DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-223

EXPLANATION

QUATERNARY

Qs — Surficial deposits
Undifferentiated fluvial and marine gravel, sand, silt, and mud; organic materials; colian sand and silt; and colluvium, Qc.
Glacial till deposited by alpine-type glaciers, Qg.

TERTIARY

QTv — Mafic volcanic rocks
Basalt lava flows and cinder cones.

Tig — Granitic intrusive(?) rock
Structureless, homogeneous-appearing rock photointerpreted as intrusive.

PRE-CRETACEOUS(?) CRETACEOUS(?)

Ks Kgm — Graywacke-siltstone sequence
Volcanic pyroclastic, siltstone, and minor amounts of pebble conglomerate and coal; probably littoral marine, Ks. Photointerpreted contact metamorphic aureole adjacent to intrusive(?) rock, Kgm.

bu — Bedrock, undifferentiated
Probably includes Cretaceous(?) undifferentiated metamorphic and intrusive rocks.

Contact
Dot and dash indicates photointerpretation.

Inferred contact

Fault
Based on photointerpretation; dotted where concealed.

Fissure
Based on photointerpretation.

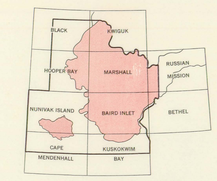
Uninterpretable feature appearing on aerial photographs.
May be geologically significant.

Anticline — Syncline
Showing trace of axial plane of fold as determined by photointerpretation.

Cinder cone
Questioned where topographic expression is not distinctive.

Fossil locality

Coal outcrop



All base maps from U. S. Geol. Survey Alaska reconnaissance topographic maps, scale 1: 250,000.

North shoreline of Nunivak Island sketched from U. S. Coast and Geodetic Survey chart 9302 (1952).

BASE COMPILATION DIAGRAM

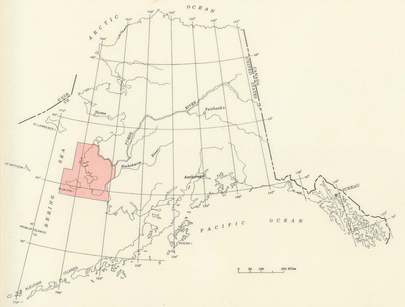


FIGURE 1. INDEX MAP OF ALASKA SHOWING LOCATION OF THE YUKON-KUSKOKWIM DELTA REGION

GEOLOGIC RECONNAISSANCE IN THE YUKON-KUSKOKWIM DELTA REGION, ALASKA

By
Warren L. Coonrad

Scale 1: 500 000

10 0 10 20 30 Miles

Depth curves in feet
Datum is mean lower low water
Shoreline shown represents the approximate line of mean high-water
1957 Magnetic declination varies from 25°00' to 29°30' east

1957

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-223

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—MR 5991

For sale by U. S. Geological Survey, price 75 cents

GEOLOGIC RECONNAISSANCE IN THE YUKON-KUSKOKWIM DELTA REGION, ALASKA

By
Warren L. Coonrad

ABSTRACT

The part of the Yukon-Kuskokwim delta region here described is an area of about 21,000 square miles in western Alaska. It lies between the Yukon and the Kuskokwim Rivers west of the town of Bethel and includes Nunivak and Nelson Islands. The region comprises a low, lake-pocked plain of unconsolidated deposits above which rise isolated hills and low mountains of bedrock.

The geologic sequence consists of sedimentary and igneous rocks that range in age from pre-Cretaceous to Recent. Mafic volcanic rocks of Tertiary and Quaternary ages constitute most of the exposed bedrock. Sedimentary rocks on Nelson Island that were previously mapped as of Tertiary age are now thought to be of Late Cretaceous age.

Known mineral resources are limited to thin coal beds cropping out on Nelson Island and possibly on Nunivak Island. More detailed work in some areas of the region could provide important Cretaceous stratigraphic data and would contribute to a better understanding of the Quaternary geologic history of western Alaska.

