DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-339

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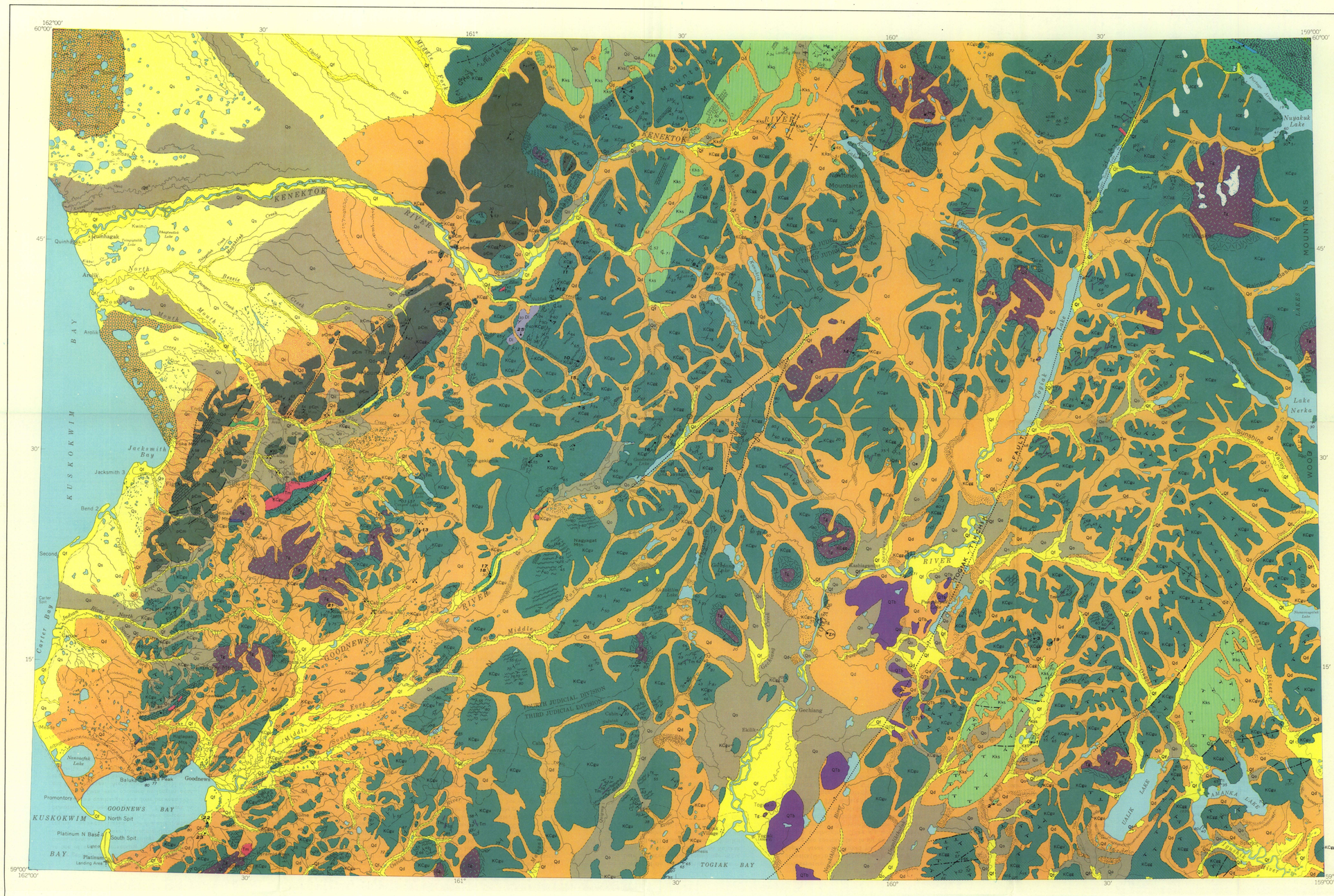


EXPLANATION

Recent — QUATERNARY

Qf — Flood plain alluvium
Includes some beach deposits

Qc — Colluvium
Chiefly frost-rived rubble, locally includes stream alluvium, terrace gravels, glacial deposits, and windblown silt

