RESUME OF INFORMATION ON ALASKAN BITUMINOUS COALS WITH PARTICULAR EMPHASIS ON COKING CHARACTERISTICS

by Robert S. Warfield

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by

Robert S. Warfield[1/]

ABSTRACT

Alaska has several coalfields known to contain bituminous coal occurrences. This report summarizes the available information on these occurrences with particular emphasis on coking characteristics. Some of the coals are known to exhibit coking properties, others are known to be noncoking, and for some, it is known only that their rank is probably bituminous. By far the greatest amount of reserves are in the Arctic coalfield north of the Brooks Range. In parts of this field, structural geology appears simple enough that modern mechanized mining could be performed. Recent sampling and testing by the Bureau of Mines demonstrated that some of the Arctic coals have significant coking properties.

INTRODUCTION

Bituminous coal is known to occur in five Alaskan coalfields as well as in at least two additional isolated localities of probable small extent. The coalfields are the Arctic, Bering River, Herendeen Bay and Chignik Bay (separated but considered as one field), Matanuska, and Yukon Basin. Much has been written about these fields in numerous reports by the Geological Survey, Bureau of Mines, and others. Some of the information resulted from early exploration and has not been updated. The early investigations were principally concerned with how well a particular coal replaced wood for steam-generated power production or space heating purposes; little attention was given to coking characteristics except to determine if the coal was suitable for blacksmithing purposes. Mention of this characteristic was often casual and had to be searched out of the detailed descriptions. Continued growth of the iron and steel industry in the Pacific Rim has caused considerable interest in Alaskan coals as possible future sources of metallurgical coke. Although no commercially exploitable deposits of high-quality coking coals have yet been defined,

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many of the Alaskan deposits have coking characteristics ranging from poor to excellent. This resumé of information on the State's principal known sources of bituminous coals gives special attention to the coking characteristics mentioned in the various reports.

The structural geology of most Alaskan occurrences of bituminous coals, as determined by reconnaissance examination has been well described in the various footnoted publications to which the reader is referred for details. With a few exceptions, the coals are relatively geologically young and have attained their bituminous rank due to heat and pressure generated during periods of strong structural deformation. As a result, many of the occurrences, as compared to Eastern United States coking coals, are structurally complex and discontinuous. Mining costs are or would be high. A notable exception appears to be the Arctic coalfield, where at least in the area that has recently been subject to a Bureau of Mines sampling program, the coals that possess coking properties have dips of 10° to 15° at the outcrop. Their structure appears fairly simple. They should be amenable to modern mechanized mining--either surface or underground.

MATANUSKA COALFIELD

The Matanuska coalfield is in the valley of the Matanuska River in South-Central Alaska, about 45 airline miles northeast of Anchorage. The coals are, in general, bituminous in rank, their geologic age Tertiary, probably Eocene. The structural geology, relative to many producing coal mine areas of the contiguous 48 states, is rather complex. Dips are generally too steep for successful use of a continuous miner. Coalbeds thicken and thin markedly within relatively short distances. The ash content may vary considerably within short distances. Faulting is usually an additional complication to mining.

The coalfield has been divided into three districts; progressing up-valley, or eastward, they are Wishbone Hill--which currently (1966) is the only producing district, Chickaloon, and Anthracite Ridge. All production is currently from surface mining and is used almost in entirety for power generation; the exception is a few thousand tons used forspace heating purposes in the Anchorage and Palmer areas.

Wishbone Hill District

The coals of the Wishbone Hill district are generally high-volatile B bituminous, but an occasional analyses will indicate coal of high-volatile

A bituminous rank. These coals are usually considered to be noncoking; however, free-swelling index and agglutinating index determinations made on Bureau of Mines drill core samples from the central part of the district indicate that some of the coal may have poor to fair coking and caking properties.2/

Coking studies at the Bureau of Mines Central Experiment Station, Pittsburgh, in 1949, were made on a high-ashsample of high-volatile B bituminous coal from No. 3 bed of the Jonesville mine.3/ The sample was run of mine production coal collected from exiting underground mine cars. At one point in the mine, No. 3 bed was measured at 97 inches thick, of which 85 inches was coal; the bed was reported to range in thickness from 8 to 12 feet.4/ The dip of No. 3 bed averaged about 35°.

The carbonizing sample was raw coal containing 21.3 percent ash, whereas washed coal was reported to contain only 10 to 12 percent ash. The sample was carbonized at 900° C in a standard 13-inch Bureau of Mines-American Gas Association retort. In addition to carbonization of the No. 3 bed sample singly, it was blended in a 70:30 proportion with strongly coking M-bed medium-volatile bituminous coal from the abandoned Chickaloon mine, Chickaloon district of the Matanuska coalfield.