INTRODUCTION

General geography.—The region described in this report has an area of approximately 21,000 square miles. It includes Nunivak and Nelson Islands and that portion of the southwestern Alaska mainland that lies between the Yukon River and the Kuskokwim River west of the town of Bethel. Isolated islands or islandlike barren hilly masses, closely underlain by bedrock, occupy 10 percent of the delta region; the remaining area is a typical arctic, lake-pocked lowland plain developed on unconsolidated materials. Relative relief throughout most of the lowland rarely exceeds 100 feet and averages 10 feet or less. Maximum relief is in the Kusilvak Mountains, which rise from nearly sea level to almost 2,450 feet.

Bethel, at the head of seagoing navigation on the Kuskokwim River, is the center of transportation and communication facilities for essentially the entire region. It is regularly served by petroleum barges and two or more seagoing freighters during the summer and by scheduled airlines throughout the year. Ocean-going vessels are unable to cross the entrance bars and to navigate the shifting shallow channels of the Yukon River; therefore, the lower Yukon River area is served by specially built shallow-draft river boats that load their cargos either at St. Michael on Norton Sound or far inland at Nenana, where goods are transshipped from the Alaska Railroad.

Summer travel within the delta region is mainly by floatplanes, although long narrow poling boats equipped with outboard motors are widely used in fishing and sealing operations and for local transportation. Skiplanes and dog sleds are used during the winter. Inhabitants of Nelson Island and the Hazen-Hooper Bay area can follow an inland all-water route to the Yukon by way of Aphrewn River and Driftwood Slough (U. S. Coast Pilot, 1955, p. 535). Small-boat travel to Bethel is along an interior waterway that leaves the north side of Baird Inlet and follows a tortuous route of sloughs, lakes, and streams to a reported short tramway portage connecting with the Kuskokwim via the Kvichavak River. Coastal navigation in small craft is generally avoided, because shallow offshore waters and frequent high winds make such trips hazardous.

Previous work.—The delta region has received only the most cursory of geologic examinations. Dall (1870) visited St. Michael and the lower Yukon River area in his early Alaskan explorations. His Neocene correlation papers (Dall and Harris, 1892, p. 245) include notes of an 1874 charting reconnaissance of Nunivak Island, Russell (1890) reported on observations made during his trip up the Yukon River in 1889. Dawson (1894) saw parts of Nunivak Island and Nelson Island on his Bering Sea cruise of 1891. Spurr made exploration traverses down both the Yukon River (1898) and the Kuskokwim River (1900). In addition to his own observations, Spurr recorded miscellaneous notes contributed by missionaries and traders. These men, while actually on exploration or other commissions, made many significant observations on the geology of the delta region.

Present investigation.—This report is based on reconnaissance field studies made in 1954 and the subsequent compilation of data obtained from published and unpublished references and from interpretation of vertical aerial photographs. The field studies were initiated by the U. S. Geological Survey in consideration of aerial and field camp logistic support offered by the U.S. Army. The supplemental material was incorporated to bring together and make available all the existing geologic information regarding a large but little-known region.

A 10-day field reconnaissance of the geology of Nelson Island and the mainland area south of 61°00' north latitude was made during June and July 1954. Foot traverses were made along most of the beaches of the western part of Nelson Island, Triangulation stations Plain, Curlew, and Tern on the mainland and several points on Nelson Island were visited by means of helicopter. Low-altitude aerial reconnaissance of the eastern shore of Nunivak Island was made from fixed-wing aircraft.

Photogeologic studies were subsequently done on north-south flights of vertical aerial photographs, at 1:40,000 scale of the mainland area and at 1:20,000 scale of Nelson Island. Photographs of Nunivak Island and several small mainland areas (as indicated on the map) were not available to the writer at the time this report was prepared.

All available information was compiled on copies of the 1:250,000-scale U.S. Geological Survey Alaska reconnaissance topographic maps.