Qr — Reworked silt
Silt, sandy silt, and bog deposits

Pleistocene — QUATERNARY

Qd — Glacial drift
Poorly to well-sorted silt, sand gravel, and boulders; stipple indicates well-defined end and lateral moraines

Qo — Outwash deposits
Poorly to well-sorted silt, and gravel, and some boulders in terraces and outwash fan-plains

Qs — Silt deposits
Light- to dark-gray silt and sandy silt

Pliocene or Pleistocene — TERTIARY OR QUATERNARY

QTb — Basalt
Vesicular basalt flows, horizontal

Lower and Upper Cretaceous — CRETACEOUS

Kks — Kuskokwim group
Interbedded medium- to dark-gray siltstone and graywacke; much boulder and cobble conglomerate in lower part in vicinity of Eek Mountains

CARBONIFEROUS TO CRETACEOUS

KCgs, KCgv, KCgl, KCgc — Gemuk group
Chiefly massive to thin-bedded siliceous siltstone, chert, and mafic volcanic rocks, with lesser amounts of calcareous siltstone,graywacke, conglomerate, and limestone, KCgu. Locally differentiated into the following units: Characteristically coarse-grained clastics but includes much siltstone and lesser amounts of chert and mafic volcanic rocks, KCgg; altered mafic volcanic rocks, KCgv; white, light-gray, and buff limestone containing fossils of Permian age, closely associated with mafic volcanic rocks, KCgl; chert, graywacke, calcareous siltstone, and limestone, with lesser amounts of mafic volcanic rocks, KCgc

DEVONIAN

Dl — Limestone
Massive to thin-bedded, gray limestone

PRECAMBRIAN

pCm — Metamorphic complex
Chiefly medium- to coarse-grained gray and pink gneiss and light- to dark-gray schist; small amounts of garnetiferous amphibolite and marble

INTRUSIVE IGNEOUS ROCKS — TERTIARY

Tm — Mafic rocks
Chiefly gabbro and diabase, forms small stocklike intrusive bodies and numerous dikes and sills

Tr — Albite rhyolite
Light- to medium-gray porphyritic; forms dikes and sills

Tg — Granitic rocks
Chiefly quartz-monzonite, granite, granodiorite, and diorite; includes minor amounts of pegmatite, aplite, and gabbroic and diabasic rocks; form numerous stocks and stocklike intrusive bodies

Tu — Ultramafic rocks
Serpentine and serpentinized dunite and peridotite

Lithologic symbols
For local differentiation within major map units

- Lava flows
- Conglomerate
- Volcanic breccia
- Limestone
- Hornfels

Trace of conspicuous beds within formation

Contact
Solid where located by field mapping or where clearly interpretable on aerial photographs; dashed where approximately located by field mapping; dashed and dotted where located solely by photointerpretation; queried where inferred

Fault
Dashed where approximately located by field mapping; dashed and dotted where located solely by photointerpretation; dotted where concealed; queried where inferred. U, upthrown side; D, downthrown side

Anticline
Showing trace of axial plane of fold, dashed where approximately located

Syncline
Showing trace of axial plane of fold and plunge of axis, dashed where approximately located

Strike and dip of beds
Probably includes some overturned beds

Strike and dip of beds based on photointerpretation
Probably includes some overturned beds

