GEOLOGIC MAP OF THE MARSHALL QUADRANGLE, WESTERN ALASKA

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INTRODUCTION

The geologic map of the Marshall quadrangle 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 unconsolidated surficial deposits were mapped by interpretation of aerial photographs and topographic maps, supplemented by a few field observations. Most of the fieldwork was accomplished with the aid of a helicopter, supplemented by a boat traverse on the Yukon River.

Rocks exposed in the quadrangle consist of an older group of deformed and metamorphosed volcanic and sedimentary rocks of Permian and probable Triassic age, a younger group of deformed sedimentary rocks of Cretaceous age, intrusive igneous rocks of presumed Cretaceous age, and undeformed lava flows and cinder cones of Quaternary age. Unconsolidated surficial deposits, chiefly silt of Quaternary age, conceal the bedrock over most of the quadrangle.

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BEDROCK

PERMIAN AND TRIASSIC(?) SYSTEMS

Metavolcanic and metasedimentary rocks.—Metamorphosed volcanic and sedimentary rocks (TRPvs) crop out along the Yukon River in the vicinity of Marshall and on Pilcher Mountain in the northeast corner of the quadrangle. Limited geophysical data from aeromagnetic profiles (Dempsey and others, 1957) indicate that they extend southwestward and underlie most of the unconsolidated deposits east of the Ingakslugwat Hills.

Near Marshall the unit consists chiefly of quartzite and quartzose schist of probable sedimentary origin, interbedded with chlorite and amphibole schists of probable volcanic origin. On Pilcher Mountain the rocks are fine- to coarse-grained greenschist consisting largely of fibrous blue-green amphibole, epidote, albite, and some quartz. The schists are contact-metamorphosed by the granitic stock that underlies Pilcher Mountain and have developed a hornfelsic texture.

Also included in this unit for mapping purposes are: dikes of granitic rocks that crop out upstream from Marshall but are too small to show on the geologic map; and a small amount of conglomerate and sandstone of uncertain but probably younger age that crops out at the upstream end of Marshall Village.

No fossils have been found in this map unit in the Marshall quadrangle. The rocks are thought to be of Permian and possible Triassic ages because: (1) They strike generally northeastward and apparently are correlative with less metamorphosed rocks that have yielded fossils of Permian age at Tuckers Slough (J. M. Hoare, unpub. data, 1960) about 45 miles farther east. (2) Lithologically similar, but less metamorphosed rocks, about 70 miles east-southeast of Marshall have yielded fossils of Permian and Late Triassic ages (Smith, 1939, p. 33; Condon, unpub. data, 1962).

CRETACEOUS SYSTEM

SEDIMENTARY ROCKS

Cretaceous sedimentary rocks crop out on the south side of the Kusilvak Mountains at the north edge of the quadrangle and in the vicinity of Pilot Station on the Yukon River. They are part of a thick sequence of interbedded marine and nonmarine sandstones and siltstones that extends northeastward at least 400 miles and probably extends southwestward beneath the unconsolidated deposits laid down by the Yukon and Kuskokwim Rivers.

The sandstones are fine- to medium-grained, light- to dark-gray or greenish, well-indurated graywackes. They consist of variable amounts of subangular to subrounded grains of quartz, feldspar, chert, siltstone, or shale, and volcanic rocks in a matrix of silt and clay-sized particles. Plagioclase is the most abundant feldspar but orthoclase locally forms as much as 20 percent of the rock. Detrital muscovite is abundant in many of the finer grained rocks. Most of the matrix, which generally constitutes 10 to 30 percent of the rocks, is too fine grained to be identified in thin section. Recognizable minerals include chlorite, sericite, biotite, quartz, and feldspar. Calcite is a cementing agent in many of the sandstones.

Individual sandstone beds vary in thickness from a fraction of an inch to massive strata many feet thick. Locally the sandstone contains light- and dark-gray laminations less than an inch thick that are not separated by shaly partings.

Siltstone constitutes at least half of the sequence, but it rarely crops out except in near-vertical exposures along streams. It generally weathers into small subconchoidal fragments but locally has a shaly fracture. Hard, fine-grained calcareous concretions are common in the siltstones, but the siltstones themselves are rarely calcareous.

