STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

MINERAL RESOURCES OF ALASKA
PREPARED AS A BRIEF GUIDE TO THE MORE IMPORTANT AREAS OF MINERAL POTENTIAL IN THE STATE

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1972

Open File Report No. 35

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INTRODUCTION

The value of 1971 mineral production in Alaska is estimated at $356 million compared with $338 million in 1970. Crude oil and gas accounted for $287 million or 86 percent of total mineral production.

Alaska's 1971 mineral production, excluding oil and gas, reached an all time high of $69 million, a 38 percent increase over the 1970 figure of $43 million. Part of this increase was due to the production of uranium at Kendrick Bay (Ross-Adams Mine).

Fossil Fuels--Coal

The present production of coal in Alaska is limited by local market demand to about 750 thousand short tons a year. Most of this production is from the Nenana coal field near Fairbanks. New exploration and mining activities include a new mine opened in the fall of 1971 in the eastern part of Nenana. The major portion of the exploratory dollars was expended in the Beluga section of the Susitna field.

The United States Bureau of Mines is active in 1972 with a core drilling program on the North Slope.

Large quantities of Alaska's coal resources can be produced by strip mining at relatively low mining costs. It is estimated that know strippable reserves in the Susitna field alone approach 2 billion short tons. Less is known about the North Slope coal fields where coal crops out along stream drainages and on ocean bluffs. However, it is expected that coal reserves that can be mined by open pit mining are very large. The future development of the coal rich areas are partially dependent on new processes--coal liquefaction and enriched coal gas--that will process coal into an easily transported commodity.

Fossil Fuels--Oil and Gas

Crude oil and natural gas from the Kenai Peninsula and offshore Cook Inlet fields continued in 1971 at approximately the same rates as for 1970. The known petroleum fields are fully developed and production cannot be expected to increase until North Slope oil from the Pruhdoe field begins to flow.

It has been estimated in a federal government study that Alaska contains more than 20 percent of the United States estimated oil and gas resources. Some 600 billion of an estimated 2900 billion barrels of oil are said to be in the onshore and continental shelf basins of Alaska.

The Naval Petroleum Reserve No. 4 to the west of the Prudhoe Oil Field and the wilderness area to the east of this field are both considered prime areas for oil exploration.

Sedimentary basins and the potential for oil and gas production from these basins are summarized in this report.

Metallic Monerals

This report outlines the areas where mineralization and past production may stimulate exploration leading to the discovery of ore bodies in the future. Several large low grade ore bodies in Alaska--copper at Orange Hill, iron at Klukwan, for example, are potentially commercial depending on the demand for the metals which in turn is related to the price--cost structure. The ore body at Lost River is an example of a fluorite-tin deposit being developed primarily for fluorite--a nonmetallic mineral in growing demand.

Nine individual areas have been summarized with attached geologic maps and in some cases cross sections. These areas were chosen as representative of particular geologic situations or as representing examples of past production.

The Bokan Mountain (Ross Adams uranium-thorium mines) represents the only area in Alaska that has commercially produced uranium. There are numerous other prospects in the area and further prospecting may lead to additional deposits. The Kasaan Peninsula is a belt of mineralization with related magnetite-copper deposits. Brady Glacier, a nickel-copper deposit represents a layered intrusive. The Klukwan iron deposit is a large magnetite enriched pyroxenite. The Kennecott Mines produced from bonanza replacement ores near the contact of the Chitistone limestone and the Nikolai greenstone. This contact is traceable for many miles and other Kennecott type replacement lodes may be found along this trend. Orange Hill is the only known porphyry deposit in Alaska. Kasna Creek has relatively large copper reserves in a limestone belt. Bornite is an active area with large copper reserves predominatly in dolomite breccia. Additional copper deposits would be expected along this trend. The Lost River Prospect is being developed primarily for fluorite--with tin as a secondary mineral.

A comparison of Alaska's mineral production to that of the eleven western states in the United States reveals that while Alaska has produced minerals equivalent in value to about $3,000 per square mile, the eleven states have produced minerals equivalent to about $83,000 per square mile. Known mineralized provinces and potential oil basins are as widespread in Alaska as the eleven western states and the potential for mineral production in Alaska is very large.

METALLIC MINERALS

In the following discussion the metallic mineral resources of Alaska are examined by commodity. All the important deposits are covered. Areas where there has been large production in the past and areas that are active at the present time have been examined in more detail and simplified geologic maps of these areas are attached. In the discussion of each commodity, the numbers that follow location names are keyed to corresponding numbers on the appropriate commodity maps. Most of the information in this report has been abstracted from published sources, chiefly bulletins and open-file reports of the U.S. Geological Survey. A selected list of these reports is attached.

Antimony

Antimony is widespread in Alaska. The areas that have been productive or where reserves are known are listed below:

1. Near Ester Dome (fig. 18, No. 1) Fairbanks district.
2. Near Pedro Dome (No. 2) Fairbanks district.
3. Kantishna district (No. 3 & 4).
4. Seward Peninsula (No. 5).
5. Kenai Peninsula (No. 6).
6. Caamano Point (No. 7) 16 miles northwest of Ketchikan.

Antimony has been found elsewhere in many of the districts in the eastern part of the interior of Alaska.

GEOLOGIC SETTING

The antimony deposits of east-central Alaska commonly are in terrain underlain by Birch Creek Schist of Early Paleozoic and/or Precambrian age. The deposits occur as veins, lenses, veinlets, and disseminations within schistose rocks. Many of the deposits are near felsic intrusive rocks. Stibnite is the dominant antimony mineral in almost all of the deposits.

PRODUCTION AND RESOURCES

Production of antimony in Alaska has been largely restricted to deposits in the Fairbanks district and the Stampede (No. 3) Mine in the Kantishna district. The known antimony resources are mainly in the Fairbanks and Kantishna districts and probably comprise less than 100 tons of high grade and about 10,000 tons of low grade ore. Several small shipments of gold-bearing antimony ore were made from deposits on the Seward Peninsula, generally in the area east of Nome. The known Alaska antimony resources probably could be enlarged if prospecting and exploration for antimony were stimulated.

In 1971, 34 tons of antimony were produced from Alaskan mines (short tons antimony content). Production was mainly limited to the metal produced as a by-product of mercury mining.

Beryllium

Almost all of Alaska's known lode deposits of beryllium occur in the

Lost River area in the western part of the Seward Peninsula (fig. 16, No. 1). The beryllium deposits consist of replacement veins, pipes and stringer lodes in limestone of Paleozoic age, in a zone 7 miles long and 2 to 3 miles wide. The limestone is faulted and intruded by dikes and stocks of granitic rock.

Sainsbury (in written communication to H.C. Berg, 1964) indicated that reserves could amount to about 1,960,000 short tons of indicated and inferred ore containing 0.18 to 0.29 percent Be. The Lost River area is presently being developed for fluorite (CaF_2) and present plans do not indicate beryllium production.

The only other known beryllium deposits of potential economic significance are the phenacite-bearing pegmatites near Bokan Mountain, Prince of Wales Island, Alaska.

However, geochemical reconnaissance indicates that additional beryllium deposits may be found elsewhere on the Seward Peninsula, principally near granite plutons on the western part of the Peninsula. Streams draining the Kigluaik and Bendeleben Mountains contain beryl in the placer concentrates and beryl may be associated with the pegmatites of that area.

No beryllium ores were mined in the State of Alaska in 1971.

Chromite

Significant chromite deposits are known in Alaska only in the Kenai Peninsula region (fig. 13). The deposits occur on the south end of the Kenai Peninsula (fig. 17, No. 1) in two general localities: an area of about 1 square mile at Claim Point near Portlock, and an area of about 6 square miles at Red Mountain 10 miles southeast of Seldovia. Occurrences of chromite also are found in the Chugach Mountains near the head of Cook Inlet, about 7 miles southeast of Tonsina, near Livengood in the Yukon region (No. 3), in southeastern Alaska on Baranof Island (No. 4), and on the Cleveland Peninsula near Ketchikan (No. 5).

GEOLOGIC SETTING

The chromite deposits constitute parts of dunite and serpentine bodies in which chromite grains have been concentrated generally in layered tabular bodies.

PRODUCTION AND RESOURCES

Production of chromite in Alaska has been 29,000 long tons of approximately 45 percent Cr_2O_3 over the time period 1917 to 1957. All the chromite production has been from the Kenai Peninsula area. The estimated remaining reserves in this area are 400,000 tons, most of which would average 15 to 17 percent Cr_2O_3. The known chromite reserves in the area near Tonsina do not exceed a few thousandtons of chromite which is low grade and would require concentrating. A few thousand tons of chromite ore might be minable from Red Bluff deposits on Baranof Island. Areas that contain ultramafic rocks and would be favorable for chromite exploration include: northwest of Fairbanks near Livengood, east of Fairbanks, along the north flank of the Chugach Mountain, in the DeLong Mountains, near Platinum in southwestern Alaska, and in southeastern Alaska.

There was no production of Cr_2O_3 in Alaska in 1971.

Copper

The known Alaska copper deposits of prospective commercial importance are grouped in southeastern Alaska, Copper River, and Yukon regions, and in the Shungnak district of northwestern Alaska (fig. 13). Listed below are areas of past production or areas where commercial production might be expected in the future:

1. Southeastern Alaska

Ketchikan Mining District

1. Kasaan Peninsula (fig. 19, No. 1)
2. Copper Mountain (No. 2)
3. Southern part of Prince of Wales and adjacent islands.
4. Yakobi (No. 3).
5. Admiralty (No. 4).
6. Chichagof (No. 5).
7. Baranof (No. 6).

Other southeastern Alaska copper deposits are on the mainland west of the Coast Range batholith.

Copper River Region.

1. Prince William Sound area (several grouped in the vicinity of Ellamar) (No. 7).
2. Valdez (No. 8).
3. Latouche (No. 9).

There are other copper deposits in the drainage basin of the Chitna River.

Yukon Region

1. Chisana district near the head of the Nabesna River (No. 15).

Shungnak District

1. Ruby Creek (Bornite No. 10).

Two other general regions which may have possible economic importance include the Iliamna Lake district (No. 11) and the area of the Chisana district around the upper White River Valley near the Canadian border (No. 12).

GEOLOGIC SETTING

Southern Alaska

Most copper deposits in the Ketchikan district are in metamorphic rocks that commonly consist of interbedded greenstone and crystalline limestone. The deposits are commonly localized in the crystalline limestone and consist of small amounts of copper minerals in magnetite ore of contact-metamorphic origin. The sulfide minerals consist of chalcopyrite, pyrite and less extensively, pyrrhotite.

At the Salt Chuck mine on the north end of Kasaan Bay on Prince of Wales Island (No. 1) bornite and chalcopyrite occur in an intrusive complex of gabbro and pyroxenite. The deposits in the northern part of southeastern Alaska consist mainly of pyrrhotite, pentlandite and chalcopyrite. At the Sumdum prospect (No. 13) about 50 miles south of Juneau, chalcopyrite and sphalerite are associated with pyrrhotite and pyrite in tightly folded metamorphic rocks.

Prince William Sound

The deposits in the vicinity of Prince William Sound are in or near mafic lava flows interbedded with slate and graywacke. Chalcopyrite is the predominate copper mineral of these deposits.

*Copper River Region

The copper deposits of the Copper River region are mainly in the basal part of the Chitistone Limestone. The Kennecott chalcocite bonanza ores consisted of tabular to irregular masses of replacement origin. Associated with the replacement ores were veins and disseminations of copper sulfides. Supergene sulfide enrichment was absent, but pre-glacial partial oxidation of primary sulfides to copper carbonates extended to a depth of 2500 feet.

The greenstone deposits are small and chiefly veins and disseminated types. They contain chiefly chalcopyrite and bornite.

Other Deposits

* 1. Orange Hill (No. 15) - Chisana district metamorphic copper deposits and the only porphyry copper deposit known in Alaska.

* 2. Ruby Creek (Bornite) - The Ruby Creek deposits consist of copper minerals, chiefly chalcopyrite in limestone and dolomite of Devonian age.

Numerous prospects in the Cape Nome, Council, and Kougarok districts on the Seward Peninsula contain copper minerals at or near contacts between marble and schist. The geologic similarity between these prospects and the Ruby Creek deposits is sufficiently great to offer hope that a major deposit may ultimately be found.

PRODUCTION

Southeastern Alaska

Since 1918 there has been very little copper mining in southeastern Alaska. Almost 13,000,000 pounds of copper metal, 7000 ounces of gold and 56,000 fine ounces of silver were produced on the Kasaan Peninsula prior to 1918.

Prince William Sound

Between 1900 and 1930 nearly 214,000,000 pounds of copper were produced from the Prince William Sound area. Nearly all this production came from deposits at Latouche and Ellamar.

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*Separate Report.

Copper River Region

The bulk of the Alaskan copper ore was produced at the Kennecott Mines (No. 14) in the Nizina district between 1911 and 1918. Four mines yielded about 1.2 billion pounds of copper from ore averaging 12.4 percent copper. The major deposits of the district are probably largely depleted and the only copper produced from them recently has been derived from small scale operations.

RESERVES

The largest known Alaska copper reserve is in the Ruby Creek deposits where reserves of 100 million tons of 1.2 percent copper revealed by drilling during the period 1957-1961 is considered high by Fritts, 1970. (See attached report on Bornite, Shungnak district, Alaska).

The copper reserves in the Prince William Sound area include 1,500,000 tons of rock containing slightly more than 1 percent copper and perhaps 5,000,000 tons of rock averaging less than 1 percent copper.

The indicated and inferred copper reserves of the Kasaan Peninsula area estimated to be about 1.5 million tons of material whose average copper content is less than 2 percent.

The Sumdum prospect contains indicated and inferred copper reserves in excess of 10,000 tons that carry between 0.5 and 1.0 percent copper, about 0.5 percent zinc, and 0.25 ounces of silver per ton.

Alaska's future copper reserves will probably depend on extensive exploration in little known areas that contain copper, such as that drained by the upper White River and more extensive examinations of old areas or geologic projections from old areas.

Iron

Iron deposits are widespread in Alaska, particularly in southeastern Alaska where they are represented by contact metamorphic deposits on Prince of Wales Island, mainly on the Kasaan Peninsula (fig. 17, No. 6), and by disseminations in igneous rocks. The location of the disseminated deposits are listed below:

1. Union Bay (No. 5).
2. Duke Island (No. 7).
3. Snettisham Peninsula (No. 8).
4. Near Klukwan at the head of Lynn Canal (No. 9).

Other iron deposits are known in the following districts and areas:

1. Chisana district (No. 10).
2. Kenai Peninsula (No. 11).
3. In southwestern Alaska near Lake Iliamna (No. 12).
4. North of Dillingham (No. 13).
5. North of Eagle in east-central Alaska (No. 14).
6. Shungnak district (No. 15).
7. Sinuk River west of Nome (No. 16).

GEOLOGIC SETTING

Alaska's iron deposits are predominantly contact metamorphic deposits and disseminations in igneous rock. The magnetic disseminations commonly are in mafic or ultramafic rocks and contain some titanium and phosphorus. The generally smaller contact metamorphic iron deposits usually consist of concentrations of magnetite that have replaced limestone in zones adjacent to igneous intrusive rocks. These deposits commonly have a high sulfur content and are practically free of titanium. The low grade ferruginous deposits in the Tindir Group north of Eagle are of sedimentary origin.

Southeastern Alaska

The titaniferous deposits of southeastern Alaska are large but low grade, ranging from 15 to 35 percent total iron and having approximately a 1:10 titania to iron ratio. The Klukwan deposit, an extensive body of mafic and ultramafic rock, is typical of this type deposit.

The best known contact-metamorphic iron deposits in Alaska are on the Kasaan Peninsula where magnitite is present in tactites developed in fractured calcareous greenstone.

Other Iron Deposits in Alaska

Most of the other contact-metamorphic iron deposits of Alaska are either too small or too remote for commercial development. Some of these deposits are listed below:

1. Orange Hill (No. 10).
2. In the Chisana district at McDougall Creek (No. 19).
3. South side of the Wrangell Mountains at the northeast end of Lake Iliamna (No. 12).
4. Near the head of Tuxedni Bay (No. 20).
5. In the Shungnak Hills (No. 15).
6. A large buried low-grade iron deposit near Kamuk Mountain north of Dillingham. (Est. several billion tons of 10.5 to 12 percent magnitite iron).
7. Low grade banded hematite deposits north of Eagle in the Tindir Group of Precambrian age.
8. A small high grade residual iron ore deposit on the Sinuk River near Nome (0.5 to 1.0 million tons of limonitic material containing from 10 to 45 percent iron.).

Molybdenum

There are 35 different localities in Alaska where molybdenum is known to occur. The best known of these occurrences are listed below:

1. Orange Hill in the Chisana district (Fig. 16, No. 2).
2. The Mount Hayes prospect in the central part of the Alaska Range (No. 3).
3. Shaken (No. 4), Muir Inlet (No. 5). and Baker Island (No. 6) deposits.

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*Separate Report

GEOLOGY

The molybdenum deposits commonly are either in or near granitic masses. They generally consist of molybdenite disseminated in the intrusive masses, or associated with quartz in shear or breccia zones.

RESERVES

The largest known Alaskan molybdenum potential is at the Orange Hill Porphyry copper deposit where it is estimated that approximately 200 million tons of dioritic rock contains 0.02 percent molybdenum. The reserves at Shakan are believed to be less than 100,000 tons containing 0.95 percent molybednum dioxide. The Baker Island deposit contains about 1,000,000 tons that carries about 0.27 percent molybdenum.

Nickel

The significant nickel deposits of Alaska are listed below:

1. In and near Bohemia Basin on Yakobi Island (Fig. 17, No. 21) about 75 miles west of Juneau.
2. Funter Bay on Admiralty Island (No. 22).
3. Mirror Harbor on the west coast of Chichagof Island (No. 21).
4. At Snipe Bay on Baranof Island about 45 miles south of Sitka (No. 23).
5. On Brady Glacier about 85 miles west of Juneau (No. 24).

In addition small low-grade deposits are located near Spirit Mountain in the Copper River region (No. 25).

GEOLOGIC SETTING

The nickel deposits of Alaska are sulfide-bearing parts of intrusive bodies or norite or related mafic rocks. The nickel deposits on Yakabi Island probably are part of a much larger, trough-shaped deposit formed by a concentration of sulfide minerals near the lower boundary between a norite mass and the surrounding rocks. The nickel-copper deposit near Funter Bay consists of a pipelike gabbroic intrusive body that contains the sulfides pyrrhotite, pentlandite and chalcopyrite. The low grade nickel-copper deposit near Snipe Bay (fig. 17, No. 23) consists of sulfide minerals disseminated throughout an altered mafic intrusive body.

PRODUCTION AND RESERVES

No nickel or copper has been produced from Alaskan nickel-bearing deposits.

Estimates of the reserves are listed below:

1. Bohemia Basin: 18,300,000 tons of material containing about 0.5 percent nickel and about 0.27 percent copper.
2. Mirror Harbor: High grade deposits about 8,000 tons of 1.54 percent nickel and 0.78 percent of copper. Disseminated deposit: about 13,500 tons of sulfide-bearing material per foot of depth containing 0.16 to 0.2 percent nickel and 0.03 to 0.1 percent copper.

3. Snipe Bay: 430,000 tons of probable 0.3 percent nickel and 0.3 copper.
4. Funter Bay: Minimum estimate of 560,000 tons containing 0.45 percent nickel and 0.40 percent copper.
5. Brady Glacier: Reserves are listed in the separate report.

Tin

Known lode tin deposits in Alaska are all in the western part of the Seward Peninsula. Cassiterite is present in placers from the Canadian border to the Bering Sea, indicating the presence of tin in numerous places throughout central Alaska. Localities where tin-bearing minerals are present with other metallic minerals are listed below:

1. Lost River area (fig. 16, No. 1).
2. Cape Mountain (No. 7).
3. Ear Mountain (No. 8).
4. Potato Mountain (No. 7).

RESERVES

The Lost River area has an estimate 2,600 tons of tin-bearing ore in measured plus indicated reserves containing 1.3 percent tin; 15,450 short tons of tin-bearing ore in inferred reserves containing 1.0 percent tin, and 181,700 short tons of tin-bearing ore in inferred material containing 0.2 percent to 0.75 percent of tin. Known tin lodes at Ear Mountain, Cape Mountain and Potato Mountain do not contain more than a few thousand tons of ore in bodies of minable size.

It is likely that continued exploration on the Seward Peninsula will reveal additional deposits of lode tin, particularly in areas where fine-grained granitic dikes cut larger granitic bodies and in areas of granite-limestone contacts.

Uranium, Thorium, and Rare Earths

The only Alaskan production or uranium has been from the Ross-Adams* Mine near Bokan Mountain on the southern part of Prince Wales Island (fig. 16, No. 13). Rare earth and thorium-bearing carbonate veins crop out near Salmon Bay on the northeastern part of Prince Wales Island (No. 14) Other occurrences are at Brooks Mountain (No. 1) on the Seward Peninsula and near Medfra (No. 15) in the McGrathe mining district. There are numerous small occurrences elsewhere in Alaska but none seem to have commercial significance.

Zinc and Lead

Deposits of zinc and lead are known at many places throughout Alaska. The better known deposits are on or near the mainland of southeastern Alaska and at Mount Eielson in the Kantishna district (fig. 19, No. 16). The

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*Separate Report

LOST RIVER PROSPECT: (FLUORITE, TIN, TUNGSTEN)

Ore Reserves. Proved ore reserves are considered sufficient to support a mining operation at a daily treatment rate of 4000 tons per day for a minimum of twenty years. These ore reserves are contained in Zones 1 and 2. (See attached location map, Map No. 2.)

Ore Potential. Additional potential ore in Zones 1 through 7, along the major Rapid River Thrust Fault are believed large enough to support the mining operation for many years.

ORE RESERVE SUMMARY

Zone	Type of Mining	Ore	% CaF_2	% Sn	% WO_3
1	Open Pit	23,527,000	16.43	0.26	0.040
	Underground	1,275,000	11.66	0.15	0.010
2	Open Pit	2,116,000	30.59	-	-
	Underground	1,695,000	30.00	-	-

PRESENT STATUS

Metallurgy. Pilot plant studies being completed.

Market. Favorable for fluorite consumption; demand rising from 4mm to 6.5mm tons by 1975.

Environmental. No major problems have been identified.

Mining. Further exploratory drilling on Zones 1 and 2 to confirm grade and tonnage for mining purposes. Additional bulk surface sampling will be completed to learn more about tin and tungsten recovery.

GEOLOGY

The Lost River Mine and associated mineralization is located in the York Mountains in the western part of Seward Peninsula, Alaska.

The bulk of the bedrock of Lost River valley consists of the Port Clarence limestone of Paleozoic Age. Near the mine the limestone is of Early Ordovician age, and is marmorized and partly replaced by silicate minerals, and cut by numerous veinlets containing silicates, ore minerals and fluorite. A granite pluton that does not appear at the surface has been penetrated by exploratory openings. Many basalt porphyry and rhyolite porphyry dikes intrude the limestone in the area.

The main ore minerals are cassiterite and wolframite in the intrusive rocks and limestone. Both the granite and the dikes are greisenized and cut by veinlets. Introduction of ore minerals probably began when the intrusive rocks were greisenized and the limestone altered to marble and tactite.

References

Map No. 2

Geology by J.B. Mertie Jr., and R.R. Coats, 1940.

Modified by P.L. Killeen, 1943 and by C.L. Sainsbury, 1954.