Acknowledgments.—Without the generous cooperation of the officers and men of Company 551, 39th Topographic Battalion, U.S. Army, and their air detachment, much of the work on which this report is based could not have been undertaken. Thanks are due Dr. R. W. Chaney of the University of California at Berkeley for reporting on fragmentary plant fossils from Nelson Island.

GENERAL GEOLOGY

The Yukon-Kuskokwim delta region is predominantly underlain by deltaic and eolian deposits. Mafic lava flows and small cinder cones crop out in the western part of the region. Folded sedimentary rocks of Cretaceous(?) age crop out on Nelson Island, in the southern part of the Kusilvak Mountains, and possibly on Nunivak Island. Intrusive rocks and associated metamorphosed rocks of Cretaceous(?) age form the high northern part of the Kusilvak Mountains. Rocks thought to represent a crystalline complex are mapped as undifferentiated bedrock in the Cape Romanzof-Askinuk Mountains area.

PRE-CRETACEOUS(?) UNDIFFERENTIATED BEDROCK

Consolidated rock outcrops in the vicinity of the Askinuk Mountains are mapped as undifferentiated bedrock, although the bulk of the evidence suggests that the area is underlain by a crystalline complex. The author has not visited the area, and published references do not agree on the nature of the bedrock. Dall (1896, p. 863) reported that Cape Romanzof is composed of metamorphic rocks, and Spurr (1898, map 14) showed the area as crystalline schists, but Smith (1939, pl. 1) indicated that the area is underlain by Cenozoic volcanic rocks. "Granite" has been reported from the vicinity of Cape Romanzof by several Bethel inhabitants. The U.S. Coast Pilot (1955, p. 538) notes "remarkable perpendicular shafts of rocks" at the extremity of Cape Romanzof. Similar shafts and occasional small-like masses of rock occur throughout the Askinuk Mountains. This type of erosional remnant is commonly developed in granitic and metamorphic rocks in other Alaskan localities. Dall's record (1870, p. 477) of an azurite occurrence near Cape Romanzof also suggests the possibility of igneous rocks in that vicinity. Photogeologic study of the available aerial photographs indicates that the Askinuk Mountains are predominantly underlain by relatively homogeneous rocks. A structural alignment or lineation in approximately an east-west direction is apparent on the aerial photographs, but it is not known if this is caused by bedding, jointing, schistosity, foliation, or some other planar element. The little evidence available indicates that the area is probably underlain by intrusive rocks or an intrusive and metamorphic rock complex of pre-Cretaceous age.

CRETACEOUS(?) GRAYWACKE-SILTSTONE SEQUENCE

Sedimentary rocks of Cretaceous(?) age crop out on the western side of Nelson Island. Coal probably from the same sequence of rocks has been reported from Nunivak Island. Study of aerial photographs of the Kusilvak Mountains has indicated another area of well-bedded rocks that look similar to rocks of known Cretaceous age.

Nelson Island.—The lithology and stratigraphy of the Cretaceous(?) rocks have not been studied in detail in this region. Where examined on the coast of Nelson Island, these rocks are predominantly graywacke-type sandstone and siltstone with minor amounts of calcareous siltstone, sandy pebble conglomerate, and thin coal beds.

The sandstone is fine to coarse grained, dark gray to greenish gray, and weathers to a light-gray or brownish color. The coarser grained sandstone generally crops out as massive, locally crossbedded, lenticular units up to 20 or 30 feet thick; the finer grained sandstone is present as thin beds interstratified with siltstone. Sandy pebble conglomerate zones as much as a foot thick are locally present in the basal portions of the thick sandstone beds. Microscopic examination shows that the sandstone is composed dominantly of volcanic rock fragments with subordinate amounts of quartz and plagioclase feldspar grains. Porosity and permeability are negligible, as most intergrain space is filled with an impervious matrix. Chlorite, albite, and occasional carbonate blebs are present as alteration and replacement products. Similar sandstone has been classified as volcanic graywacke by Williams and others (1954, p. 289-304).