For mapping purposes, the Cretaceous sedimentary rocks have been divided into two lithologic units on the basis of the predominantly calcareous or noncalcareous character of the sandstones. Most of the sandstones in the calcareous unit effervesce freely when treated with cold dilute hydrochloric acid, but the unit also includes strata that are noncalcareous or weakly calcareous. Conversely, the noncalcareous unit contains numerous beds that are at least weakly calcareous. In the adjoining Kwiguk quadrangle to the north, a third unit containing laumontitized strata has been mapped (Hoare and Condon, 1966) but no laumontitized rocks have been recognized in the Marshall quadrangle.

The structural and stratigraphic relations of the calcareous and noncalcareous units are not known because the rocks are deformed and poorly exposed. Contacts between the two units in general cannot be definitely placed except along faults; the units may represent calcareous and noncalcareous facies that were deposited during the same time interval.

The two outcrop areas in the Marshall quadrangle are southwestern extensions of long belts of calcareous and noncalcareous rocks which trend northeastward across the adjoining Kwiguk quadrangle.

Noncalcareous sandstone.—The noncalcareous sandstone unit (Ks) crops out north of the Yukon River and in the Kusilvak Mountains. The two outcrop areas are parts of two different belts of noncalcareous rock that in the adjoining Kwiguk quadrangle are separated by broad belts of laumontitized and calcareous strata. The unit probably includes both marine and nonmarine deposits. The rocks in the eastern outcrop area probably are chiefly nonmarine or near-shore marine, as they commonly show ripple marks, crossbedding, and mud cracks. They also contain abundant plant trash and sparse broad-leaf plant fossils and fresh-water mollusks. In the Kusilvak Mountains, most, or all, of the noncalcareous rocks are altered by contact metamorphism. Near the southern edge of the mountains they show only incipient signs of recrystallization but farther north the sandstones are altered to biotite-hypersthene hornfels.

The rocks consist of fine- to medium-grained, light- to dark-gray and greenish sandstone interbedded with dark-gray to black siltstone. The sandstone is hard and well-indurated. Beds 1 to 5 feet thick are common, especially in the eastern area, where some beds are even thicker. Calcareous sandstone beds in this unit are generally thicker and less calcareous than those in the calcareous sandstone unit (Kcs). Siltstone interbeds are generally thinner than the sandstone, but siltstone and shale intervals several tens of feet thick are not uncommon. The siltstone commonly is highly micaceous.

Fossil plants and mollusks found near Pilot Station indicate that the rocks in that area are late Early and early Late Cretaceous (Albian and Cenomanian) in age. The plant fossils (USGS paleobot. loc. 9916) consist of leaves of dicotoledons: *Aralia wellingtoniana* of Hollick and *Credneria grewiopsoides* Holl. J. A. Wolfe, who identified the plant fossils, states that both species are of Cenomanian (early Late Cretaceous) age. D. L. Jones identified the mollusks (USGS Mes. loc. M1173) as a Unionid clam, close to *"Cultellus?" kokolikensis* Imlay from the Kukpowruk Formation, and undetermined snails. Jones states that the mollusks indicate a probable nonmarine environment and are generally similar to fossils of Albian (Early Cretaceous) age from the north slope of Alaska but that the material was too poor for a definite correlation.

It is highly probable that the plant fossils were also deposited in a nonmarine environment or in a near-shore marine environment, as the rocks in which they occur contain abundant ripple marks, crossbedding as much as 12 inches high, mud cracks, and scattered quartz pebbles.

Calcareous sandstone.—The calcareous sandstone unit (Kcs) probably underlies a small area at the north edge of the quadrangle in the vicinity of Pilot Station. There are no known exposures of the unit in the Marshall quadrangle, but it crops out near the southern edge of the adjoining Kwiguk quadrangle. The contact between the calcareous and noncalcareous units was projected southwestward into the Marshall quadrangle parallel to the regional strike.

The following description of the calcareous sandstones is based upon observations made in the Kwiguk quadrangle. They are fine to medium grained and medium to dark gray. The sandstone is generally thin bedded with thin shaly partings and commonly weathers into plates 1 to 2 inches thick and several inches wide. Weathered fragments have a soft, brown noncalcareous rind. Predominantly sandy sequences of beds 10 to 30 feet thick are separated by equal or greater amounts of siltstone, much of which is micaceous, noncalcareous, and commonly shaly. 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 comconly surmounted by isolated ribs and sharp conical outcrops a few feet high.