Carbonization of the No. 3 bed sample, which contained 15 percent oxygen, yielded what was described as poorly fused coke or char and the blend yielded an incompletely fused poor coke. A search of the literature revealed no other published results of actual coking studies on Wishbone Hill district coals.

During 1964, the University of Alaska initiated a graduate student research project, "to utilize petrographic data as the major parameter in studying the possibilities for blending certain Alaskan coals in order to produce better grade coal or to predict coking ability."5/ Samples from seven seams of the Matanuska Valley coalfield were used in this

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2/ Warfield, Robert S. Bituminous Coal Deposits of the Matanuska Coalfield, Alaska: Central and Western Parts, Wishbone District. BuMines Report of Investigations 5950, 1962, 190 pp.

3/ Davis, J. D., D. A. Reynolds, R. E. Brewer, B. W. Naugle, D. E. Wolfson, F. H. Gibson, and G. W. Birge. Carbonizing Properties: British Columbia, Matanuska Valley (Alaska), and Washington Coals and Blends of Six of Them With Lower Sunnyside (Utah) Coals. BuMines Bull. 510, 1952, 42 pp.

4/ Toenges, Albert L. and Theodore R. Jolley. Investigation of Coal Deposits in South Central Alaska and the Kenai Peninsula. BuMines Report of Investigations 4520, 1949, 37 pp.

5/ Hankinson, Fred C. The Mineral Industry Research Laboratory, Part II - Petrography in Coal Preparation. Paper presented at AIME conference, University of Alaska campus, College, Alaska, March 18-21, 1964.

research project; one sample was from the Moose Creek area of the Wishbone Hill district, four from the Evan Jones strip mine, and two from the idle Castle Mountain mine of the Chickaloon district. The results of this study, according to the final report,[6] "indicate that all coals under study have inferior qualities for use as metallurgical coke with the possible exception of LCM seam." LCM is the abbreviation for lower Castle Mountain which is believed to be the same seam recently sampled and on which coking studies were made by the Bureau of Mines.[7] This study is discussed under the Chickaloon district of the Matanuska coalfield.

The eastern part of the Wishbone Hill district is served by a branch of The Alaska Railroad to the Evan Jones mine washery and to the Mrak Coal Co. washery (inactive) at Eska. Annual production of 5 or 6 thousand tons from surface operations at the Premier mine on Moose Creek in the western part of the district must be trucked to market.

Chickaloon District

The Chickaloon district has a history of exploration and development that dates from the early 1900's but very little recorded commercial production. This is so even though the quality of coal encountered was, for the most part, strongly coking bituminous. The lack of production can be attributed to many causes, but the main deterrent has been the complex structural geology and thickening and thinning of coalbeds within short distances that exploration everywhere encountered. Most exploration was in the form of underground workings that, in case of subsequent mining, would serve as development workings.

The most extensive underground exploration took place along Chickaloon River and Coal Creek short distances above their confluence with the Matanuska River. A large part of this exploration was conducted by the Federal Government under the direction of the Alaska Engineering Commission (later The Alaska Railroad) on the Chickaloon River and the Navy Department on Coal Creek. Several thousand tons of coal were mined at the Chickaloon and Coal Creek mines incidental to exploration, and in 1922 a large sample was washed and shipped for a Naval steaming test.

The Matanuska branch of The Alaska Railroad was completed to Moose Creek (Wishbone Hill district) in 1916 and on to Chickaloon in 1917.

6/ Hankinson, Fred C. Petrographic Evaluation of Coking Potential of Selected Alaskan Coals and Blends. Report No. 3, the Mineral Industry Research Laboratory, University of Alaska, 1965, p. 28.

7/ Warfield, Robert S., W. S. Landers, and Charles C. Boley. Sampling and Coking Studies of Coal From Castle Mountain Mine, Matanuska Coalfield, Alaska. BuMines Open-File Report, released March 1966, 14 pp.

Mining and development was discontinued by the Government in 1922 at the Chickaloon and Coal Creek mines and use of the railroad from the Wishbone Hill district to Chickaloon was also discontinued a few years thereafter.

The coking properties of coal from the Chickaloon district were early recognized by Martin of the U.S. Geological Survey who wrote:8/

> "A rough test of the coking qualities of the coal from tunnel No. 2 on Chickaloon Creek was made during the summer of 1905 by coking a large pile of coal under a covering of stones and dirt. The resulting coke was hard and firm and had a good ring and a good texture. The test showed conclusively that a satisfactory grade of coke can be produced."

In 1918, two coking tests made on samples of Chickaloon coal were submitted by the Bureau of Mines;9/ one test was made at the Wilkeson Coal and Coke Co. of the Seattle, Wash. area; the other at the laboratory of H. Koppers Co., Mellon Institute, Pittsburgh, Pa. The results of both tests were favorable; the following remarks from the report of the Koppers Co. laboratory are excerpted:

> "This is a coking coal similar in quality to Pocahontas. It would probably produce a similar coke, but the exact character of the coke can only be determined by making an oven test. Such coal usually requires mixing with some high-volatile coal in order to avoid trouble due to expanding and sticking."

