12.1	20.7	82.4
10.	#3-2	24-36		66.7	11.4	13.2	82.8
11.	#3-3	43-52	basal peat above silt with trace silt	57.5	9.6	19.8	83.3
12.	#3-4	52-55	silty basal peat	19.5	3.8	26.3	80.5
13.	#4-1	18	fine grained peat upper layer	723.7	210.3	15.0	70.9
14.	#4-2	18-36	lower coarse grained	481.5	188.5	16.8	60.9
15.	#5-1	0-48	upper fine grained	363.5	93.5	16.8	74.3
16.	#5-2	48-96	lower coarse grained	783.5	221.2	10.3	71.8
17.	#6-1	12-24		49.2	9.7	16.5	80.3
18.	#6-2	24-36		55.4	10.4	13.5	81.2
19.	#6-3	36-48	peat in silty section	44.5	13.3	58.6	70.1
20.	#7-1	12-24		42.1	5.4	13.0	87.2
21.	#7-2	24-36		47.1	7.5	14.7	84.1
22.	#7-3	36-48		45.3	6.2	22.6	86.3
23.	#8-1	12-24		57.7	7.1	14.1	87.7
24.	#8-2	24-36		71.0	12.3	13.0	82.7
25.	#8-3	29-41		74.3	10.9	14.7	85.3
26.	#9-1	12-24		62.6	11.5	14.8	81.6
27.	#9-2	22-34		65.1	13.6	13.2	79.1

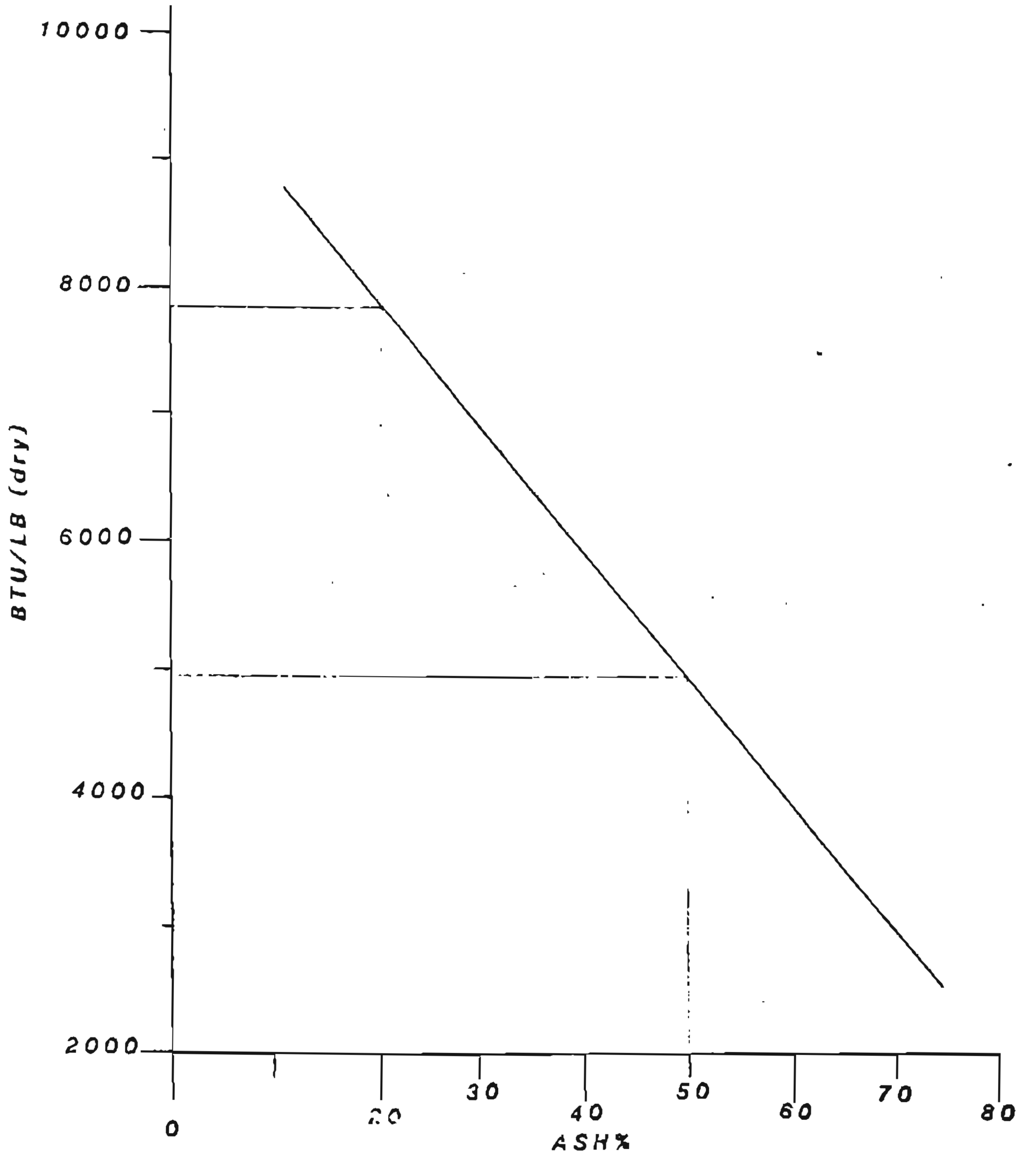

Figure 3. Graph for determining peat fuel quality from Kline (1983).