Siltstone forms a major portion of the rocks of Cretaceous(?) age on Nelson Island, although the sandstone beds are more conspicuous because of their greater resistance to erosion. The finer grained rocks tend to be somewhat more calcareous than the conglomerate and coarse-grained sandstone but otherwise are similar in composition. Locally the siltstone contains limy nodules and abundant plant fossils.

The general lithology and the presence of carbonaceous material suggest that the origin of the sequence may be partly marine, but it is mostly littoral marine and nonmarine.

The exposed rocks of Cretaceous(?) age on Nelson Island are estimated to be as much as 5,000 feet thick. Although stratigraphic sections are well exposed both on the north side of Cape Vancouver and along the coast of the bay southeast of the Cape, the writer was unable to measure them in the time available.

The Cretaceous(?) age of these rocks is based on the identification of plant fossils and lithologic similarity to rocks known to be of Cretaceous age. Fossil plant remains are abundant in much of the siltstone and occasionally present in the lower part of the thick sandstone beds. G. M. Dawson collected a few leaf impressions on Nelson Island in 1891 and submitted them to Sir J. William Dawson, who identified them as a probable Tertiary flora (Dawson, 1894, p. 134-135). Later collections made by F. H. Wasley (1954, written communication) and the writer were submitted to Dr. R. W. Chaney, of the University of California, who reported (1954, oral communication) that they contained a floral assemblage of probable Late Cretaceous age. No other fossils have been found. In many respects the lithology of the Nelson Island rocks of Cretaceous(?) age is similar to that of the rocks forming the upper unit in the border facies of the Koyukuk Cretaceous basin in the Shaktolik area (Patton and Bickel, 1956).

Kusilvak Mountains.—The bedded rocks cropping out in the Kusilvak Mountains are inferred to be of Cretaceous(?) age from photogeologic comparison with rocks of known Cretaceous age. On aerial photographs bedding features are readily discernible along most of the ridges, and in general these rocks closely resemble rocks of known Cretaceous age cropping out north of the Yukon River near Andreafski (Harrington, 1918, p. 31).

Nunivak Island.—The possibility of rocks of Cretaceous age cropping out on Nunivak Island is suggested by Spurr's report (1900, p. 262) of a coal occurrence. The limited information available indicates that coal and associated sedimentary rocks similar to those on Nelson Island crop out on the north side of Nunivak Island. The area has not been visited by U.S. Geological Survey personnel, nor were aerial photographs available for photointerpretation at the time this report was prepared.

MAFIC VOLCANIC ROCKS

Mafic volcanic rocks form lava sheets and numerous small cinder cones in the western part of the Yukon-Kuskokwim delta. This area is a part of a discontinuous volcanic belt that extends from eastern Seward Peninsula southward along the Bering Sea to Nunivak Island and possibly to the Pribilof Islands.

For convenience of description the delta region has been divided into five main areas of volcanic rock outcrops; Nunivak Island, Nelson Island, Kinia River, Ingakslugwat Hills, and Ingichuak Hill. In addition some of the individual cinder cones are referred to by the names of the survey triangulation stations located on them.

Nunivak Island.—Nunivak Island is predominantly of volcanic origin. Basaltic lava flows overlying altered sedimentary rocks were reported by Dall (Dall and Harris, 1892, p. 245) after a brief examination of the Etolin Harbor anchorage area in 1874. Dawson (1894, p. 133-134) visited the same locality in 1891 and reported that all the rocks he saw were of volcanic origin. Smith (1939, pl. 1) shows most of the island as volcanic rock, but he has mapped the entire northeastern coastal area as underlain by sedimentary rocks of Tertiary age. The U.S. Coast Pilot (1955, p. 526) notes the volcanic nature of Nunivak Island with the following description: "Near the center of the Island is Roberts Mountain, 1,675 feet in altitude, the highest of a group; this mountain is built up of a series of volcanic benches, the top being the steep side of a breached crater." Available hydrographic information (U.S. Coast and Geodetic Survey, 1952) suggests the presence of submarine volcanic cones in the adjacent offshore waters. In the present investigation the eastern shoreline of Nunivak Island was examined from a low-flying airplane. At no place between Cape Etolin on the north and Cape Corwin on the south were sedimentary rocks identified. The volcanic origin of the rock was evident by the abundant polygonal columnals seen in almost every sea cliff and by the presence of small maars and cinder cones immediately inland from the coastline. On the basis of the evidence outlined above, the eastern part of Nunivak Island has been mapped as mafic volcanic rock.