In 1925, the Coal Creek mine was opened by a private operator on the west side of the creek, on the extension of beds earlier prospected by the Navy. From 1925-30, about 1,650 tons were produced, most of which was sold to the railroad. The railroad converted the coal into coke in an oven at Anchorage and used the product in the foundry of the railroad shops.10/

So far as can be determined from searching the literature, the Chickaloon district was inactive from 1930 to about 1956 or 1957 except, possibly, for a small amount of prospecting. In 1958 and 1960, the Castle Mountain mine, located on the south slope of Castle Mountain about 3 miles northwest

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8/ Brooks, Alfred H. and Others. Progress of Investigations of Mineral Resources in Alaska in 1905. U.S. Geol. Survey Bull. 284, 1906, p. 97.

9/ Martin, G. C. and Others. Mineral Resources of Alaska, Report on Progress of Investigations in 1918. U.S. Geol. Survey Bull. 712, 1919, pp. 138-39.

10/ Waring, Gerald A. Geology of the Anthracite Ridge Coal District, Alaska. U.S. Geol. Survey Bull. 861, 1936, p. 25.

of the early development along Chickaloon River produced 20,700 tons of coal that was sold for power generation purposes at military bases in Anchorage. The mine consisted of two open pits offset from each other a short distance by faulting and with a combined strike length of about 650 feet. The beds dip 40° to 45° E and apparently thinned at each end of the pits to uneconomic mining thicknesses.

In 1964, a sample for coking studies was cut by the Bureau of Mines from near the base of a small stripped but unmined segment remaining in the southern open pit. The coking studies were made by the Denver Coal Research Laboratory. The studies which included cleaning of the sample to reduce the ash content from 16.5 to 10.4 percent, moisture-free, indicated that the Castle Mountain coal would produce a large and extremely strong coke, probably of foundry quality.11/

Although exploration of the Chickaloon district has been fairly extensive, large areas remain unprospected because of thick unconsolidated overburden, mostly glacial. Undoubtedly, reserves that probably underlie at least some of this area also have complex geology, but perhaps new mining technology will make a search for and mining of these probable reserves economically attractive sometime in the future.

Anthracite Ridge District

The Anthracite Ridge district of the Matanuska coalfield is the most eastern upvalley part of the field and probably the most geologically complex.

The district was geologically mapped in 1931 by the U.S. Geological Survey in connection with similar intensive studies of deposits of other minerals accessible to The Alaska Railroad. The coal basin is about 4 miles wide and 7 miles long and lies between Anthracite Ridge on the north side of the valley and the Matanuska River. The basin is, in general, synclinal, sharply folded, and faulted along its north border. The coal-bearing beds of the Chickaloon formation have been intruded by igneous dikes and sills.12/

A 20-acre area high on the ridge on the northwest border of the basin contains an estimated 750,000 tons of anthracite and semianthracite.

11/ Work cited in footnote 7.

12/ Richards, Ralph W. and Gerald A. Waring. Progress of Surveys in the Anthracite Ridge District, Alaska. U.S. Geol. Survey Bull. 849-A, 1933, p. 5.

The area is folded and faulted and the coalbeds are much shattered with inclusions of bone and shale and intrusions of igneous rock. All other mapped beds in the district of workable thickness are of bituminous rank and most of this coal probably has some coking properties. Their outcrops are of small extent and the beds so irregular in thickness that estimates of reserves were considered impossible without close order exploration.13/

The synclinal area south of the anthracite outcrops was tested in 1932 by diamond-core drilling eight holes totaling 8,000 feet. The deepest hole was drilled 1,820 feet. None of the holes intersected coalbeds other than thin coal veinlets (1/8-inch) and fragments of coal in sandstone and conglomerate horizons. Coal-forming materials apparently were not deposited in the present synclinal area. With one exception, 10 analyses made of samples scraped from veinlets of coal in the diamond-drill cores indicated bituminous coking coals. The exception was a coal veinlet a few feet below a 25-inch sill of diabase which was of semibituminous (semianthracite under current specifications for classification of coals by rank) rank and noncoking.14/

HERENDEEN BAY AND CHIGNIK BAY COALFIELDS

The presence of coal in the Herendeen Bay and Chignik Bay areas was known for a number of years prior to 1905. Several attempts at exploitation, which included some underground exploration, resulted in very little production from the Herendeen Bay field and only enough from the Chignik Bay field to supply fuel for a cannery on Chignik Lagoon and for steamers engaged in the fisheries.15/16/

Chignik Bay lies on the Pacific side of the Alaska Peninsula, while Herendeen Bay, a part of Port Moller, lies on the Bering Sea side of the peninsula; the two fields are about 100 miles apart. Each field has a reported areal extent of about 40 square miles of bituminous coal and the coals occur in the Chignik formation of Upper Cretaceous age. A search of the literature found no mention of any coking properties of Chignik Bay coals, but Herendeen Bay coal obtained from development tunnels along Mine Creek and used in cook stoves of the U.S. Geological Survey was reported to fuse and cake somewhat on beginning to burn.17/

13/ Waring, Gerald A. Geology of the Anthracite Ridge Coal District, Alaska. U.S. Geol. Survey Bull. 861, 1936, p. 2.

