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ALASKA COAL RESOURCES

by

D.L. McGee and K.S. Emmel

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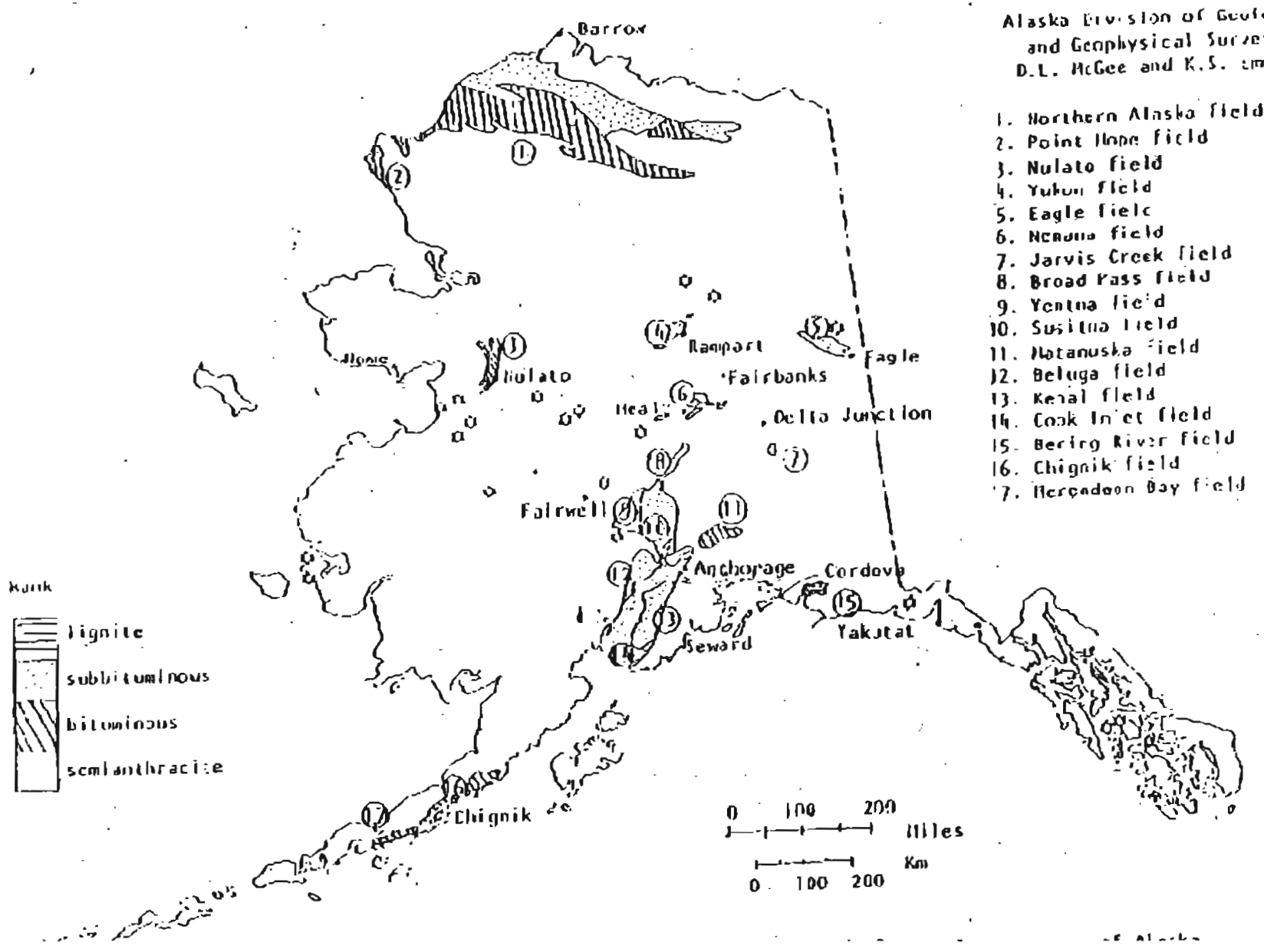
INTRODUCTION

The estimated coal resources of Alaska are very difficult to ascertain because of the lack of data control beyond outcrop areas and drilled areas adjacent to outcrop areas. However, as in this report, it sometimes becomes necessary to compare resources values from other areas with those in the state of Alaska. A comparison of total coal resources between Alaska and the United States involves figures generated with minimum data from Alaska and a large data base from coal areas in the United States. A total resource value for the contiguous United States is a more accurate figure than could possibly be made for Alaska because of the increased amount of data that is available in the United States. For this reason it may not be valid to make comparisons between the resources of the two areas.

In many areas in Alaska there is a wide range in the undiscovered resource estimates, which reflects the scarcity and ambiguity of the available data. The main purpose of this summary is to condense the data into single values that can be used for comparison purposes and yet at the same time be aware of the hazards of comparing the values.

The coal resources have been broken into three simple categories. Measured Resources are those resources that have a high probability of being accurate. Indicated and Inferred Resources are somewhat similar and have been grouped into one category in this summary. The two represent the resources in a zone of decreasing accuracy between measured and hypothetical resources. Hypothetical Resources, as the name implies, are those resources for which there is a wide range of possible error.

The parameters which control the resource values are those proposed by the United States Geological Survey and the Bureau of Mines. The economics of extracting the coal and the percent recovery expected do not enter into this resource summary.



Map compiled from Conwell, C.N., 1977, Energy Resource map of Alaska, Alaska Department of Natural Resources, DGGS.

COAL FIELD	MEASURED RESOURCES	INDICATED & INFERRED RESOURCES	HYPOTHETICAL RESOURCES	DATA SOURCES AND REMARKS
Northern Alaska NPR-A	200 million stripping coal	49-120 billion short tons	330 billion to 3.3 trillion short tons	Barnes, 1967 Martin, 1978 McGee, 1975
	200 million	85 billion	1.5 trillion	values used in charts
Northern Alaska West of NPR-A	35 million	7-12 billion	153 billion includes 3 billion tons within three mile zone along coast	Callahan, 1975 Barnes, 1967 McGee, 1975
	35 million	9 billion	153 billion	values used in charts
Northern Alaska East of NPR-A	- -	2-5 billion	50 billion	Barnes, 1967 McGee, 1975
	- -	3.5 billion	50 billion	values used in charts
Nenana Coal Field	861.6 million	6.0 billion	8.7 billion	Barnes, 1967 Holloway, 1977 McGee, 1975
Jarvis Creek Coal Field	- -	13-76 million	- -	Barnes, 1967 Holloway, 1977
	- -	44 million	- -	values used in charts

Figure 2

COAL FIELD	MEASURED RESOURCES	INDICATED & INFERRED RESOURCES	HYPOTHETICAL RESOURCES	DATA SOURCES AND REMARKS
Susitna Coal Field	275 million	2.7 to 10.2 billion	27 billion	Barnes, 1967 Holloway, 1977 McGee, 1975 Placer Amex Inc., 1977
*	275 million	6.5 billion	27 billion	values used in charts
Matanuska Coal Field	6.6 millin	108-130 million	149 million	Barnes, 1967 Holloway, 1977 McGee, 1975
	6.6 million	112 million	149 million	values used in charts
Kenai Coal Field Onshore	0.2 million	318 million	34 million	Barnes, 1967 Holloway, 1977 Magoon, 1976 McGee, 1975
Kenai Coal Field Offshore	- -	- -	100 billion	McGee, 1974 values not used in totals
Broad Pass Coal Field	- -	64 million	- -	Hopkins, 1951 Barnes, 1967 Holloway, 1975
Chignik Bay	- -	100 million	300 million	McGee, 1977 unpublished field notes Cretaceous coal only
Herendeen Bay Coal Field	- -	10-100 million	Less than 300 million	McGee, 1977 unpublished field notes Cretaceous coal only
	- -	45 million	300 million	values used in charts
Bering Glacier Coal Field	- -	- -	36 million to 1 billion	Barnes, 1951 Saunders, 1976
	- -	- -	500 million	values used in charts

*The Beluga coal field is a part of the Susitna coal province. The 275 million short tons of measured coal and 2.3 billion short tons of indicated and inferred coal represent the Beluga resources.