Strike of vertical beds

Strike and dip of overturned beds

Strike and dip of foliation

Strike and dip of foliation and plunge of linlation

Strike of vertical foliation

Strike and dip of flow cleavage

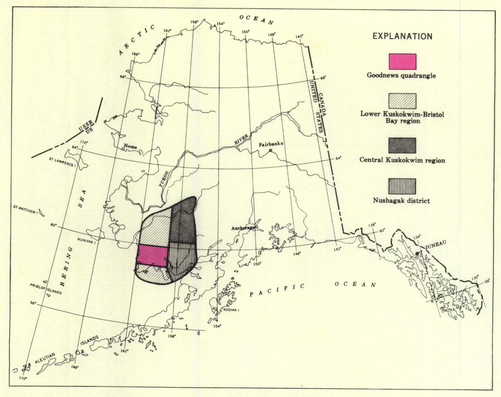
Strike of vertical flow cleavage

Placer mine

Placer prospect

Lode prospect
Letter symbol indicates chief mineral

Fossil locality
Number refers to list of fossil collections



INDEX MAP OF ALASKA

INTRODUCTION

The geologic map of the Goodnews quadrangle is one of several presenting the results of reconnaissance study of the geology and mineral resources of the Lower Kuskokwim-Bristol Bay region, southwest Alaska. Field studies, which began in 1946 and ended in 1953, were concerned primarily with bedrock geology. Fieldwork in the Goodnews quadrangle was done between 1950 and 1953. Data were obtained on lengthy boat and foot traverses. Areas covered by field traverses are fairly well indicated by the distribution of strike symbols with numerical dip values.

Trimetrogon vertical and oblique 1:40,000-scale aerial photographs facilitated both the planning of fieldwork and the mapping. Recently obtained vertical aerial photographs cover about three-fourths of the quadrangle. Stereoscopic study of vertical photographs provided much structural data. Surficial deposits have been mapped almost entirely on the basis of photointerpretation supplemented by numerous field observations.

Lithologic symbols have been used to indicate known exposures of distinctive types of rocks, which have been identified in the field. The rocks are more extensive than shown on the map but have not been traced out parallel to their strike.

The topographic base map is highly generalized but is adequate in most areas for presenting the results of this reconnaissance study. Locally the small scale of the map has necessitated the generalization or exaggeration of some geologic details. The writers made a more accurate and detailed planimetric map from aerial photographs of most of the area west of 161° W. longitude.

Previous investigations in the Goodnews quadrangle were made by J. E. Spurr (1900) who traveled up Kanektok River and down Togiak River, by G. L. Harrington (1919) who mapped the area north of Goodnews Bay, and by J. B. Mertie, Jr., (1938) who mapped on reconnaissance scale in the Tikchik and Wood River Lakes area near the east edge of the quadrangle.

The writers were efficiently assisted in the field at different times by R. P. Nickolsen, L. A. Brubaker, D. B. Snodgrass, T. A. Konigsmark, Mark Christensen, Brainerd Mears, Jr., and M. E. Kauffman. Fossil collections were identified by R. W. Imlay, J. B. Reeside, Jr., James Steele Williams, J. M. Berdan, Helen Duncan, and E. L. Yochelson of the U. S. Geological Survey and G. A. Cooper of the U. S. National Museum. Appreciation is expressed to the Goodnews Bay Mining Co., to Mr. and Mrs. Joe Jeans, and Rev. and Mrs. R. B. Michael for their assistance, information, and hospitality.

BEDDED ROCKS

Bedded rocks ranging in age from Precambrian to late Cenozoic and associated intrusive rocks of Tertiary age crop out in the Goodnews quadrangle. Unconsolidated surficial deposits, largely glacial, of Quaternary age mantle the low coastal area in the western part of the quadrangle and conceal the bedrock in valley bottoms elsewhere in the quadrangle. Bedrock formations consist primarily of fine- to coarse-grained clastic rocks, chert, and mafic volcanic rocks. Bedded rocks older than lava flows of late Tertiary or early Quaternary age are complexly folded and faulted. Major structural elements strike generally northeast.

METAMORPHIC ROCKS

A metamorphic complex, pCm, crops out in the northwest corner of the quadrangle from near Jacksmith Bay northeast to the north edge of the quadrangle. It is predominantly a sequence of highly metamorphosed sedimentary and volcanic rocks but probably includes some recrystallized intrusive rocks. Pink and gray gneiss and light- to dark-gray schist form most of the complex. White crystalline limestone, quartz-muscovite schist, and black garnetiferous amphibolite constitute a minor part of the complex.

Most of the gneiss shows a well-developed foliation, which is assumed to be bedding-plane foliation because it is parallel to bedding planes in nearby limestone. Some of the schistose rocks show a well-developed lineation resulting from parallel orientation of amphibole needles.