14/ Work cited in footnote 13, p. 45.

15/ Brooks, Alfred H. and Others. Report on Progress of Investigations of Mineral Resources of Alaska in 1905. U.S. Geol. Survey Bull. 284, 1906, pp. 101-08.

16/ Atwood, Wallace W. Geology and Mineral Resources of Parts of the Alaska Peninsula. U.S. Geol. Survey Bull. 467, 1911, 137 pp.

17/ Work cited in footnote 16.

Mining for cannery fuel in the Chignik Bay field was on a 5-foot bed dipping at 24°. The as-received analyses of a sample from this bed was as follows: Loss on air drying, 5.2 percent; total moisture, 7.06 percent; volatile combustible, 31.48 percent; fixed carbon, 39.68 percent; ash, 21.78 percent; sulfur, 1.3 percent; hydrogen, 4.83 percent; carbon, 55.14 percent; nitrogen, 0.61 percent; oxygen, 16.34 percent; and Btu, 9,846. Analyses of other beds were similar. The geologic structure in this field was reported to be much simpler than that near Herendeen Bay.[18/]

During World War II, in 1943, an examination of the Herendeen Bay coalfield was made by Robert S. Sanford, Bureau of Mines, and G. O. Gates, Geological Survey.[19/]

According to Sanford, the coalbeds have been faulted and pinched to such an extent that exploration would be difficult and mining expensive. The dip of most beds is in excess of 30°. Reserves are probably not great. The analyses of 11 samples taken during the early 1940's, 9 by the Army engineers during 1942 and two by Sanford, classified the coals as high-volatile C bituminous. Most of the samples were nonagglomerating but two samples were classified as poor caking.

Gates described geology as follows:

> "The coal measures form the central part of the Chignik formation which is upper Cretaceous in age; this part of the formation is about 300 feet thick. Though the coalbeds range from a few inches to 5 feet thick, most of them are less than 2 feet. Most of the exposures of coal are on the edge of the south limb of a gently westward plunging syncline. This limb has been largely removed by erosion and the remaining reserves are not great; the minable reserves were inferred at a maximum of 500,000 tons.
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> "On the north limb of the syncline, however, the eroded edge of the Chignik formation crops out several thousand feet up the dip from Mine Creek; the synclinal axis coincides approximately with the creek. If the coal exposed on the south limb is also present throughout the north limb, and no evidence to the contrary is known, 5 to 10 million tons of minable coal can be inferred.
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> "The south limb of the syncline is broken into blocks by at least three major transverse faults. Minor faults that displace the coal beds a few inches to a few feet are numerous."

18/ Work cited in footnote 16.

19/ Gates, George O. Part of the Herendeen Bay Coalfield, Alaska. U.S. Geol. Survey mimeographed report, 1944.

BERING RIVER COALFIELD

The Bering River coalfield was discovered in 1896, and practically all of it was covered by coal claims entered under the law of 1904. The field is in South-Central Alaska, about 50 miles southeast of Cordova and 12 miles northeast of the coastal village of Katalla. Known coal-bearing rocks are exposed in a belt roughly 21 miles long and 2 to 5 miles wide trending northeast from the east shore of Bering Lake. The coals increase in rank from low-volatile bituminous in the western part of the field through semianthracite to anthracite in the eastern part of the field. U.S. Geological Survey Circular 146[20/] reviews and brings together the considerable amount of information contained in a number of publications (including some that were published only in Congressional hearings). Bureau of Mines Technical Paper 682[21/] presents a number of analyses of Bering River coals as well as analyses of coals from other Alaskan coalfields. The following brief summary is taken mainly from U.S. Geological Survey Circular 146.

The coals of the Bering River field occur in the Kushtaka formation of Tertiary age. The thickness of the formation is reported to exceed 2,000 feet; it consists predominantly of coarse arkose, some sandstone and shale, and a large but unknown number of coalbeds.