No criteria have been found in the calcareous sandstones to indicate whether they are mostly marine or mostly nonmarine. In the Kwiguk quadrangle, however, they are closely associated with the laumontitized sandstone, which is nonmarine, (Hoare and others, 1964) probably at least part of the calcareous sandstone is nonmarine.

INTRUSIVE ROCKS

Intrusive rocks include a few dacite, rhyodacite, and aplite dikes (Ki) in the Kusilvak Mountains near the north edge of the quadrangle and coarser grained granitic rock (Kg) on Pilcher Mountain at the east edge of the quadrangle. Both map units extend into adjoining quadrangles, where they are more widely exposed. A Cretaceous age for the intrusive rocks is inferred from potassium-argon age determinations made (Hoare and Condon, 1966, p. 7) on similar rocks in adjoining quadrangles.

Rhyodacite, dacite, and aplite.—Dikes of rhyolite, dacite, and aplite were mapped primarily on the basis of float. Some of them trend generally east-west parallel to the strike of the enclosing sediments; others trend northward. Most of them probably are less than 30 feet thick. Dikes probably are more abundant than shown on the geologic map; only a small part of the area was examined in the field.

The aplite is a fine grained, sugary-textured, white or cream colored mixture of quartz, orthoclase, and muscovite. The dacite and rhyodacite dikes are chiefly light to medium-gray porphyritic felsites. The felsic groundmass consists of variable amounts of plagioclase, orthoclase, and quartz; the phenocrysts are plagioclase, orthoclase, quartz, biotite, and green hornblende. Quartz phenocrysts are embayed and partly resorbed; a few of the plagioclase phenocrysts appear to be as calcic as labradorite, but most of them probably are oligoclase and andesine. They are generally complexly zoned and twinned. Hornblende is partially replaced by calcite and green chlorite that in doubly polarized light is an anomalous blue and brown.

The dikes probably are apophyses from an underlying granitic pluton, for most of the sedimentary rocks in the Kusilvak Mountains are baked and altered by contact metamorphism. At the north edge of the quadrangle, some of the sandstones are altered to biotite-hypersthene hornfels. Metamorphism becomes progressively weaker southward and is not directly related to the dikes themselves. Roof pendants of sedimentary rocks in granodiorite in the Askinuk Mountains (Hoare and Condon, 1968, p. 1) about 30 miles southwestward are similarly altered.

Granitic rocks.—Small areas of granitic float occur on the south slope of Pilcher Mountain at an elevation of about 500 to 750 feet and at about the same elevation on the east and northeast sides in the adjoining Russian Mission quadrangle. The contact between the intrusive and the altered amphibolite schist that forms the top of Pilcher Mountain is inferred at a break in slope at an elevation of about 900 feet on the south slope and about 500 feet on the north slope. Elsewhere the contact is even more indefinite. It is inferred a short distance east of the village of Marshall, because some of the rocks exposed at Marshall are hornfelsed and intruded by small granitic dikes.

The intrusive rock is fine to medium grained, light gray, and slightly foliated. It consists of about equal amounts of orthoclase and plagioclase plus quartz and biotite and is quartz monzonite.

QUATERNARY SYSTEM

Basalt.—Isolated areas of basalt lava flows and cones are widely distributed within the quadrangle. The areas range in size from less than one square mile to the extent of the Ingakslugwat Hills, which consists of six groups of cones and associated flows that together cover an area of about 200 square miles. The outer limits of the volcanic areas are approximately known because they are mantled by silt deposits, and the distribution of the volcanic rocks is inferred from their relative elevation and scattered basalt boulders. In the oldest volcanic areas most of the original volcanic features, except for their low convex shape, have been destroyed by frost action and erosion; only a few retain remnants of crater rims.

