GEOLOGIC MAP OF THE KWIGUK AND BLACK QUADRANGLES, WESTERN ALASKA

By J. M. Hoare and W. H. Condon

INTRODUCTION

The geologic map of the Kwiguk and Black quadrangles is a result of regional geologic investigations in the lower Yukon-Norton Sound region, western Alaska. Field studies, begun in 1960 and completed in 1963, were concerned primarily with bedrock geology. The surficial deposits were largely differentiated by photogeologic and topographic interpretations, supplemented by a few ground observations in 1963.

The rocks exposed in the Kwiguk and Black quadrangles range in age from mid-Jurassic(?) to Quaternary. The bedrock consists of an old group of deformed, dominantly volcanic rocks, a younger group of deformed sedimentary rocks, intrusive igneous rocks, and young undeformed lava flows. The major structural feature is a northeast-trending belt of intensely folded Mesozoic sedimentary rocks cut by two sets of faults. Unconsolidated surficial deposits, largely silt of Quaternary age, cover more than half the area.

The writers wish to acknowledge the efficient field assistance of Richard White in 1960 and N. W. Rutter in 1961. The generous assistance of members of St. Mary's Mission greatly facilitated the fieldwork. Appreciation is expressed to the U.S. Air Force, for living accommodations provided at their facility on Cape Romanzof during field operations. Fossil collections were studied by R. W. Imlay, D. L. Jones, and J. A. Wolfe.

BEDROCK

Volcanic rocks

Dark, gray-green, altered andesitic flows, volcanoclastic rocks, and some fine- to medium-grained graywacke (KJv) crop out along the Chuilnak River in the southeastern part of the area and on the coastal plain in the north-central part. The coastal plain exposures are chiefly volcanic conglomerate consisting of well-rounded pebbles and cobbles as much as 6 inches in diameter in porphyritic and amygdaloidal lava.

The volcanic rocks are probably as old as Early Cretaceous and may be as old as mid-Jurassic. Although no fossils have been found in this map unit, the rocks are lithologically similar to rocks elsewhere in western Alaska which contain pelecypods of Early Cretaceous age and fragmentary belemnites and ammonites, possibly as old as mid-Jurassic.

Cretaceous sedimentary rocks

The Cretaceous sedimentary rocks include both marine and nonmarine deposits lithologically similar to and probably correlative with the Kaltag and Nulato Formations in the Koyukuk Basin (Dall and Harris, 1892, p. 247-248; Martin, 1926, p. 395-414). However, the Kaltag and Nulato Formations cannot be differentiated here owing to structural complexities and lack of exposures.

The deposits comprise a thick sequence of interbedded marine and nonmarine sandstones and siltstones, some of which are tuffaceous, and a small amount of tuff. The section, as a whole, is unusually fine grained. Thin beds of pebble conglomerate were noted at only three places. Although beds of intraformational, shale-chip conglomerate are fairly common, the general lack of conglomerate indicates that there was little or no tectonic activity in or near the quadrangle.

The sandstones are mostly fine- to medium-grained, well-indurated graywackes consisting of subangular and subrounded grains in a matrix of silt and clay-sized particles. The sand grains consist of different amounts of quartz, feldspar, chert, siltstone or shale, and volcanic rocks. Most of the feldspar is plagioclase, but orthoclase locally forms as much as 20 percent of the rock. Detrital muscovite is very common in the finer grained rocks. Most of the matrix, which commonly constitutes 10 to 30 percent of the rock, is too fine grained and altered to be identified in thin section; recognizable minerals include chlorite, biotite, sericite, quartz, and feldspar. Calcite and/or laumontite, a calcium zeolite, is the chief cementing material in some of the sandstones.

Siltstone makes up at least half the sequence but rarely crops out except in cutbanks. Some of the siltstone is quite shaly, but most of it weathers into small blocky subconchoidal fragments. The composition of the siltstones approximates that of the matrix of the sandstones. Calcareous concretions are common, but the siltstones themselves are rarely calcareous. Laumontite is not nearly so abundant in siltstone as it is in sandstone.

For mapping purposes, the Cretaceous sedimentary rocks have been divided into three lithologic units on the basis of the predominantly calcareous, noncalcareous, or laumontitized character of the sandstones. Most of the rocks in the calcareous unit effervesce freely when treated with cold, dilute hydrochloric acid, but the unit also includes many strata that are noncalcareous or slightly calcareous. Conversely, the noncalcareous unit includes numerous beds that are at least weakly calcareous. The laumontitized unit includes an equal or slightly greater amount of calcareous and noncalcareous strata which contain little or no laumontite.