The structural geology of the coalfield is extremely complex, having been complicated by folding, faulting, and igneous intrusions. The degree of complexity increases from west to east as does coal rank. Dips are steep, averaging about 40°, with some beds apparently overturned. Several major faults have been mapped and faults of lesser displacement are reported to be exceedingly numerous. More important than the major folding and faulting in affecting the quality and minability of the coal, have been the shearing, crushing, and repeated small-scale faulting. Fisher and Calvert, investigators in 1912 for the U.S. Navy to determine the best localities from which samples could be taken for steaming tests, after examining many tunnels and outcrops, concluded that almost every part of the field is traversed by an intricate system of faults, making underground development everywhere tedious and costly and in many places impracticable.

Changes in thickness of coalbeds within short distances is a common feature; both structural deformation in the form of squeezing and faulting and stratigraphic thinning are causes. Barnes[22/] cites a number of examples of which the following are representative:

20/ Barnes, F. F. A Review of the Geology and Coal Resources of the Bering River Coal Field, Alaska. U.S. Geol. Survey Circ. 146, 1951, 11 pp.

21/ Analyses of Alaska Coals. BuMines Technical Paper 682, 1946, 114 pp.

22/ Work cited in footnote 20.

> "An 8-foot seam on the west side of Trout Creek was traced for 600 feet along the surface, within which distance it thinned to 16 inches and became dirty. A 30-foot bed near the same locality was similarly found to thin to 18 feet and become softer several hundred feet to the southwest and at about 1,000 feet from the original prospect tunnel to consist of only 4 feet of soft dirty coal."

Most of the coals of the field, where observed, are of a friable nature, many beds having been severely crushed and sheared.

The literature indicates that the coking properties of at least some of the low-volatile bituminous coals may be questionable. To illustrate, the following paragraph which had its source in several publications is quoted from U.S. Geological Survey Circular 146:

> "As a result of field coking tests, Martin (1908, p. 82) concluded that practically all the coal of the field classed as semibituminous was of good coking quality. Starrs (1910, p. 23-29) and Fisher and Calvert (1914, p. 38) concurred in this conclusion. However, the results of tests reported by Evans (1920, pp. 18-20) indicate that the Carbon Creek coal does not make a satisfactory coke in a beehive oven or in by product ovens of conventional type."

The most recent work in the Bering River coalfield was conducted in 1958 and 1959 under the auspices of the Jewel Ridge Coal Co. of Tazewell, Va.

Old underground workings in both the Carbon Creek and Trout Creek areas were reopened, and large samples were obtained for coking tests in Japan and elsewhere. A number of outcrops also were freshened and sampled. Samples from both areas are reported to have produced good coke when blended with high-volatile Eastern United States coals.

YUKON BASIN

Occurrences of coal in the Alaskan and Canadian Yukon River Basin have been known since prior to the turn of the century. Some of these coals were exploited to a very limited extent with varying degrees of success during the early 1900's for river boat fuel, and to an even lesser extent for blacksmithing purposes and domestic fuel. These uses are described in U.S. Geological Survey Bulletin 218[23/] which to the knowledge of this writer is the only comprehensive report available on Yukon

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23/ Collier, Arthur J. The Coal Resources of the Yukon, Alaska. U.S. Geol. Survey Bull. 218, 1903, 71 pp.

Basin coals. For a number of coal occurrences, this bulletin apparently contains the only published information. This is especially true of bituminous coals that may have some coking characteristics.

The most recent known work on Yukon coals was Bureau of Mines sampling and analyses during 1962 of several occurrences within or near the impoundment area of the proposed Rampart Dam. The coals sampled by the Bureau were mostly classified as subbituminous which apparently directly corresponds with a lignite classification of the same coals in 1902.

Yukon Basin coals that may have future economic significance occur in two geologic age sequences--Eocene and Upper Cretaceous. The Eocene coals occur at a number of localities in the upper Alaskan Yukon River Basin that includes an area from near Rampart to the International Boundary. These coals are probably all subbituminous or lower in rank, except possibly, in rare instances where geologic action has highly deformed them to a higher rank. Therefore, it seems improbable that Eocene bituminous coking coals of significance occur in this, the upper part of the basin.

Upper Cretaceous coals, some of which are reported to be of bituminous rank with possibly some coking characteristics, occur in the Nulato province. The Nulato province includes the area adjacent to the Yukon River from the confluence of the Melozitna River with the Yukon River to the mouth of the Yukon River. The coals outcrop at intervals along the north and west bank of the river for about 200 miles below the mouth of the Melozitna River; the area containing coalbeds of the same age sequence probably extends westward to Norton Sound and also extends northward up Koyukuk River a distance of at least 35 miles. None of the reported coal occurrences are known to have any great extent; the predominant enclosing rock is reported as sandstone and shale.