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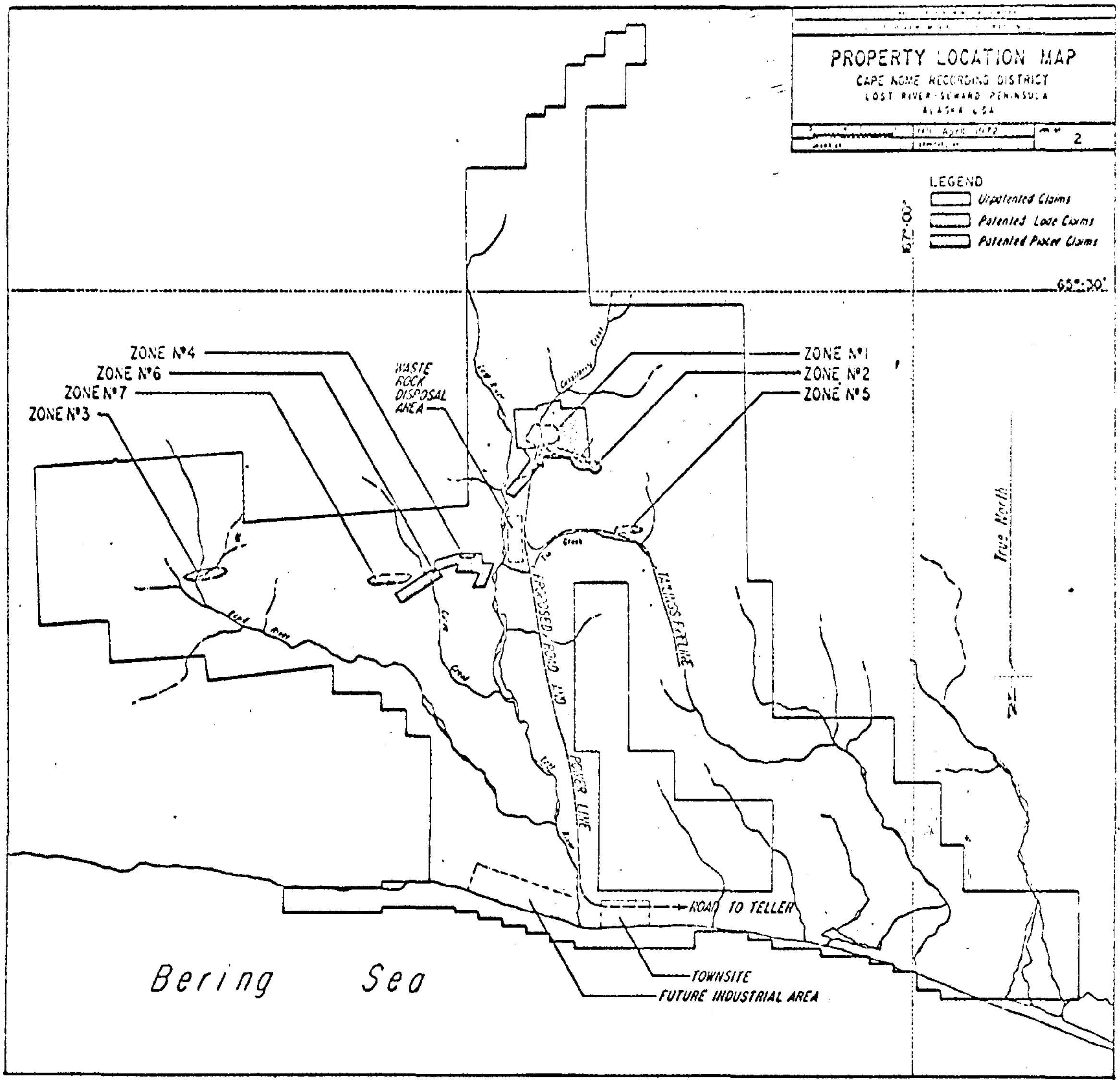
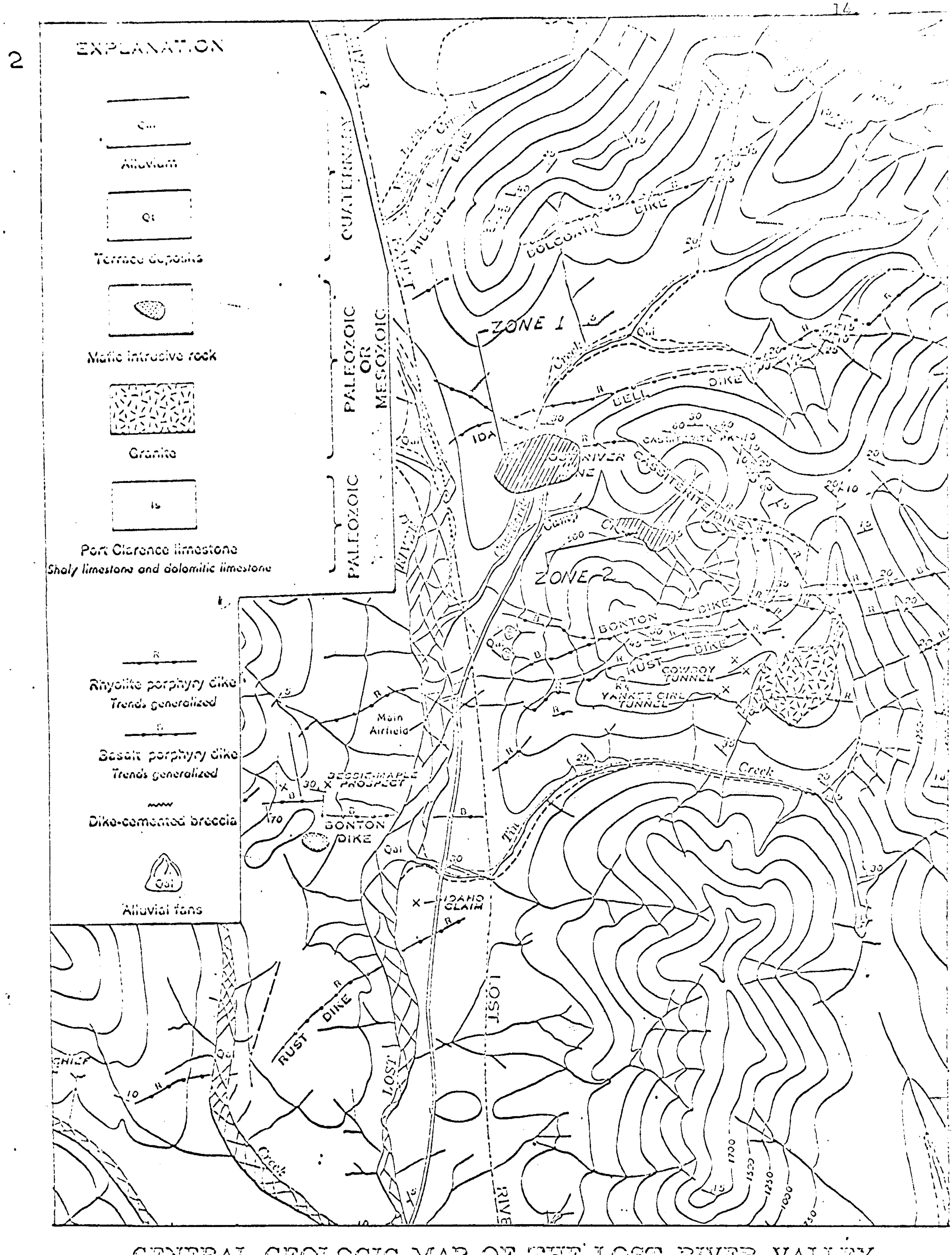


MAP ABOVE DEPICTS PROPERTIES OF LOST RIVER ON THE SEWARD PENINSULA OF ALASKA. THE MINE-MILL COMPLEX, DESIGNED TO FUNCTION AT AN INITIAL 4,000 TON DAILY RATE, WILL BE LOCATED APPROXIMATELY SIX MILES INLAND, IN THE AREA OF THE NOS. 1 AND 2 ZONES. INITIAL PRODUCTION WILL BE BY OPEN PIT ON THE NO. 1 ZONE. TAILINGS, THE WASTE PRODUCT OF THE MILL FACILITY, WILL BE PIPED TO A DAMMED-OFF DISPOSAL AREA CAREFULLY SELECTED AND ENGINEERED WITH A VIEW TO THE MOST STRINGENT ECOLOGICAL REQUIREMENTS. THE MINE-MILL SITE WILL BE CONNECTED WITH THE TOWNSITE BY ALL-WEATHER ROAD, AND A POWER TRANSMISSION LINE WILL FOLLOW THE ROAD ROUTE. THE TOWNSITE AS ENVISAGED WILL BE A REGIONAL SERVICE CENTRE, SERVING NOT ONLY THE LOST RIVER MINE COMPLEX, BUT ALSO THE ENTIRE REGION. EMPHASIS WILL BE PLACED ON TRAINING AND EMPLOYING LOCAL LABOUR. THE HARBOR FACILITY WILL PERMIT DELIVERY OF GOODS TO THE AREA AT COSTS APPRECIABLY LOWER THAN PRESENTLY POSSIBLE, WHILE POWER, WATER AND OTHER SERVICES WILL BE AVAILABLE LOCALLY AND, IN TIME, REGIONALLY ON A COSTS BASIS NOT AVAILABLE AT THE PRESENT.



GENERAL GEOLOGIC MAP OF THE LOST RIVER VALLEY

KENNECOTT MINES, KENNECOTT, ALASKA, COPPER

History of the Discovery

The discovery leading to the development of the Kennecott Group of mines has been credited to Jack Smith and Clarence Warner in 1900. The copper discovery described as "green cliffs of copper" was a great mass of copper carbonate and represents the outcropping of the ore body mined in the Bonanza mine. A mile to the northwest of the Bonanza discovery along the limestone-greenstone contact thin chalcocite veinlets were noted in a small outcrop of limestone. This was the surface expression of the Jumbo mine which was the greatest producer of the four mines, the Bonanza, Jumbo, Erie and Mother Lode which opened up the Copper district.

Geology - (See attached sketch map of the Geology in the vicinity of Kennecott, Alaska)

The Nikolai greenstone of Triassic? Age is a dynamically metamorphosed amygdaloidal basalt? flow or series of flows at least 5000' thick. It is overlain by the massive Chitistone Limestone (Upper Triassic) but separated by a 2 to 4 foot red and green shale. The basal units of the Chitistone limestone (50'-80') are typically dark gray siliceous limestones. Above these units are the dolomitic limestones associated with most of the massive chalcocite replacement deposits.

A quartz diorite stock about 6 miles long by 2 miles wide has been mapped by the United States Geological Survey between McCarthy Creek and Kennecott.

The limestone between Kennecott Glacier and McCarthy Creek is cut by numerous faults and fractures. Two of these fault systems are considered directly related to ore deposition in that they directed the course of circulating waters and controlled the deposition of copper minerals. These systems in turn are cut by cross faults of the same age? and by fractures that originated after the ore was deposited.

Copper Minerals

Included in the copper minerals found in the ores of the Kennecott group of mines are chalcocite, covellite, azurite, malachite, enargite, bornite, chalcopyrite and chalcanthite. In addition to the copper minerals it was common to find 14-16 ounces of silver per ton in the richer copper ore.

Origin of the Copper Ore

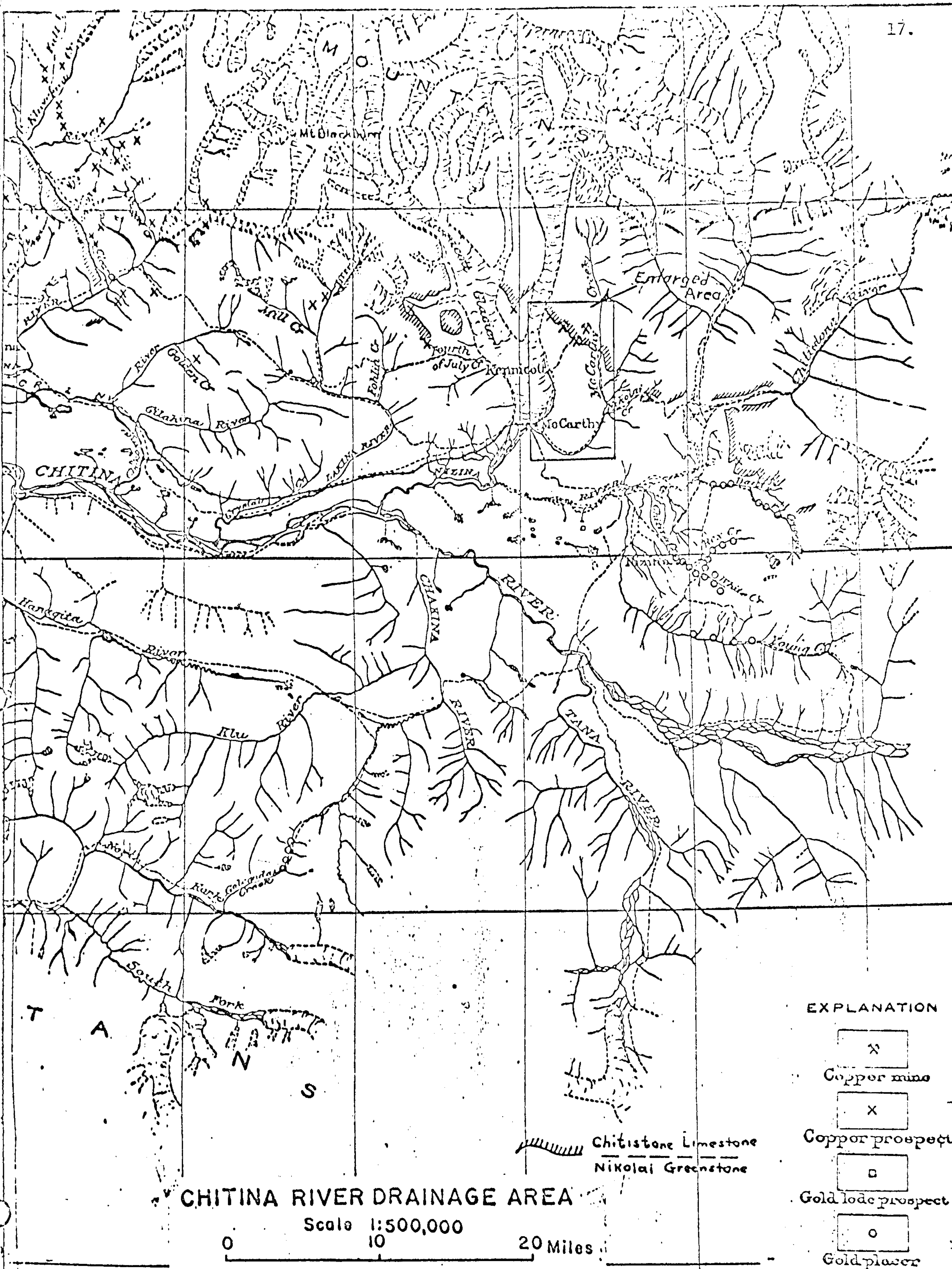
There are several hypotheses for the origin of the ore bodies. Many geologists believe that the source is the Nikolai greenstone which contains a fractional percent of copper disseminated throughout. Others think that copper was deposited from hydrothermal solutions that emanated from a concealed granitic pluton in the mine area. Another alternative is that both sources contributed copper to the rich deposits.

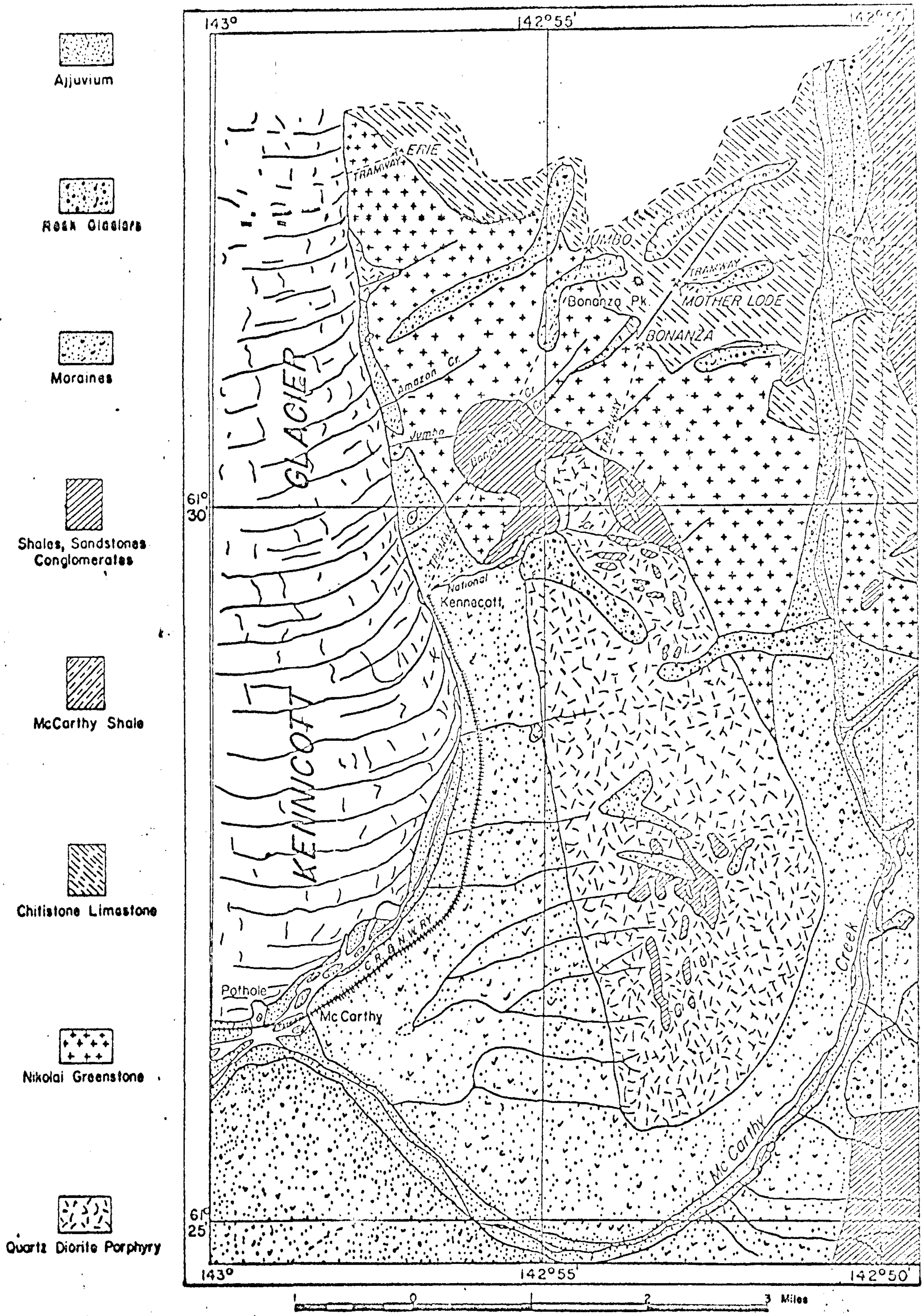
Production

From 1900-1938 more than a billion pounds of copper was recovered from this area.

Present Status

Interest has continued in the areas along the Chitistone-Nikolai Greenstone contact. Exploration has consisted mostly of diamond coring. The environment for replacement ore bodies and past productive history strongly support an optimistic view for the possibility of developing additional large ore bodies.


Enlarged Area
Kennicott
McCarthy
CHITINA
NIZINA
RIVER
CHAKINA
TANA
Klu River
Hanagita
South Fork
Fourth of July Cr.
Gilahina River
Golden Cr.
Lakina River
Chitistone Limestone
Nikolai Greenstone
EXPLANATION
Copper mine
Copper prospect
Gold lode prospect
Gold placer
CHITINA RIVER DRAINAGE AREA
Scale 1:500,000
0
10
20 Miles



SKETCH MAP OF GEOLOGY — VICINITY OF KENNECOTT
U.S.G.S. BULLETIN NO. 662

KLUKWAN, ALASKA

Magnetite Ore

The Klukwan iron deposit is located about 23 miles northwest of Haines, Alaska. At Klukwan, an Indian village, the paved Haines-cutoff Highway passes over the outwash fan of the deposit approximately one mile from the lode.

The deposit is a large intrusive of basic composition or a magnetite-enriched pyroxenite. The body as mapped has a maximum width of 1-1/4 miles and a length of about three miles. The vertical range as exposed by erosion is approximately 3,000'.

The reserves of magnetite-bearing rock, as mapped by the Geological Survey, is estimated at 13 billion short tons.

The magnetite is disseminated uniformly throughout the pyroxenite except where magnetite has been segregated into enriched lenses. These lenses contain 45 to 50 percent iron content.

Sampling of the entire pyroxenite body is limited. However, a series of chip samples across an 800 foot expanse of uniformly crystallized pyroxenite averaged approximately 20 percent magentite iron and five percent iron contained in silicates.

Genetically the deposit may be a magmatic differentiation from the dioritic magma that surrounds this pyroxenite body.

Concentrates

The concentrates made from Klukwan ore are low in sulfur and phosphorus with a titanian oxide content from 2.2 percent in the concentrate from low grade ore to 4.2 percent Tio2 from the high grade ore.

Most of the present interest is in the reserves contained in the outwash fan. Both the U.S. Steel Corporation and Kaiser Steel are active in this area. Testing of the alluvial fan indicates that it contains several hundred million tons of rock having a magnetite content of about 10 percent.

following is a list of the better known areas:

1. Sedanka Island (No. 17).
2. Iliamna Bay on Cook Inlet (No. 11).
3. Golovin Bay on Seward Peninsula (No. 18).
4. Near Kantishan (No. 19).
5. South of Ruby in the central Yukon region (No. 20).

At Mahoney Creek south of Ketchikan (No. 22) a small fissure vein has yielded Alaska's only production of sphalerite shipping concentrates. There was no production of zinc or lead from Alaska in 1971.

Silver

Silver has been found in numerous deposits in Alaska (fig. 15) but is not generally as plentiful as in similar deposits in the Rocky Mountain States. Most of the silver produced in Alaska is a byproduct of operations involving production of other metallic sulfides. The better known silver-bearing deposits are listed below:

1. Near Hyder-Kassan Peninsula (No. 24).
2. Near Juneau in the gold belt from low-grade stringer lodes that follow the foliation of the slate and schist country rock.
3. East of Wrangell (No. 26) in Glacier and Groundhog Basins and at the Lake Claims.
4. Central and northern Kenai Peninsula.
5. Copper River region as a byproduct of the Kennecott copper production.
6. Chulitna district in mineralized biotite quartz diorite porphyry.
7. Seward Peninsula in small vein-type deposits.

The 1971 silver production of Alaska was less than 4000 fine ounces.

Tungsten

Only three important areas of tungsten deposits are known in Alaska. The Fairbanks district in the Yukon region and the Hyder district in southeastern Alaska each contain two tungsten deposits. A large low grade wolframite deposit occurs at the Lost River Tin Mine (fig. 16, No. 1).

In the Lost River mine on the Seward Peninsula the tungsten occurs in altered dikes, granite, and in marmorized limestone. In the Fairbanks district tungsten deposits consist of lenses of scheelite in metamorphosed limestone and in gold quartz veins. In the Hyder district quartz veins containing tungsten are developed at the Riverside and Mountain View Mines.