These three lithologic units form several fairly well-defined, northeast-trending belts. The stratigraphic and structural relations of the three lithologic units and their belts of outcrop are uncertain because the rocks are highly deformed and poorly exposed. The belts of outcrop probably reflect large-scale structural repetition by folding or faulting, although they may represent stratigraphic repetition. Scanty fossils from the Kwiguk quadrangle and adjoining areas indicate that most of or all the rocks are probably late Early and early Late Cretaceous (Albian and Cenomanian) in age. The age and the marine and nonmarine character of the rocks suggest that the three lithologic units may represent three different facies deposited during the same time interval.

Most of the fossils come from the noncalcareous unit but some of them may come from noncalcareous beds in the calcareous unit. The plant fossils consist of leaves of ferns, Anemia sp.; conifers, Glyptostrobus specialis Holl.; Sequoia concinna Heer; and dicotyledons, Populites sp., Credneria sp., and Credneria cf. C. elegans Holl. J. A. Wolfe, who identified the plant fossils, states that they are Cretaceous in age, probably Albian or slightly younger (see list of fossil collections). Fossil mollusks include Unio sp., Inoceramus cf. I. cadottensis McLearn, and Trigonia cf. T. leana. D. L. Jones, who identified these forms, states that the Unios probably indicate a nonmarine depositional environment but are not diagnostic of age. He considers I. cadottensis McLearn to be of Albian age. Trigonia has a long range, at least mid-Jurassic to Late Cretaceous.

The age relations between the lithologic units described below are not known.

Noncalcareous sandstone

Noncalcareous sandstone unit (Ks) crops out in two northeast-trending belts, an eastern belt west of the Chulinak River in the southeast part of the map area and a western belt extending northeast from Kuzilvak Mountains to the Pikmiktalik River. The rocks consist of fine- to medium-grained, light- to dark-gray and greenish-gray sandstone interbedded with dark-gray siltstone. Much of the sandstone is hard and well indurated and commonly breaks into flaggy fragments 1 to 4 inches thick and 8 to 12 inches across. Sandstone beds 1 to 5 feet thick are common, especially in the eastern belt. Beds of calcareous sandstone in this unit are generally thicker bedded and less calcareous than those of the calcareous sandstone (unit Kcs).

The noncalcareous sandstone contains both marine and nonmarine deposits. Ripple marks, crossbedding, and mud cracks were noted in rocks of the eastern belt. These rocks also contain abundant carbonitized plant trash, broad-leafed plant fossils, and fresh-water mollusks. Marine mollusks and broad-leaf plant fossils in noncalcareous strata at the mouth of Andreafsky River are closely associated with highly calcareous sandstones. They are mapped with the noncalcareous sandstone (unit Ks) but may belong with the calcareous sandstone (Kcs).

The western belt of noncalcareous rocks appears to be mostly marine. The rocks contain some plant trash but have no diagnostic fossils or other strong evidence of fresh-water deposition.

Calcareous sandstone

Highly calcareous sandstones and interbedded noncalcareous siltstones crop out in a belt extending from near the mouth of Andreafsky River into the northeast corner of the map area. The belt widens northeastward where the calcareous sandstones are infolded and probably intertongue with laumontitized sandstones (Kls). A second poorly defined, discontinuous belt of calcareous sandstone crops out near the west edge of the mountains and extends northeast to the Pikmiktalik River. Bedrock exposures a few miles north of the map area indicate that much of the coastal plain west of the mountains and east of the Pastolik River is underlain by highly calcareous sandstone.

Some of the sandstone is more than 50 percent calcium carbonate and could be termed impure limestone. The calcareous sandstone is well indurated but is not as hard as the noncalcareous sandstone. Hills and ridges formed on the calcareous sandstone are generally lower and more rounded than those formed on the noncalcareous sandstones (Ks), and they are commonly surmounted by isolated ribs and sharp conical outcrops a few feet high.

The calcareous sandstone is mostly fine to medium grained, and medium to dark gray. Most of it is thin bedded and weathers into plates 1 to 2 inches thick and several inches across. Weathered fragments have a soft, brown, noncalcareous rind. Sandstone beds are separated by thin shaly partings. Predominately sandy sequences of beds 10 to 30 feet thick are separated by equal or greater amounts of siltstone, much of which is noncalcareous, micaceous, and commonly shaly.