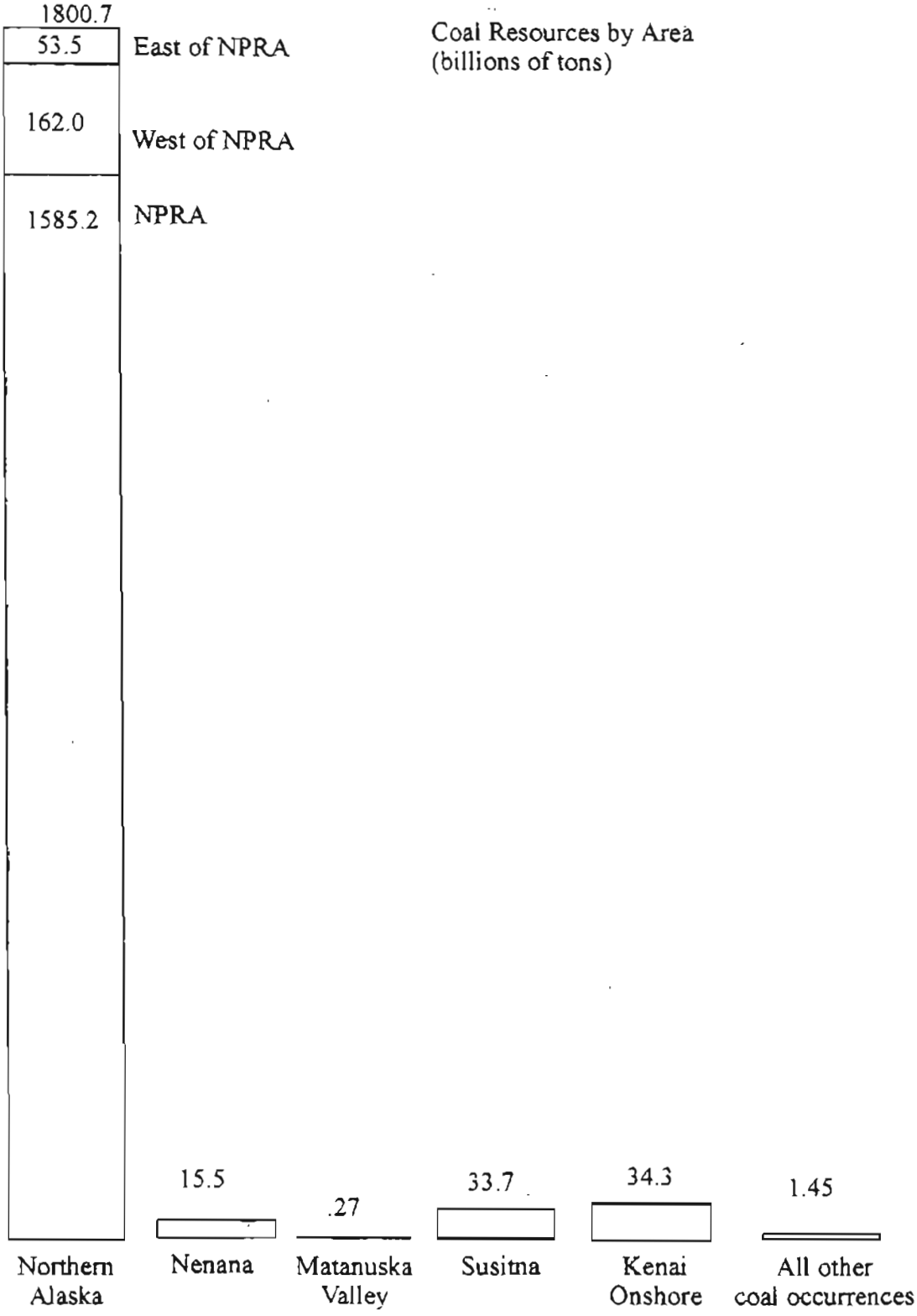
Figure 2, continued

COAL FIELD	MEASURED RESOURCES	INDICATED & INFERRED RESOURCES	HYPOTHETICAL RESOURCES	DATA SOURCES AND REMARKS
Isolated Coal Occurences	Listed below are the more important isolated occurrences of coal in Alaska. There are numerous other areas where thin coals crop out.			
Eagle Circle	- -	- -	10-100 million	
	- -	- -	45 million	values used in charts
Nation River	- -	- -	1-50 million	
	- -	- -	25 million	values used in charts
Yukon River	- -	- -	10-50 million	Chapman, 1963 Collier, 1903
	- -	- -	30 million	values used in charts
Little Tonsina River	- -	- -	- -	Coal outcrop thicknesses suggest large resources Sloan, et al: 1979
Unga Island	- -	- -	Probably minor	Hollway, 1977
Tertiary Coal Alaska Peninsula	- -	- -	Probably large	McGee, 1977 Unpublished
Southeast Alaska	- -	- -	Unknown probably small	Wright, 1906
All of Alaska	*1.4 billions short tons	*110.7 billion short tons	*1774.0 billion short tons	Does not include an estimated 100 billion tons under the offshore Cook Inlet

*Figures rounded.