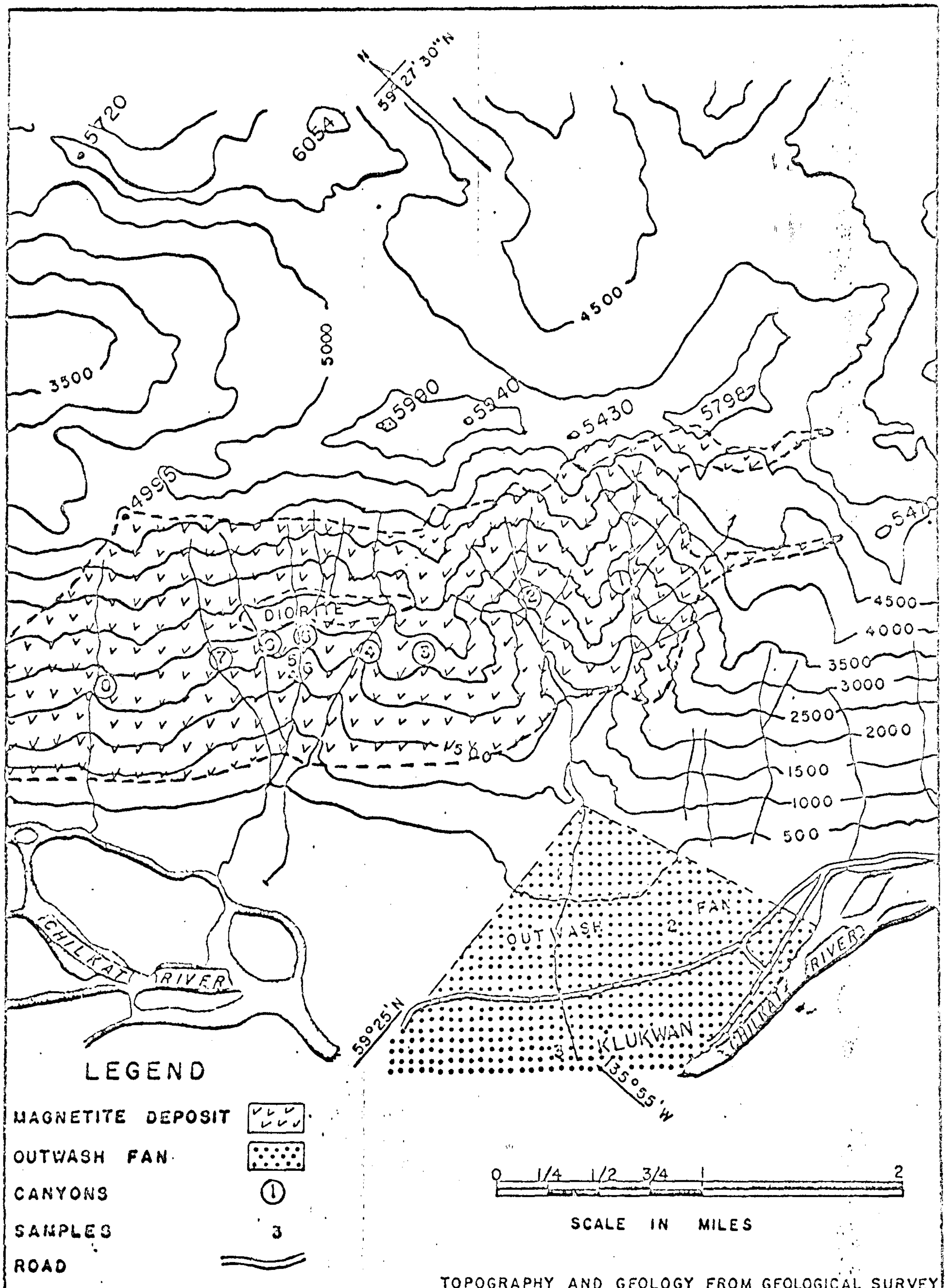


Figure 1. - Map of Klukwan iron deposit.

BOKAN MOUNTAIN URANIUM - THORIUM AREA, SOUTHEASTERN ALASKA

Ross Adam Mine

This mine shipped 55,000 tons of 1.5% U_3O_8 in 1971 and has had a history of several active exploratory periods. It is mentioned in this summary beacuase it has been the only commercial uranium producer in Alaska and because there exists potential for additional uranium reserves in the immediate area.

History

Discovered by use of an airborne geiger counter on May 18, 1955. Confirmed by ground investigations. Exploratory diamond drilling was followed by production of 15,000 tons of uranium ore containing more than 0.80% U_3O_8 in 1956.

Geology, See attached Geologic map of the Bokan Mountain Area.

The Ross-Adams Mine is within peralkaline granite stock and the size of the ore body was about 400' long by 50' wide and 50' deep. The small granite body is believed to be Tertiary in age. The south end of the ore deposit was downfaulted by steeply dipping faults that strike N. 70 degrees W. to No. 80 degrees E. Other minor faults with little displacement are exposed in the open pit. Most of the faults are characterized by iron-stained gouge zones a few inches thick.

The ore body has a gentle southerly plunge increasing near the faulting at the south end of the deposit.

The granite within the mine area ranges from fine-grained to medium-grained, and to porphyritic varieties with coarse to medium-grained quartz phenocrysts in a medium to fine-grained groundmass.

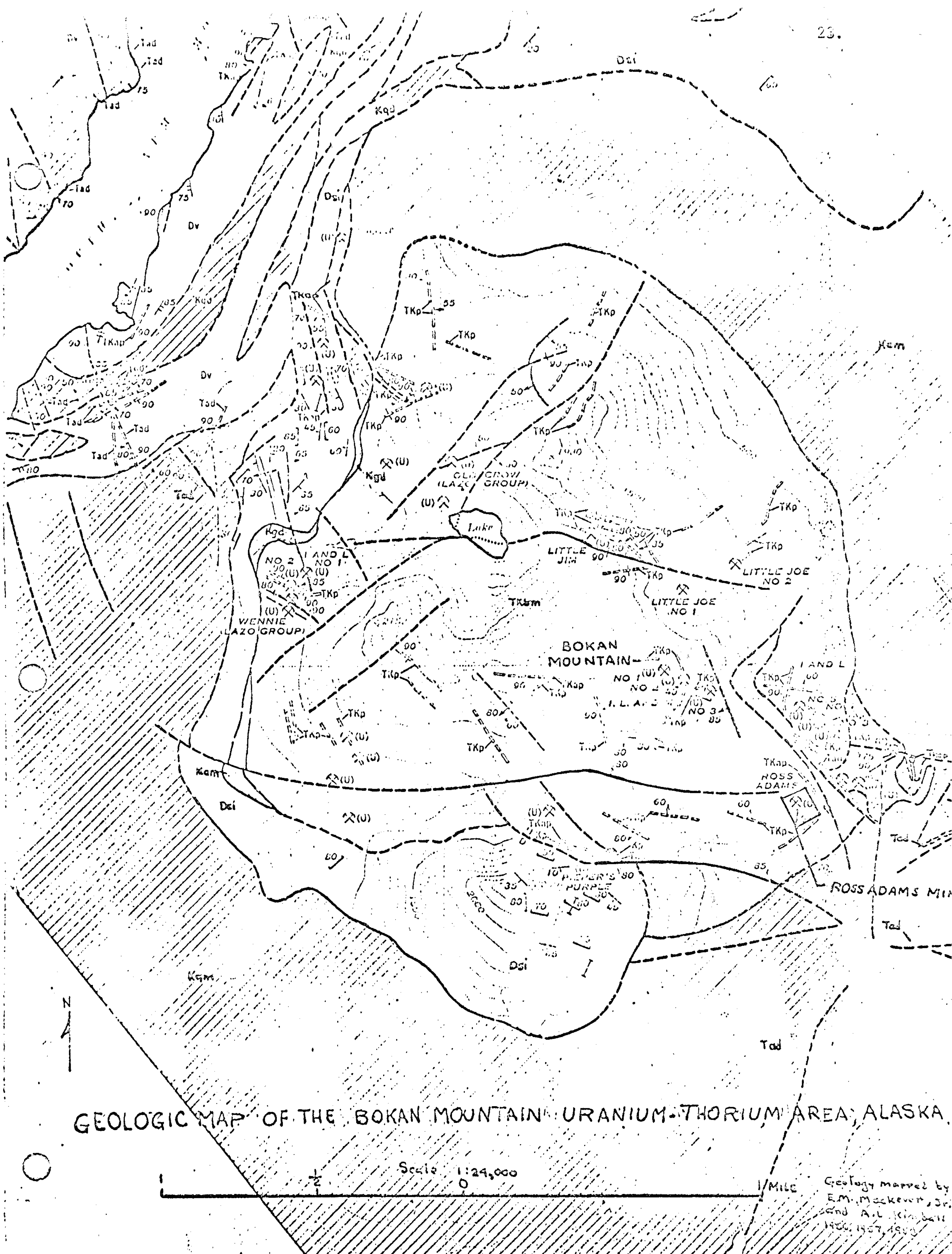
Probable Genesis of the Ore

Considered to be two processes: (1) Concentration of uraninite and uranoan thorianite in the granite. (2) Subsequent formation of uranium and thorium-bearing veinlets at the site of the ore body (enrichment). The strong fault of the south end of the ore body may have acted as a channel way for hydrothermal activity.

Other small radioactive deposits have been found within a 71 square mile area. Deposits not directly related to the granite have been found in aplite and pegmatite dikes.

Summary

The Bokan Mountain area and the numberous radioactive anomalies of other localities in southeastern Alaska makes this the most promising part of the State of Alaska for uranium prospecting.



GEOLOGIC MAP OF THE BOKAN MOUNTAIN URANIUM-THORIUM AREA, ALASKA

EXPLANATION

Dc

Marble and calc-hornfels

Dsl | Dgn | Dsc | Dam

Metamorphic rocks

Dsl, *chiefly black slate*
Dgn, *gneiss*
Dsc, *schist*
Dam, *amphibolite*

Dv

Metavolcanic rocks

Chiefly quartz keratophyre

DEVONIAN(?)

Tad / Td / Tr

Dikes

Tad, *andesite, dacite, or, uncommonly, lamprophyre*
Tr, *rhyolite or quartz latite*
Td, *diabase*

TERTIARY?

TKp

Pegmatite dikes

Related to the Bokan Mountain granite. Dashed where approximately located

TKap | TKap

Aplite, aplite dikes, and subordinate alaskite

Related to the Bokan Mountain granite

TKbm

Bokan Mountain granite

CRETACEOUS AND TERTIARY(?)

Kp

Pegmatite dike

Probably related to quartz monzonite and granodiorite

Kap | Kap

Aplite, aplite dikes, and subordinate alaskite

Probably related to quartz monzonite and granodiorite

Ksy | Ksy

Syenite, syenite dikes, and monzonite

Kqg

Gneissic quartz monzonite

Kqm

Quartz monzonite and granodiorite

Single hatched where albitized; extent of albitization approximate

Kqd

Quartz diorite and diorite

Single hatched where albitized; extent of albitization approximate

Kg

Gabbro

Kpy

Pyroxenite

CRETACEOUS

90

Vertical contact

55

Fault, approximately located, showing plunge of slickensides

60

Contact, showing dip

Dashed where approximately located; short dashed where indefinite; dotted where concealed

90

Vertical fault

Dashed where approximately located

(U)

Mine or prospect

(U), *uranium-thorium*
(Cu), *copper*
(Au), *gold*

30

Strike and dip of beds

?20

Probable strike and dip of beds

40

Strike and dip of flow banding in metavolcanic rocks

Strike of vertical flow banding in metavolcanic rocks

75

Strike and dip of foliation

Strike of vertical foliation

60

Strike and dip of cleavage

Strike of vertical cleavage

60

Dike, showing dip

Dashed where approximately located; dotted where concealed

90

Vertical dike

Dashed where approximately located

85 qtz, c, py

Vein, showing dip

Dashed where approximately located
qtz, *quartz*
c, *calcite*
py, *pyrite*

90 qtz, c, py

Vertical vein

Dashed where approximately located
qtz, *quartz*
c, *calcite*
py, *pyrite*

BRADY GLACIER NICKEL - COPPER PROSPECT

History

The deposit was discovered in 1958 by geologists of the Fremont Mining Company which staked the claims and drilled 32 relatively shallow core holes before turning the exploration over to Newmont Exploration Ltd. in 1960.

Geology

The sulfides occur at the southeast margin of a large lopolithic intrusion of gabbro and peridotite called the Crillion-La Perouse intrusion. This intrusion nearly 17 miles long and 8 miles wide consists predominantly of layered gabbro. The mafic complex is intruded into amphobole and biotite schist.

The exposures in the nunataks of Brady Glacier indicate that the structures in this area are more complex and layered relations less apparent. This is due in part to post-crystallization faulting near the margin of the intrusive and to later intrusions. In the nunatak, exposures of peridotite overlay fine to medium grained gabbro. These rocks are intruded by dikes and irregular bodies of gabbro, diorite, aplite and possibly peridotite.

Ore Deposits

The predominant host rock for the Brady Glacier deposits is peridotite commonly consisting of a mixture of forsterite and enstatite. Fine to coarse grained olivine gabbro is also a common host rock for the nickel-copper sulfide deposits.

The sulfides, pyrrhotite, pentlandite and chalcopyrite, occur in the host rocks as disseminated grains, veinlets, and lenticular masses as large as 35 feet long and 5 feet in diameter. The sulfide veinlets occur along fractures and fissures and are commonly less than 1 mm thick. Most of the host rock contains scattered sulfides which are most abundant in altered peridotite and gabbro pegmatite.

Pyrrhotite is the most common sulfide followed in order by pentlandite and erratically scattered chalcopyrite. Textural relations suggest that the chalcopyrite was formed slightly later than the iron and nickel sulfide.

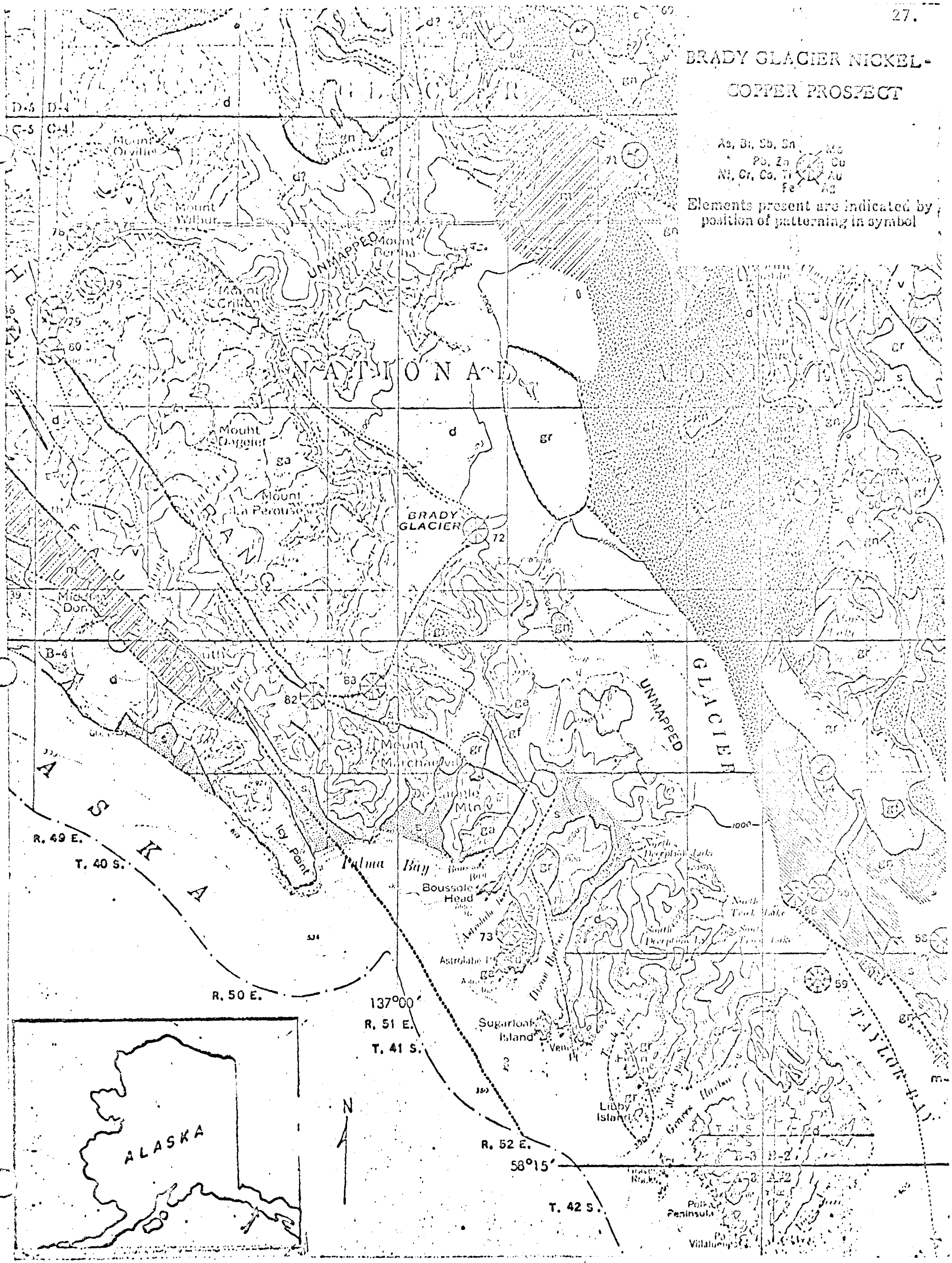
Ore Grade

Ore grades have been established by sampling the nunataks and by diamond drilling. The results are still incomplete and further drilling is contempiated. The overall average grade of the nunataks would be probably less than 0.5 percent each of nickel and copper. Sulfide masses in 1 to 1.4 percent copper and 0.25 percent cobalt.

Present Status

Newmont Exploration Ltd. is planning a deep diamond coring program in an attempt to block out greater reserves of ore. Tentative plans for an access adit to explore the ore body at depth and to obtain large samples for pilot plant studies have been made. Development of this large low grade nickel-copper deposit will be influenced by environmental and political overtones.

BRADY GLACIER NICKEL-COPPER PROSPECT



EXPLANATION

Contact
Dotted where concealed

Fault
Dotted where concealed

Surficial deposits
Mainly glacial outwash and till, but include lake deposits, recent marine clays, colluvium, beach deposits, and alluvium

d

Detrital clastic rocks
Mainly graywacke, shale, siltstone, calcarenite, and minor conglomerate, metamorphosed to hornfels or to schist in some areas; include small amounts of carbonate and (or) volcanic rocks locally

c

Carbonate rocks
Mainly limestone, minor dolomite locally; metamorphosed to marble or calcsilicate hornfels in some areas; include small amounts of detrital clastic and (or) volcanic rocks locally

v

Volcanic rocks
Mainly mafic to intermediate lava flows and breccia; metamorphosed to hornfels or to greenstone, greenschist, or amphibolite in some areas; include some detrital clastic rocks locally

Undifferentiated metamorphic rocks

Heterogeneous gneisses and mixed contact zones
Gneisses mainly dioritic to tonalitic, commonly foliated, but with some massive breccia. Contact zones consist of abundant large hornfels masses surrounded by rock of adjacent intrusive body

Foliated granitic rocks
Mainly diorite, tonalite, and granodiorite; form partly discordant plutons

Unfoliated granitic rocks
Mainly granodiorite, adamellite, and granite; form discordant plutons

ga

Gabbroic rocks

KASNA CREEK, COPPER DEPOSIT, LAKE KONTRASHIBUNA, LAKE CLARK REGION, ALASKA

Location

The Kasna Creek copper prospect is in the Lake Clark region, southwest Alaska, about 160 miles southwest of Anchorage, Alaska. The copper prospect is on Kasna Creek, a small tributary to Lake Kontrashibuna.

History

Initial staking of claims was in 1906 by Brooks and von Hardenberg. The area was first described by the Geological Survey in 1909. The leases were acquired under option to the St. Eugene Mining Corp. Ltd. in 1943. There has been no production reported for this area.

Geology

The copper mineralization of Kasna Creek is in a limestone belt 1500 feet wide. The belt of limestone is exposed on both shores of Kontrashibuna Lake and extends to the eastern shore of Lake Clark. Martin and Katz (1912) considered the limestone to be Paleozoic, probably Devonian in age. The Bureau of Mines in mapping indicates that the limestone belt is in contact with a rhyolite porphyry on the east and the diorites? form most of the western contact and apparently terminate the limestones on the south. There are small intrusives of basaltic porphyry (dikes and sills) around the edges of the limestone ore deposits.

The ore deposits are classified as contract metamorphic types. Mineralization consists of specular hematite, amphibole, chlorite, calcite and quartz. The deposits are not homogeneous.

Chalcopyrite is disseminated throughout the mineralized area as scattered grains. There are also concentrations of chalcopyrite in the form of small lenses and veinlets. The massive chalcopyrite itself contains numerous inclusions of sphalerite.

The two main ore bodies exposed at the surface are the Barnes and Gilt Edge ore bodies. The approximate outlines of these bodies are shown in figure 3. The barnes deposit assayed 1.14 percent copper; the Gilt Edge deposit assayed 0.69 percent copper from several hundred samples.

There is a basic problem in the ore treatment and this problem is summarized below:

This type of ore cannot be concentrated by simple methods at relatively coarse sizes. Further, even by fine grinding and flotation, only low recoveries in low-grade copper products are possible. None of the methods tried proved effective in recovering the iron-oxide content of the ore as a separate product.

Reserves

Although considerable trenching, sampling and mapping has disclosed an ore body of considerable size, tonnages of ore have not been determined and a diamond drilling program would be required before exploitable reserves could be calculated.

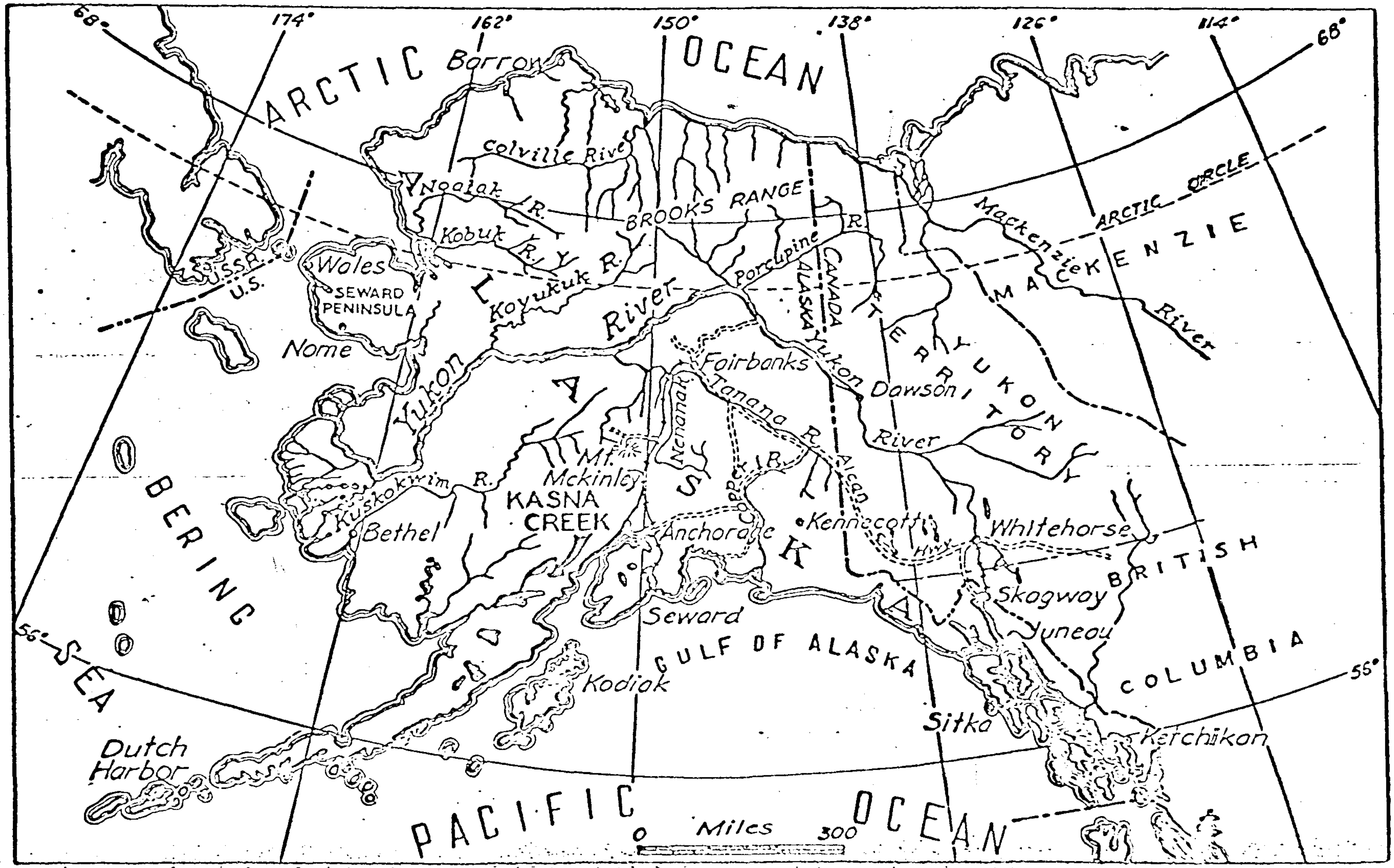


Figure 1. - Index map of Alaska.