The attitude of the foliation and lineation indicates that the rocks are tightly folded and that they trend northeastward parallel to their outcrop pattern and to the regional strike. Near the north edge of the quadrangle, isolated patches of siltstone and conglomerate of Cretaceous age overlie the gneiss and schist. Farther north in the adjoining Bethel quadrangle isolated exposures of gneiss and schist are surrounded by broad areas underlain by sedimentary rocks of Cretaceous age. Most of the rocks that comprise the metamorphic complex are thought to be Precambrian in age, because they are much more metamorphosed than limestone of Devonian age, which crops out south of Kanektok River, and they are lithologically similar to rocks that elsewhere in Alaska are considered to be Precambrian. However, the unit probably includes some small areas of Paleozoic rocks.

DEVONIAN LIMESTONE

Limestone that contains fossils identified as Devonian in age, Dl, crops out south of the great south bend of Kanektok River. The limestone is finely crystalline, light to dark gray, and massive to thin bedded. It is compressed into a number of small tight folds that trend northeastward. Structural complexity precludes an accurate estimate of thickness of the limestone, but probably not over 800 feet of rock is exposed. Fossils of Devonian age occur in a 20- to 30-foot zone of dark argillaceous limestone in the upper third of the sequence.

GEMUK GROUP

As originally defined (Cady and others, 1955, p. 27-34) the Gemuk group in the central Kuskokwim region included rocks of Triassic and Early Cretaceous age and possible equivalents of rocks assigned by Mertie to the Mississippian(?), Permian, and Triassic periods and the Early Cretaceous epoch in the adjoining Nushagak district (Mertie, 1938, p. 37-59). In the lower Kuskokwim region rocks of the Gemuk group have yielded sparse fossil collections ranging in age from Carboniferous to Early Cretaceous. The rocks are complexly folded and faulted, and no reliable estimate of their total thickness can be made. They probably are between 15,000 and 25,000 feet thick.

For the most part this thick sequence of rocks is mapped as a single undifferentiated unit. However, locally the unit has been subdivided on the basis of lithology. Rocks mapped as KCgc are possibly of Mississippian age, because they underlie rocks of Permian age and are lithologically different from rocks of Permian age or younger. Areas underlain by fossiliferous limestone of Permian age, KCgl, and volcanic rocks of Permian age, KCgv, are differentiated and indicated by letter symbols. The upper part of the Gemuk group is characterized by coarse-grained pelitic rocks probably of Early Cretaceous and Late Jurassic(?) age. Areas underlain by these rocks are indicated by the letter symbol KCgg. Lithic symbols have been used to indicate known occurrences of distinctive types of rocks.

The Gemuk group, undifferentiated, KCgu, consists chiefly of massive to thin-bedded siliceous siltstone, chert, and mafic volcanic rocks. Calcareous siltstone, fine-grained graywacke, calcareous conglomerate, and limestone occur in lesser amounts. Most of the siltstone and chert is light to dark green, but black, white, gray, and buff varieties are also common. Much of the siltstone is probably tuffaceous. The volcanic rocks comprise dark-green and gray flows, breccias, tuffs, and agglomerates. The flows are fine-grained dark rocks that are rarely porphyritic but are commonly amygdaloidal. Pillow structure is common in massive flows, but columnar structure was not observed. At many places the volcanic rocks are altered to greenstone; locally they are schistose or gneissoid.

Most of the undifferentiated rocks of the Gemuk group are probably of Jurassic, Triassic, and Permian age. Nine collections of well-preserved fossils of Triassic and Permian age and several collections of poorly preserved specimens, which have been determined as of probable Permian, Carboniferous, or late Paleozoic age, have been found in the Goodnews quadrangle. Fossils of Middle Jurassic and probable Early Jurassic age occur on Hagemeister Island about 24 miles south of the quadrangle. They are associated with sedimentary and volcanic rocks that are similar to rocks mapped as undifferentiated Gemuk group in the Goodnews quadrangle.