Individual occurrences, some of which have had some mining activity and small amounts of production, are described in detail by Collier.[24/] These are located as follows: several, including the Pickart and Blatchford mines are near Nulato, and the Williams and No. 1 mines, 100 and 125 miles below Nulato, respectively. The Pickart and Williams mines as described by Collier seem representative of the better known bituminous coal occurrences along the Yukon; their descriptions are briefly summarized as follows:

The Pickart coal mine was located 10 miles above Nulato on a 30-inch seam that strikes N 75° E and dips 35° N. The coal was used for steaming purposes on river boats for at least five years, 1898-1902. The year of cessation of operations is not known, but Atwood[25/] who visited the mine in 1907 reported that no work had been in progress for several years.[26/]

24/ Work cited in footnote 23.
25/ Work cited in footnote 16.
26/ Smith, Philip S. and H. M. Eakin. A Geologic Reconnaissance in Southeastern Seward Peninsula and Norton Bay-Nulato Region, Alaska. U.S. Geol. Survey Bull. 449, 1911, p. 138.

During the mining process, two parallel rolls or horsebacks were encountered in the floor of the coalbed updip from the main gangway; these rolls at their apex pinched the coal down to a knife edge thickness. Full seam thickness was again encountered upon cutting through the first roll, but the second roll had not been cut through at the time of Collier's visit. The rolls pitched toward the main gangway so that at the end of the gangway, a distance of 600 feet from the entrance, the coal was pinched to a thickness of 18 inches and was somewhat crushed. The Pickart coal was reported to make a good coke. The analysis of a sample taken in the main gangway 300 feet from the surface was as follows:

	Percent
Water	1.02
Volatile combustible matter	27.33
Fixed carbon	65.03
Ash	6.62
	100.00
Sulfur	.60
Fuel ratio[1/]	2.38

Coke, compact.

1/ Fuel ratio is the quotient obtained by dividing the percentage of fixed carbon by the percentage of volatile combustible matter. Before the present ASTM (American Society for Testing Materials) specification for classification of coals by rank was put into use, fuel ratio was used to give some indication of coal rank. Under the system, lignites have a fuel ratio less than 1, bituminous coals 1 to 5, etc.

The Williams mine was located about 100 miles below Nulato on the west bank of the Yukon. The mine was opened on a 39-inch seam that strikes N 70° W and dips 45° N. In 1902, the mine workings had progressed a distance of 400 feet from the portal. In this distance, the coalbed showed no variation in strike or thickness; about 1,700 tons of coal had been produced. The sandstone bluff in which the coalbed outcrops rises above the river a vertical distance of about 150 feet to a plateau-like area.

The coalbed is divided into two nearly equal benches by a clay parting about three-fourths of an inch thick. Analyses of samples from the two benches are reproduced from U.S. Geological Survey Bulletin 218[27/] as follows:

27/ Work cited in footnote 23.

	Upper bench, percent	Lower bench, percent
Water	7.17	6.15
Volatile combustible matter	33.05	40.46
Fixed carbon	51.15	49.86
Ash	8.63	3.53
	100.00	100.00
Sulfur	.40	.53
Fuel ratio	1.54	1.23

Coke, noncoherent.

According to Collier,[28] the sediments containing the Williams mine are of Eocene age and undoubtedly younger than the coal-bearing sediments nearer Nulato. The coalbed of the Williams mine is overlain by at least 2,000 feet of sandstones, conglomerate, and black shales. Although only the one coalbed of commercial thickness was known at the time of Collier's visit, he conjectured that probably other coalbeds underlie.

Collier mentions a report of the occurrence of coal along the Anvik River which he thought was located only about 10 miles generally west of the Williams mine and probably correlative with the sediments of the Williams mine. Study of a modern map and a later report, however, places the two localities a minimum of 40 miles apart and the coal occurrences on the Anvik River southwest of the Williams mine. According to the later report,[29] the Anvik River cuts diagonally across a sedimentary series made up of sandstone, shales, and coalbeds for a distance of about 5 miles. One seam of 10 feet thickness and several of 2 feet thickness were reported. This coal was used by the natives in the manufacture of a black pigment and a small amount was used for blacksmith coal at Anvik.

Harrington[30] also reported that coal occurs on one of the creeks which flows into a slough of the Yukon about 20 miles above Marshal. No information concerning this deposit, other than the fact of its occurrence, was obtainable.

ARCTIC COALFIELD

The existence of coal of good quality and apparent large quantities in Arctic Northwestern Alaska has been known for many years; it was first

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28/ Work cited in footnote 23.

29/ Harrington, George L. The Anvik-Andreafski Region, Alaska. U.S. Geol. Survey Bull. 683, 1918, p. 65.

30/ Work cited in footnote 29.

reported by Mr. A. Collie who accompanied Captain Beechey of the Beechey expedition to the Arctic Ocean in 1826-27.[31] The earliest reported use of these coals was during the late 1800's and early 1900's to replenish the fuel supply of whaling ships, a small amount locally, and about 1,000 tons was mined, shipped, and sold at Nome in 1900-1901. This coal was produced from several different beds in the Corwin Bluff area east of Cape Lisburne. No coal is mined now in the region except for very small amounts periodically used locally by Eskimos from coastal villages.