No criteria were noted that indicate whether the calcareous sandstone is mostly marine or nonmarine. However, it is closely associated with the laumontitized sandstone, which is nonmarine, so probably at least part of the unit is nonmarine.

Laumontitized sandstone

Laumontitized sandstone (unit Kls) forms a broad, northeast-trending belt north of the Yukon River between the belts of calcareous sandstone. Near the Yukon the laumontitized belt is about 16 miles wide. About 35 miles farther north it narrows and the laumontitized rocks appear to be infolded and to intertongue with calcareous sandstone on the east. The unit consists of laumontitized sandstone interbedded with equal or greater thicknesses of calcareous and noncalcareous strata containing little or no laumontite. The laumontitized strata are also at least slightly calcareous and some of them are highly calcareous. Laumontitized tuff composed of fine-grained volcanic ash forms part of the belt along its western margin. It grades laterally into laumontitized tuffaceous sandstone.

The laumontitized strata are easily recognized by their dark-gray color mottled or spotted with light-gray areas. Rocks containing a large amount of laumontite (40 to 50 percent), such as the tuff, have an earthy appearance, are light gray or greenish gray and are mottled with dark gray.

The laumontitized sandstone is mostly medium grained; the fine-grained siltstone commonly contains little or no laumontite. The sandstone is a poorly sorted mixture of subangular and subrounded mineral and rock fragments in a poorly defined matrix containing chloritized biotite, sericite, calcite, and laumontite. The clasts are chiefly quartz, albite, chert, finely porphyritic volcanic detritus, shale chips, and carbonitized plant trash. Epidote, apatite, pyroxene, and sphene are very minor constituents. Laumontite replaces part of the albite, but most of the laumontite appears to be cement.

The laumontitized unit is probably largely or entirely nonmarine. The rocks contain very abundant plant trash, and are locally crossbedded. In the Koyukuk Basin, about 150 miles northeast from the map area, some laumontitized tuffs contain mud cracks and vertical plant stems. On Nelson and Nunivak Islands, 100 to 150 miles southwestward from the map area, laumontitized sandstone beds contain many well-preserved deciduous plant fossils of Albian and Cenomanian ages.

The laumontite probably was formed diagenetically by the interaction of volcanic glass and alkaline water either at the time of deposition or shortly thereafter (Hoare and others, 1964). The natural formation of sodic zeolites through the reaction of volcanic glass and alkaline solutions has been described by Bradley (1929) and Hay (1963), and similar zeolites have been synthesized in the laboratory (DiPiazza and others, 1959). However, laumontite, a calcic zeolite, has not yet been synthesized and the exact chemical conditions necessary for its formation are not known.

Structure and thickness

The Cretaceous sedimentary rocks were deposited in the Yukon-Koyukuk geosyncline (Payne, 1955; Hoare, 1961, fig. 3), which trends northeastward across the map area. The western margin of the geosyncline probably crosses the northwest corner of the map area. This boundary is suggested by the northeastward trend of tectonic elements in this part of Alaska, the exposures of old volcanic rocks (KJv) on the coastal plain, and several beds of cobble conglomerate which crop out near Norton Sound a few miles north of the map area. The eastern margin is 60 to 70 miles southeast of the map area.

The sedimentary rocks are regionally unconformable upon volcanic rocks of probable Jurassic and Early Cretaceous age similar to those that crop out in the north-central and southern parts of the map area. The pattern and intensity of folding in the sedimentary rocks indicate that they have been compressed southeastward to a fraction of their former width.

The rocks strike northeastward, and in the vicinity of the Yukon River they dip consistently westward. They probably are isoclinally folded and overturned southeastward. Farther northeast the rocks are apparently not so tightly folded, for there are numerous dip reversals showing relatively wide synclines and very narrow anticlines. Cutbanks along the East Fork of the Andreafsky River reveal numerous northeast-trending folds which are highly asymmetric to the southeast. The southeast limbs of the synclines are long and dip gently westward. The northwest limbs are short, steep, and locally overturned southeastward. Locally, minor anticlinal axes are faulted out.

The fault traces shown on the geologic map are clearly visible on air photos and on the ground. They have been selected from many other less obvious traces. The faults form two well-defined sets; one trends N. 40°-60° E., the other north to N. 60° W. The faults of the northeast set are generally longer and better defined than those of the northwest set, which are probably more numerous.