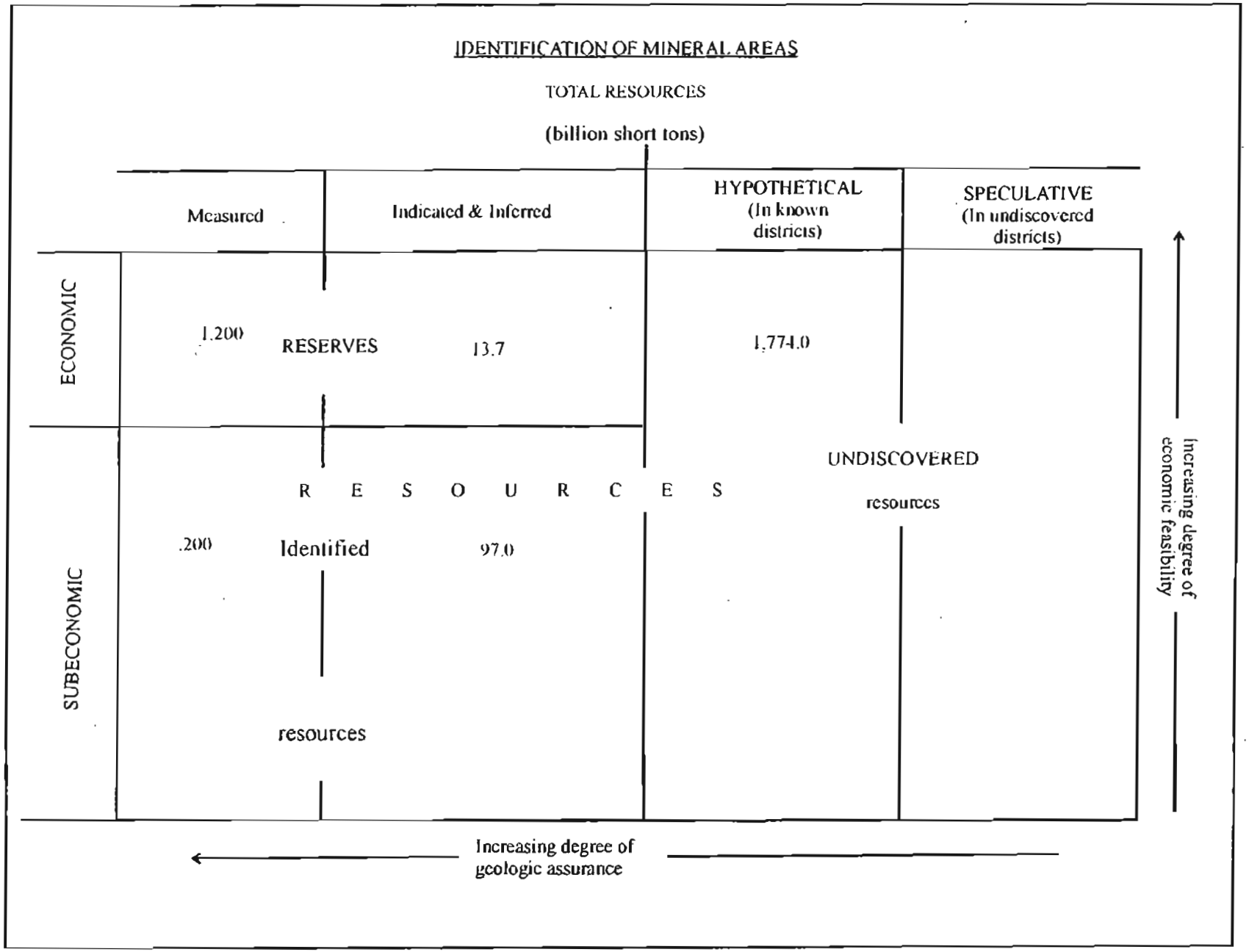
Summarized by D.L. McGee and K.S. Emmel, Alaska Division of Geological and Geophysical Surveys, 1979.

Figure 2, continued



See Alaska Coal Resources (this report) for references.

Compiled by D.L. McGee and K.S. Emmel, Alaska Division of Geological and Geophysical Surveys, 1979.



See Alaska Coal Resources Summary (this report) for references.

CAN ALASKA'S COAL COMPETE WITH WESTERN UNITED STATES COALS?

The Stanford Research Institute in 1974 completed a study titled "The Potential for Developing Alaskan Coals for Clean Export Fuels." This study was directed toward evaluating the potential for development of coals in the Beluga area. Mining costs for developing a moderate to large mine were listed and averaged $5.32 per short ton. Marine transportation costs per long ton (in and out cost excluding cargo handling costs) to Long Beach, California, were estimated tat $4.90. Since 1974 inflation has increased the cost of mining and transporting coal over ten percent per year and the present cost of landing a ton of coal in the Long Beach area would be in the range of $16 to $18. The accuracy of this range is estimated to be 33 percent above or below the range. Coal from the Beluga area would be competitive with western United State coal of equal Btu content.

In 1975, Joe Usibelli estimated his price to the customer was $12.00 per ton (FOB).* The shipping rates from Healy to Whittier, 307 miles, were estimated at $7.33 per short ton. Thus the cost of a ton of coal at Whittier would have been $19.33 in 1975.

In 1975, Robert Bottge, U.S. Bureau of Mines, Juneau, Alaska gave a talk titled "Changing Economics of Alaska's Coals" at a coal conference in Fairbanks, Alaska. This report estimated the cost of producing one million tons of coal annually in four different areas of Alaska. He also projected these costs to 1978 and compared them with the estimated cost of producing oil and gas on a comparable Btu basis.

Bottge suggested that cost estimates for the four areas may be no closer than plus or minus 33%. The areas are listed below with their economics calculated for 1975 and projected to 1978.

Atigun area (Northern Alaska) 7500 Btu Selling price $23.59 ($1.57/Btu)	Healy Area 8500 Btu $8.60 ($0.51 Btu)
Jonesville Area (12,500 Btu Selling price $17.03 ($0.68/Btu)	Beluga Area 7500 Btu $9.39 ($0.63/Btu)

Projected prices to 1978. Assume a 10% inflationary rate from 1975 to 1978.

Atigun Area $2.30/Btu Jonesville Area $0.98/Btu	Healy Area $0.73/Btu Beluga Area $0.90/Btu

An analysis of the preceding would suggest that coal from the Healy and Beluga areas would be competitive with western coals delivered to a coast city. At the present time the Northern Alaska coals are considered non economic. Suggested costs of mining and transporting western coals from source to the west coast were obtainable only as a range from $12 to $18 per short ton. The accuracy of this range could not be established.

*From a talk given by Joe Usilbelli at a conference in Fairbanks, Alaska, 1975.

The effect of Sec. 522 6e (1) and (2) of Public Law 95-87 on development of Alaska coal is evaluated and discussed below:

The bill reads, After the enactment of this act and subject to valid existing rights no surface coal mining operations except those which exist on the date of enactment of this act shall be permitted:

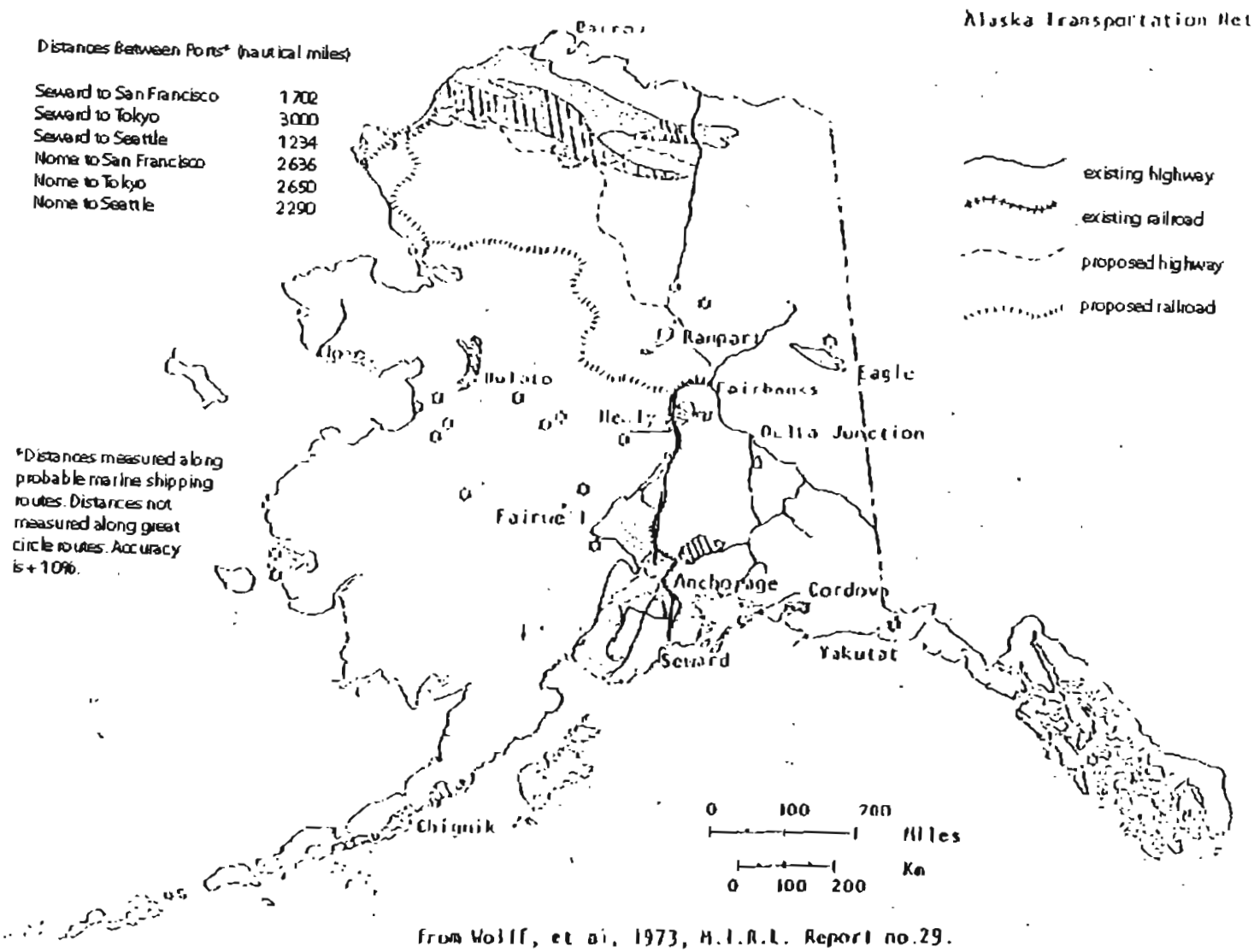
1. On any lands with the boundaries of units of the National Park System, the National Wildlife Refuge Systems, the National Systems of Trails, the National Wilderness Preservation System, the Wild and Scenic Rivers System and National Recreation Areas designated by act of congress.