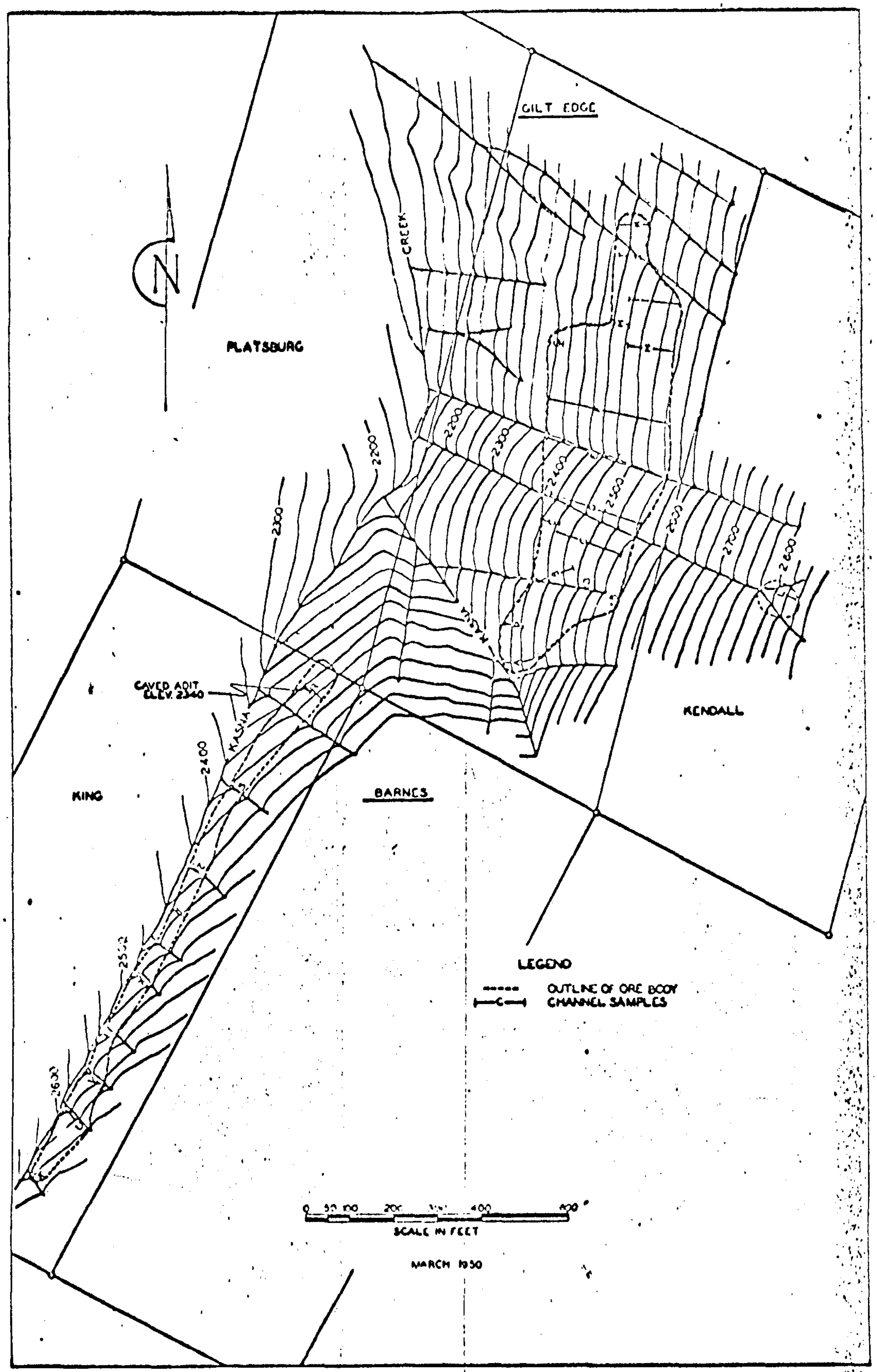


Figure 3. - Topographic and claim map of Kasna Creek copper deposit.

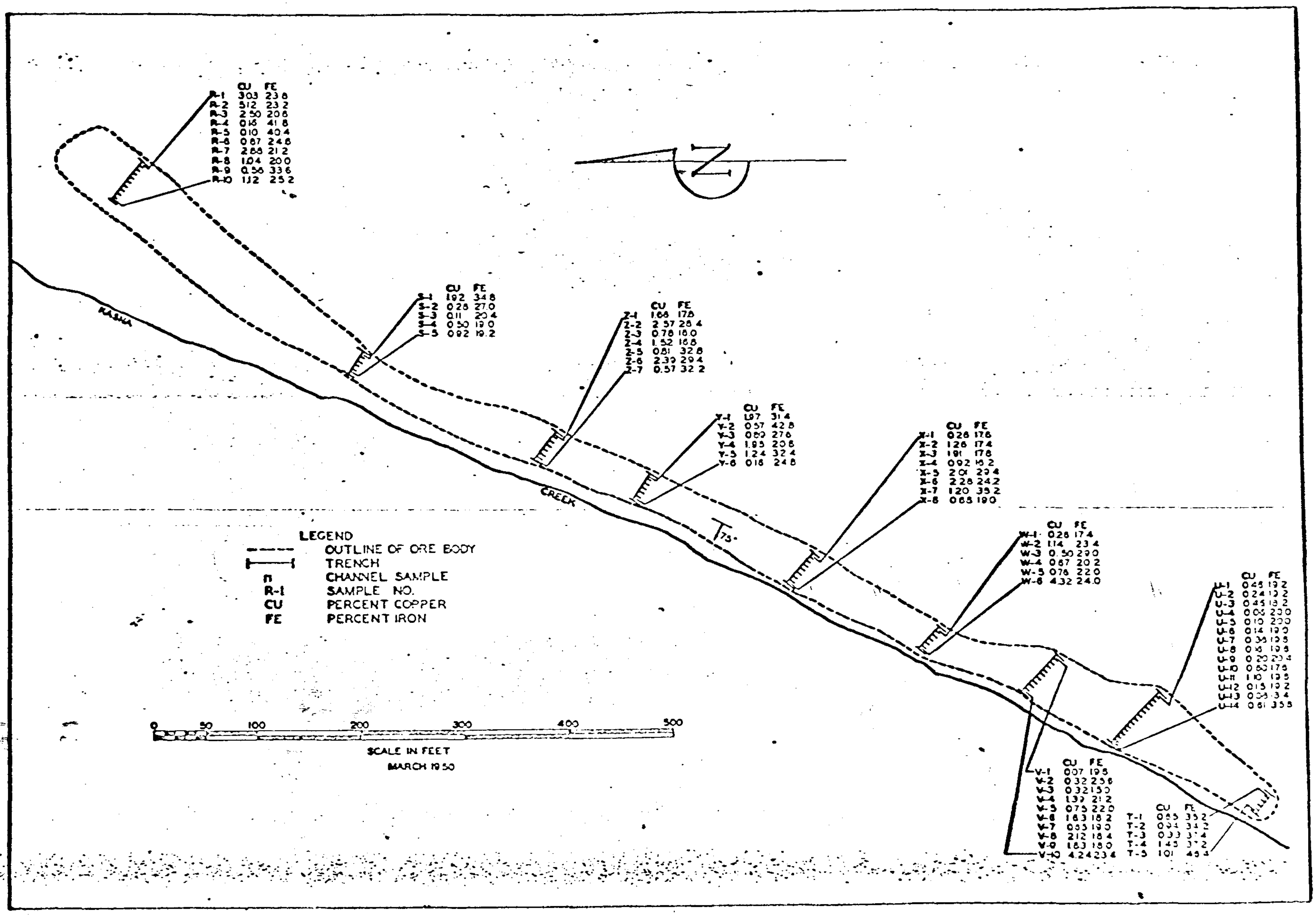


Figure 5. - Assay map Barnes ore body, Kasna Creek.

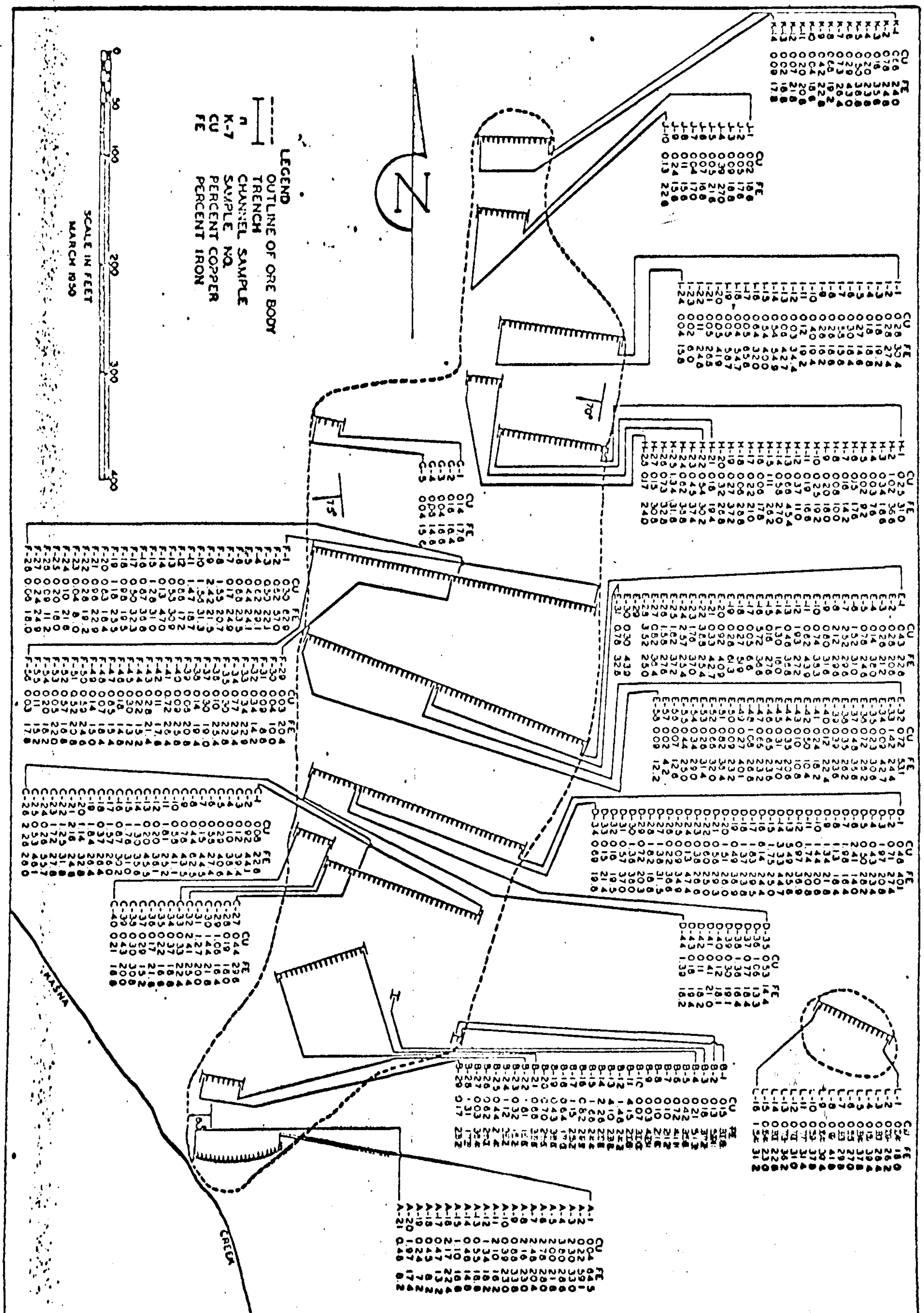


Figure 4. - Assay map Gilt Edge ore body, Kasna Creek.

BORNITE, COSMOS HILLS, SHUNGNAK MINING DISTRICT, ALASKA, COPPER

History

Early prospecting began shortly after the gold rush of 1898. Two locations were prospected: one on the northeast end of Pardners Hill (three miles west of Bornite); the other was on the west side of Ruby Creek opposite and near the present exploration camp of Bornite. The early prospecting consisted of shallow shafts and adits and minor surface trenching. Nearly all these early exploratory efforts penetrated mineralized dolomite containing chalcopyrite and bornite.

In 1948, Rhinehart Berg discovered radioactivity in copper-bearing vein material (disseminated pitchblende?) collected from old mine dumps at Ruby Creek. Continued surface exploration by Berg and his associated included trenching and some diamond drilling. Saunders (1953, 1955, and 1956) examined and appraised these properties and showed that the copper content was high enough to be of interest to mining companies.

In 1957 Bear Creek Mining Company (the exploration subsidiary company for Kennecott Copper Company) obtained an option on the Berg prospect and vicinity. This was followed by 13 years of exploratory efforts. Thousands of feet of diamond drilling was completed with the greatest concentration in a 5000' x 6000' area near Bornite. This drilling revealed a close relationship between dolomite breccia, pyrite and copper sulfides.

Kennecott acquired control of the mineralized ground in 1963 for $3 million and eventually invested $10 million or more in the area. A deep exploratory shaft was started in 1964 and on October 27, 1966 the shaft suddenly became flooded at a depth below 1000 feet. Pumping was not effective and the lower 23 feet of the shaft was plugged with cement. The shaft was pumped dry and some underground work completed.

All underground work closed in 1968. Sporadic diamond drilling has continued to the present date.

Geology-Stratigraphy

Phyllitic Schist: The oldest stratigraphic formation exposed in the area under discussion is a phyllitic schist which consists of weakly to moderately metamorphosed pelitic calcareous and volcanic strata. Included in this formation in addition to the predominant graywacke-phyllitic schist unit are units of crystalline limestone and greenschist-greenstone of probable metavolcanic origin. The formation underlies at least 65 square miles in the central part of the Cosmos Hills and is more than 5000' thick. The age of this formation is uncertain but it probably is paleozoic.

Main Dolomite Limestone and related rocks: A thick sequence of metamorphosed limestone, dolomite and dolomitic breccia underlies more than 20 square miles in the northern, western and southern parts of the mapped area. The formation is known to be allochthonous. A middle Devonian age has been assigned to this formation.

Upper Phyllite and related rocks: A thrust slice composed primarily of phyllite and subordinate greenstone and carbonate rocks overlies the main Dolomitic Limestone in the western part of the Cosmos Hills. The phyllite is medium to dark gray and its metamorphic grade is lower than the marble over which it has been thrust.

Upper Carbonates: Bedded carbonate rocks most likely part of the main thrust-faulted stratigraphic sequence of Devonian age.

Metaconglomerate and related rocks: The highest stratigraphic sedimentary formation in the Cosmos Hills consists of a predominant conglomeratic sandstone and slate unit thrust over the underlying Devonian strata and is considered Cretaceous in age.

Intrusive rocks - Cretaceous: Gneissic granite forms a pluton 1 3/4 miles in diameter near the Kogoluktuk River (Southeast portion of attached geologic map).

Tertiary Rocks - Serpentinite: Tabular intrusive bodies are parallel to bedding, foliation and overthrust faults. These beds range from 100 feet to five miles long, but only from 10 feet to 400 feet in thickness.

Structure

The most important structural feature in the Cosmos Hills is the thrust faulting and the associated window about 20 miles long and two to eight miles wide. Four major overthrust faults have been recognized.

Host Rocks

The predominate host rock at Bornite is dolomite breccia, but limestone breccia, impure limestone and phyllite are mineralized in some places.

Shape of Deposit

Copper sulfide minerals are concentrated in units with greater horizontal than vertical extent within the favorable host rocks. Thus they form lenticular concentrations approximately parallel to the bedding.

Ore Mineral

Common minerals in the dolomite host rocks include siderite, pyrrhotite, cymrite, pyrite, chalcopyrite, bornite, chalcocite, tennantite-tetrahedrite, sphalerite and galena plus other minor minerals.

Origin of Copper

Believed to be a low temperature hydrothermal deposit and post-metamorphic in age.

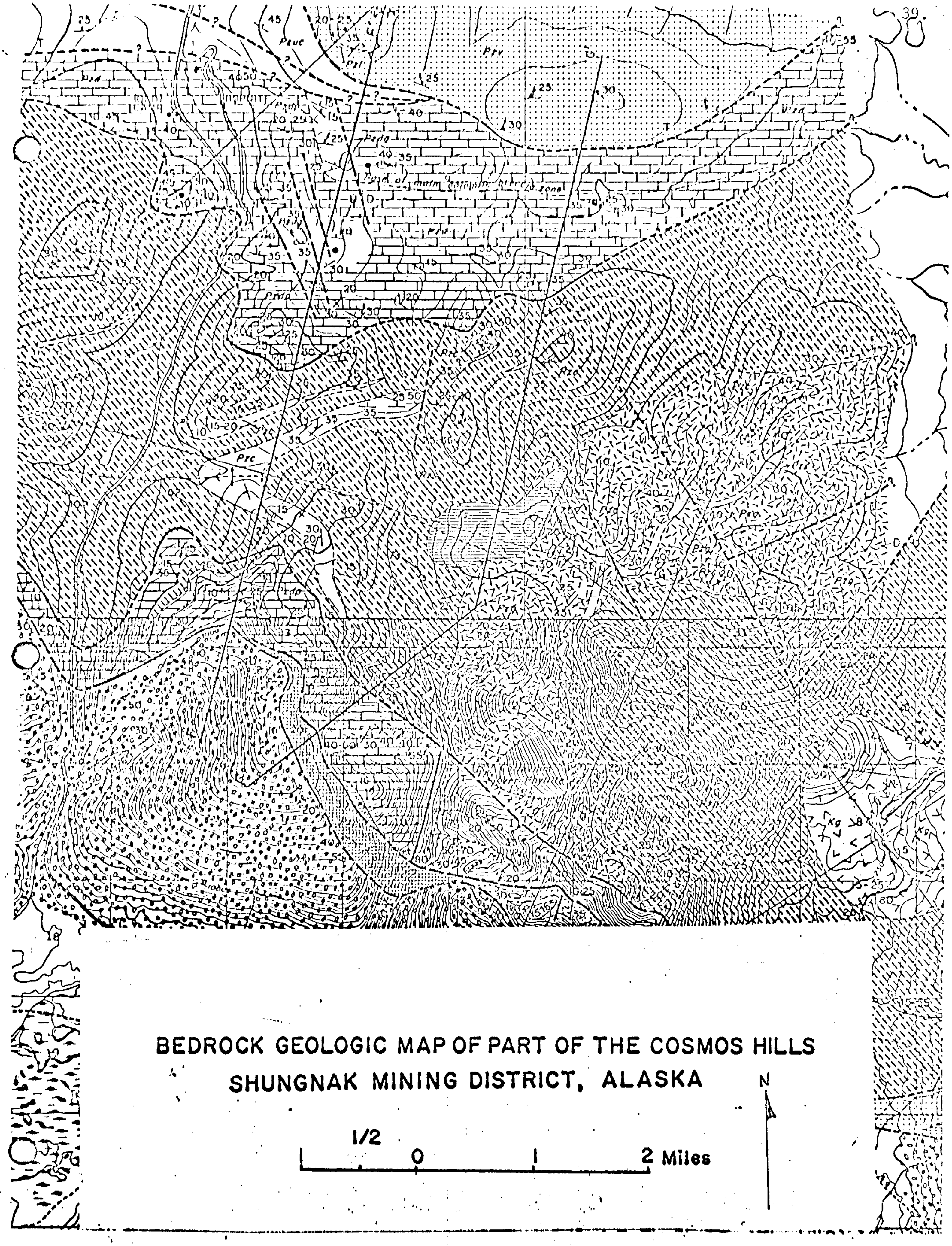
Reserves

Reliable estimates of the reserves in the vicinity of Bornite have not been released by the mining companies. An estimate of 100 million tons of

1.2% copper revealed by drilling during the period 1957-1961 (Lund, 1961) is considered high by Fritts (1970).

References

Fritts, Crawford E., 1970, Geology and Geochemistry of the Cosmos Hills, Ambler River and Shungnak quadrangles, Alaska: Alaska Division of Mines and Geology, Geol. Report 39.

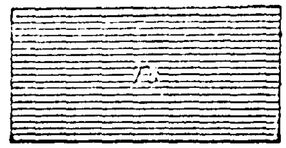


BEDROCK GEOLOGIC MAP OF PART OF THE COSMOS HILLS
SHUNGNAK MINING DISTRICT, ALASKA

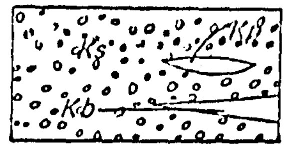
1/2 0 1 2 Miles

N

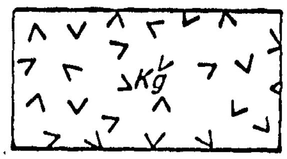
COSMOS HILLS EXPLANATION



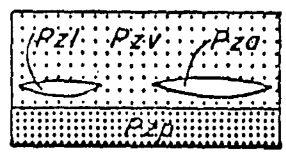
Serpentinite



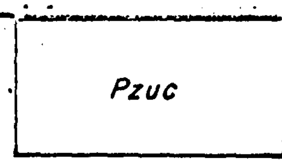
Metaconglomerate and related rocks



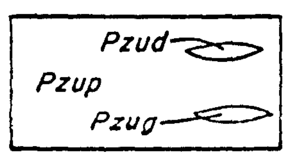
Granite



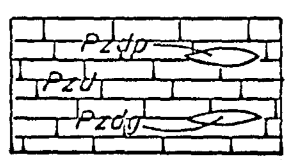
Metabasalt and related rocks



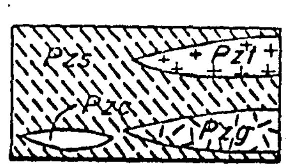
Upper carbonates



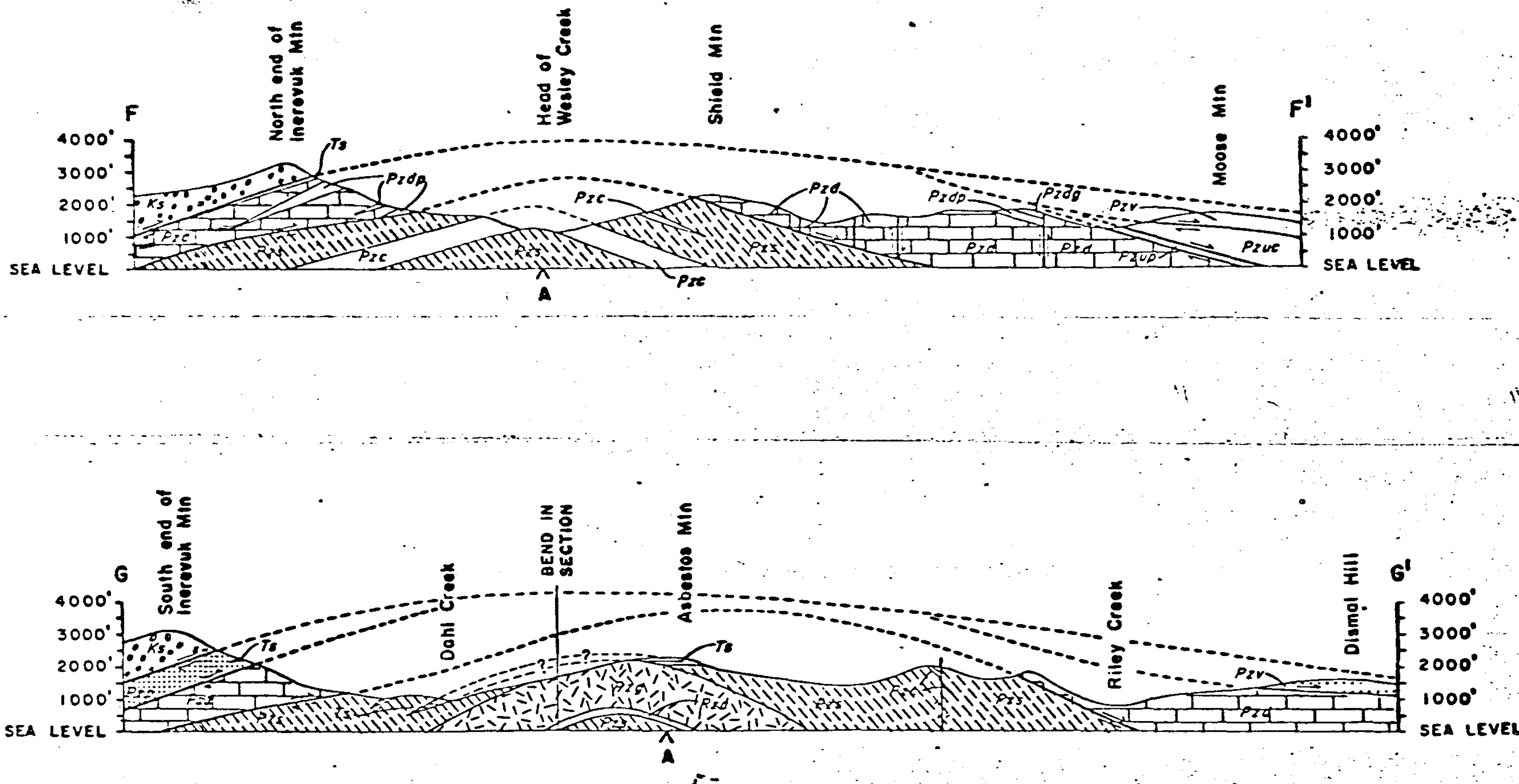
Upper phyllite and related rocks



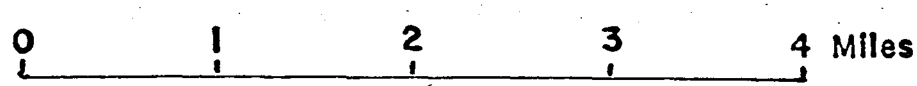
Main dolomitic limestone and related rocks



Phyllitic schist and related rocks



COSMOS HILLS – SHUNGNAK MIÑING DISTRICT, ALASKA
CROSS-SECTIONS, FF' GG'



KASAAN PENINSULA, PRINCE OF WALES ISLAND, ALASKA, IRON-COPPER DEPOSITS

History

Copper-bearing magnetite deposits on Kasaan Peninsula, Prince of Wales Island, Alaska, have been known since about 1865. Mining and exploration began between 1895 and 1900 and has continued intermittently since.