Nelson Island.—Basaltic flow rocks cap most of the Nelson Island highlands. The presence of 8 to 20 individual flows, with an aggregate thickness of 200 feet or more, is indicated by topographic benches at numerous places.

The flows dip gently eastward but otherwise are undeformed. Columnar structure is seen in most of the cliff-forming outcrops. The bottom of the section is marked by an angular unconformity between the volcanic rocks and the folded sedimentary rocks of Cretaceous(?) age beneath them. The top of the section of volcanic rocks is probably absent, as the uppermost recognized flows consist of small erosional remnants cropping out on the highest parts of the island. No dikes were seen in the underlying sedimentary rocks, nor was there recognized evidence of source vents on the island itself. Microscopic examination of thin sections indicates that the rocks are fine-grained, holocrystalline olivine basalt.

Kinia River.—The Kinia River area of volcanic rocks in the southwestern part of the region was visited by helicopter. Dense basaltic flow rocks underlie the lower slopes of the hills on which the triangulation stations Tern, Curlew, and Plain are located. Two cinder cones are well preserved on Tern, and abundant scoriaceous material is present around the crest of Curlew. Examination of Kinia, Kegum, and the small outcrops 10 miles west of Kegum from a low-flying helicopter indicated that these hills are probably of volcanic origin even though they lack well-defined craters.

Ingakslugwat Hills.—Aphrewn Mountain and the high points occupied by triangulation stations Kochee and Ingri have been included with the Ingakslugwat Hills for descriptive purposes. The writer did not visit this area; the following discussion is based on interpretation of vertical aerial photographs.

The Ingakslugwat Hills area appears to have been one of the most recently active volcanic areas in the Yukon-Kuskokwim delta region. Several ages of cones and flows can be differentiated on the basis of superposition and topographic expression. The largest tuff-ring(?) crater is approximately a mile across and within it are several smaller scoria mounds with distinct craters. Various discernible micro-relief features suggest that the flows are dominantly aa lava. Small sharp cinder cones are aligned along a fissure in the northwestern part of the Ingakslugwat Hills (see map). The topographic expression of the fissure is a shallow ditchlike depression about 4 miles long.

Ingichuak Hill.—Four well-defined and two questionable cinder cones have been identified on aerial photographs of the Ingichuak Hill area. Although Spurr (1898, p. 246) stated that "there were no solid rocks (cropping out) below (old) Andreafski," Smith's map (1939, pl. 1) did show volcanic rocks of Cenozoic age west of the Yukon River in the vicinity of Ingichuak Hill. The contact between the volcanic rocks and the thick unconsolidated sediments has not been precisely located because of a loess mantle and lack of distinguishable features on the base map in this area.

Aerial photographs of the area north of Ingichuak Hill near Kwemeluk Pass show small outcrops that are probably volcanic rock, though definite criteria for recognition are lacking on the photographs.

Age of the volcanic rocks.—The age of these extrusive rocks is not known; some of the volcanic rocks may be as old as late Tertiary, and others erupted so recently as to be almost within historical times. The massive volcanic flows of Nelson Island and some of the eruptive centers on the mainland are definitely older than the silt of probable Pleistocene age that surrounds and partly buries them. The thin loess mantle that covers most of the flows and cones is probably of Wisconsin age or older (Péwé, 1955, p. 722). The sharp-edged cinder cones and identifiable flow features in parts of the Ingakslugwat Hills suggest a more recent age for some of the volcanic rocks in that area.