Most of the cones and flows in the Ingakslugwat Hills are relatively young and not much modified. The youngest flows are practically barren or covered by a thin veneer of vegetation; they are free of silt. Some of them retain most of their original flow features; others are a confused jumble of frost-rived boulders. The older volcanic vents apparently were low, wide cones with saucer-shaped craters up to a mile in diameter. The younger eruptions formed relatively small, steep cones of various types. Numerous small spatter and breccia cones about 100 feet high occur on the northwest side of the volcanic area. Some of these are alined west-northwest and apparently define a fracture. The largest cones are as high as 300 feet and are steep-sided composites of small, thin, highly vesicular flows, ash, cinders, spatter, and breccia. Also present are three or four extremely steep cones about 150 to 200 feet high which have slope angles that exceed 45° near their summits. These cones contain craters 100 feet or more deep and 300-500 feet wide with vertical and near-vertical walls. The rims of the craters are very narrow and all but one are broken away near the top of the cone to form flat or V-shaped spillways through which lava cascaded down the side of the cone. Sectional views of the crater walls reveal that the cones consist chiefly of countless small, agglutinated, highly vesicular flow units a few inches thick. The flow units commonly are horizontal where they cross the crater rim; some continue for a few feet down the outside of the cone. They apparently represent small splashes of viscous lava that froze on the crater rim and added height to the cone but seldom were voluminous enough to flow down the sides of the cone and add much width. The spillways were caused by a final voluminous upsurge of lava after the cones reached their maximum height. The cones that lack a spillway clearly show that the lava drained back down the conduit beneath the cone without a final voluminous discharge.

The basalt is fine to medium grained, finely porphyritic, and medium to dark gray. Highly vesicular and scoriaceous phases are black and aphanitic to glassy. Most of the flows are 5 to 20 feet thick and columnar jointed.

Thin-section examination of the rocks in the Ingakslugwat Hills shows that they are mostly alkali-olivine basalt. They consist of abundant olivine and augite phenocrysts in an intergranular groundmass of labradorite, augite, and accessory magnetite. Large olivine phenocrysts are generally rounded but lack pyroxene reaction rims; small phenocrysts are generally euhedral. No groundmass olivine was seen. Some of the groundmass pyroxene is lavender and probably titaniferous. Titaniferous pyroxene is reported to be characteristic of alkali basalts in Hawaii (MacDonald and Katsura, 1964, p. 92).

Numerous mafic and ultramafic inclusions as large as 10 inches in diameter occur in olivine nephelinite ash on the south side of the southwest cone complex in the Ingakslugwat Hills. Small, very sparse inclusions also occur in alkali olivine basalt that forms the north side of the complex and in the youngest flow, which came from the complex. This is the only known occurrence of inclusions in basalt in the delta area. The inclusions consist of olivine gabbro and lherzolite (White, 1966, p. 252, 281, spec. 298). Some of the gabbro inclusions are thinly layered granulites, but most of them have an intergranular texture and are not layered.

The flows and cones are assigned a Quaternary age on the basis of their physiographic expression and magnetic polarity. Many paleomagnetic measurements made on the ground revealed only normally magnetized rocks. The field measurements confirm earlier aeromagnetic data (Dempsey and others, 1957) that indicate normally magnetized rocks everywhere except on the extreme northern edge of the lava flows, where a single sharp negative anomaly indicates a small amount of reversely magnetized rock. The normally polarized basalts cooled during the latest normal polarity epoch, the Brunhes, the reversely polarized basalts probably cooled during the preceeding reversed polarity epoch, the Matuyama (Cox and others, 1964, 1965). Recent studies (Dalrymple and others, 1965; Doell and others, 1966) place the Matuyama-Brunhes polarity epoch boundary at about 0.7 million years ago, and the beginning of the Matuyama at about 2.4 million years ago.

The basalt mapped at the east edge of the quadrangle is more weathered than the other basalts and is undoubtedly older. It may be Pliocene in age.

SURFICIAL DEPOSITS

QUATERNARY SYSTEM

The surficial deposits in the Marshall quadrangle are chiefly fluvial but include large amounts of wind-deposited material as well as small amounts of colluvium on the lower slopes of the mountains. They include both coastal plain deposits and old deltaic deposits laid down by the ancestral Yukon and Kuskokwim Rivers and their distributaries. In the western and southern parts of the quadrangle, some of the fluvial deposits have been reworked by tidal currents. South and southwest of the Yukon River, they have been extensively reworked by the wind.

Except for a small amount of gravel of colluvial and fluvial origin, the surficial deposits are silt and fine sand with admixed woody material. Water wells drilled at various places in the delta area show that the deposits include appreciable amounts of coarse sand, gravel, and clay at depth.

Most of the deposits are permanently frozen to depths of at least 200 to 300 feet. Surficial thawing has produced most of the myriad lakes. Large areas of rectangularly patterned ground caused by intersecting ice wedges are common.

The maximum thickness of the surficial deposits is not known. However, the bedrock "islands" suggest that the thickness is highly variable. They probably are thinnest in the central part of the quadrangle and thickest in the northwestern and southeastern parts, which are underlain by old flood-plain deposits. These two areas probably include the deeply alluviated ancestral channels of the Yukon River and perhaps the Kuskokwim. Drilling operations about 15 miles south of the quadrangle penetrated as much as 1,000 feet of unconsolidated deposits.