Ore Deposits

The deposits are nearly all small but relatively high grade. Ore minerals include magnetite, pyrite and chalcopyrite. Sulfur content is high, averaging about 2 percent. Phosphorus and titanium are present but only in small quantities. The ore deposits are predominatly contact metasomatic with a small number classified as hypothermal.

Geology

Nearly all the country rock on the Peninsula is greenstone of andesitic composition and probable Mesozoic age. Rocks included in the greenstone consist of limestone and various clastic rocks including siltstone, graywacke, quartzite and conglomerate. The suggested geologic history is that large sills intruded a Paleozoic sequence of sedimentary rocks which were broken into discontinuous slabs which now appear as lenses and layers in the greenstone. The sequence of greenstone and sedimentary rock was then intruded by dikes and stocklike bodies of igneous intrusive material. Following the intrusions the region was faulted and ore-bearing solutions replaced brecciated greenstone and lenses of calcareous clastic material. The ore deposits are commonly associated with areas in which rocks of sedimentary origin form a considerable amount of the country rock.

Reserves

Reserves in 1961 were estimated at 5.5 million tons. These include 4 million long tons of high grade iron ore, the remainder being in short tons of low grade copper ore.

The magnetite deposits contain more than 50 percent iron with gold, silver and copper in amounts averaging $2.00 per ton.

Most of the known copper reserves have been mined. However, a considerable amount of relatively low grade (2 percent) ore has not been exploited.

Future Possibilities

The localization of ore deposits along the southwestern coast of the peninsula suggests that future discoveries will be more likely along this zone than elsewhere. The size of the present ore bodies would indicate that future discoveries will be small but of probable high grade ore.

References

Warner, L. A., Goddard, E. M., 1961, Iron and Copper Deposits of Kasaan Peninsula, Prince of Wales Island, Southeastern Alaska, U.S. Geological Survey Bulletin 1090.

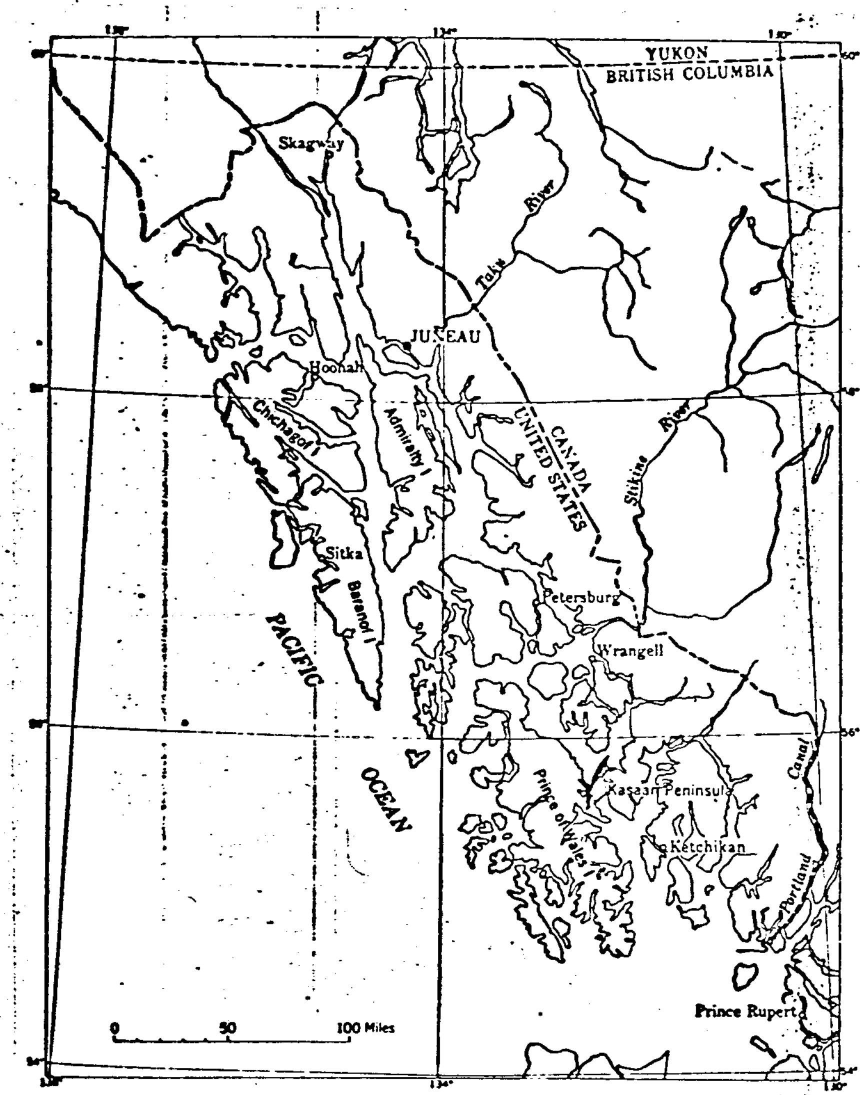


Figure 1.—Index map of southeastern Alaska showing location of Kasaan Peninsula.

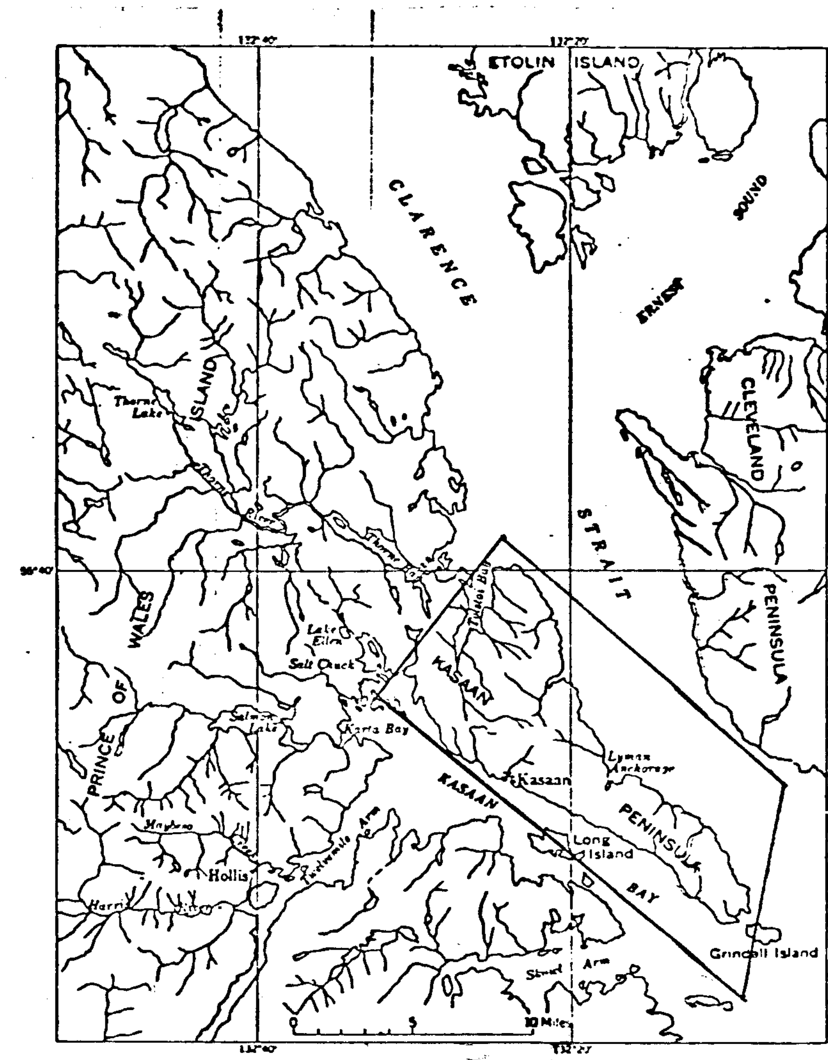
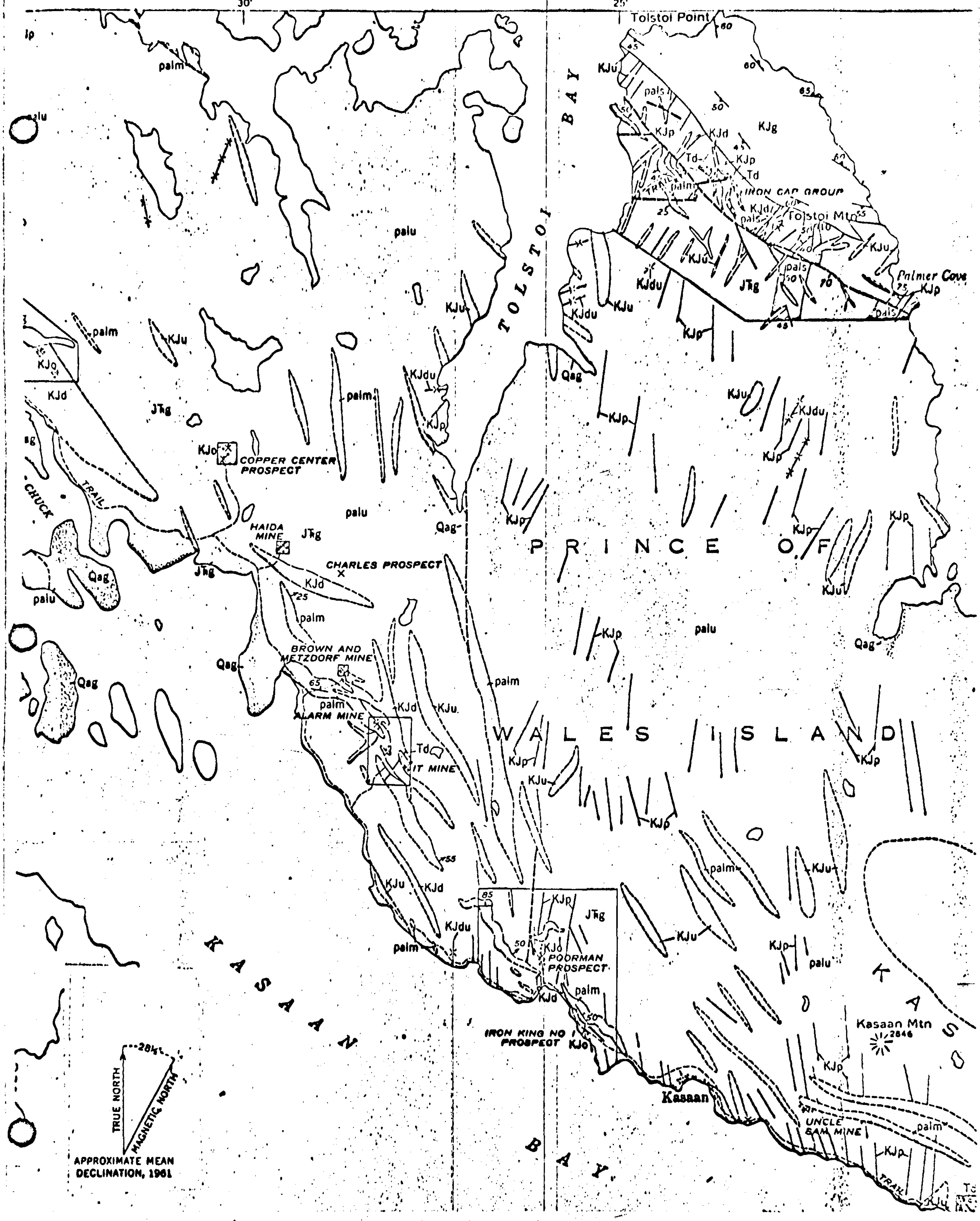


Figure 2.—Map showing relationship of Kasaan Peninsula to adjacent areas.

GEOLOGIC MAP OF KASAAN PENINSULA, PRINCE OF WALES ISLAND, ALASKA

Scale 1:63360

1 ½ 0 1 2


30'
25'
Tolstoi Point
TOLSTOI BAY
PRINCE OF WALES ISLAND
KASAAN BAY
KAS
IRON CAP GROUP
Tolstoi Mtn
Palmer Cove
COPPER CENTER PROSPECT
HAIDA MINE
CHARLES PROSPECT
BROWN AND METZDORF MINE
ALARM MINE
IT MINE
POORMAN PROSPECT
IRON KING NO I PROSPECT
UNCLE SAM MINE
Kasaan
Kasaan Mtn
2846
TRAIL
CHUCK
palu
palm
pals
KJu
KJd
KJdu
KJp
KJg
KJo
JTRg
Td
Qag
TRUE NORTH
MAGNETIC NORTH
28½°
APPROXIMATE MEAN DECLINATION, 1961

EXPLANATION

Qag
Alluvium and glacial gravels

QUATERNARY

Td
Diabase dikes

TERTIARY(?)

KJn
Ore
Mainly magnetite, pyrite, and chalcopyrite

KJg
Granodiorite
Includes some diorite

KJp
Porphyry dikes, undifferentiated

KJd
Diorite and gabbro
Includes some pyroxenite, monzonite, and granodiorite

Upper Jurassic or Lower Cretaceous(?)

KJdu
Mafic rocks, undifferentiated

KJu
Diorite, granodiorite, and gabbro, undifferentiated

JURASSIC OR CRETACEOUS(?)

JŦg
Greenstone
Includes some metamorphosed sedimentary rocks

TRIASSIC OR JURASSIC(?)

palm
Marble

pals
Metamorphosed clastic sedimentary rocks
Includes siltstone, quartzite, graywacke, and conglomerate

palu
Greenstone and metamorphosed clastic sedimentary rocks, undifferentiated

PALEOZOIC(?)

50
Contact, showing dip
Dashed where approximately located; short dashes where inferred

70
Fault, approximately located, showing dip

45
Strike and dip of beds

50
Strike and dip of planar flow structure in igneous rocks

×
Mine or prospect

Areas mapped in detail 1942-44

ORANGE HILL, NABESNA DISTRICT, ALASKA
COPPER PORPHYRY

Location

Orange Hill is a rounded isolated knob on the east side of the Nabesna River near the end of the Nabesna Glacier.

History

Many claims, predominantly for copper, were staked as early as 1899 by prospectors attracted to the area because of the iron stained rocks from which the hill derived its name. Van Alstine, of the U.S. Geological Survey, investigated the area in 1942 and R. F. Black in 1944.

Prior to 1970 the Alaska Nabesna Corporation completed an extensive diamond drilling program. In 1970 and 1971 the American Exploration Co. drilled a large low grade copper deposit at Orange Hill. Other companies including Alvenco of Anchorage were also active.

In 1971 Wallace McGregor of Salt Lake City, Utah was active with a crew of geologists and Orange Hill was mapped in detail.

Geology

Orange Hill is part of a mass of quartz diorite of probable Jurassic age intruded into the group of bedded Permian rocks that includes basic lava flows, graywacke and a thick deposit of limestone. The limestone contains associated dikes and sills.

Ore Minerals

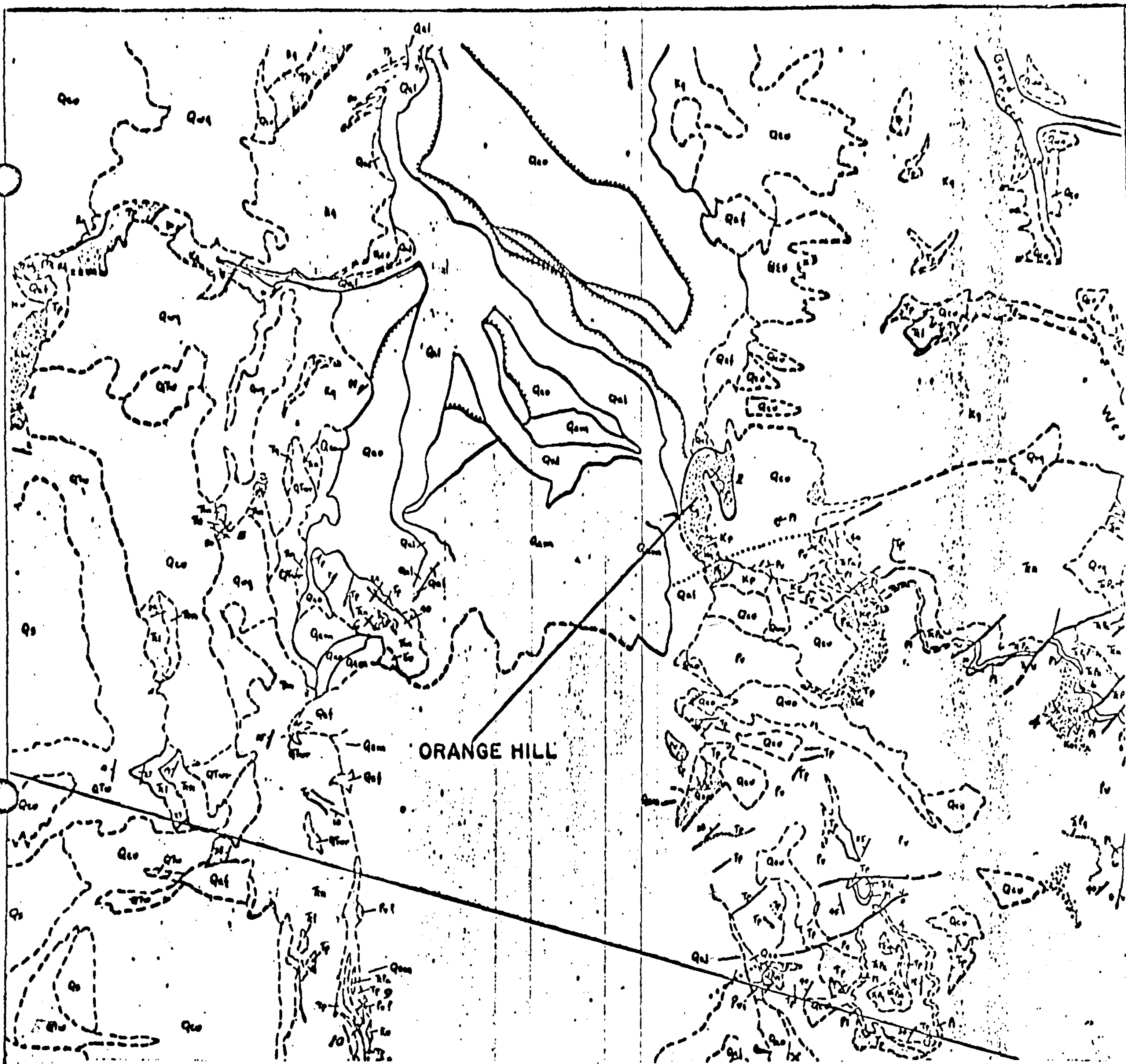
The predominant sulfide minerals include bornite, chalcopyrite, molybdenite, and sphalerite.

Reserves

The results of the diamond drilling completed by various companies is considered proprietary information and is not generally available. However, the reserves are considered to be of large magnitude (several hundred million tons of ore that ranges from .3 to .5 percent copper). There is also the possibility of molybdenum production from this area.

Future of the Prospect

Copper sulfides are widely and uniformly distributed throughout a great mass of rock. Development will be dependent on the discovery of enough high grade ore to give an initial stimulus to allow building mining and milling facilities. An increase in the price of copper or demand for additional copper could also make the prospect commercially feasible.



RECONNAISANCE GEOLOGIC MAP OF PART OF THE NABESNA A-4 QUADRANGLE

(ORANGE HILL AREA)

Scale 1:63360

0 1 2 3 Miles

N

Geology by D.H. Richter

EXPLANATION

U / D

Contact
Dashed where approximately inferred

Fault
Dashed where approx., dotted where concealed

Terrace Scarp
Hachures point Downslope

Anticline

Syncline

Strike & Dip

5 — vertical

Horizontal

Altered Rocks
Limonite Staining and hydrothermal alteration

Qal, Qaf	Younger Alluvium
Qao	Older Alluvium
Qam	Alaskan Glaciation Drift
Qwg, Qwo, Qam	Colluvial Deposits
Qtw	Wrangel Lava
Kbv	Bonanza Creek Volcanics
TRl	Limestone
TRn	Nikolai Greenstone
TRPa	Argillite
Pl	Limestone
Pv	Volcanic & Volcaniclastic Rocks
Tp	Hornblende - Plagioclase Porphyry
TRPg	Gabbro
Kg	Nabesna Batholith
Kgg	Grafite Granodiorite

C O A L

The principal coal fields in Alaska are included in five major regions: (1) the northern Alaska region which includes extensive but little known and undeveloped coal fields in the Arctic slope north of the Brooks Range; (2) the central Alaska region which includes the Nenana coal field, the only coal field being exploited at the present date, and minor occurrences of coal-bearing rocks on the Seward Peninsula and in the Yukon and Kobuk River basins; (3) the Cook Inlet-Susitna region including the Kenai, Susitna, Matanuska and Broad Pass coal fields; (4) the Alaskan Peninsula region, including Herendeen Bay, Unga Island and Chignik coal fields; and (5) the southeastern Alaska region, including the Bering River coal field and several minor coal localities to the southeast of the mainland and on several islands south of Juneau (See map showing coal field locations).

NORTHERN ALASKA REGION

Coal-bearing rocks of late Cretaceous age underlie an estimated 27,000 square miles north of the Brooks Range in an area extending along the foot of the mountains from Cape Lisburne eastward to the longitude of the lower Colville River, and northward to the Arctic Coast at Peard Bay. Structural folding of these beds has been moderate, decreasing in intensity to the north.

East of Cape Lisburne in the Corwin district there are at least 20 beds of bituminous coal from 2 1/2 to 9 feet in thickness exposed in the coastal bluffs. Some 37 coal beds 2 to 10 feet thick are exposed along the lower 25 miles of the Kukpowruk River. These beds range from 2 to 10 feet in thickness and are of bituminous rank.