At intersections of the two fault sets there is no visible offset of the fault traces. Yet elsewhere the *northeast* set apparently displaces depositional contacts 1 to 2 miles by right-lateral separation, and the northwest set certainly displaces steeply dipping intrusive contacts at least a few tens of feet by left-lateral separation. The relative ages of the two fault sets is unknown; they probably are about the same age. If the dominant northeast set is slightly older, the northwest set should offset the northeast set. However, the observed left-lateral movement on the northwest faults is less than the width of the northeast-trending fault traces, which are generally a few tens of feet wide. It is therefore doubtful that the displacement would be topographically expressed.

Neither of the two fault sets is parallel to the regional strike or to the fold axes. Small axial plane faults were noted, and it is possible that the rocks may be offset by one or more large-scale, west-dipping reverse faults which are parallel to the regional strike.

The thickness of the sedimentary sequence cannot be determined directly because the rocks are highly deformed and poorly exposed. A reconnaissance airborne magnetometer survey in the Koyukuk geosyncline about 200 miles northeast of the map area yielded data suggesting a maximum depth of as much as 25,000 feet for the geosyncline (Zietz and others, 1959). Similar geophysical data in a parallel depositional trough about 100 miles south of the quadrangle indicate a depth of 15,000 to 20,000 feet (Dempsey and others, 1957). The sedimentary sequence in the map area probably is of comparable thickness. Because the rocks are isoclinally folded and possibly broken by large reverse faults, their true stratigraphic thickness may be much less than the thickness of the sedimentary pile.

Intrusive rhyodacite and dacite

Intrusive igneous rocks (Ki) crop out in the Kuzilvak Mountains in the southwest part of the map area and between the forks of the Andreafsky River near the eastern edge of the map area.

The rocks are chiefly light- to medium-gray porphyritic felsites, most of which are rhyodacite and dacite. The felsic groundmass consists of quartz, plagioclase, and orthoclase; the phenocrysts are plagioclase, quartz, biotite, and green hornblende. Quartz phenocrysts are rounded and embayed. Biotite and hornblende are commonly replaced by calcite and chlorite.

These fine-grained hypabyssal rocks typically form tabular, sill-like intrusive bodies which are elongate parallel to the strike of the enclosing strata but which dip more steeply than the bedding. They range in size from a few feet thick and several hundred feet long to several thousand feet thick and more than 20 miles long. The larger bodies extend into the adjoining Holy Cross quadrangle. Individual bodies pinch and swell along their length and locally form circular or elliptical domes which, in the adjoining quadrangle, are more than 2 miles wide.

Sedimentary rocks intruded by the large dacitic bodies near the eastern edge of the quadrangle show little or no contact metamorphism. In the Kuzilvak Mountains, however, the sedimentary strata are baked and recrystallized by contact metamorphism; much of the sandstone, particularly in the northern part of the mountains, is altered to biotite-hypersthene hornfels. The fine-grained igneous rocks which crop out in the Kuzilvak Mountains are probably apophyses from an underlying granitic pluton which has metamorphosed the sedimentary strata. Similar metamorphic effects occur on Cape Romanzof, about 50 miles west-southwest of the Kuzilvak Mountains, where sedimentary strata are intruded by a large pluton of granodiorite.

The potassium-argon ages of biotite from the Cape Romanzof pluton, and from a large sill-like body of microgranite about 25 miles northeast of the map area, were determined by M. A. Lanphere of the U.S. Geological Survey. Lanphere (written communication, 1964) states that the age of the Cape Romanzof pluton is 78.7 ± 4 m.y. (million years) and the microgranite is 67.1 ± 3 m.y. The difference in the two ages is probably significant because it is greater than the range of experimental error. According to recent compilations of the geologic time scale (Kulp, 1961, p. 1107; Evernden and others, 1964, p. 167), both bodies are Late Cretaceous in age. Since they intrude sedimentary strata of Albian or Cenomanian age, their radiogenic ages agree with the intrusive relationship.

Quaternary basalt

Horizontal and near-horizontal basaltic lava flows (Qb) crop out on the coastal plain west of the Yukon River. The flows are fine-grained, gray to black, olivine basalt that is mostly finely porphyritic and vesicular and scoriaceous. The rock consists of scattered phenocrysts of pyroxene and olivine in an intergranular groundmass of labradorite, magnetite, and pyroxene. The flows are commonly 5 to 15 feet thick and were extruded locally from small craters which have been greatly modified by erosion but are still recognizable. The flows are mostly or entirely terrestrial; many of them show columnar jointing. They are widely covered by silt deposits, so their distribution is inferred from their relative elevation and scattered boulders.