The age of the deposits ranges from Pleistocene to Holocene. Wood obtained at a depth of about 600 feet from a well 5 miles west of Bethel (about 15 miles southeast of the Marshall quadrangle) yielded a carbon-14 age of more than 34,000 years (Ives and others, 1964). Fossil mammoth remains have been found in the upper part of the old alluvial deposits elsewhere in the delta region. If the fossils were not recently reworked, the deposits are at least 10,000 years old, because the mammoth became extinct about 10,000 years ago (Hester, 1960).

The deposits cannot be easily subdivided on the basis of composition or texture, but they can be subdivided and mapped on the basis of physiographic expression and origin through the study of air photos and topographic maps. They have been subdivided into five map units that mark stages in the evolution of the delta region rather than lithologic differences. At many places, the map units are sharply defined by erosional scarps; elsewhere they are transitional and contacts are arbitrarily drawn.

Old alluvial deposits.—The exposed upper part of the old alluvial deposits (Qoa) consists of silt and fine sand with admixed plant material. The lower parts of the unit probably include large amounts of gravel and coarse sand. The coarse-grained material and some of the fine-grained material in the lower parts are fluvial in origin, but much of the fine-grained material in the upper part of the unit has probably been reworked and redeposited by the wind. The areas mapped as old alluvial deposits lack the typical dune and swale topography of wind deposits. Any original eolian surface features have been erased by solifluction and the repeated freezing and thawing of the upper few feet of the permafrost over a period of many thousands of years. The eolian origin of most or all of the fine-grained material in the upper part of the old alluvial deposits is inferred from grain size and distribution: (1) The material is uniformly fine grained. (2) It mantles all but the youngest Quaternary basalts and reaches elevations far above any known sea level. None of the Quaternary basalt areas were traversed by through-running streams that could have deposited the high silts.

The deposits form a barren tundra-covered plain which rises gently eastward toward the mountains. On the north, south, and west sides of the Ingakslugwat Hills, the plain is about 40 to 50 feet above sea level. A few miles farther east, its height is 60 to 70 feet. Near their eastern edge, the old alluvial deposits reach a height of 90 to 100 feet and are overlain by younger wind-blown deposits (Qw). Before the Yukon River assumed its present course, the old alluvial plain extended east and north to the foot of the mountains as it presently does farther north in the Kwiguk quadrangle.

"Island" remnants of the old alluvial plain in the northwest and southeast parts of the quadrangle show that it was formerly much more extensive before dissection by the Yukon, Kuskokwim, and smaller coastal rivers.

The plain is drained by an intricate network of first-, second- , and third-order streams. Its surface is pitted by innumerable small thaw lakes and several large lakes. Most of the larger lakes are stream fed and drained. The small lakes commonly have neither inlet nor outlet, but many of them are at the head of the tiny third-order streams. Lake-free, circular areas a mile or more in diameter are mostly old, drained lakes, or vegetation-filled lakes.

The old alluvial deposits generally are separated from the flood-plain deposits by outward-facing erosional scarps as high as 50 feet. Locally there is no scarp and the contact is indefinite.

Old flood-plain deposits.—The old flood-plain deposits consist of silt and sandy silt with admixed plant material. Areas mapped as old flood-plain deposits (Qof) include many small areas of young flood-plain deposits that are not differentiated on the map. The old flood-plain deposits are transitional with the young flood-plain and estuarine deposits, but generally are separated from higher areas and remnants of old alluvial deposits by erosional scarps.

The surface of the old flood-plain deposits is characterized by countless thaw lakes, many of which are more than a mile wide, several sluggish meandering large streams, numerous small streams, numerous old stream scars and oxbow lakes, and narrow to wide belts of natural levees. Relatively few of the thaw lakes are drained by the streams because the streams flow between natural levees and are generally above lake level.

The old flood-plain deposits in the northeast part of the quadrangle were laid down in the present valley of the Yukon River. In the southeast, west, and northwest parts of the quadrangle they occupy former channels and distributaries of the ancestral Yukon. Alternatively, the old flood-plain deposits in the southeast part of the quadrangle may indicate an ancestral channel of the Kuskokwim River or a combination of the Yukon and Kuskokwim Rivers.