2. On any Federal lands within the boundaries of any National Forest, may permit mining if the Secretary finds there are no significant recreational, timber, economic or other values which may be incompatible with such surface mining operations.

The future status of land within the boundaries of the National Petroleum Reserve – Alaska has not been defined although recommendations have been made that if enacted would prevent development of coal resources by the most economical method of extracting the coal. Further, the area has not been adequately evaluated although there are sufficient data to indicate very large coal resources.

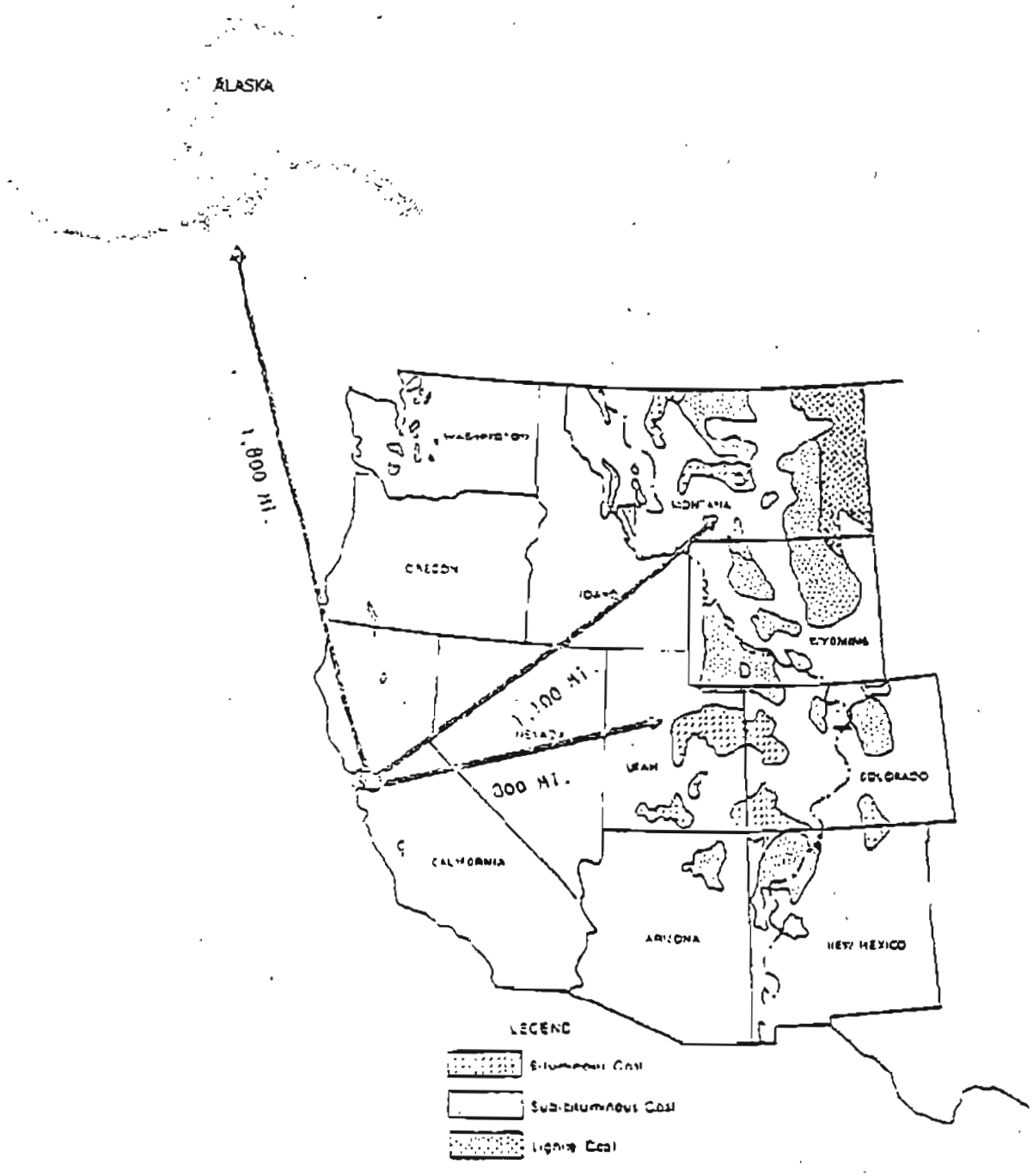
Classifying NPR-A into any of the categories that prohibit coal extraction by surface stripping may prevent development and use of a large percentage of the Nation's coal resources. Extraction of coal by underground techniques is not specifically prohibited although conflict could occur as surface facilities and roads are constructed.

The percentage of coal underlying lands within the boundaries of NPR-A is approximately 83% of the total coal resources of Alaska. Much of this coal resource is hypothetical and additional exploration will be required to establish this resource as part of the reserve base.



From Wolff, et al, 1973, H.I.R.L. Report no.29.

compiled by D.L McKee and K.S. Emmel, Alaska Division of Geological and Geophysical Surveys, 1979.



Comparison of shipping distance for Alaskan and Midwestern coals.