The flows are assigned a Quaternary age because paleomagnetic measurements made on a specimen from a point a few miles south of Ingrichuak Hill show that the flow is normally polarized. Recent work by Cox, Doell, and Dalrymple (1963) and by McDougall and Tarling (1963) shows that the present normal polarity epoch began about a million years ago. This date, together with physiographic expression and lack of deformation and alteration, indicates that the flows are Quaternary.

SURFICIAL DEPOSITS

Most of the unconsolidated surficial deposits in the map area lie west and south of the mountains. Part of this great area is underlain by deltaic deposits of the Yukon River, but most of it is an ancient coastal plain which flanks the mountains on the west and probably includes much of the area west of the Yukon between Ingrichuak Hill and Kwemeluk Pass.

The steep, broadly arcuate escarpment which marks the west edge of the mountains is probably a wave-cut feature. The width of the old coastal plain is not known, because the silt which mantles the surface merges with similar deltaic deposits farther west, but it probably is at least 10 miles. Most of the deposits on the old coastal plain are sand and fine to medium gravel deposited as coalescing alluvial fans by streams draining the adjacent mountains. These coarse-grained deposits are mantled by several feet of silt in which many small thaw lakes have formed.

Silt, fine sand, and woody material make up most of the unconsolidated deposits, but deep drill holes about 100 miles south of the map area reveal that coarse sand and gravel form a substantial part of the deposits at depth. The deposits are chiefly water laid, probably in fresh or brackish water. They have been extensively reworked by the shifting mouth of the Yukon and its distributaries and by ocean currents and waves. No wind-deposited material has been recognized, but it is reasonable to assume that some of the silt and sand has been reworked by wind action. Perennial frost is present in most of the deposits. Surficial thawing of the deposits has produced most of the myriad lakes on the delta.

Most of the material making up the delta region was derived from the interior highlands of Alaska and transported to the region by the Yukon River. Some of the material, however, was derived locally from isolated bedrock areas on the coastal plain and from mountains bordering the delta region on the east. These deposits have been subdivided into five units and mapped largely on the basis of physiographic expression and origin through the study of topographic maps and vertical air photos. Local examination of the deposits shows that they cannot be easily subdivided on the basis of composition or texture. The map units more nearly mark stages in the evolution of the delta region rather than lithologic differences.

Areas mapped as young flood-plain deposits (Qyf), and old flood-plain deposits (Qof) mark successive stages in the dissection and erosion of the old alluvial deposits (Qoa). Areas mapped as old beach deposits (Qob) and young beach deposits (Qyb) consist of fine-grained material which has been transported and redeposited by waves and longshore ocean currents.

Over most of the map, these five units are rather sharply defined, but locally there are transitional stages and the contacts are arbitrarily drawn.

The maximum thickness of the unconsolidated deposits in the delta region is not known. However, projecting bedrock within the region indicates that the thickness is highly variable and that the deposits are probably not more than a few hundred feet thick. Drilling operations about 100 miles south of the map area penetrated as much as 1,000 feet of unconsolidated deposits.

The age of the surficial deposits ranges from Pleistocene to Recent. Fossil mammoth remains have been found in the upper 20 to 30 feet of the old alluvial deposits at two places in the map area and at several other places in the delta region. If the fossils have not been recently reworked, the deposits are at least 10,000 years old, because the mammoth became extinct about 10,000 years ago (Hester, 1960). A Carbon-14 age determination of wood at a depth of about 600 feet is reported to be more than 34,000 years (Ives and others, 1964). The wood was obtained from a hole drilled 5 miles west of Bethel and about 100 miles south of the map area.

Old alluvial deposits

Old alluvial deposits (Qoa) include chiefly silt, sand, and gravel of fluvial origin. Locally they contain peat and scattered bones of fossil mammals. They make up the oldest coastal plain deposits, but also include terrace and fan gravels and colluvial deposits in and near the mountains.

In the western part of the map area, these deposits form a barren, tundra-covered alluvial plain that slopes gently seaward. The general distribution of the deposits probably marks the approximate shape of an old coastal plain which is now bordered on the west by the present delta of the Yukon and beach deposits. The plain is broadly rolling with a fairly well developed drainage pattern. Although it contains thousands of thaw lakes, it is drier and better drained than the younger deposits.