These old channels incise the old alluvial deposits and were probably cut when sea level was considerably lower than at present. Each year they are widely inundated by silt-laden flood waters and are probably receiving more silt than they are losing. Present and recently abandoned channels of the larger streams, such as the Black and Kashunuk Rivers, meander widely between natural levees which are 2 to 5 miles wide and 5 feet or more above the adjacent terrain. In the northwest corner of the quadrangle, the old flood-plain deposits probably include part of an old subdelta of the Yukon that extends northwest into the Black quadrangle and southwest into the Hooper Bay quadrangle.

The height of the old flood-plain deposits above sea level is somewhat variable because they include older and younger channels that have been eroded and alluviated in varying degrees. Their average minimum elevation in the southwest part of the quadrangle is about 15 to 25 feet. They rise generally northeastward to a maximum average height of about 35 to 45 feet in the present Valley of the Yukon.

About 9 miles south of Pilot Station, old flood-plain deposits are mapped in a valley about 10 miles long that is incised in the old alluvial deposits (Qoa) and drains westward. The valley is beheaded on the east by the Yukon Valley. The beheaded valley is at least 35 feet higher than the Yukon Valley and is separated from it by a steep east-facing scarp.

There are two possible origins for the beheaded valley. It probably is the truncated remnant of a former distributary of the Yukon that was cut when the Yukon was at a higher elevation and drained by way of the Kashunuk and Black Rivers. But it could be part of a much older stream system that drained the nearby mountains before it was beheaded by the northward shift of the Yukon.

Radiometric dating of the old flood-plain deposits in the old beheaded valley might reveal when the Yukon first assumed its present westward course in the Marshall quadrangle.

Wind-blown deposits.—Extensive wind-blown deposits (Qw) consist of silt and sandy silt. The deposit overlies the old alluvial deposits in the eastern part of the quadrangle and forms a broad, older northeast-trending belt that intersects a relatively narrow, younger, northwest-trending belt near the east edge of the quadrangle. The southern edge of the broad southern belt is a dissected outward-facing scarp 20 to 60 feet high. The scarp and the small islands of probable wind-deposited silt farther south suggest that the deposits once extended to the southern edge of the old alluvial deposits. The deposits apparently thin westward and northward and their contact with the old alluvial deposits is indefinite.

Near their western edge the wind-blown silts are 70 to 100 feet above sea level. They apparently thicken eastward, reaching a maximum height of 200 to 210 feet and a maximum thickness of about 100 feet near the present Yukon flood plain.

The source of the younger northwest-trending belt of wind-blown silt is clearly the present flood plain of the Yukon. The belt is characterized by small fixed dunes and many blowouts, some of which contain lakes. Westward the original depositional features are more modified, the drainage is better integrated, and the deposits are older. The location and northeast trend of the older wind-blown silts suggest that their source was the old flood-plain deposits in the southeast corner of the quadrangle. The old stream-cut scarp on the south side of the older wind-blown silts suggests that the ancient channel that crosses the southeast corner of the quadrangle may have been reoccupied by a major stream after it was abandoned.

Young flood-plain deposits.—Young flood-plain deposits (Qyf), chiefly silt and sandy silt, are mapped along the Yukon and Johnson Rivers. Small areas of young flood-plain deposits also occur along the other streams but have not been differentiated.

Estuarine deposits.—Areas mapped as estuarine deposits (Qe) near the southern and western edges of the quadrangle consist of fluvial silt and sandy silt which has been reworked and re-deposited by tidal currents. Most of them were deposited in relatively quiet brackish estuaries and on the sides of bays near the present sea coast, but locally, as in the southeast corner of the quadrangle, they probably extend far inland along former estuarine channels of the ancestral Yukon or Kuskokwim rivers. They range in elevation from 2 to 3 feet to about 13 feet. They are generally separated from older deposits by a low scarp and commonly surround residual "islands" of older higher deposits. Most of the deposits probably are above normal tide range but they are probably widely innundated by occasional high "storm" tides.

The Quaternary volcanic rocks contain a few vague to well-defined lineaments, probably fracture traces. They are approximately parallel to many other lineaments previously mapped in the adjoining Hooper Bay and Kwiguk quadrangles (Hoare and Condon, 1966, 1968). The northwest-trending lineament on the northwest side of the Ingakslugwat Hills is defined by a trough and sevearal small alined volcanic vents.