Other coal beds 2 to 10 feet in thickness occur along the middle courses of the Kokolik and Utukok rivers. Coal beds also crop out along the Colville River and its principal tributaries and along the Arctic Coast. Although the coal outcrops are limited to stream valleys and exposures along the coast, it has been assumed that the observed beds underlie much of the intervening areas and the reserves of bituminous and subbituminous coals are very large. (Latest estimates are 120 billion tons).

CENTRAL ALASKA REGION

Kobuk River: Coal (of probable Late Cretaceous age) has been found in the following areas:

1. Along the Kobuk River and eastward to the headwaters of the Koyukuk River.
2. On the north side of the Kobuk between Trinity Creek and the Kallarichuk River (several thin coal beds are exposed in the river bluffs including several 2 to 3 feet thick).
3. On the Hunt River.
4. Lower Ambler River.

5. Kogoluktuk River.
6. In the Lockwood Hills near the Pah River. Farther east in this same belt, 9 to 10 feet of clean coal occurs on the middle fork of the Koyukuk River.

Nearly all the coal in the Kobuk River area is bituminous in rank.

Seward Peninsula: The only significant coal deposits are on the Kugruk River, about 15 miles west of Candle. Along the river 18 feet of lignite in three seams separated by several inches of clay has been reported. These probable Late Cretaceous coal beds dip nearly 70°. One bed on Chicago Creek dips 55° and is reported to be at least 85 feet thick. A drill hole half a mile northwest of the coal outcrop penetrated the top of the coal at 7 feet indicating the possibility of stripping part of the area.

Unalakleet District: Lignite coal has been reported at two localities near Unalakleet. A small amount of coal was mined from the shore of Norton Sound. This field is about 16 square miles in area in a shallow Tertiary structural basin in which dips around the border range from 5 to 10° (includes 30 coal beds ranging from 1 foot to 7 feet in thickness). The coal is subbituminous in rank and relatively high is ash.

Cook Inlet-Susitna Region: This region includes the Broad Pass, Susitna, Matanuska and Kenai coal fields, all of which are Tertiary in age. The Broad Pass, Susitna and Kenai fields contain subbituminous and lignite coals; the Matanuska field coals are predominantly bituminous with minor subbituminous and anthracite ranked coals.

Broad Pass Coal Field: Located just south of the divide of the Alaska Range on the headwaters of the Chulitna River. There are only two known areas of coal-bearing rocks; seven square miles on Costello Creek and 1 1/2 square miles near Broad Pass. However, the total area underlain by these coal-bearing rocks is probably much larger.

Matanuska Coal Fields: The Matanuska Coal Field occupies much of the Matanuska Valley and includes several beds of coal in a belt extending from a point near the head of the Valley westward to the Susitna River Valley. All the coal occurs in sediments of Tertiary age. The area is broken down into several districts further defined as the western part and the eastern part with a graduation in coal rank from subbituminous in the west to a small area of anthracite in the east. The western part consists of the Little Susitna and the Wishbone Hill districts. The Little Susitna district is between the Little Susitna River and the southern front of the Talkeetna Mountains. The only coal mined from this district has been from a strip mine near Houston.

The Wishbone Hill district is about 10 miles northeast of Palmer. Coal underlies an area of about 15 square miles occuring in a northeastward trending syncline with moderately dipping limbs. The early Tertiary age coal is bituminous in rank and ranges from a few inches to 23 feet in thickness.

To the east the Chickaloon coal district includes an area of about 12 square miles. The structure is dominantly synclinal with belts of tight folding locally superimposed on the syncline. The coal is low-volatile bituminous in rank and occurs in lenticular beds ranging from a few inches to 14 feet or more in thickness.

The Anthracite Ridge district is about 12 miles east of Chickaloon. The district is about 30 square miles in area and extends from the south slope of Anthracite Ridge southward to the Matanuska River. The structure of most of the district is characterized by broad open folds but around the front of Anthracite Ridge the beds have been compressed into tight folds with complex high-angle faulting. The coals range in rank from anthracite in the deformed western part to bituminous in the southern part. The coal beds range in thickness from a few inches to 34 feet, but all tend to pinch out rapidly in lateral directions.

Susitna Coal Field: The Susitna Coal Field is located north of Cook Inlet between the Talkeetna Mountains on the east and the Alaska Range on the north and west. Much of the coal-bearing rocks are covered but their exposure, distribution, and attitudes suggest that they underlie an area of about 5000 square miles. However, nearly all the potential reserves lie within a 400 square mile area in the basins of the Beluga and Chuitna Rivers.

A large number of coal beds of subbituminous and lignite rank ranging from 2 feet to more than 50 feet in thickness are in the Beluga-Chuitna area. The attached geologic map and cross-sections demonstrate the distribution of the coal beds. A considerable amount of this coal could be mined by stripping.

Kenai Coal Field: The Kenai Coal Field is on the east side of the Kenai Peninsula, on the lowland between the Kenai Mountains and Cook Inlet. The area is broken down into two districts: the Kenai district is overlain by several hundred feet of surficial deposits and although the coal-bearing beds are present, it probably will not be economically feasible to attempt to mine the coal. The Homer district is 1100 square miles in area and includes a thick sequence of Tertiary coal-bearing sediments in the area of Kachemak Bay and along the shores of the Cook Inlet. The rocks are in a broad structural basin modified by high angle faulting. In this area there are 30 or more coal beds ranging from 3 to 7 feet in thickness. The coal ranges in rank from lignite to subbituminous B, but the greater part is subbituminous C. Only a few thousand tons of coal have been produced from this area.

ALASKA PENINSULA REGION

Coal is present in three areas:

1. Herendeen Bay Coal Field: Coal occurs in the Late Cretaceous and underlies at least 40 square miles of the Alaska Peninsula between Herendeen Bay and Port Moller. The beds are moderately folded and cut by small faults. The coal is bituminous in rank and occurs in closely spaced beds ranging from a few inches to 7 feet in thickness.

The extent of these beds is not known and no reliable estimates of coal reserves are available.

2. Unga Island Coal Field: About 40 square miles are underlain by coal-bearing rocks of Tertiary age on the northwest part of Unga Island. The maximum thickness of one bed approached 4 feet but most are only a few inches thick. The dips of coal-bearing beds range from 8° to 10°.

3. Chignik Coal Field (Alaskan Peninsula): The Chignik coal field is on the west shore of Chignik Bay about 250 miles southwest of Kodiak.

The age of the coal-bearing rock is Late Cretaceous. The coal is confined to a belt about 25 miles long and 1 to 3 miles wide. The coal is bituminous in rank and the beds range from 1 to 5 feet in thickness. The structure is thought to be moderate with dips of 21° to 34°.

SOUTHEASTERN ALASKA REGION

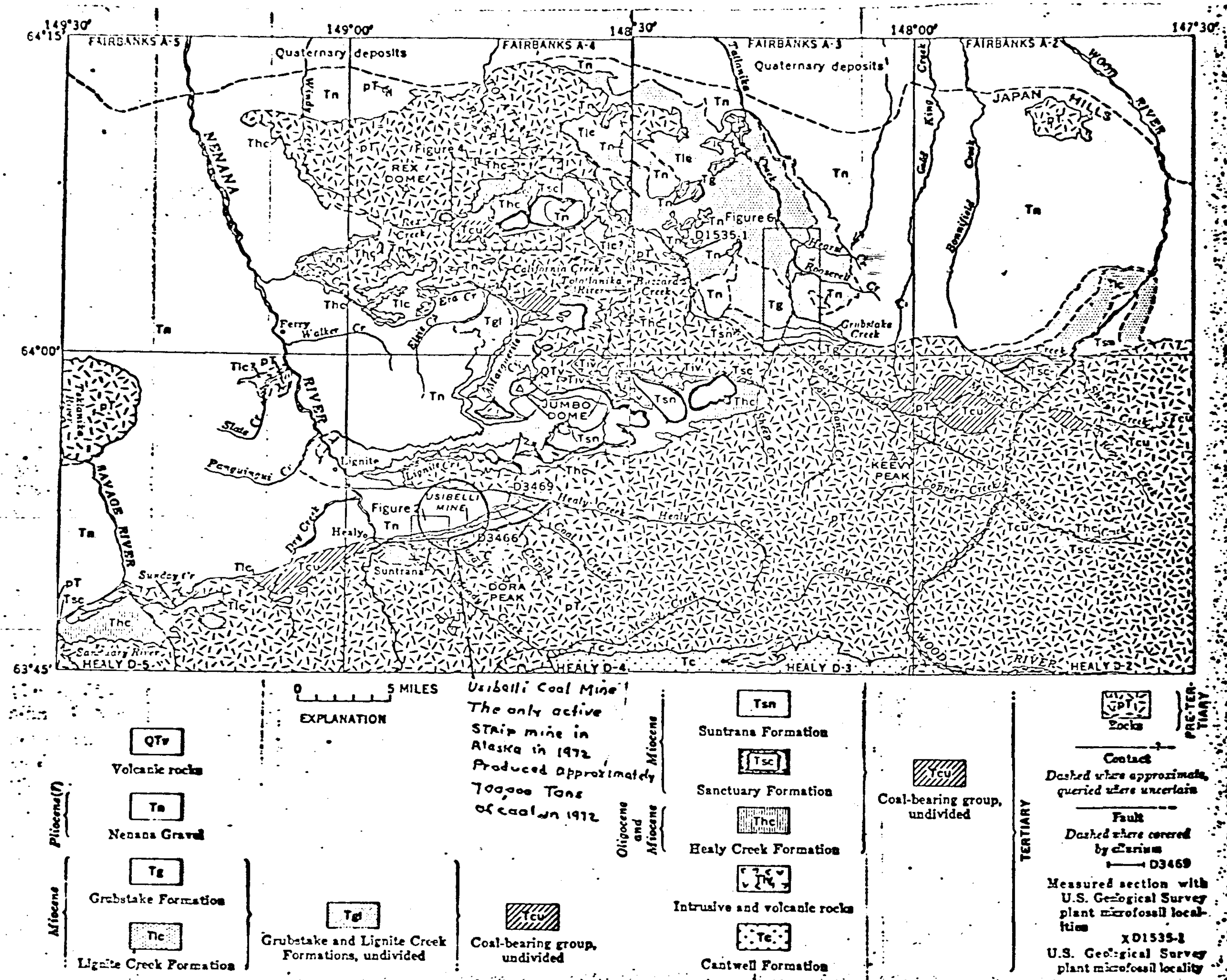
The southeastern Alaska region includes a narrow coastal belt extending from Cordova eastward to Yakutat Bay as well as southeastern Alaska. There are two areas of interest:

1. Bering River Coal Field: Coal-bearing rocks of Early Tertiary age have been mapped in a more or less continous belt (about 50 square miles) northeastward from the east shore of Bering Lake. The structure is complex with tight folds and numerous faults. The coal ranges in rank from low-volatile bituminous to anthracite in the eastern part. Thickness ranges from a few inches to 60 feet, but much of the coal is strongly crushed and sheared. No reliable estimate of reserves can be given because of complex structure and lack of continuity of the beds.

KOOTZNAHOO INLET

Tertiary beds that locally contain coal underlie about 20 square miles on the north and south side of Kootznahoo Inlet on the west side of Admiralty Island. The bituminous beds are 2 to 3 feet thick but contain shale partings.

The estimated original coal resources in Alaska and analyses showing range in composition and heating volumes for selected coals are attached.



Generalized Geologic Map of the Healy Coal District, Alaska

TABLE 4a.—*Analyses showing range in composition and heating value on as-received-basis of some Alaskan coals*

Region, field, and district	Source of samples	Rank of coal	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	B.t.u.
Central Alaska Region:								
Nenana coal field	Mine	Subbituminous	17.8-27.1	33.2-42.0	27.1-35.3	3.6-13.2	0.1-0.3	7,670- 9,430
	Outcrop	do	11.7-32.7	31.2-42.9	22.7-30.0	3.3-15.9	.1-.4	6,320-10,385
Jarvis Creek coal field	Outcrop, 4 samples	Subbituminous C	20.0-23.0	35.1-43.4	24.1-35.3	8.2-13.1	.3-1.4	7,815- 9,415
Cook Inlet-Susitna Region:								
Broad Pass coal field:								
Costello Creek area	Mine	Subbituminous	11.0-18.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	do	do	8.7-18.9	31.3-43.4	23.2-41.4	7.6-21.[illegible]	.3-[illegible]	7,955-10,115
Broad Pass area	Tunnel and trench, 5 samples.	Lignite	21.8-35.8	27.8-34.5	20.7-28.3	10.6-21.0	.2-.3	5,410- 7,040
Matanuska coal field:								
Little Susitna district	Mine	Subbituminous	14.1-20.3	31.3-32.5	34.1-38.9	9.2-20.5	.4	8,400- 9,210
Wishbone Hill district:								
Western part	do	High volatile	3.2- 8.6	31.6-44.6	41.0-51.0	4.4-20.3	.2-1.0	10,390-13,190
Eastern part	do	Bituminous	2.7- 7.0	33.7-42.0	38.4-48.0	5.5-21.7	.2-.8	10,390-13,030
Chickaloon district:								
Chickaloon area	Tunnel, 20 samples	Low volatile	1.2- 3.5	16.2-20.8	60.0-72.2	8.0-19.5	.5-.7	11,960-13,750
Coal Creek area	Tunnel, 9 samples	Bituminous	1.1- 4.1	13.8-22.9	59.1-70.5	5.8-18.4	.4-.8	12,180-14,350
Anthracite Ridge district:								
Northern part	Outcrop and drill core, 18 samples.	Semianthracite to anthracite.	2.2- 8.7	6.6-31.5	47.4-80.6	3.8-19.7	.2-.7	10,800-14,130
Southern part	Outcrop and drill core, 5 samples.	Bituminous	1.9- 6.8	14.2-29.9	54.1-78.4	2.4-11.3	.5-.7	11,510-14,210
Susitna coal field:								
Beluga-Chuitna area	Outcrop samples	Subbituminous and lignite.	10.7-33.1	32.9-37.7	25.5-40.6	2.0-14.2	.1-.3	7,200-9,490
	Drill core, 28 samples	do	11.9-18.6	20.8-37.9	29.4-31.6	13.3-24.6	(?)	7,200-8,890
	Trench, 1 sample	do	24.4	30.1	28.7	16.8	.2	7,160
Kenai coal field:								
Homer district	Outcrop, 16 samples	Lignite to subbituminous B, mostly subbituminous C.	21.2-30.4	31.2-41.3	24.1-33.7	3.2-22.6	.1-.4	6,650-8,660
Cooper bed	Mine, 4 samples		10.5-22.4	30.3-37.7	31.1-41.1	8.4-12.1	.3-.4	8,340-9,020
Alaska Peninsula Region:								
Herendeen Bay coal field	Tunnel, 2 samples	Bituminous	7.5- 8.0	32.1-33.5	48.8-51.4	7.1-11.6	.3-.4	11,200-11,770
	Outcrop, 9 samples	do	4.2- 6.7	35.2-38.6	47.2-53.0	5.0-12.0	.4-.6	11,150-12,420
Unga Island coal field	Outcrop	Lignite [1]						
Chignik coal field	Tunnel and outcrop, 4 samples.	Bituminous	5.0-10.8	27.2-34.3	39.6-45.4	14.9-25.3	.7-2.3	9,640-11,240
Southeastern Alaska Region: Bering River coal field	Tunnel and outcrop	Low-volatile bituminous to semianthracite and anthracite.	1.0-12.9	5.0-17.5	47.1-84.7	1.7-25.4	.3-5.2	9,070-15,020

[1] Low heat value, high ash content in only available analysis.

TABLE 4(b).—*Estimated original coal resources in Alaska*

SUBBITUMINOUS COAL AND LIGNITE

[In millions of short tons]

Coalfield and district	Overburden (feet)	Measured resources: Bed thickness (feet) 2½–5	5–10	>10	Total measured	Indicated resources: Bed thickness (feet) 2½–5	5–10	>10	Total indicated	Inferred resources: Bed thickness (feet) 2½–5	5–10	>10	Total inferred	Total resources: Bed thickness (feet) 2½–5	5–10	>10	Total all categories
Nenana coal field																	
Rex Creek	0–1,000						0.6		0.6	23.0	79.8	10.7	113.5	23.0	80.3	10.7	123.0
Tatlanika Creek	0–1,000						4.0	113.4	117.4	31.2	8.0	37.0	77.1	31.2	12.0	150.4	194.5
	1,000–2,000										2.4	74.0	76.4		2.4	74.0	76.4
Wood River	0–1,000		15.0		15.0		12.0		12.0		201.0	40.0	241.0		228.0	40.0	268.0
	1,000–2,000						15.0		15.0						15.0		15.0
	2,000–3,000						18.0		18.0						18.0		18.0
California Creek	0–1,000		4.0	2.0	6.0		27.0	206.6	233.6	12.3	50.6	317.0	379.9	12.3	81.6	525.6	619.5
	1,000–2,000						1.0	6.0	7.0		11.0	121.0	132.0		12.0	127.0	139.0
Lignite Creek	0–1,000		16.0	250.6	266.6		93.0	1,326.0	1,419.0	29.0	279.3	1,043.0	1,351.3	29.0	388.3	2,619.6	3,036.9
	1,000–2,000						7.0	458.0	465.0	3.0	52.0	226.0	281.0	3.0	59.0	684.0	746.0
	2,000–3,000											327.0	327.0			327.0	327.0
Healy Creek	0–1,000			300.0	300.0		1.0	93.5	94.5		27.0	114.2	141.2		28.0	507.7	535.7
	1,000–2,000			274.0	274.0		1.0	63.0	64.0		21.0	112.4	133.4		22.0	449.4	471.4
	2,000–3,000							245.0	245.0		23.0	87.8	110.8		23.0	332.8	355.8
Savage River	0–1,000										12.0		12.0		12.0		12.0
Total field	0–1,000		35.0	552.6	587.6		146.5	1,739.5	1,886.0	95.5	658.6	1,561.9	2,316.0	95.5	840.8	3,854.0	4,789.6
	1,000–2,000			274.0	274.0		24.0	527.0	551.0	3.0	86.4	533.4	622.8	3.0	110.4	1,331.4	1,447.8
	2,000–3,000						18.0	245.0	263.0		23.0	414.8	437.8		41.0	659.8	700.8
	0–3,000		35.0	826.6	861.6		188.5	2,511.5	2,700.0	98.5	768.0	2,510.1	3,376.6	98.5	991.7	5,848.2	6,938.2
[illegible]	0–1,000					0.8	5.1		5.9	45.0			45.0	45.8	5.1		50.9
	1,000–2,000									25.6			25.6	25.6			25.6
Jarvis Creek coal field	0–2,000					.8	5.1		5.9	70.6			70.6	71.4	5.1		76.5

TABLE 4(b).—*Estimated original coal resources in Alaska*—Continued

SUBBITUMINOUS COAL AND LIGNITE

[In millions of short tons]

Coalfield and district	Overburden (feet)	Measured resources: Bed thickness (feet) 2½–5	5–10	>10	Total measured	Indicated resources: Bed thickness (feet) 2½–5	5–10	>10	Total indicated	Inferred resources: Bed thickness (feet) 2½–5	5–10	>10	Total inferred	Total resources: Bed thickness (feet) 2½–5	5–10	>10	Total all categories
Broad Pass coal field																	
Broad Pass	0–1,000						.3		.3		63.3		63.3		63.6		63.6
Costello Creek	0.1,000					.3			.3					.3			.3
Total field						.3	.3		.6		63.3		63.3	.3	63.6		63.9
Susitna coal field	0–1,000					60.6	98.6	2,235.5	2,394.7					60.6	98.6	2,235.5	2,394.7
Kenai coal field																	
Homer district	0–1,000					245.4	54.6		300.0					245.4	54.6		300.0
Total subbituminous coal and lignite	0–1,000		35.0	552.6	587.6	307.1	305.1	3,975.0	4,587.2	140.5	721.9	1,561.9	2,424.3	447.6	1,062.0	6,089.5	7,599.1
	1,000–2,000			274.0	274.0		24.0	527.0	551.0	28.6	86.4	533.4	648.4	28.6	110.4	1,334.4	1,473.4
	2,000–3,000						18.0	245.0	263.0		23.0	414.8	437.8		41.0	659.8	700.8
	0–3,000		35.0	826.6	861.6	307.1	347.1	4,747.0	5,401.2	169.1	831.3	2,510.1	3,510.5	476.2	1,213.4	8,083.7	9,773.3

BITUMINOUS COAL

Coal field and district	Overburden (feet)	Measured resources: Bed thickness (inches) 24–28	28–42	>42	Total measured	Indicated resources: Bed thickness (inches) 24–28	28–42	>42	Total indicated	Inferred resources: Bed thickness (inches) 24–28	28–42	>42	Total inferred	Total resources: Bed thickness (inches) 24–28	28–42	>42	Total all categories
Matanuska coal field																	
Wishbone Hill	0–2,000	0.1	0.7	5.8	6.6	1.2	9.5	41.0	51.7		10.0	43.7	53.7	1.3	20.2	90.5	112.0
Chickaloon	0–2,000							.7	.7			24.3	24.3			25.0	25.0
Total, bituminous coal		.1	.7	5.8	6.6	1.2	9.5	41.7	52.4		10.0	68.0	78.0	1.3	20.2	115.5	137.0
State totals					868.2				5,453.6				3,588.5				9,910.3

COAL RESERVES, BELUGA AND CHUITNA RIVERS AND CAPPS GLACIER AREAS, ALASKA

INTRODUCTION

This report outlines the major known coal resources of the Beluga and Chuitna River drainages and the area south of Capps Glacier, Alaska. This area has previously been mapped (Barnes, 1966) as a part of the Beluga-Yentna region. The area covered by the present investigation is about 468 square miles in extent and is defined as the area between Beluga River and Nikolai Creek, bounded on the north by Beluga Lake and on the south by the northwest shoreline of Cook Inlet. The mouth of the Beluga River at the south end of the area under investigation is approximately 50 airmiles due west of Anchorage, Alaska.

This report was written to aid in the appraisal of the coal resources of this area. The size of the area under study was deliberately limited to include the largest reserves and those that could be most easily recovered and transported.

Previous investigations include Atwood (1909, p. 117-121) who in 1906 examined and measured sections of coal-bearing rocks on the beach near Tyonek and on the Beluga River. In 1927 Capps traversed from the coast south of Tyonek northwestward to Chakachamna Lake and mapped an area of Kenai formation on the headwaters of Straight Creek.

In 1959-1961 the U.S. Bureau of Mines examined a small area of T15N., R12W., using a diamond drill to determine the quality and extent of a coal bed more than 50 feet thick exposed on the west bank of Drill Creek (Warfield, 1963). Field investigations of coal deposits in the Beluga and Chuitna River basins were made by geologists of the U.S. Steel Corporation in 1961 and 1962. The Utah Construction and Mining Co. examined the same areas with the aid of a portable drill in 1962 and 1963.

The most comprehensive geologic study was completed by Barnes (1966) who did the field work during the summers of 1961 and 1962 preceded by reconaissance trips in 1949, 1953 and 1954. Barnes (1967) estimated that the reserves of the Susitna area approach 2.395 billion short tons of subbituminous and lignite coals mostly confined to a 400 square mile area in the Beluga-Chuitna River drainage areas.

GEOLOGY

GENERAL STRATIGRAPHY

Tertiary age rocks

The uppermost bedrock unit exposed in the Beluga-Chuitna area is a sequence of interbedded claystone, siltstone, sandstone and conglomerate that includes beds of subbituminous coal and lignite. This sequence is considered to be a continuation of the Tertiary Kenai formation exposed on the west side of the Kenai Peninsula. Barnes (1966) further separates the Kenai formation in the Beluga-Chuitna area into a lower and middle member. The lower member is a non-marine sequence of light gray to light yellow pebbly sandstones and conglomerates that contain little or no coal. The middle member overlies this member conformably as seen from exposures on several of the east-flowing headwater tributaries of the Chuitna River. The Middle Kenai is a sequence of non-marine gray and light yellow claystone, siltstone, sandstone and conglomerate. Calcareous cemented beds of siltstone are locally common. The Middle Kenai member contains nearly all the coal reserves with numerous beds of subbituminous coal and lignite with several beds exceeding 50 feet in thickness. Barnes (1966) felt that the Kenai formation is widespread under the Quaternary cover because of the prevalence and continuity of outcrops. For this reason the coal beds probably continue laterally for greater distances than postulated in the reserve calculations and reserve figures are considered very conservative.