Geological Survey reserve estimates which, because of the lack of detailed mapping and exploration, are intended to show the general order of magnitude of reserves only, place almost 85 percent of the State's total coal reserves in the northern fields; this includes 20 billion tons of bituminous and 60 billion tons of subbituminous and lignite.[32] The principal coal-bearing belt is believed to have a continuous east-west length of nearly 300 miles from Corwin to the Colville River and a width of as much as 120 miles.

The Arctic coals are reportedly of two geologic age sequences, Paleozoic--Carboniferous and Mesozoic--Cretaceous.[33] The Carboniferous coal-bearing formation outcrops in several small areas along the coast south of Cape Lisburne. These lenticular coalbeds, bituminous and anthracite in rank, occur in highly folded rocks of the Lisburne formation, and so far as is known, they are of small extent.[34] The thickness of the coal-bearing member is not very great, probably not exceeding a few hundred feet. The Lisburne formation in total, however, is several thousand feet thick and mostly of marine origin.[35]

The coal-bearing member because of its relative incompetence, has absorbed more of the strains to which the formation was subjected; this has resulted in intense crumpling of at least some of the coalbeds. A

31/ Brooks, Alfred H. and Others. Report on Progress of Investigations of Mineral Resources of Alaska in 1904. U.S. Geol. Survey Bull. 259, 1905, pp. 172-85.

32/ Averitt, Paul. Coal Reserves of the United States--A Progress Report, January 1, 1960. U.S. Geol. Survey Bull. 1136, 1961, p. 46.

33/ Work cited in footnote 31.

34/ Work cited in footnote 21.

35/ Kachadoorian, Reuben, Russell H. Campbell, George W. Moore, David W. School, Arthur H. Lachenbruch, Gordon W. Greene, B. Vaughn Marshall, David F. Barnes, Rex J. Allen, Roger M. Waller, and Marvin J. Slaughter. Geologic Investigations in Support of Project Chariot, Phase III, In the Vicinity of Cape Thompson, Northwestern Alaska--Preliminary Report. Trace Elements Investigations Report 779. U.S. Geol. Survey Open-File Report, released April 3, 1961, 104 pp.

typical description of coalbeds that outcrop about 13 miles south of Cape Lisburne is summarized from U.S. Geological Survey Bulletin 259 as follows: The upper bed strikes N 75° E and dips northward at an angle of 40°. It is 4 feet thick, but is considerably crushed and only fine material can be obtained from the croppings. The seam has one indistinct parting near the middle. Two smaller beds, which could not be measured, outcrop south of this at intervals of about 50 yards. Collier thought it probable that a small amount of development would uncover additional beds. A sample taken across the entire 4-foot face of the above-mentioned coalbed had the following analyses:

	Percent
Fixed carbon	70.33
Volatile hydrocarbon	21.16
Moisture	5.51
Ash	3.00
	100.00
Sulfur	.96

Coke, none

Color of ash, brown.

The Cretaceous coals of the belt which is believed continuous from Corwin to the Colville River, contains by far the preponderance of known Arctic coal reserves. Principally because of the numerous geologic studies and drilling programs that were under taken from 1944-53 as part of the search for oil and gas in Naval Petroleum Reserve No. 4, a great deal of knowledge about the general geology of Arctic Northwestern Alaska that contains this coal belt was accumulated, but detailed investigations, except recently, of the numerous reported coalbeds have been practically nonexistent.

The Cretaceous formation that probably contains most of the bituminous coals has been named the Corwin formation; its type locality is in the Corwin Bluff vicinity about 25 miles east of Cape Lisburne where more than 80 coalbeds that exceed 1 foot in thickness are known and at least 17 of these beds are between 2.5 and 9 feet thick.

On the basis of a limited number of analyses, the rank of these coals appears to gradually decrease from west to east. The coals of the Corwin-Cape Beaufort area, the Kukpowruk, Kokolik, and Utukok Rivers, a region that has been termed the Utukok-Corwin region,[36/] are mostly bituminous

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

coals, whereas the coals that outcrop in the Wainwright and Pt. Barrow areas are subbituminous.

The structural geology of coalbeds of the western part of the Utukok-Corwin region, an area that includes Corwin Bluff, appears relatively more complex than beds outcropping northeastward along the Kukpowruk, Kokolik, and Utukok Rivers. The contact between the highly deformed Carboniferous Lisburne formation and the Corwin formation lies between Cape Lisburne and Corwin. Some coalbeds outcropping along the Corwin coastal bluffs have measured dips of as much as 45°, whereas beds to the northeastward, at least in the synclines, are generally more gently folded.