The chief structural feature of the quadrangle is a large northeast-trending fault that probably is the southwestern extension of the Chirosky fault zone, which splits off the Kaltag fault 150 miles northeast (Patton and Hoare, 1969, p. D151, fig. 5). The reasoning and evidence which suggest that the Chirosky fault zone may extend across the Marshall quadrangle are: (1) The straight escarpment on the southeast side of the Cretaceous rocks is parallel to the inferred fault zone and extends northeastward to the area where the Chirosky fault zone is expressed in bedrock in the Unalakleet quadrangle. (2) Geologic investigations elsewhere in western Alaska (Hoare and Coonrad, 1961a, 1961b) indicate a close association between late Tertiary and Quaternary volcanism and large northeast-trending faults. (3) There is a short, but well-defined northeast-trending lineament on the southeast side of the Ingakslugwat Hills. (4) Gravity data obtained by D. F. Barnes (unpub. data, 1968) indicate a sharp change from a high positive value on the east to a low positive value on the west where the fault crosses the Yukon. Southwest of the Marshall quadrangle, the fault is inferred to pass through, or near, the north side of the volcanic rocks on Nelson Island and Nunivak Island.

STRUCTURE

Both the pre-Cretaceous metamorphic rocks and the Cretaceous sandstones strike northeastward parallel to the regional structure. The Cretaceous sedimentary rocks dip generally westward, but direction of dip in the metamorphic rocks is variable.

MINERAL POSSIBILITIES

A little pyrite was noted in some of the old sedimentary rocks near Marshall and a small amount of disseminated arsenopyrite was found in the Kusilvak Mountains, but no mineralization of probable economic interest was seen. Several years ago there was an unconfirmed report of "zinc ore" in the Kusilvak Mountains, but the mountains have not been examined in sufficient detail to confirm or deny this report.

The exposed sedimentary rocks are considerably deformed and relatively impermeable and thus the region is considered to have a low petroleum potential. However, the character of the sedimentary rocks that probably underlie the surficial deposits in the western part of the quadrangle has not been determined. They might possibly be less deformed and more permeable.

REFERENCES CITED

Cox, Allan, Doell, R. R., and Dalrymple, G. B., 1964, Reversals of the earth's magnetic field: Science, v. 144, no. 3626, p. 1537-1543.

1965, Quaternary paleomagnetic stratigraphy, *in* Wright, H. E., Jr., and Frey, D. G., eds., The Quaternary of the United States: Princeton, N. J., Princeton Univ. Press, p. 817-830.

Dalrymple, G. B., Cox, Allan, and Doell, R. R., 1965, Potassium-argon age and paleomagnetism of the Bishop Tuff, California: Geol. Soc. America Bull., v. 76, no. 6, p. 665-674.

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

Doell, R. R., Dalrymple, G. B., and Cox, Allan, 1966, Geomagnetic polarity epochs—Sierra Nevada data, [Pt. 3]: Jour. Geophy. Research, v. 71, no. 2, p. 531-541.

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

Hoare, J. M., and Coonrad, W. L., 1961a, Geologic map of the Goodnews Bay quadrangle: U.S. Geol. Survey Misc. Geol. Inv. Map I-399, scale 1:250,000.

-1961b, Geologic map of the Hagemeister Island quadrangle: U.S. Geol. Survey Misc. Geol. Inv. Map I-321, scale 1:250,000.

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.

Hoare, J. M., and Condon, W. H., 1966, Geologic map of the Kwiguk and Black quadrangles, western Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-469, scale 1:250,000.

1968, Geologic map of the Hooper Bay quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-523, scale 1:250,000.

Ives, P. C., Leven, Betsy, Robinson, R. D., and Rubin, Meyer, 1964, U.S. Geological Survey radiocarbon dates VII: Radiocarbon, v. 6, p. 37-76.

MacDonald, G. A., and Katsura, T., 1964, Chemical composition of Hawaiian lavas: Jour. Petrology, v. 5, p. 82-133.

Patton, W. W., Jr., and Hoare, J. M., 1969, The Kaltag fault, west-central Alaska: U.S. Geol. Survey Prof. Paper 600-D, p. D147-D153.

Smith, P. S., 1939, Areal geology of Alaska: U.S. Geol. Survey Prof. Paper 192, 100 p.

White, R. W., 1966, Ultramafic inclusions in basaltic rocks from Hawaii: Contr. Mineralogy and Petrology 12, p. 245-314.