Most of the old alluvial deposits are of Pleistocene age, but the unit also includes some Recent colluvial and probably wind-deposited material. Local inhabitants report finding fossil bones in these deposits on the Yukon River about 20 miles below Mountain Village. Bones and fossil ivory are also reported from the high silt banks of the large lake drained by Nanvaranak Slough. The fossil material was not available for study, but the ivory suggests that at least part of it was mammoth.

Old flood-plain deposits

Areas mapped as old flood-plain deposits (Qof) include many small areas of young flood-plain deposits which are not differentiated on the map. The old flood-plain deposits are transitional with the young flood-plain deposits, and are separated from higher areas and remnants of old alluvial deposits by erosional scarps.

The old flood-plain deposits are chiefly silt, sandy silt, and bog deposits in former channels of the Yukon River and its distributaries. The channels were probably cut at a time when sea level was considerably lower than at present. The deposits which are less than about 8 feet above sea level are inferred to have been deposited in estuaries and bays which formed at the mouth of the Yukon River and its distributaries when sea level rose to about its present height. A well-preserved looped bar (Lobeck, 1939, p. 352-353) on the north side of the Kuzilvak Mountains probably formed while the Kuzilvak Mountains were an island in a former estuarine mouth of the Yukon. In the southwest area of the map, the old flood-plain deposits probably form part of an ancient subdelta and flood plain which was deposited when the Yukon flowed south of the Kuzilvak Mountains. The deposits are interpreted as deltaic because they underlie an arcuate area 20 to 25 feet above sea level, which is well above the average altitude of the adjoining modern(?) alluvial deposits. They are incised from southeast to northwest by a large abandoned meandering channel, probably a former course of the Black River when it was the main course or a major distributary of the Yukon River. The area is also characterized by the incised remnants of numerous small distributaries which flowed generally northwestward.

Locally, as around the south side of the lava flows northeast of the Kuzilvak Mountains, the deposits cover areas as much as 10 to 30 feet above sea level. These areas are remnants of old erosion surfaces cut by the Yukon River in the old alluvial deposits.

Near the north edge of the map area the unit includes a narrow belt of northeast-trending ridges 20 to 35 feet above sea level and a wider parallel belt of swampy, near-sea-level deposits on the landward side. The ridges probably represent an old offshore bar behind which low-lying lagoonal sediments were deposited.

The surface of the old flood-plain deposits is characterized by countless thaw lakes, many of them more than a mile wide, a few sluggish meandering streams, extensive swamps, numerous old stream scars and oxbow lakes, and a lack of trees. Much of the area mapped as Qof is inundated during flood stages of the Yukon River.

The age of the deposits ranges from Pleistocene to Recent. Most of the deposits are younger than the old alluvial deposits which occur at higher elevations.

Old beach deposits

Silt and sandy silt mapped as old beach deposits (Qob) form part of a belt of old beach ridges (cheniers) about 65 miles long. The belt begins south of the main mouth of the Yukon River and extends southwestward into the Hooper Bay quadrangle. The ridges are usually 1/4 to 1 mile apart and are generally not more than 3 feet higher than the intervening swales which contain shallow lakes. The average elevation of the ridges near the northwestern end of the belt is about 5 to 10 feet above sea level, much less than those farther south whose average elevation is 15 to 20 feet above sea level. The difference in elevation probably is original and reflects stronger wave activity towards the southern end of the belt. It is less likely that the difference in elevation is due to differential compaction or crustal warping.

In comparing the cheniers on the delta plain of the Mississippi River with the beach ridges (ritsen) on the Surinan coast, Price (1955, p. 76-80) points out that they form on sea coasts near the mouths of large, low-gradient rivers. Detailed studies of the Mississippi River cheniers (Gould and McFarlan, 1959, p. 263-264) show that they form on a generally prograding coast and are made up of the coarser particles winnowed out of the sediment being transported by longshore currents.

Most of the material making up the old beach ridges in the old flood-plain deposits came from the Yukon River. However, at the time the ridges were formed the main mouth of the Yukon was farther north than it is now. The present main mouth and modern delta of the Yukon and a probable former mouth of the Yukon (Kwemeluk Pass) are all younger than the beach ridges because they cut across them. A small area of beach ridges at the north edge of the map has been mapped with the old flood-plain deposits. However, it may be a northeastern extension of the beach ridges.