ALASKA COAL RESOURCES BY RANK – BILLIONS OF SHORT TONS**

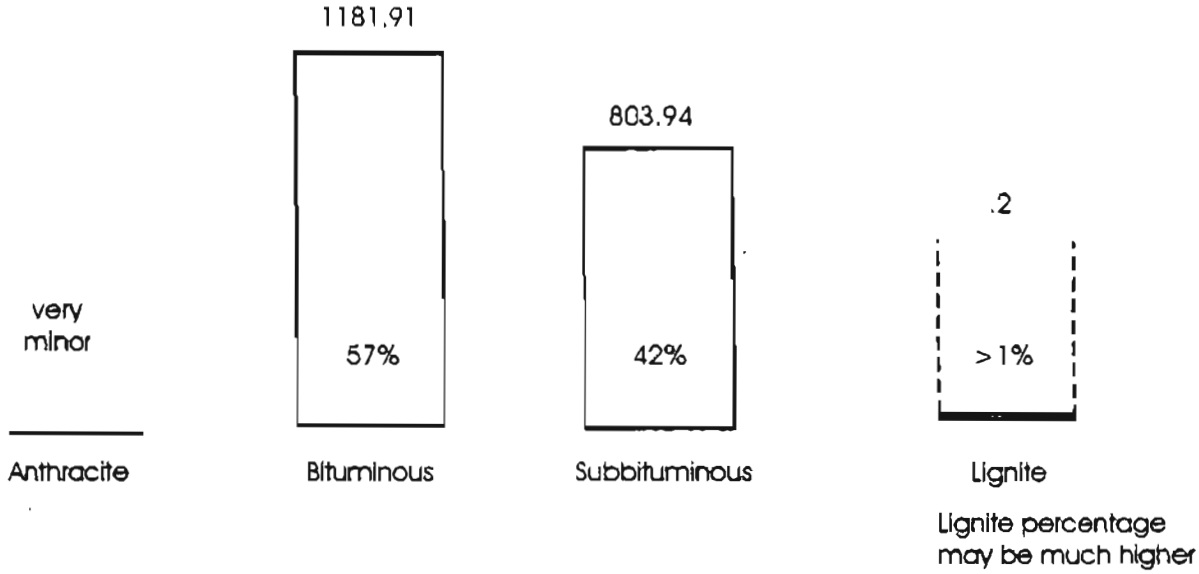
AREA	BITUMINOUS COAL INCLUDES MINOR ANTHRACITE COAL WHERE NOTED	SUBBITUMINOUS COAL	LIGNITE COAL
NPR-A	951	634	--
WEST OF NPR-A	97.2	64.8	--
EAST OF NPR-A	32.1	21.4	--
NENANA	--	15.6	--
JARVIS CREEK	--	.04	--
MATANUSKA*	0.27	Minor	Minor
SUSITNA	--	33.7	Minor
KENAI ONSHORE	--	34.3	Moderate
BROAD PASS	--	--	Minor
CHIGNIK BAY HERENDEEN BAY	0.74	Minor	--
BERING GLACIER*	.5	Moderate	Minor
ISOLATED COAL OCCURENCES	0.1	0.1	0.2
TOTALS	*Minor anthracite resources		
	1081.91	803.94	0.2

**Ratio of 60% bituminous and 40% subbituminous from Callahan in Martin and Callahan, 1978.

Summarized by D.L. McGee and K.S. Emmel, Alaska Division of Geological and Geophysical Surveys.

Figure 7

PERCENTAGE OF ALASKA'S COAL RESOURCES BY RANK*



An estimated 50% of the subbituminous coal in Alaska is at the bottom of the subbituminous range approaching lignite.

*Ratio of 60% bituminous and 40% subbituminous from Callahan in Martin and Callahan, 1978.

From: Alaska Regional Energy Resources, Alaska Division of Energy and Power Development, 1977.

Compiled by D.L. McGee and K.S. Emmel, Alaska Division of Geological and Geophysical Surveys, 1979.

ENERGY EQUIVALENT STATEMENT – COAL TO BARRELS OF OIL (42 gal.)

The equivalent energies for crude oil and coals are listed below:

Coal per 2,000 pound ton

Bituminous coal equals 26.2×10^6 Btu
Subbituminous coal equals 19.0×10^6 Btu
Lignite coal equals 13.4×10^6 Btu

Crude oil equals 5.60×10^6 Btu

Alaska's total coal resource is predominantly bituminous although most of the easily accessible coal is subbituminous. A value of 23.0×10^6 Btu was used and from this value one ton of coal is equivalent to about four barrels of oil. The values are average values and not precise equivalents.

Alaska's coal resources in billions of short tons and the equivalent in crude oil (42 gal. barrels) is listed below:

Measured Coal Resources
1.4 billion tons equals about 5.2 billion barrels of crude oil.

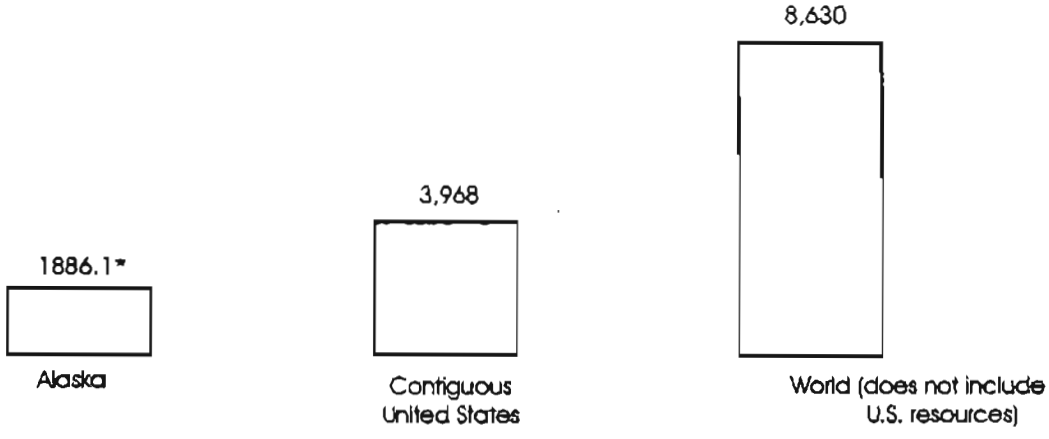
Indicated and Inferred Coal Resources
111.0 billion tons equals about 444.0 billion barrels of crude oil.

Hypothetical Coal Resources
1,761.0 billion tons equals about 7,044.0 billion barrels of crude oil.

For comparative purposes the largest oil field in North America is the Prudhoe Bay field which contains about 9.6 billion barrels of recoverable oil.

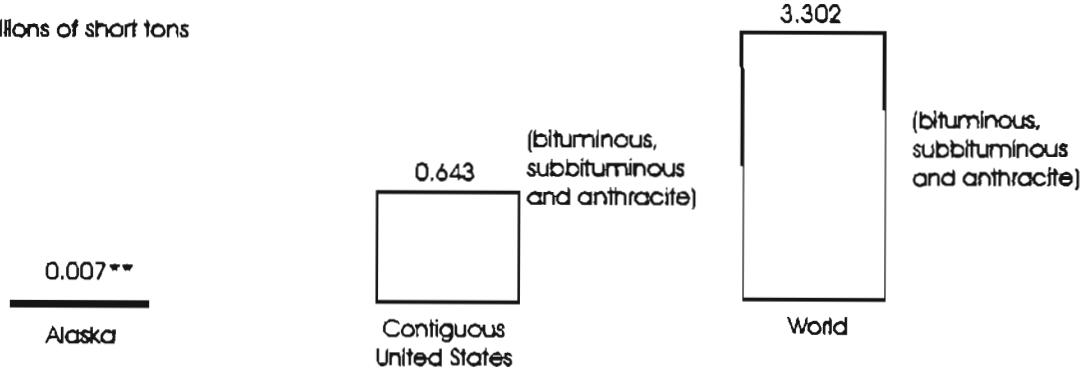
Comparison of Resources and Production Values Between Alaska, the Contiguous United States and the World