Direct correlations between the coal-bearing Middle Kenai formation in the Beluga-Chuitna area and the Kenai formation in drilled wells in the Cook Inlet have not been made. However, based on the occurrence of thick coals in the upper part of the Tyonek formation, a logical correlation would indicate that the Middle Kenai coal-bearing beds of the Beluga-Chuitna area are equivalent to the upper part of the Tyonek formation where thick coals are seen in drilled wells throughout the Cook Inlet Basin.

Quaternary rocks

Much of the surface cover in the Beluga-Chuitna-Capps Glacier areas is glacial deposits, both morainal and outwash. Other Quaternary deposits include talus and landslide masses. The maximum thickness of Quaternary deposits is about 300 feet along the Beluga and Chuitna Rivers. Recent deposits are limited to alluvial deposits along present stream systems.

Pyroclastic deposits

South of Capps Glacier an area of about 17 square miles is covered with volcanic breccia and tuff considered to be at least in part of Tertiary age (Barnes, 1966).

Intrusive rocks

The only known occurrence of an intrusive rock mass in the area under study is the Lone Ridge granite, probably of Middle Jurassic age (Grantz and others, 1963, p. 56-59).

STRUCTURE

Structural details are visible only in those areas along the Beluga and Chuitna Rivers, south and southeast of Capps Glacier, and along Drill Creek east of Beluga Lake. Most of the area studied is covered with thin Quaternary sediments.

Castle Mountain Fault

Evidence for the Castle Mountain fault is seen in the steep dips and sheared beds on the Chuitna and Beluga Rivers and further supported by the presence of Middle Kenai sediments against older Lower Kenai sediments. This fault zone is probably the southwest continuation of the Castle Mountain fault mapped by Barnes and Payne (1956) along the north side of the Matanuska Valley.

Section II', drawn at approximately right angles to the bed strike along the Beluga River demonstrates the Castle Mountain fault zone and field mapped faults near the axial plane of the postulated anticline and near location 132 on the base geologic map. Steep dips are associated with both these faults. Minor faulting has also been mapped along the Chuitna drainage in section 23, T12N, R12E.

Folding

There is a simple anticlinal structure about 6 miles above the mouth of the Chuitna River. This structure has a gently dipping east limb and a moderately steep dipping west limb. The axial trend is about N15°E.

The Beluga River is crossed by an easterly plunging gentle syncline in sections 33 and 34, T14N, R11W. An anticlinal structure is suggested south of the syncline by sparse dips and structural cross-section 11' has been drawn to include this feature. Barnes (1966) has suggested that faulting may be responsible for this dip pattern. Folding and faulting may be related to splay patterns developed from the Castle Mountain fault.

Dips are generally very gentle other than when related to faulting. This is especially true along the Chuitna River drainage and this area is most favorable for commercial strip mining of the coal deposits.

SUMMARY AND CONCLUSIONS

Cross-sections were constructed in the Chuitna, Beluga and Capps Glacier areas to demonstrate the low structural relief. Measured coal sections were integrated into these cross-sections and the cumulative coal thicknesses were used in the reserve calculations.

Section II' along the Beluga River at right angles to the strike indicates that structural problems would be encountered along the Beluga River, but in general structural relief is low with most of the dips under 15 degrees. Maximum thickness of Quaternary overburden is about 300 feet and the ratio of overburden to coal thickness is favorable.

Evaluation of the reserves away from the outcrop areas will require additional core hole information.

ECONOMIC CONSIDERATIONS

Physical aspects of the coal

The coal is classified as subbituminous to lignite and is dull black, locally with a slight brownish tinge and includes a few thin layers and lenses of bright vitrain. The moisture content is high, 21-33 percent and ash content is generally high ranging from 2.1 to 22.2 percent. Sulfur content is low, generally .2-.3 percent and heating values average 10,500 BTU for a composite average of 47 samples (Barnes, 1966).

Reserve calculations and parameters

Reserve calculations have been made using the limiting parameters established by the U.S. Geological Survey as follow: "In computing the reserves the area underlain by a flat or gently dipping coal bed was determined by assuming that an outcrop establishes continuity for half a mile in all directions except where the bed is known to be terminated at a shorter distance by thinning, faulting or erosion."

The Chuitna, Beluga and Capps coal beds because of their thickness and outcrop continuity have more lateral continuity and it was assumed that each bed extends back from the outcrop for a distance equal to half the known outcrop length. Areas with structural complications and coal beds that project below the 1000 foot overburden limit were not included in the reserve calculations. Coal beds less than 1 foot thick were not included in the cumulative reserves.

Reserve calculations in this report are limited to three areas (Beluga River, Chuitna River, and Capps Glacier) where outcrop control is sufficient to indicate potentially commercial coal production. There is, in addition to the above areas, a small coal body along Drill Creek, section 10, 11, 14 and 15, T15N., R12W., which was diamond drilled by the U.S. Bureau of Mines in 1959-1961, blocking out approximately 20 million tons of coal reserves.

For comparative purposes one ton of coal is considered equivalent to 4 barrels of oil. This ratio is based on the type of coal, BTU content, and the amount of moisture and ash contained in the coal.

COAL RESERVES (in short tons)

Capps Glacier Area	550,000,000 short tons
Beluga River Area	150,000,000 short tons
Chuitna River Area	1,560,000,000 short tons
TOTAL	2.26 billion short tons

OIL AND GAS

Oil and gas seeps are present near the Arctic coast, on the Alaska Peninsula, and in the vicinity of the Gulf coast of Alaska.

Oil was first produced in 1902, when the small Katalla field was located in the midst of a seepage area, but no important production was obtained until the discovery of the Swanson River oil field in 1957 and the Kenai gas field in 1959. Presently there are 5 oil fields and 4 gas fields producing in the upper Cook Inlet province, with a cumulative production through 1971 of 400 million barrels of oil and about 850 billion cubic feet of natural gas.

The only other production in the state at this time is from the small South Barrow gas field, which supplies gas for the town of Pt. Barrow, and from one well at Prudhoe Bay, which supplies fuel for local use there.

The enormous oil and gas reserves in the Prudhoe Bay field area, discovered in 1968, are still at least 3 years from production due to delays in pipeline construction.

In addition to the proven reserves listed above, there are a number of sedimentary provinces within the state that are favorable for oil and gas exploration, and these areas are briefly described in the following text. A map outlining the most prospective provinces also accompanies this report (Figure 14).

NORTHERN ALASKA

The Arctic Slope province consists of about 100,000 square miles lying between the southern Brooks Range and the Arctic Ocean. Most of this area can be considered prospective for oil and gas.

The oldest rocks are metasediments and volcanics of pre-Cambrian through Ordovician age that are exposed in the eastern Brooks Range. Overlying these are limes, dolomites, sands, conglomerates and shales ranging from Silurian through Devonian age. Some of the limestones have considerable porosity. The Mississippian-Pensylvanian Lisburne Group, mainly lime, dolomite, and chert up to 5000 feet thick, makes up a major portion of the Brooks Range from east to west and extends in the subsurface at least to the Arctic Ocean. This unit is commonly petroliferous, and forms a commercial oil and gas reservoir at Prudhoe Bay.

The Southern Foothills province is a severely faulted and folded band 10 to 40 miles wide in front of the Brooks Range, underlain by marine Permo-Triassic shales and cherts, some of which grade eastward into sandstone, overlain by Jurassic and early Cretaceous graywacke and mudstone. With the exception of local oil shales and some asphaltic matter, these beds are poorly prospective. The Permo-Triassic sandstones become highly porous to the north, and contain the bulk of the giant Prudhoe Bay oil reserves.

The Northern Foothills province is 30 to 80 miles wide across most of the Slope, and is characterized by broad open folding. This province is underlain by middle to late Cretaceous sand, conglomerate, and shale with minor volcanics and coal, from 6,000 to 20,000 feet thick. These beds are mainly non-marine in the south, grading northward to marine beds. Generally porosities are low, but local strand deposits have resulted in oil and gas reservoirs at Umiat, Gubik, East Umiat, Meade, and Square Lake. Shows of oil and gas occur in nearly all wells drilled in this province.

The Arctic Coastal Plain province, a vast lake-dotted tundra plain, stretches from the foothills to the Arctic Ocean. Most of the cover is unconsolidated Quaternary deposits, with a few low rolling hills underlain by Tertiary gravels. Structurally, the Plain is south-dipping monocline that rises and thins northward onto the Barrow arch and the Prudhoe Bay anticlinal trend. Over 20,000 feet of Paleozoic through Tertiary rocks are present at the south edge of the Plain, thinning to less than 3000 feet at Barrow and about 12,000 feet at Prudhoe Bay. Mississippian-Pennsylvanian Lisburne limes and Permo-Triassic sandstones produce oil and gas at Prudhoe Bay. Jurassic sandstone is the gas reservoir at South Barrow, and Cretaceous sands form the oil reservoirs at Kuparuk, Simpson, and Fish Creek. Sands of probably Tertiary age contain the vast reserves of heavy black oil of the West Sak-Kavearak Point field, west of Prudhoe Bay.

The Arctic coastal shelf, covering an area of 80,000 square miles of water shallower than 600 feet, may have an important potential for oil and gas in rocks ranging from Mississippian through Tertiary age.

The 37,000 square-mile Naval Petroleum Reserve 4 was set aside in 1923, and an extensive exploration program was carried out by the U.S. Navy from 1944 to 1953. This project resulted in the discovery of Umiat (70 million barrels), Simpson (12 million barrels), and Fish Creek oil fields; and Gubik (300 billion CF), South Barrow (7 billion CF), Meade and Square Lake gas fields.

Subsequent exploration by the oil industry has resulted in the discovery of Prudhoe Bay (15 billion barrels), Kuparuk (2 billion barrels), and West Sak (about 15 billion barrels of heavy oil). Gas discoveries include East Umiat, Kavik, and Fin Creek fields, all of undetermined reserves.

Productive reservoir rocks range from Mississippian to Tertiary in age. The bulk of the vast Prudhoe Bay reserves are in Permo-Triassic sandstone, with minor reserves in the Mississippian-Pennsylvanian Lisburne limestone section (see illustrations). Permo-Triassic sandstones contain the gas reserves at Kavik and Fin Creek. Nearly all the remaining reservoirs on the Arctic Slope are in Cretaceous sandstones, with the conspicuous exception of the West Sak heavy oil accumulation in sandstones of probably Tertiary age.

Large areas of the western and southern Slope are completely unexplored -- areas underlain by thousands of feet of prospective Paleozoic and Mesozoic rocks, and strewn with anticlinal structures. In the Arctic Wildlife Range, on the eastern Slope, lies the large Marsh Creek anticline with several thousand feet of marine Tertiary beds, including outcropping oil sands.

PRUDHOE BAY FIELD

After this discussion of the stratigraphy and structure of the Prudhoe Bay field as it relates to the surrounding areas, a more detailed description will now be given of the Prudhoe Bay field itself. Figure 7 shows in a diagrammatic way, and it must be emphasized that it is only diagrammatic, the form of the Prudhoe Bay field and the nature of the trapping mechanism. Throughout most of the field the beds dip to the south and southwest, and there is only a slight turn-over near the fault at the northern margin. Closure on the eastern side of the field is provided by the truncation of the Sadlerochit sand and its sealing under the impermeable cover of Cretaceous shales which have an easterly to northeasterly dip at the truncation. Figure 8 is an east-west cross section across the Colville and Prudhoe structures which illustrates the nature of the Prudhoe Bay trap. Although in the general discussion it was stated that the Upper Sequence has a northerly dip, in fact in this area there is also a distinct easterly component to the dip.

One feature of great interest and importance which can be readily observed from the map and the sections is that the oil could not possibly have been present in the Prudhoe Bay structure until after the unconformable seal had been laid down. We can say with certainty, therefore, the oil was not present in the Sadlerochit sand pool of the Prudhoe Field until later than the Barremian.

The question of the age of the oil is one of absorbing interest to petroleum geologists, and it may be a long time before this question can be answered with certainty. There are two main hypotheses concerning the age of the oil. The first is that the oil was generated within the sediments of the Lower Sequence and was spilled from traps deeper in the basin, after the Prudhoe Bay structure was sealed, by the pronounced southerly tilting of the northern flank of the Colville Basin during the Cretaceous period. The second hypothesis is that the oil is of Cretaceous age and migrated into the Triassic reservoir across the plane of unconformity. The sediments of both the Lower Sequence and the Cretaceous are both of types normally regarded as suitable source rocks and oil shows are also known in both sequences and, therefore, little can be proved by this approach.

RESERVOIR FLUIDS

A very brief account shall now be given of the fluids in the main Sadlerochit pool of the Prudhoe Bay field.

(1) Oil reserves in the main pool cannot be given at present. However, we do have the report given by DeGolyer and MacNaughton that in the BP leases alone the minimum reserves recoverable by primary means are 4.8 billion barrels. This is a conservative estimate, and it is safe to say that this is the largest oil pool in North America. Although the productive capacity of the field cannot be given at present, the results of tests of one well, the BP Put River No. 1 (27-11-14), will give some idea of the potential of the field. The 7-inch casing was selectively perforated from 8,700 feet to 9,000 feet through a 300-foot sand interval. Tubing and surface test equipment were installed, and the well was tested at various rates by flowing oil from the annulus between the 7-inch casing and the 2-7/8-inch tubing through a 3-inch surface choke. During a four-hour flow period the oil rate was estimated at 21,500 b/d at a flowing surface pressure of 775 psi. This was the maximum rate at which the well was tested.

(2) Figure 9 shows in tabular form the composition of the oil and of the dissolved gas. Some of the most significant features in this table are as follows. The reservoir temperature is 200°F which indicates a fairly high thermal gradient to the base of the permafrost of about 2.3°F/100 ft. The gravity of the oil is about 28° API, and there is some heavier oil at the base of the oil column. The sulphur is moderately low, 0.8-0.95 percent. There is a low wax content, low viscosity, and low pour point (25°F) which is a very fortunate feature of the oil in view of its production in the frozen north. A most interesting feature of the oil is the very low proportion of the lighter fractions of the oil in the range of C_3-C_6. The solution gas has an unusually high content of carbon dioxide.

(3) The formation water has a relatively low salinity of about 20,000 ppm total dissolved solids.

SUMMARY

A summary is given below of what appear to be the most important facts known at present which could have a bearing on the generation, migration, and trapping of the oil in the Prudhoe Bay field.

(1) The reservoir beds are on the north flank of the basin of deposition.

(2) The field is at the southerly limit of the northward downwarping toward the new Arctic Ocean basin.

(3) It is basically a stratigraphic trap, with a Triassic reservoir sealed by an unconformable cover of Lower Cretaceous shales.

(4) The trap was not filled with oil until after the Barremian times.

(5) There is a fairly high temperature gradient at the field.

(6) The formation-water salinity is low.

(7) There are various peculiarities in the oil composition, notably the low content of the lighter fractions.

(8) There is heavier oil at the base of the oil column.

That is a list of what appear to be the most important facts known at the present relating to the origin of the Prudhoe Bay Sadlerochit pool. The task facing the petroleum industry is to develop this enormous new asset of the United States without producing any adverse effect on the surface of the ground on this unspoilt northern frontier. We, in the petroleum industry, know we have the means and the will to accomplish this.

PAPER BY F. K. RICKWOOD, B.P. ALASKA
NORTH SLOPE SEMINAR
A.A.P.G. 1970

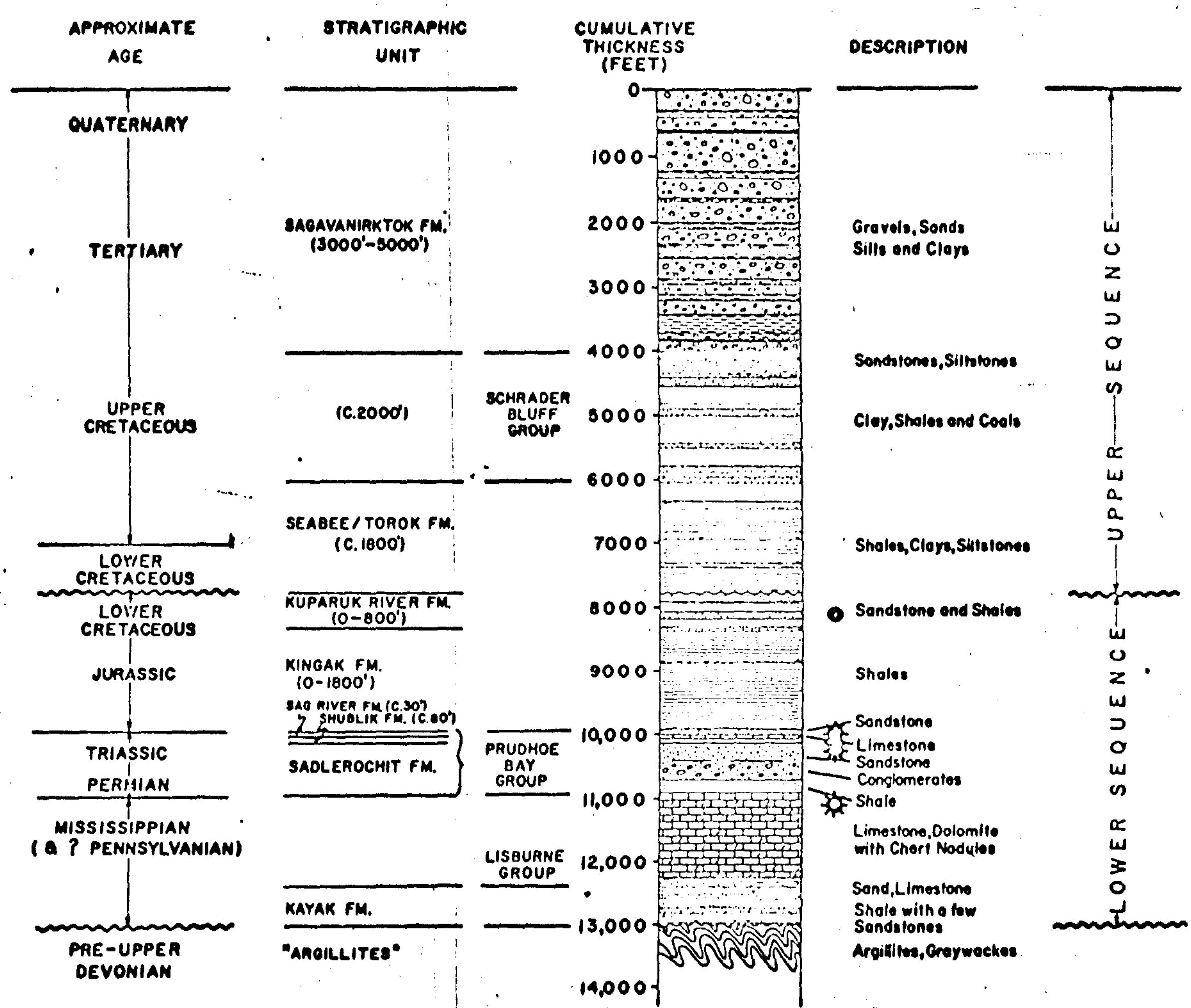


Figure 3 **Generalized stratigraphic column, Prudhoe Bay area**

SOUTHERN ALASKA

Alaska Peninsula - Cook Inlet Province

This province is located on the Matanuska Geosyncline -- a narrow belt of moderately deformed marine Mesozoic sedimentary rocks more than 900 miles long and from 5 to 50 miles wide, which extends from the Chitina Valley near Canada to the outer Alaska Peninsula. Oil and gas seeps have long been known from these rocks on the Peninsula. These Jurassic and Cretaceous strata, with a composite thickness of 35,000 feet or more, and the overlying Tertiary sediments, whose composite thickness exceeds 25,000 feet, together make up the favorable rocks of the Alaska Peninsula-Cook Inlet petroleum province. About 30,000 square miles of this area are considered more or less prospective for oil and gas, with the remainder of the province being unfavorably affected by metamorphism, intrusions, extreme deformation, and low permeability. Test wells in the late Mesozoic rocks have found numerous oil and gas shows, but no production has yet been obtained, due mainly to impaired permeability.

Fossiliferous Permian and Triassic limestone is known to underlie the later Mesozoic rocks, and the Traissic limes are locally petroliferous.

Successful oil and gas prospecting in these Mesozoic strata will depend on finding adequate reservoir rocks in favorable structural and stratigraphic situations.

Non-marine Tertiary sedimentary rocks are exposed along the northwest shore of Shelikof Strait (west of Kodiak Island), and both marine and non-marine Tertiary sediments are present in the Unga Island area. Scanty seismic information suggests as much as 5,000 feet or so of Tertiary section is present in Shelikof Strait, so this area can be considered prospective in Tertiary and underlying Mesozoic rocks. The outstanding obstacles to exploration are deep water and consistently atrocious weather conditions.

Reserves of about 2 billion barrels of oil and 5 trillion cubic feet of gas, with a current oil production of over 200,000 barrels per day have established the Cook Inlet area as a major petroleum province. The oil and gas reservoirs are in non-marine, deltaic, and estuarine Tertiary deposits trapped by closed anticlines (see report and map showing Kenai Group isopachs and oil and gas fields). The Susitna lowland, a sedimentary embayment of about 1000 square miles lying north of Cook Inlet, contains up to 10,000 feet of Tertiary non-marine sediments, but has been tested by only a single well. The lower part of Cook Inlet, southwest of Kalgin Island, has likewise been untested by the drill, although a thick prospective Tertiary section is present. Part of the reason here is existing litigation between the U.S. and Alaska governments as to ownership.

The thick Cook Inlet Tertiary section is underlain by Mesozoic rocks ranging from Triassic through late Cretaceous, but to date no significant oil saturation has been found in wells penetrating the pre-Tertiary rocks.

PRELIMINARY REPORT

KENAI GROUP OF COOK INLET BASIN, ALASKA

INTRODUCTION

The Cook Inlet Basin in southcentral Alaska is a northeast-trending intermountain trough about 200 miles long and 60 miles wide, bounded on the northwest by the southern Alaska Range and the Castle Mountain fault, and on the southeast by the Chugach Mountains. The basin is filled with about 20,000 cubic miles of Tertiary Kenai Group sediments containing known recoverable reserves of at least 1.5 billion barrels of oil and 3.5 trillion cubic feet of gas (Kirschner, 1971). Exploration for new reserves is continuing.

This preliminary report is a summary interpretation of presently-known stratigraphy of the Kenai Group (early middle Tertiary to Quaternary age) in the north-central part of the basin, where nearly all Cook Inlet wells have been drilled. As seismic information is not available to the State, detailed subsurface structure cannot be incorporated in this report, which is intended to be a guide to areas containing types and thicknesses of Kenai rocks most favorable for oil and gas exploration.

STRATIGRAPHY

General

The Kenai Group is more than 20,000 feet thick in the deepest parts of Cook Inlet Basin, and is divided into five formations as proposed by Calderwood and Fackler (Bull. AAPG, v. 56, #4); named from oldest to youngest the West Foreland Formation, Hemlock Conglomerate, Tyonek Formation, Beluga Formation, and Sterling Formation. In this study, strata of Quaternary age are included with the Sterling Formation due to uncertainty in determining their contact.

Using limited outcrop and locally abundant well data, an isopach map has been made for each formation of the Kenai Group, as well as for the total thickness of the Group. These maps show thickness penetrated by wells uncorrected for dip.