Principally on the basis of the extensive Geological Survey reconnaissance[37/] during the 1940's and 1950's and very limited reconnaissance by the Bureau of Mines,[38/] the Utukok-Corwin region of the Arctic Northwest coalfield was selected by the Bureau as probably containing the most likely coals to exhibit coking properties; consequently, some of the most easily accessible coalbed outcrops within this area--along the Kokolik River, along the Kukpowruk River, and in the vicinity of Cape Beaufort, were sampled for coking studies during the field seasons of 1962-64. Coking studies made by the Denver Coal Research Laboratory on these samples demonstrated that a 20-foot bed outcropping along the Kukpowruk River has significant coking properties[39/] and that a coalbed outcropping along the Kokolik River has some coking properties. Laboratory work on other samples from a number of different coalbeds outcropping along the Kokolik River, the Kukpowruk River, and in the Cape Beaufort area, a linear distance spread of 65 miles, demonstrated that within practical limits of outcrop freshening, samples from these other coalbeds had high oxygen contents, low heating values, and no coking properties. This was the case even though each outcrop was freshened about the same amount and noncoking samples in some cases were taken very close stratigraphically to coking coal samples. In all cases, the outcrops were excavated beneath the seasonal thaw zone and the sample taken from perennially frozen ground (permafrost). Determination of the depth and extent to which oxidation of coalbeds may have reached and its possible effect on coking properties is currently (1966) under investigation.

The coalbeds sampled along the Kukpowruk and Kokolik Rivers that possess some coking properties, have dips of 10° to 15° at the outcrop; their structure appears fairly simple, and they should be amenable to mechanized mining.

37/ Work cited in footnote 36.

38/ Toenges, Albert L. and Theodore R. Jolley. Investigation of Coal Deposits for Local Use in the Arctic Regions of Alaska and Proposed Mine Development. BuMines Report of Investigations 4150, 1947, 19 pp.

39/ Warfield, Robert S., W. S. Landers, and Charles C. Boley. Sampling and Coking Studies of Coal From the Kukpowruk River Area, Arctic Northwestern Alaska. BuMines Report of Investigations 6767, 1966, 59 pp.

OTHER BITUMINOUS COAL OCCURRENCES

Reports of several other occurrences of bituminous coal, some of which possibly have some coking characteristics, were noted as follows:

Yanert Mine

The Yanert mine was located within Mt. McKinley National Park near Mile 341 of The Alaska Railroad.[40/] An old sketch plan of the mine showed a main gangway driven 700 feet with some additional development work on a medium-volatile bituminous bed[41/] having a probable strike of S 70° W and a dip of from 40° to 60° N. The mine was inaccessible in 1946 and the thickness of the seam was not determined, but from the large size of the dump it was judged the seam has a thick parting of claystone. Production from the mine was small, but one railroad car was shipped to Nenana and tested in the steam plant; the test proved unsatisfactory because clinker was formed which covered the entire grate in the boiler.

Several analyses of samples from the Yanert mine are shown in Bureau of Mines Technical Paper 682, page 30, but no agglomerating index is given for any of the samples.

The formation containing the coalbed was identified as Cantwell formation of Cretaceous age, which generally comprises thin coalbeds, sandstones, gray claystone, black claystone, and conglomerates.

Nelson and Nunivak Islands

Occurrences of bituminous coal were reported as early as 1900 on Nelson and Nunivak Islands in Southwestern Alaska;[42/] these islands are located west of the mouth of the Kuskokwim River.

In 1954, several thin beds on Nelson Island were examined and their outcrops mapped during a reconnaissance investigation by the Geological Survey.[43/] Most of the seams examined were less than 6 inches thick,

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40/ Work cited in footnote 4.
41/ Work cited in footnote 21.
42/ Spurr, J. E. A Reconnaissance of Southwestern Alaska. U.S. Geol. Survey 20th An. Rept., 1900, pt 7b, p. 262.
43/ Coonrad, Warren L. Geologic Reconnaissance in the Yukon-Kuskokwim Delta Region, Alaska. U.S. Geol. Survey Miscellaneous Geologic Investigations Map I-223, 1957, 1 fig.

but on the south side of Nelson Island two coalbeds about 12 and 16 inches thick separated by 8 inches of carbonaceous siltstone outcrop. The beds dip 5° to 10° E, crop out in a low beach bluff, and a few tons have been mined. The coals are believed to be Cretaceous in age.

Analyses of four samples from Nelson Island were all agglomerating--one fair caking, one good caking, and two firm agglomerate. A fifth sample from an 18-inch bed, submitted by a trader in 1925, was described as weathered bituminous coal.[44/]

According to Map I-223,[45/] there is little information available regarding coal reported on the north side of Nunivak Island. This locality has not been visited by Geological Survey personnel.

44/ Work cited in footnote 21.
45/ Work cited in footnote 43.