A water well was drilled in 1962 by the Bureau of Indian Affairs at Sheldon Point in old beach deposits. The driller's record shows gray, blue, and light-brown silt to a depth of 67 feet and fine sand and clay from 70 to 83 feet. The deposits are frozen to a depth of at least 52 feet.

The absolute age of the beach ridges is unknown. However, the height of some of the beach ridges above sea level (at least 20 feet high south of Melatolik Creek) suggests that the ridges were probably formed after sea level had risen to its present maximum height. The highest ridges in the Mississippi River delta region are 10 to 12 feet (Gould and McFarlan, 1959, pl. 2) so it is unlikely that the much higher ridges in the Yukon River delta region were formed when sea level was lower than at present. It is generally agreed that sea level has been at its present height for 3,000 to 5,000 years (Hopkins, 1959, fig. 4; Gould and McFarlan, 1959, p. 264). A recent paper (Coleman and Smith, 1964) presents new data and reviews older data which indicate that sea level reached approximately its present height about 3,650 years ago. It is therefore probable that the oldest ridges are younger than this.

Young beach deposits

Young beach deposits (Qyb) form a belt of silt and sandy silt recently deposited by longshore currents and waves. The unit includes young flood-plain and estuarine deposits along streams. The belt trends northeastward across the southeast corner of the map area. At the south edge of the map it is about 1 mile wide; north of Black River about 7 miles wide.

The deposits are essentially barren of vegetation and are generally separated from the tundra-covered old beach deposits by a distinct 2- to 4-foot break in slope. The division between the two groups of deposits is most clearly marked south of Melatolik Creek where a line of small tundra-covered dunes form the west boundary of the old beach deposits. The break in slope appears to be a wave-cut erosional feature reflecting a change in the character and quantity of material being carried along shore. The change was probably caused by a shift of the main flow of the Yukon River from a more northerly distributary to its present position.

For about 7 miles south of Black River the shoreline is prograding, and the young beach deposits contain numerous low, poorly defined beach ridges. Since the area was photographed for topographic mapping in 1951, a new beach ridge has formed, and the shoreline appears to be about a quarter of a mile farther west. Along this part of the coast the shore is relatively smooth and there is little or no break between the young beach deposits and the present-day tidal mud flats. Elsewhere the tidal flats and beach deposits are separated by a low ragged scarp and the shoreline is apparently retreating.

Young flood-plain deposits

Young flood-plain deposits (Qyf) are chiefly silt and sandy silt along the Yukon River and the smaller streams on the delta plain. Within the mountains, the flood-plain deposits are mostly sand, gravel, and boulders.

Most of the young flood-plain deposits occur at lower elevations than the old flood-plain deposits but locally natural levees along the Yukon River are higher than adjoining areas of old flood-plain deposits.

MINERAL POSSIBILITIES

No mineralized rocks or areas of hydrothermal alteration were noted during geologic investigations of the map area. However, according to local report an unknown person found "zinc ore" in the Kuzilvak Mountains some years ago. A small amount of disseminated arsenopyrite was found in the Kuzilvak Mountains during the present investigation, but the mountains were not examined in sufficient detail to confirm or deny the reports of "zinc ore."

At present there is no commercial use for the calcic zeolite, laumontite.

The probability of petroleum in the sedimentary rocks appears to be slight, because the exposed rocks are relatively impermeable and considerably deformed.

Fossil Collections
[Mollusks identified by D. L. Jones; plants by J. A. Wolfe]

Field No.	Mollusks USGS Mesozoic locality	Age
61AHr 86-B	M1174	Indet. (*Unio* sp.)
61AHr 271	M1175	Early Cretaceous (Albian)
61AHr 272	M1176	Cretaceous(?)
61AHr 196-A	M1177	Indet. (*Unio* sp.)
61AHr 302-A	M1178	Indet. (*Unio* sp.)
	Plants USGS Paleobot. locality	
61AHr 86-A	9919	
196-B	9920	Cretaceous (probably Albian or slightly younger)
302-B	9921	

Age determinations for biotite

[Constants: $K^{40}/K = 1.19\times10^{-4}$; $\lambda_e = 0.585\times10^{-10}$/year; $\lambda_\beta = 4.72\times10^{-10}$/year]