Resources in billions of short tons



*Does not include large accumulations under Cook Inlet

Production in billions of short tons

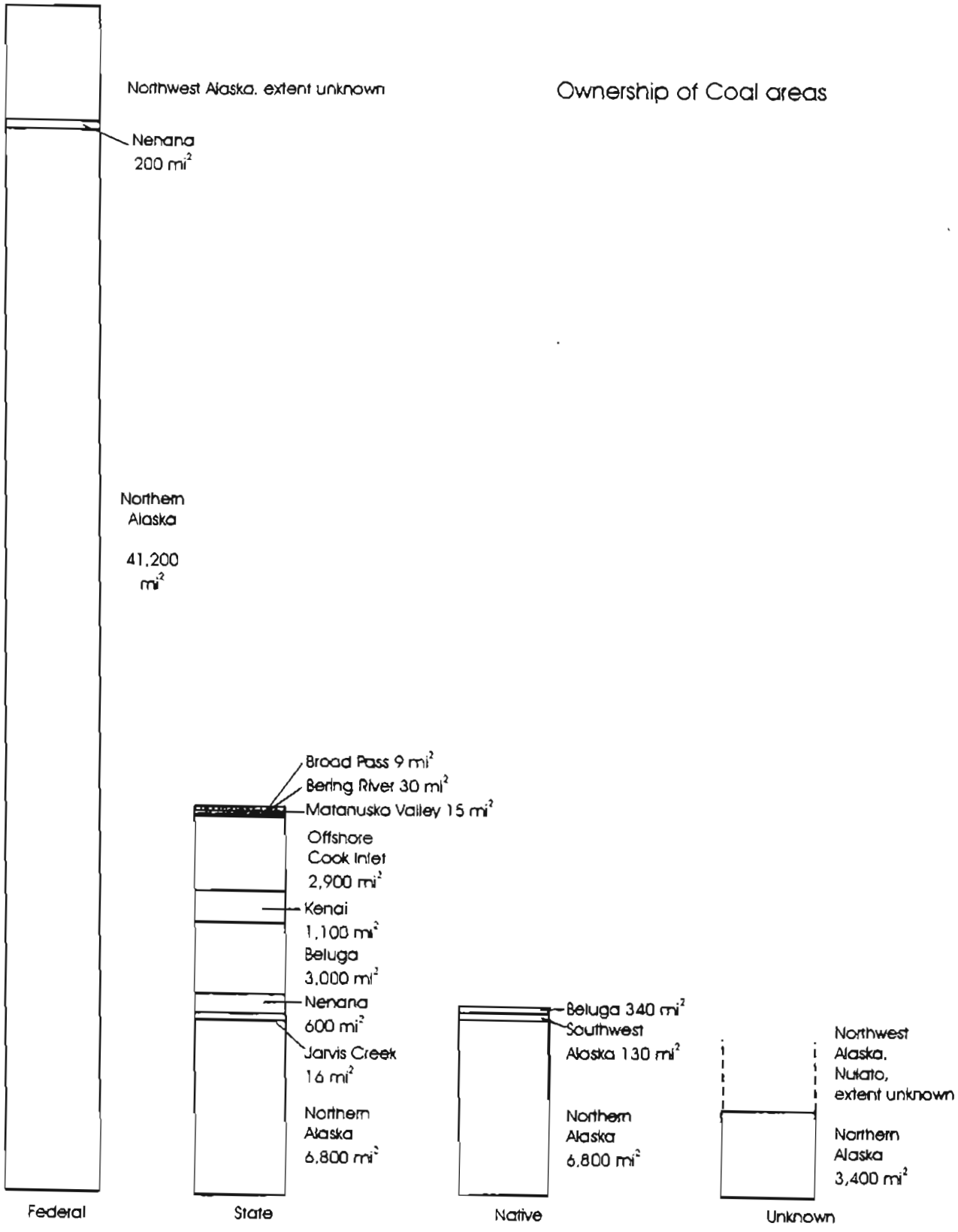


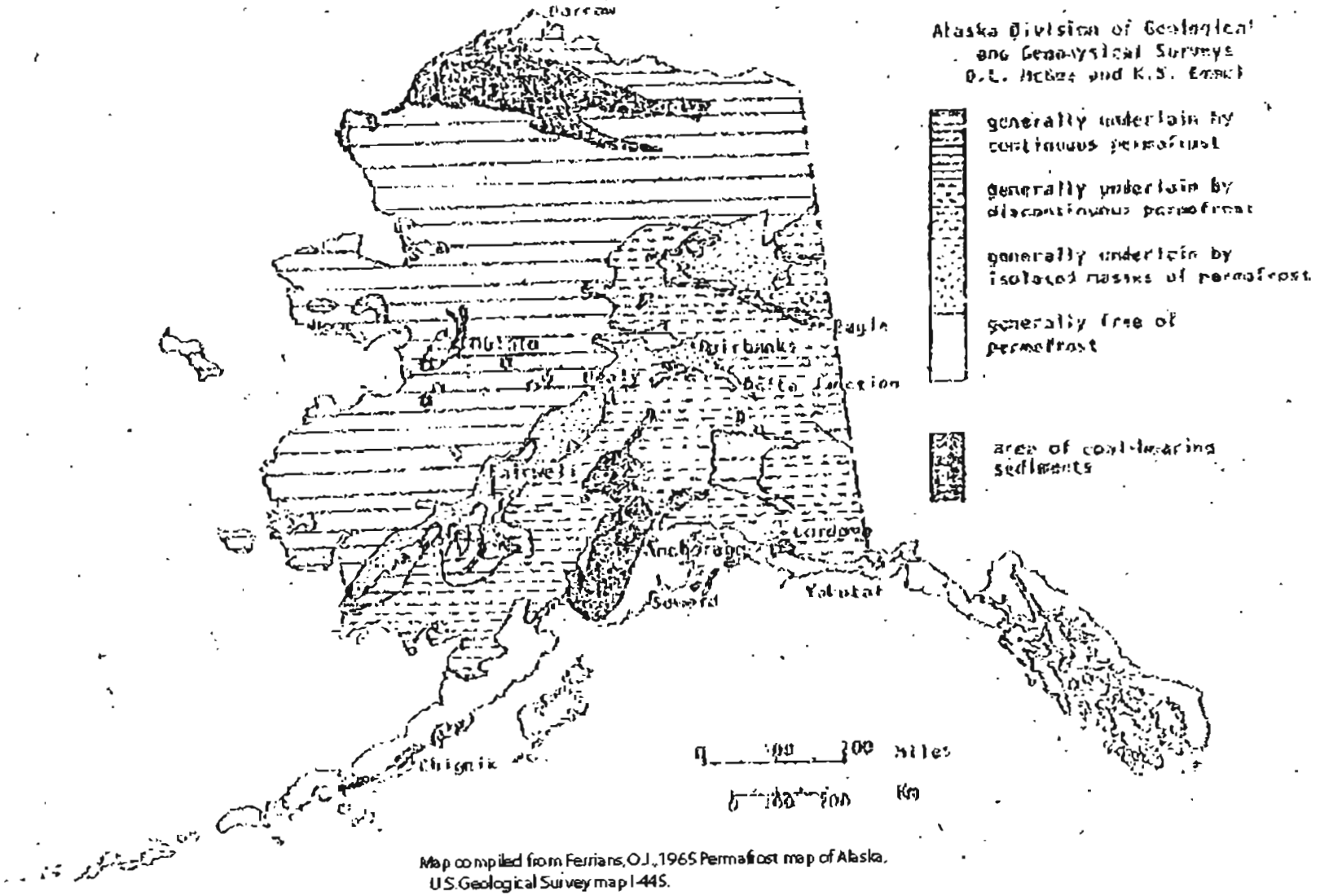
**from one mine

From: Alaska Regional Energy Resources, Alaska Division of Energy Resources, Alaska Division of Energy and Power Development, 1977.