North of the region under study, but still in the same volcanic belt, there is even more graphic evidence of relatively recent activity. The natives of St. Michael had a tradition (Dall, 1870, p. 472) that their volcanic island village had been submerged three times. Flows emanating from The Sisters, a small group of volcanic cones about 15 miles southeast of St. Michael, are recent enough so that many of the original microrelief features are still clearly distinguishable on 1:40,000-scale vertical photographs.

SURFICIAL DEPOSITS

The presence of unconsolidated deposits of glacial origin has been inferred from the presence of highly modified cirques and U-shaped valleys in the higher parts of the Askinuk Mountains.

The other types of surficial deposits have not been differentiated for this report. They include silt, sand, gravel, and organic materials ranging in age from early Pleistocene to Recent. Much of the region is mantled with loess, but there are also extensive areas of alluvium, colluvium, and marine beach and lagunal deposits. Stabilized sand dunes are present in several small areas. Permafrost has a sporadic distribution throughout the region. At Bethel it has been found to a depth of approximately 600 feet, according to Arthur L. Nickolson, partner, Nickolson Drilling Co., in a written communication regarding drilling of the Bethel Alaska Native Service hospital well in 1953.

Deposits of peat and other organic materials are common throughout most of the region. Peat hummocks are particularly large and abundant along the southeastern side of Nelson Island. Natives report that fossil ivory has been recovered from the two indicated localities near Baird Inlet (see map).

TERTIARY INTRUSIVE(?) ROCKS

A structureless mass that is clearly distinguishable on aerial photographs of the Kusilvak Mountains has been interpreted as being a small stocklike granitic intrusive(?) body. A contact-metamorphic aureole has been inferred from the gradational appearance of the rocks outward from the homogeneous central zone of the intrusive(?) body to the obviously bedded surrounding rocks. The metamorphic zone indicated on the map is considerably wider than any that has been recognized in adjacent regions. A Tertiary age for this intrusive(?) body is inferred because rocks of Cretaceous(?) age are intruded and because intrusive rocks of known Tertiary age in adjacent regions present a similar appearance on aerial photographs.

STRUCTURE

Traces of fold axes have been mapped on rocks of Cretaceous(?) age in the Kusilvak Mountains and on Nelson Island. The dominant northeast trend of the fold axes and faults in the Kusilvak Mountains approximately parallels the trend of similar structures in adjacent regions (Hoare and Coonrad, 1954; Cass, 1955). The folds are tight, with the dip of the bedding estimated to range between 45° and 90°. Major faults probably bound the entire Kusilvak Mountains block, although actual fault scarps are identified only at the northwest end of the mountains. Cross faults with minor displacement are abundant and easily recognized on the aerial photographs.

On Nelson Island the major fold axes and faults trend about N. 70° W., approximately normal to the trend of similar structures in the Kusilvak Mountains and adjacent areas. The mapped flexures are open, asymmetric folds, with the steeper southwest limbs dipping 40°-90° SW. and the northeast limbs dipping generally less than 40°. Several high-angle reverse faults and numerous normal faults with minor displacement are exposed in the sea cliffs. Most of the structural features antedate the extrusion of the overlying lavas, but a few of the normal faults displace the volcanic rocks.

The significance of the northwest-trending folds and the less intense deformation of the rocks of Cretaceous(?) age on Nelson Island is not known at the present time. Unrecognized larger-scale tectonic elements could be involved in the structural history of the Nelson Island area, or there may be considerable age difference between the rocks of questionable Cretaceous age on Nelson Island and the better-known rocks of Cretaceous age in adjacent regions. However, more information is required for a thorough evaluation of these and other possibilities.

MINERAL RESOURCES

Known mineral resources of the Yukon-Kuskokwim delta region are very few. Thin coal beds are present at several places. No mineral deposits of economic interest have been found, although there was possibly some mineralization associated with the intrusion of the plutonic(?) rocks in the Kusilvak Mountains area.