CONCLUSIONS

It is emphasized that coal, peat, and geothermal rankings presented in this paper are dependent on the quality of the data. The Kuskokwim Area Plan is one of the most remote areas in the state and geologic data is quite poor particularly the southern portion of the study area.

For example, coal resources have been examined by reasonably good investigations along the flank of the Alaska Range, but only in site-specific areas elsewhere. Coal resources have been identified, but proven reserves must be tested with more detailed subsurface investigations. With the exception of the McGrath peatland, peat remains an unassessed but probably significant resource.

All geothermal sites represent resources of unknown extent and significance. Recreational potential exists, but it needs to be documented and tested in the field.

The data that show significant resources don't imply or predict economic utilization. Factors that must be considered include development of markets in remote areas, climate, physiography, government policy, and high technology innovation, transportation and solutions of other geotechnical problems.

BIBLIOGRAPHY

Barnes, F.F., 1967, Coal resources of Alaska: U.S. Geological Survey Bulletin 1242-B, 36 p.

Brooks, A.H., 1911, The Mt. McKinley region, Alaska: U.S. Geological Survey Professional Paper 70, 118 p.

Brooks, A.H., 1925, Alaska's mineral resources: U.S. Geological Survey Bulletin 773-A, p. 3-52.

Bundtzen, T.K., and Gilbert, W.G., 1983, Outline of geology and mineral resources of Upper Kuskokwim region, Alaska: Alaska Geological Society Journal, v. 3, p. 101-118.

Bundtzen, T.K., Laird, G.M., and Lockwood, M.S.., 1985, Geologic map of Iditarod C-3 Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys PDF 85-6, 1 pl. 18 p.

Bundtzen, T.K., Eakins, G.R., Green, C.B., and Lueck, L.L., 1986, Alaska's mineral industry - 1985: Alaska Division of Geological and Geophysical Surveys Special Report 39, 69 p.

Dickey, D.B., 1984, Cenozoic non-marine sedimentary rocks of the Farewell fault zone, McGrath Quadrangle, Alaska: Sedimentary Geology, v. 38, p. 443-463.

Gilbert, W.G., 1981, Preliminary geologic map and geochemical data, Cheeneetnuk River area, Alaska: Alaska Division of Geological and Geophysical Surveys Open-file Report 153, 10 p., scale 1:63,360, 2 plates.

Harding, J.E., 1923, How to calculate tonnage and grade of an ore body: English Mining Journal, v. 116, p. 445-448.

Kline, J.T., 1983, Material studies of McGrath area: Alaska Division of Geological and Geophysical Surveys unpublished report, 20 p.

Lukens, P.R., 1981, Annual book of ASTM standards---Gaseous fuels; Coal and coke, atmospheric analysis: American Society for testing and materials, Philadelphia, Pennsylvania, 920 p.
McKinstry, H.E., 1948, Mining Geology, New York, Prentice-Hall, Inc., 680 p.
Mertie, J.B., 1936, Mineral deposits of the Ruby-Kuskokwim region, Alaska, U.S. Geological Survey Bulletin 864-C, p. 115-247.
Motyka, R.M., and Liss, Shirley, Geothermal map of Alaska: Alaska Division of Geological and Geophysical Surveys Special Report 33, 1 pl., scale 1,000,000.
Player, Gary, 1976, Little Tonzona coal field: unpub. Private contractor report, 24 p.
Sainsbury, C.L., and MacKevett, 1965, Quicksilver deposits of southwestern Alaska: U.S. Geological Survey Bulletin 1187, 89 p.
Solie, D.N., and Dickey, D.B., 1982, Coal occurrences and analyses, Farewell-White Mountain area, Alaska: Alaska Division Geological and Geophysical Surveys Open-file Report 160, 17 p., 2 pl.
Sloan, E.G., Shearer, G.B., Eason, J.E., and Almquist, C.L., 1979, Reconnaissance survey for coal near Farewell: U.S. Geological Survey Open-file Report 79-410, 18 p., 2 pl.
Thorpe, W.H., 1981, Tonzona project - summary report for 1980: Canadian Superior Exploration Ltd., unpublished report, 26 p., 5 appendices.
Thorpe, W.H., 1982, Tonzona project - summary report for 1981: McIntyre Mines Ltd., unpublished report, 125 p., 5 pl.
Wahrhaftig, Clyde, Wolfe, J.A., Leopold, E.B., and Lanphere, M.A., 1969, The coal bearing group in the Nenana coal field, Alaska: U.S. Geological Survey Bulletin 1274-D, p. 1-30.