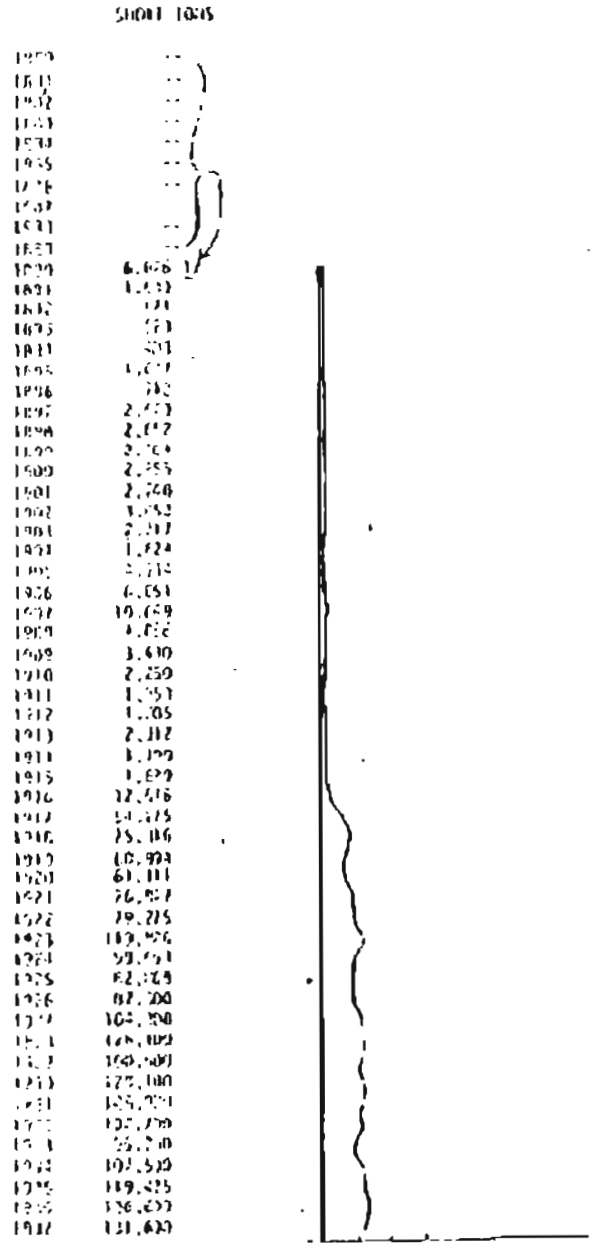
Commodity Data Summaries, 1976, U.S. Bureau of Mines.

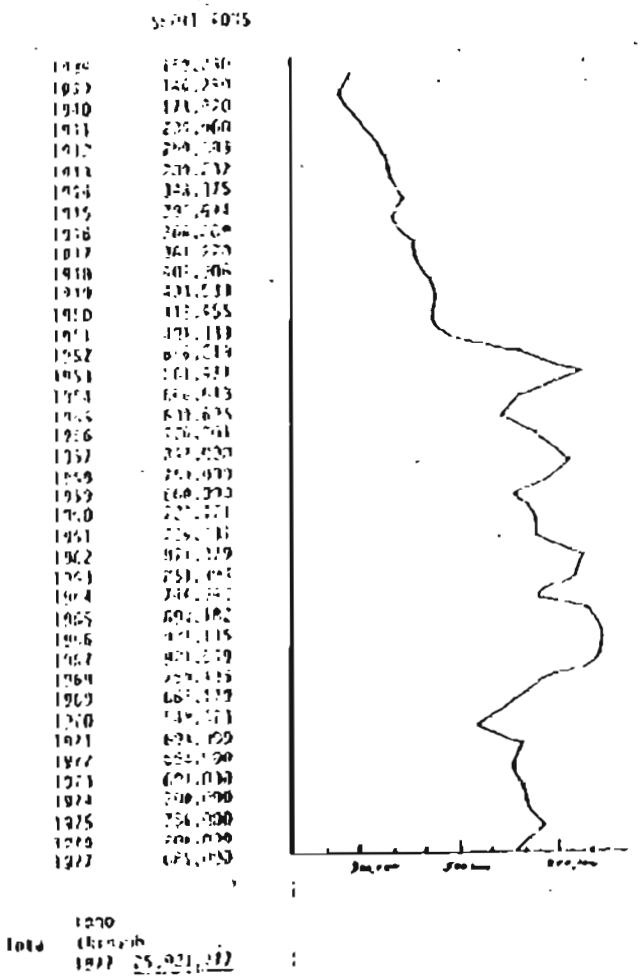
Ownership of Coal areas





Map compiled from Ferrians, O.J., 1965 Permafrost map of Alaska, U.S. Geological Survey map I-445.





From: Alaska Regional Energy Resources, Alaska Divisi
of energy and Power Development, 1977.

Compiled by D.L. McGee & K.S. Emmel, Alaska Division of
Geological and Geophysical Surveys, 1979.

Significant Events in Coal Development and Production in Alaska, 1786-1977

1786	Capt. Nathaniel Portlock, English trader, finds coal at Coal Cove (presently Port Graham) on the Kenai Peninsula
1855	First Alaska coal mine opened by the Russian-American Company at Coal Cove.
1879	Whaling ships and U.S. Revenue cutters start using coal from the Corwin mines along the coast between Cape Sabine and Cape Lisburne, Northern Coal Field on the Arctic Coast.
1888	Wharf Mine near Port Graham opens.
1898	Sternwheelers use coal as fuel to transport gold seekers to gold fields.
1900	Extension of coal laws to Territory of Alaska.
1902	Yukon River steamers convert coal and wood burners to petroleum engines.
1904	Coal Act enacted, allowing coal claim locations without previous surveys.
1906	President Theodore Roosevelt closes Alaska public land to entry under coal laws due to Pinchot-Ballinger feud.
1914	U.S. Congress passes Alaska Coal Leasing Act.
1916	Alaska Railroad is built to Matanuska Coal Field.
1922	Alaska Railroad reaches Nenana Coal Field.
1924	U.S. Navy begins converting its coal burning ships to oil.
1940	Nearly all coal mined in Alaska comes from Evan Jones Coal Mine in the Matanuska Field and Healy River Coal Mine in the Nenana Field. Coal used to power dredges and large placer mining operations near Fairbanks.
1942	Alaska Railroad reopens Eska Mine. Coal needed for new Army Posts and military airfields.
1943	Traditional underground coal mining in Alaska gives way to surface mining methods.
1946	Alaska Railroad converts coal burning engines to diesel engines, Eska Mine closes in Matanuska Field.
1968	Fort Richardson and Elmendorf Air Force Base convert coal fired steam power plants to natural gas. Matanuska Field shuts down except for small local needs.
1973	Organization of Petroleum Exporting Countries (OPEC), a predominantly Middle East cartel, set high oil prices and reduced supplies to the U.S., prompting increased demand for other energy sources, including coal.
1977	President Carter's energy policy includes conversion of utilities and industry to coal prompting an interest in opening the Beluga and Jarvis Coal Fields.

Resources. Concentrations of coal in such forms that economic extraction is currently or may become feasible.

Identified Resources. Specific bodies of coal whose location, rank, quality, and quantity are known from geologic evidence supported by engineering measurements.

Undiscovered Resources. Unspecified bodies of coal surmised to exist on the basis of broad geologic knowledge and theory.

Reserve Base. That portion of the Identified Coal Resource from which Reserves are calculated.

Reserve. That portion of the Identified Coal Resource that can be economically mined at the time of determination. The reserve is derived by applying a Recovery Factor to that component of the Identified Coal Resources designated as the Reserve Base.

Recovery Factor. The percentage of total tons of coal estimated to be recoverable from a given area in relation to the total tonnage estimated to be in the Reserve Base in the ground.