Coal.—Occurrences of coal on Nelson and Nunivak Islands were reported by Spurr (1900, p. 262). Reference to Spurr's report was made in several later publications that dealt more fully with Alaskan coals, but no new information was added.

During the present reconnaissance investigation, exposures of several thin coal beds were examined and the known outcrops are shown on the map. Most of the seams are less than 6 inches thick, but at the easternmost locality on the south side of Nelson Island there are two coal beds about 12 and 16 inches thick separated by 8 inches of carbonaceous siltstone. The beds dip 5°-10° E. Although the overburden is thin and the coal crops out in a low bench bluff, only a few tons have been mined. Occasionally a small amount of coal is used locally, but driftwood and imported petroleum products supply most fuel needs.

Analyses of coal samples from Nelson Island (Cooper et al., 1946, p. 38, 82) indicate that these coals of Cretaceous(?) age are subbituminous to bituminous in rank. However, the high ash content and the thinness of the beds leave little possibility of commercial development.

There is little information available regarding the coal reported on the north side of Nunivak Island near the head of one of the unmapped bays, approximately halfway between Nash Harbor and Cape Etolin. This coal locality has not been visited by U. S. Geological Survey personnel nor were aerial photographs of the area available for examination at the time this map was prepared.

Large quantities of sphagnum moss and peat are found at scattered localities throughout the region, but no attempt has been made at commercial development of these natural products.

Petroleum possibilities.—Smith (1941, p. 1440, 1445) outlined a large area presumably underlain by rocks of Cretaceous age or younger and stated that "the composition and structure of the bedrock are such as to afford some inducement for exploration by the seeker for deposits of oil." Gryc and others (1951, p. 152-153, 168), Gryc and Miller (1953, map p. 1478), and Gates (1954, map p. 1255) have all included the delta region within a possible petroliferous province adjacent to the Bering Sea. Waskey (1946, p. 353) reported friable, "oily" sandstone associated with soft coal beds on the north side of Nelson Island, but the exact locality and occurrence has not been verified.

The identification of the Nelson Island sedimentary rocks as of Cretaceous(?) rather than Tertiary age, as previously reported, considerably extends the known areal distribution of rocks of probable Cretaceous age. It has also somewhat narrowed the area possibly underlain by sedimentary rocks of Tertiary age and in conjunction with the recognition of widespread volcanism of late Cenozoic age considerably modifies Payne's configuration (1955) and history of the Bethel Basin.

Amber.—Amber has been reported (Waskey, 1946, p. 351) from the beaches of Nelson Island near Tamunak. The source of the amber has not been definitely determined; probably it is the nearby exposures of carbonaceous sedimentary rocks of Cretaceous(?) age.

Azurite.—Azurite has been reported from the Kuskokwim region near Cape Romanzof (Dall, 1870, p. 477). The exact location of this occurrence is unknown; it may be within the Askinuk Mountains near the Cape or possibly even in the Kusilvak Mountains.

Cassiterite.—Many years ago it was rumored that prospectors had found pebbly cassiterite (stream tin) in the area south of the Yukon River between Andreafski and Cape Romanzof. The exact location of the placer deposit is unknown. Like the azurite occurrence, it could be either within the Askinuk Mountains near Cape Romanzof or in the Kusilvak Mountains.

Ground water.—Supplies of ground water suitable for domestic use recently have been developed in the Bethel area. The new Alaskan Native Service hospital at the western edge of Bethel obtains its water from a well 620 feet deep. Permafrost was found to a depth of 405 feet. Water is produced from unfrozen water-bearing sand beneath the perennially frozen ground. Shortly after drilling, the well was reported by Arthur L. Nickolson, Nickolson Drilling Co., in a written communication, to have water standing at 38 feet below the top and to pump 55 gallons per minute with a 15-foot drawdown. Suitable deep-well ground-water supplies could probably be developed throughout much of the region.

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