Field No.	Latitude and Longitude	Geologic unit	K_2O percent	A^{40} (moles/gm)	Ar^{40} rad / Ar^{40} total	Age (million years)
62AHr 218	63°09' N 161°20'W	Ki	8.08	8.155×10^{-10}	0.85	67.1±3.0
61AHr 91	61°45'N 165°09'W	Ki	7.39	8.757×10^{-10}	0.80	78.7±4.0

Argon analyses and age calculation: M. A. Lanphere, 1964
Potassium analyses: H. C. Whitehead and L. B. Schlocker, 1964

REFERENCES CITED

Bradley, W. H., 1929, The occurrence and origin of analcite and meerschaum beds in the Green River formation of Utah, Colorado, and Wyoming: U.S. Geol. Survey Prof. Paper 158-A, p. 1-7.

Coleman, J. M., and Smith, W. G., 1964, Late Recent rise of sea level: Geol. Soc. America Bull., v.75, p. 833-840.

Cox, Allan, Doell, R. R., and Dalrymple, G. B., 1963, Geomagnetic polarity epochs--Sierra Nevada II: Science, v. 142, no. 3590, p. 382-385.

Dall, W. H., and Harris, G. D., 1892, Correlation papers--Neocene: U.S. Geol. Survey Bull. 84, 349 p.

Dempsey, W. J., Meuschke, J. L., Andreasen, G. E., 1957, Total intensity aeromagnetic profiles of Bethel basin, Alaska: U.S. Geol. Survey open-file report, June 10, 1957, 3 sheets.

DiPiazza, J. J., Regis, A. J., and Sand, L. B., 1959, Formation of zeolites by the alteration of a volcanic glass by alkaline solutions [abs.]: Geol. Soc. America Bull., v. 70, no. 12, pt. 2, p. 1589-1590.

Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: Am. Jour. Sci., v. 262, no. 2, p. 145-198.

Gould, H. R., and McFarlan, Edward, Jr., 1959, Geologic history of the chenier plain, southwestern Louisiana: Gulf Coast Assoc. Geol. Socs. Trans., v. 9, p. 261-270.

Hay, R. L., 1963, Stratigraphy and zeolitic diagenesis of the John Day Formation in Oregon: California Univ., Dept. Geol. Sci. Bull., v. 42, p. 199-262.

Hester, J. J., 1960, Late Pleistocene extinction and radiocarbon dating: Am. Antiquity, v. 26, no. 1, p. 58-77.

Hoare, J. M., 1961, Geology and tectonic setting of Lower Kuskokwim-Bristol Bay Region, Alaska: Am. Assoc. Petroleum Geologists Bull., v. 45, no. 5, p. 594-611.

Hoare, J. M., Condon, W. H., and Patton, W. W. Jr., 1964, Occurrence and origin of laumontite in Cretaceous sedimentary rocks in western Alaska: U.S. Geol. Survey Prof. Paper 501-C, p. C74-C78.

Hopkins, D. M., 1959, Cenozoic history of the Bering Sea land bridge [Alaska]: Science, v. 129, no. 3362, p. 1519-1528.

Kulp, J. L., 1961, Geologic time scale: Science, v. 133, no. 3459, p. 1105-1114.

Ives, P. C., Devin, B., Robinson, R. D., Rubin, Meyer, 1964, U.S. Geological Survey Radiocarbon Dates VII: Radiocarbon, v. 6, p. 37-76.

Lobeck, A. K., 1939, Geomorphology, an introduction to the study of landscapes, 1st ed.: New York, McGraw-Hill Book Co., Inc., 731 p.

Martin, G. C., 1926, The Mesozoic stratigraphy of Alaska: U.S. Geol. Survey Bull. 776, 493 p.

McDougall, Ian, and Tarling, D. H., 1963, Dating of polarity zones in the Hawaiian Islands: Nature, v. 200, p. 54-56.

Payne, T. G., 1955, Mesozoic and Cenozoic tectonic elements of Alaska: U.S. Geol. Survey Misc. Inv. Map I-84, scale 1:5,000,000.

Price, W. A., 1955, Environment and formation of the chenier plain: Quaternaria, v. 2, p. 75-86.

Zietz, Isidore, Patton, W. W., Jr., and Dempsey, W. J., 1959, Preliminary interpretation of total intensity aeromagnetic profiles of the Koyukuk area, Alaska: U.S. Geol. Survey, open-file report, Nov. 12, 1959, 7 p.