Identified Subeconomic Resources. The part of coal resources that occurs in Demonstrated and Inferred Resources that is not now minable economically.

Hypothetical Resources. Undiscovered Coal Resources in beds that may reasonably be expected to exist in known mining districts under known geologic conditions. In general, Hypothetical Resources are in broad areas of coal fields where points of observations are absent and evidence is from distant outcrops, drill holes, or wells. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as a Reserve or Identified Subeconomic Resources.

Speculative Resources. Undiscovered coal beds that may occur either in known types of deposits in a favorable geologic setting where no discoveries have been made, or in deposits that remain to be recognized. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as Reserves or Identified Subeconomic Resources.

The following definitions are applicable to both the Reserve and Identified Subeconomic Resource Components.

Measured. Coal for which estimates of the rank, quality, and quantity have been computed, within a margin of error of less than 20 percent, from sample analyses and measurements from closely spaced and geologically well-known sample sites.

Indicated. Coal for which estimates of the rank, quality, and quantity have been computed partly from sample analyses and measurements and partly from reasonable geologic projections.

Demonstrated. A collective term for the sum of coal in both Measured and Indicated Resources and Reserves.

Inferred. Coal in unexplored extensions of Demonstrated Resources for which estimates of the quality and size are based on geologic evidence and projection.

Rank. The classification of coals relative to other coals, according to their degree of metamorphism, or progressive alteration, in the natural series from lignite to anthracite (Classification of Coal by Rank, 1938, American Society for Testing Materials, ASTM Designation D-388-38, p. 77-84).

Quality or grade. Refers to individual measurements such as heat value, fixed carbon, moisture, ash, sulfur, phosphorus, major, minor, and trace elements, coking properties, petrologic properties, and particular organic constituents. The individual quality elements may be aggregated in various ways to classify coal for such special purposes as metallurgical, gas, petrochemical,S and blending usages.

References

Alaska Division of Energy and Power Development, 1977, Alaska regional energy resources, Vol. 11, Alaska's energy resources: inventory of oil, gas, coal, hydroelectric, and uranium resources, pp. 133-216.

American Society for Testing and Materials, 1965, Specifications for classification of coals by rank (tentative), ASTM designation D388-64T, in pt. 19, Gaseous fuels; coal and coke: 1965 Book of ASTM Standards, p. 73-78.

Atwood, W.W., 1911, Geology and mineral resources of parts of the Alaska Peninsula: U.S. Geological Survey Bulletin 467, 137 p.

Averitt, Paul, 1961, Coal reserves of the United States—A progress report, January 1, 1960: U.S. Geological Survey Bulletin 1136, 116p.

Barnes, F.F., 1951, A review of the geology and coal resources of the Bering River coal field, Alaska: U.S. Geological Survey Circular 146, 11 p.

———, 1966, Geology and coal resources of the Beluga-Yentna Region, Alaska: U.S. Geological Survey Bulletin 1202-C.

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

Barnes, F.F. and Cobb, E.H., 1959, Geology and coal resources of the Homer district, Kenai coal field, Alaska: U.S. Geological Survey Bulletin 1058-F, p. 217-260.

Barnes, F.F. and Payne, T.G., 1956, The Wishbone Hill district, Matanuska coal field, Alaska: U.S. Geological Survey Bulletin 1016, 88 p.

Barnes, F.F. and Sokol, Daniel, 1959, Geology and coal resources of the Little Susitna district, Matanuska coal field, Alaska: U.S. Geological Survey Bulletin 1058-D, p. 121-138.

Barnes, F.F. and others, 1951, Coal investigations in south-central Alaska, 1944-1946; U.S. Geological Survey Bulletin 963-E, p. 137-213.

Bass, N.W., Smith, H.L., and Horn, G.H., 1970, Standards for the Classification of public coal lands: U.S. Geological Survey Circular 633, 10 p.

Callahan, J.E., 1971, Geology and coal resources of T.6S., R.51W., unsurveyed, Umiat principal meridian, in the Cape Beaufort coal field, northwestern Alaska: U.S. Geological Survey Open-File Report[DR1] 71-61, 18 p., 5 sheets, 3 tables.

Callahan, J.E., 1975, Coal investigations in western arctic Alaska, in Focus on Alaska's coal "75", Conference of the University of Alaska, Fairbanks, pp. 48-53.

Callahan, J.E., et al., 1969, Geology of T.1S., R.44W., unsurveyed, Umiat principal meridian, in the Kukpowruk coal field, Alaska: U.S. Geological Survey Open-File Report[DR2], 19 p., 1 pl., 1 fig., 2 tables.

Chapman, R.M., 1963, Coal deposits along the Yukon River between Ruby and Anvik, Alaska: U.S. Geological Survey Bulletin 1155.

Chapman, R.M. and Sable, E.G., 1960, Geology of the Utukok-Corwin region, northwestern Alaska—Exploration of Naval Petroleum Reserve No. 4 and adjacent areas, northern Alaska, 1944-53, Pt. 3, Areal Geology: U.S. Geological Survey Professional Paper 303-C, p. 47-167.

Sanders, R.B., 1976a, Coal resources of Alaska, in Roa, P.D. and Wolff, E.N., eds. Focus on Alaska's coal "75" Conference of the University of Alaska, Fairbanks, pp. 21-32.

————1976b, Geology and coal resources in the Bering River field, in Roa, P.D. and Wolff, E.N., eds. Focus on Alaska's coal "75", Conference of the University of Alaska, Fairbanks, pp. 54-58.

Sloan, E.G., et al., 1979, Reconnaissance Survey for coal near Farewell, Alaska, U.S. Geological Survey Open-File Report 79-410.

U.S. Bureau of Mines, 1973, Alaska 1:250,000 scale quadrangle map overlays showing mineral deposit locations, principal minerals, and number and type of claims: U.S. Bureau of Mines Open-File Report 20-73.

———1976, Commodity Data Summaries, 1976. pp. 38-41.

Wahrhaftig, Clyde, 1973, Coal reserves of the Healy Creek and Lignite Creek coal basins, Nenana coal field, Alaska: U.S. Geological Survey Open-File Report 73-355.

Wahrhaftig, Clyde and Hickcox, C.A., 1955, Geology and coal deposits, Jarvis Creek coal field, Alaska: U.S. Geological Survey Bulletin 989-G, pp. 353-367.

Wahrhaftig, Clyde, et al., 1969, The coal-bearing group on the Nenana coal field, Alaska: U.S. Geological Survey Bulletin 1274-D, 30 p.

Warfield R.S., 1967, Resume of information on Alaskan bituminous coals with particular emphasis on coking characteristics: U.S. Bureau of Mines Open-File Report,[DR3] 20 p.

Waring, G.A., 1936, Geology of the Anthracite Ridge coal district, Alaska: U.S. Geological Survey Bulletin 861, 57 p.

Wolff, E.N., et al., 1973, Optimum transportation systems to serve the mineral industry North of the Yukon Basin in Alaska, M.I.R.L. Report no. 29.

References for Economics

Energy, global prospects 1985-2000, 1975 Report of the Workshop on Alternate Energy Strategies, sponsored by the Massachusetts Institute of Technology.

Bottge, R., 1975, Economics of Alaska coals in Roa, P.D. and Wolff, E.N., eds. Focus on Alaska's coal "75", Conference of the University of Alaska, Fairbanks, pp.139-149.

The potential for developing Alaskan coals for clean export fuels, work performed under contract, Stanford Research Institute, Menlo Park, California. Office of Coal Research, Department of Interior, Washington D.C.