West Foreland Formation

West Foreland strata were distributed widely over the basin upon an undulating erosional surface of Mesozoic and early Tertiary rocks, probably by stream and current action in a shallow estuarine environment. Volcanics are present in wells near Trading Bay, but more typical are interbedded siltstones, tuffaceous claystones, sandstones, and conglomerates with a few coal beds. There is some possibility that outcrops of conglomerate and tuff south of Capps Glacier (up to 3500 feet thick) may be equivalent to West Foreland, but they were not mapped as such in this report. Oil production from the West Foreland is presently limited to sands in the McArthur River field, where cumulative production is about 6,000,000 barrels.

Chugach range and Alaska range, which were being uplifted strongly at this time. This depositional phase, modified by Quaternary to Recent glacial scour and recession, has left the basin essentially in its present state.

Lower Sterling sands are major gas reservoirs at the Swanson River, Beaver Creek, Kenai, Beluga River, and North Cook Inlet fields. Cumulative production is over 330 billion cubic feet.

SUMMARY AND CONCLUSIONS

A set of six isopach maps accompanies this report, showing the form and approximate extent of the various formations of the Kenai Group in Cook Inlet Basin, and also the relation of productive fields to thickness.

In general, producing fields are arrayed along the flanks of the thicker deposits of each formation, suggesting origin of hydrocarbons in the deeper parts of the basin and subsequent migration toward the shallower areas.

Three major areas of the basin appear to be relatively untested: 1) An eastern basin flanking the Chugach range was active during Hemlock, and again during Beluga and Sterling deposition; this area may be prospective for both oil and gas. Unfortunately, it is also involved in the proposed Kenai Wilderness withdrawal. 2) A possible eastern edge line is indicated for the Hemlock Conglomerate, trending roughly southeastward from Beshta Bay, passing several miles east of Swanson River, and heading toward the Skilak Lake area. Both of these prospective areas will depend on favorable structure for commercial oil or gas accumulations. 3) Lower Cook Inlet, southwest of Kalgin Island, is virtually untested, due mainly to existing litigation as to ownership between the Federal and State governments. There are, then, large areas of the Cook Inlet Basin that are quite prospective for important new oil and gas reserves.

Copper River Lowland

The southern part of the Copper River lowland is underlain by the same series of Mesozoic rocks as the rest of the Alaska Peninsula-Cook Inlet province, with the addition of a Paleozoic sedimentary and volcanic section which is exposed to the north and southeast of the lowland margins. The Paleozoic rocks are severly deformed and altered, which tends to remove them from consideration as prospective petroleum reservoirs. Tertiary rocks are limited to a local thin veneer of fluvial gravel. The composite Mesozoic section totals about 25,000 feet in thickness, but because of abundant unconformities and overlaps the section is usually less than half that thickness in any particular location. Marine strata predominate, and some early Cretaceous limestone and graywackes have a petroliferous odor, but several test wells drilled in the province have found a lack of reservoir development. One test, the Pan American Moose Creek well, encountered a gassy salt water flow in Cretaceous sandstone, but without significant oil shows. Several springs with mud mounds occur in the eastern part of the area, accompanied by gas composed of nitrogen and methane. As in the Alaska Peninsula area, success in hydrocarbon exploration in the Copper River area will depend on local development of permeable reservoir rocks.

Bristol Bay-Nushagak Lowland

A broad alluviated plain slopes north to Bristol Bay from the mountainous backbone of the Alaska Peninsula, forming the Nushagak lowland. This apron is underlain by Tertiary volcanic and marine sediments up to at least 13,000 feet in thickness. The area of the province underlain by a significant thickness of Tertiary rocks is 30 miles wide and at least 250 miles long, or 7,500 square miles. To the north, northwest, and northeast, the lowland is bordered by granitic rocks and by late Mesozoic shale and graywacke intruded by granitic rocks. To the south, the lowland is bounded by the petroliferous Mesozoic rocks of the Alaska Peninsula and the marginal Tertiary sediments and volcanics of the Bristol Bay province.

A pair of test wells near Becharof Lake penetrated 8,800 and 11,000 feet respectively of intermingled marine and non-marine clastic rocks ranging from Paleocene to Miocene in age. This section consists of conglomerate, sandstone, siltstone, shale, and coal resting on a basement of igneous and metamorphic rock, and overlain by late Cenozoic volcanic rocks.

The petroleum possibilities of the Bristol Bay Tertiary province stem from the thick sequence of interbedded and intertonguing marine and non-marine Tertiary rocks. Porous and permeable reservoir sandstones are present, and some encouraging oil and gas shows were encoutered in the Gulf Oil Company Sandy River test well near Port Moller. Exploration in this province is continuing, and prospectiveness is considered high.

Bering Sea Shelf

Very little is known about the Bering Sea continental shelf, but it extends off the southwestern Alaska coast for 300 miles and covers an area of some 180,000 square miles. It is likely that the major Mesozoic

tectonic elements on the mainland continue across the shelf area, so that parts of the shelf may be underlain by belts of late Mesozoic sedimentary rocks, whose petroleum potential should be similar to their conterparts on land.

Tertiary rocks are exposed to the southeast, in the Bristol Bay Tertiary province. Although most of the shelf may have been above sea level during most of Tertiary time, it is possible that sediments could have been carried across the shelf to accumulate near its outer edge, perhaps developing thicknesses sufficient to generate petroleum deposits. A systematic geophysical survey will be needed to interpret the distribution and thickness of sedimentary strata in this region.

Pacific Coast Tertiary Province

Petroliferous Tertiary sedimentary rocks are exposed along the Pacific coast from Icy Point in southeastern Alaska to Chirikof Island in southwestern Alaska, a distance of some 1000 miles, and may extend offshore to fringe the entire Pacific margin of Alaska. Along the Gulf of Alaska these rocks contain many oil and gas seeps and the small Katalla oil field. The combined area onshore and offshore inferred to be underlain by these rocks between Icy Point and Chirikof Island is about 40,000 square miles. This province can be divided conveniently into two areas, as follows:

Gulf of Alaska

Tertiary sedimentary rocks extend from the foothills of the Chugach-St. Elias Mountains to the edge of the continental shelf between Icy Point and the Copper River delta, 300 miles to the west, and also form Middleton Island, near the shelf edge 75 miles southwest of the Copper River. The areas involved are 5,200 square miles onshore and 18,000 square miles offshore.

The Tertiary rocks are bounded and underlain on the north by Mesozoic metasediments and metavolcanics, which have no apparent petroleum potential. The Tertiary section is clastic, marine and non-marine, and represents each epoch from Eocene to Pleistocene. The aggregate thickness of Tertiary strata is about 25,000 feet, resting with angular unconformity on the late Mesozoic metamorphic rocks.

The oldest Tertiary unit is dark Eocene siltstone, about 3,000 feet thick, which is a probably petroleum source rock. The siltstone grades upward into a 9,300-foot unit of intertonguing marine and non-marine, thick-bedded sandstone, siltstone, shale, and coal. Some oil and gas seeps from outcrops of these rocks. These lower Tertiary rocks are overlain with possible disconformity by marine mudstone, siltstone, and sandstone, characterized by glauconite and interbedded tuff and agglomerate. Maximum thickness of this unit is 6,100 feet, and age ranges from Oligocene to early Miocene. The mudstones and siltstones are highly organic in places, and the sequence contains many oil and gas seeps and petroliferous beds. Resting on this sequence with local unconformity is up to 15,000 feet of marine clastic rocks characterized by abundant glacial material, ranging in age from middle Miocene to early Pleistocene. This section consists of sandstone, siltstone, and marine tillite, and contains a few oil and gas seeps.

To the north, the Tertiary section is bounded by the Chugach-St. Elias thrust fault system, and in general structures consist of asymmetric folds and north-dipping high-angle thrust faults. Intensity of deformation is greatest near the north boundary, and decreases steadily to the south.

The Gulf of Alaska province has been intensively explored in recent years, spurred by the abundant oil and gas seeps, the presence of the old Katalla oil field, and the thick Tertiary sedimentary rock sequence with both source and reservoir beds. More than 20 test wells have been drilled onshore since 1954, without commercial success, due apparently to lack of suitable reservoir rocks in very complex structural situations. Nevertheless, abundant evidence of petroleum makes the area very prospective. The continental shelf area is from 10 to 50 miles wide in this province, and seismic exploration to date has reportedly revealed the development of broad, open folding in the thick offshore Tertiary section. Many of the anticlines are structurally closed, affording a great number of important offshore prospects that should be offered for lease by U.S. and State governments in years to come.

Kodiak Tertiary Subprovince

Tertiary sedimentary rocks similar to those in the Gulf of Alaska province were deposited along the same belt, and some of these rocks are exposed along the east margin of Kodiak Island, in the Trinity Islands, and on Chirikof Island. These occurrences extend the known Gulf Tertiary basin some 450 miles southwest from Middleton Island. If they are part of a continuous Tertiary sequence, then about 17,000 square miles of the Kodiak shelf area may be underlain by these petroliferous rocks.

The Kodiak Tertiary rocks are underlain unconformably to the west by late Mesozoic argillite and graywacke of the Chugach Mountains complex, and separated from them by a high-angle fault system similar to the Chugach-St. Elias system.

The Kodiak area outcrops range from Oligocene to Pliocene in age, and are entirely clastic. The lowest unit is mixed marine and non-marine sandstone, siltstone, and conglomerate with coal and plant remains, with a thickness approaching 25,000 feet. They are steeply-dipping and are usually much deformed. This unit is apparently of Oligocene age, and is overlain by at least 2,200 feet of late Oligocene to late Miocene marine sandstone and siltstone with gentle to moderate dips. The youngest Tertiary unit exposed is of Pliocene age, and consists of gently-dipping marine sandstone, siltstone, conglomerate, and tillite aggregating over 3,500 feet in thickness.

Petroleum possibilities in this area are as yet poorly known. No test wells have been drilled, and the outcrop sequence is discontinuous and incomplete. Prospectiveness of the exposed rocks is fair to poor due mainly to severe deformation in the Oligocene-early Miocene section and lack of oil or gas seeps. However, the younger rocks have gentler dips, and the entire section may open structurally in the offshore as in the Gulf of Alaska. Major obstacles to drilling offshore will be deep water and frequent severe storms.

SOUTHEASTERN ALASKA

The petroleum potential of southeastern Alaska is slight, as igneous and metamorphic rocks underlie most of this part of the State. Heceta and Keku Islands, however, are underlain by unmetamorphosed Paleozoic and Mesozoic rocks with a possible potential for oil and gas, and parts of Keku, Zarembo, and southern Admiralty Island contain non-marine Tertiary sedimentary rocks with a conceivable petroleum potential.

Heceta Island

A small, 30 by 10-mile area in the vicinity of Heceta Island is underlain by more than 22,000 feet of marine sedimentary rocks, including 17,000 feet of middle and early late Silurian limestone, conglomerate, sandstone, and shale; about 5,000 feet of late Silurian sandstone and minor shale, reef limestone, and conglomerate; and more than 600 feet of dark middle Devonian limestone. These rocks are deformed into a moderate syncline that extends offshore into Sea Otter Sound, and are intruded by diorite stocks along the north margin, thus limiting the area of potential interest.

Some beds have a petroliferous odor, and there are potential reservoir rocks present. Unfavorable factors are limited size, synclinal structure, firm lithification, and much faulting.

Keku Islands

Moderately deformed Silurian to early Cretaceous rocks are exposed in the Keku Islands and the adjacent northern parts of Kupreanof and Kuiu Islands over an area of some 300 square miles. The sequence here consists of marine sedimentary and volcanic rocks at least 20,000 feet in composite thickness. Rocks of Silurian, Carboniferous, Permian, and Triassic age consist of limestone, conglomerate, chert, sandstone, and black shale. Early Cretaceous rocks are shale and sandstone. Much of the limestone has a petroliferous odor.

Details of geological structure and stratigraphy are poorly known, so the degree of prospectiveness for oil and gas is unknown.

Tertiary Basins

Coal-bearing rocks of early Tertiary age crop out in small areas of southeastern Alaska, but principally between Kootznahoo Inlet on southern Admiralty Island and the west side of Zarembo Island, as well as part of the Keku Islands area. The area involved is 60 miles long and 10 to 15 miles wide. Coal-bearing rocks underlie about half this area, and are generally covered by younger volcanics.

The Tertiary section consists of sandstone, siltstone, shale, and conglomerate with minor coals, attaining a thickness of at least 5,000 feet of Kootznahoo Inlet, and grading upward into Oligo-Miocene volcanic rocks. Maximum dips are 15° to 40°, and conditions are favorable for the occurrence of dry gas or possibly petroleum.

INTERIOR ALASKA

Yukon-Koyukuk Province

The Yukon-Koyukuk province covers about 85,000 square miles over a broad triangular-shaped area in west-central Alaska. It is bounded on the west by the Bering Sea and Seward Peninsula, on the north by the Brooks Range, and on the southwest by the Kuskokwim, Kokrines, and Ray mountains.

Large parts of the province are underlain by Cretaceous sedimentary rocks that may be potentially petroliferous.

Kobuk Basin

The Kobuk Basin extends 300 miles along the south edge of the Brooks Range, from Kotzebue Sound to the upper Koyukuk River, covering about 11,000 square miles.

The basin sediments may be entirely mid-Cretaceous in age, and consist of an older sequence of dirty, dark marine graywacke and mudstone that grades into a younger sequence of better-sorted, shallow marine to non-marine sandstone, conglomerate, shale, and coal. The total thickness is not certain, but probably is much greater than 5,000 feet. Tight folds are the structural rule, except along the north edge of the basin where some broad open folds are exposed, and faulting is close and widespread. Intrusive rocks are limited to small scattered porphyry bodies to the southeast.

Structural complexity and impermeability in Cretaceous rocks render most of the basin poorly prospective for petroleum, but cleaner sands may occur along the northern edge of the basin in the zone of intertonguing marine and non-marine rocks, together with more open folding.

Recent studies have indicated that the metamorphic grade of the Paleozoic rocks of the adjacent Brooks Range may decrease abruptly to the south, in which case there may well be prospective Paleozoic sedimentary rocks underlying the Cretaceous section of the Kobuk Basin.

Selawik Lowland

Exploratory efforts in the lowlands east of Kotzebue Sound have indicated no significant thickness of Mesozoic or Tertiary strata occurring between the Quaternary alluvium and shallow igneous basement-type rocks.

Along the north side of the Seward Peninsula, the lowlands are again mantled with Quaternary alluvium and flat-lying Cenozoic volcanics, but in this area aeromagnetic profiles suggest that a possible thick section of Cretaceous and/or Tertiary rocks may overlie the igneous basement. Further geophysical studies or test wells are needed to outline the petroleum potential of this area.

Lower Yukon Basin

The Lower Yukon Basin subprovince covers about 30,000 square miles, extending in a 100-mile-wide belt from the Yukon-Kuskokwim delta northward to the Seward Peninsula. The basin is underlain mainly by Cretaceous sediments, but also includes sizeable areas of volcanic and intrusive rocks. The area is transected by the major Kaltag Fault, which may offset the basin laterally by as much as 50 miles.

North of the fault, extensive exploration and leasing culminated in the drilling of a deep test well near Nulato in 1959, which was abandoned without signs of oil or gas. The Cretaceous section here, as in the Kobuk Basin, can be divided into a lower mudstone-graywacke unit as much as 20,000 feet thick, overlain by a marine-non-marine unit of sandstone, conglomerate, shale, and coal up to several thousand feet thick. The western two-thirds of the basin is exceedingly complex in structure, with steep to vertical beds predominating. The eastern margin of the basin, from Nulato northward to the lower Kateel River, is marked by the development of a few broad open folds. Generally the petroleum prospects are very slim due to almost complete lack of permeability. No oil or gas indications have been verified in this part of the basin.

South of the Kaltag Fault, the Cretaceous beds are invaded by a variety of small intrusive bodies and by extensively interbedded volcanic rocks. As much as half of this area may be underlain by igneous rocks. The Cretaceous section is apparently substantially thinner than to the north of the fault, and much of it consists of interfingering marine and non-marine sandstone and shale. Some coal is exposed along the east side of the basin, and some relatively clean sands occur in this area, but generally the Cretaceous rocks are everywhere so tightly folded and closely faulted as to preclude all but a slight chance of petroleum accumulation.

A 5,000 square-mile tract of Cretaceous sediments that are relatively free of igneous rocks occurs in the Andreafsky River area, to the southwest, but the rocks are impermeable mudstones and volcanic graywackes.

In summary, the Lower Yukon Basin subprovince is poorly prospective for oil or gas in view of the sedimentary conditions, complex structure, and widespread occurrence of igneous rocks.

Melozitna Basin Subprovince

A belt of Cretaceous sediments extends northeastward from the Yukon River along the Melozitna and upper Dubli drainages, and may connect northeastward with the Kobuk Basin. The Cretaceous stratigraphy and structure appears to be similar to that of the Lower Yukon area, so that the oil and gas prospects seem to be of the same low order.

Koyukuk Flats

A number of aeromagnetic profiles have been run across this area, and all of them show large-amplitude anomalies suggestive of highly magnetic rocks of shallow depth. This data, together with surface mapping, indicates that Quaternary alluvium is underlain chiefly by volcanics and intrusives, and possibly by some infolded belts of Cretaceous sedimentary rocks. The flats do not appear to be underlain by any appreciable thickness of Tertiary of Cretaceous sediments, and therefore are regarded as unfavorable for petroleum.

Norton Sound

Recent aeromagnetic and seismic profiles across the Norton Sound area have indicated the existence of a sedimentary section in excess of 5,000 feet overlying igneous basement rocks in an area bounded on the south by the Yukon Delta and St. Lawrence Island, and on the north by the Seward Peninsula. Little is known of the age or exact character of the sediments, but the strongest possibility is that they are of late Mesozoic and/or Tertiary, and as such may have considerable petroleum potential.

Chukchi Sea

The same comments as for Norton Sound can apply to a large offshore area bounded on the east by the Seward Peninsula and western Delong Mountains, on the west by the Chukotsk Penninsula, and on the north by a line connecting Cape Lisburne and Wrangell Island. As in Norton Sound, several thousand feet of Mesozoic to Tertiary sediments are indicated by recent seismic profiles, and there is a possibility that the two sedimentary basins coalesce in the vicinity of the Bering Strait. Petroleum prospects could be favorable here.

Yukon-Kuskokwim Lowland (Bethel Basin)

Aeromagnetic profiles, surface exploration, and a deep test well drilled about 50 miles southwest of Bethel have shown that the Cretacc sediments of the Lower Yukon area extend southward beneath a cover of Cenozoic alluvium and volcanics. Some Tertiary sands and siltstones possibly overlie the Cretaceous section in this region. No shows of oil or gas have been reported here, but subsurface structure is very poorly known to date. Cretaceous rocks appear to be chiefly impermeable mudstones and graywackes similar to the lower Yukon rocks, so prospectiveness might depend on finding petroleum accumulations in Tertiary sands, if present.

Yukon-Porcupine Province

The Yukon-Porcupine province covers 15,000 square miles in a triangle bounded by the Yukon River, Porcupine River, and the Canadian boundary. The presence of a thick section of unaltered pre-Cambrian through Paleozoic sedimentary rocks has made this area a promising potential oil province.

In the past several years the search for petroleum has been given added impetus by the discovery of oil and gas in Paleozoic rocks in the Eagle Plains, east of the Canadian border. To date, no wells have been drilled in the Yukon-Porcupine.

Paleozoic Areas

Unaltered pre-Cambrian and Paleozoic sedimentary rocks are exposed in the southeastern part of the Yukon-Porcupine province in the Nation-Tatonduk region, along the Black River, and to the northeast along the Procupine River. In the Nation-Tatonduk area, rocks from late pre-Cambrian through all the periods of the Paleozoic era, with the exception of Pennsylvanian, are present. About 15,000 feet of this section is potentially petroliferous. Predominant rocks are carbonates, chert and shale, and sandstone, with many highly organic beds and some rich oil shales.

Northwest of the Nation River Paleozoic strata dip beneath the Mesozoic sediments of the Kandik Basin, but appear in some anticlinal axes in the basin. Southward, the Paleozoic section is faulted against metamorphic rocks of the Tanana upland along the major Tintina Fault, and to the west, Paleozoic rocks appear to interfinger with volcanics.

The Nation-Tatonduk Paleozoic and pre-Cambrian structure is broad open folding with minor crenulations and local overturning, shearing, and faulting.

Along the Black River are late Ordovician and Devonian? carbonates and Permian clastic rocks.

A sequence of unaltered Paleozoics from Ordovician to Carboniferous in age is exposed in the valley of the Porcupine River. These are intricately folded and faulted limestone, dolomite, and shale.

Kandik Basin Subprovince

The Kandik Basin extends in a belt about 40 miles wide from the Yukon River northeastward across the Yukon-Porcupine area to the Canadian boundary. The basin sediments are chiefly early Cretaceous argillite and graywacke with a basal well-sorted sedimentary quartzite. Aggregate thickness may approach 20,000 feet. Permeability in these rocks is very low, and their petroleum potential is likewise low. The Cretaceous section is underlain by dark shale, oily shale, and bituminous limestone of Triassic age, with a thickness of about 2,000 feet.

Structure in the basin is broad folding, with superimposed faulting and crushing of the argillite, which has a local slaty cleavage. Oil prospects seem limited to the Paleozoic section which underlies anticlines in the Kandik basin.

Yukon Flats

Aeromagnetic profiles suggest that the Paleozoic volcanics exposed to the south extend northward into the Yukon Flats under a shallow cover of Quaternary alluvium. In the central and eastern parts of the flats, aeromagnetics indicate that interbedded Paleozoic sediments, volcanics, and metamorphics are overlain by alluvium. Only in the northeastern part, along the lower Porcupine and Black Rivers, do aeromagnetic profiles indicate an appreciable sedimentary thickness, probably Paleozoic and perhaps Mesozoic rocks which would limit the oil and gas prospects of the flats to this area. Non-marine Cretaceous and Tertiary sediments crop out in several small areas around the margins of the Yukon Flats -- these sediments may also extend into the flats beneath the alluvial cover.

Interior Lowlands

An arcuate belt of lowlands covered with Quaternary sediments extends about 500 miles along the northern side of the Alaska Range. Petroleum possibilities are discussed below.

Kuskokwim Lowland

Aeromagnetic profiles have indicated that a relatively thin alluvial cover overlies altered Paleozoic rocks over most of this area, but reports persist that several thousand feet of non-marine Tertiary sediments are exposed on the margins of the lowland, in the vicinity of Minchumina Lake. If this is the case, petroleum prospects are at least possible, especially the possibility of gas being generated in coal-bearing rocks. Exploration has been nearly nil.

Tanana Lowland

The Tanana Lowland lies between the Tanana River and the northern foothills of the Alaska Range, from the Gerstle River on the east to the Kantishna drainage on the west, forming an area 200 miles long and 10 to 50 miles wide. It is mantled by Quaternary sediments over an area of 7,000 square miles. The Quaternary deposits are thick, exceeding 1,000 feet east of Nenana.

In most places the lowland is bordered by somewhat metamorphosed sedimentary and volcanic rocks of pre-Cambrian?, Paleozoic, and Cretaceous age, but along the southern margin are extensive exposures of non-marine Tertiary sands, silts, clays, coals, and gravels. These attain a thickness of 5,000 feet or more in the Alaska Range foothills, but thin northward to 2,000 feet or less in the Tanana lowland area. The region southwest of Minto Flats may contain as much as 5,000 feet of non-marine Tertiary sediments.

The older altered rocks are considered to have little or no petroleum potential, and the Tertiary section would probably be prospective only for small gas deposits.

Northway-Tanacross Lowland

The Northway-Tanacross Lowland lies along the south side of the upper Tanana River, between the eastern Alaska Range and the Tanana Upland. This lowland area is from 10 to 30 miles wide and about 100 miles long, and Quaternary deposits cover about 1,500 square miles of its floor.

Outcrops around the lowland margins are pre-Cambrian? and Paleozoic metamorphic rocks, with a variety of intrusive igneous rocks. Surficial deposits may reach a thickness of 1,000 feet, and at least two water wells have encountered small flows of methane gas generated from decayed vegetation.

The only chance for oil or gas resources would be the presence of a Tertiary section beneath the alluvium. To date, no evidence of this situation has been found.

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