Chert, siltstone, graywacke, and limestone, all of Mississippian(?) age, KCgc, crop out in the northeast corner of the quadrangle. The chert is massive to thin bedded, black, white, gray, or buff; green chert, which is characteristic of younger lithologic units of the Gemuk group, was not observed. Most of the siltstone and fine-grained graywacke are calcareous and contain abundant ellipsoids (boudinage) of gray silty limestone. The siliceous, cherty rocks and the calcareous rocks are apparently interbedded, but they generally constitute separate zones that are 50 to 500 feet thick or more. Within a single sequence of either calcareous or siliceous rocks, little or none of the other types of rocks were noted. Mafic volcanic rocks, consisting of altered flows, tuffs, and breccia, are interbedded with both siliceous and calcareous rocks but are more commonly associated with the calcareous rocks.

The rocks are intensely deformed; structural complexity precludes an accurate estimate of thickness, but the section is probably not less than 3,000 feet thick or more than 8,000 feet thick. Mertie (1938, p. 39-42, 45-46) concluded that an angular unconformity is present between these rocks and overlying rocks of Permian age (KCgl). The writers think that the evidence for an unconformity is inconclusive. No fossils have been found in these or definitely correlative rocks. The rocks are tentatively considered to be of Mississippian age, because they are lithologically similar to rocks of Mississippian age elsewhere in Alaska (Mertie, 1938, p. 42). Fossils of Carboniferous age have been collected from possibly correlative rocks near Goodnews Bay.

Limestone, KCgl, forms several relatively small, isolated outcrops most of which are in the northwestern part of the quadrangle. The limestone is finely crystalline, white, light gray, or buff, and contains varying amounts of detrital quartz grains. It is closely associated with altered mafic volcanic flows and breccia. Good exposures—such as those north of Nuyakuk Lake, south of Kanektok River, and near the head of Narogarum River—reveal that the limestone grades upward into volcanic rocks through a few feet of calcareous tuff and breccia. Mafic volcanic rocks and cherty sedimentary rocks are interbedded with several hundred feet of thin-bedded and massive limestone south of Kanektok River, between Nukluk and Klak Creeks. The thickness of the limestone is variable. Estimates of thickness range from a few tens of feet in small exposures to a maximum of several hundred feet in the large exposures south of Kanektok River. It is probable that the limestone was deposited as a number of lenticular bodies, because it seems to thin laterally by interfingering volcanic and siliceous sedimentary rocks.

Fossils of Permian age have been obtained from each of the limestone exposures mapped in this unit. Some of the limestone indicated by lithologic symbol in the undifferentiated part of the Gemuk group is probably also of Permian age.

Volcanic rocks, KCgv, crop out north of Nuyakuk Lake in the northeast corner of the quadrangle. They are the southern end of a belt of altered volcanic rocks that extends northward about 36 miles into the Bethel quadrangle. In the Goodnews quadrangle the belt trends about north-northwest. Northward the trend changes to about N. 10° E. The rocks are predominantly dark green to almost black altered mafic volcanic rocks containing abundant amygdules but few identifiable phenocrysts. Volcanic breccia, calcareous tuff, and pillow lava constitute the basal beds. Lavas with well-formed pillow structure also occur higher in the unit. Thin-bedded phyllitic calcareous tuff and tuffaceous limestone constitute the top of the sequence. In Mertie's report (1938, p. 45-46, 74-75) these volcanic rocks are classified and mapped as greenstone. He estimates that they are at least 4,500 feet thick on Nuyakuk Lake (Mertie, 1938, p. 46).

The greenstone grades downward through tuffaceous beds into limestone (KCgl) containing fossils of Permian age (Mertie, 1938, p. 43-45, 46). Hence the basal part of the greenstone probably is also of Permian age, but its upper part may be of Triassic age. Factors suggesting that the upper part of the greenstone is Triassic are: (1) The proximity of reported fossils of Triassic age in limestone on the south shore of Nuyakuk Lake (Mertie, 1938, p. 47-48) about 2 miles east of the Goodnews quadrangle, (2) calcareous tuff constitutes the upper part of the greenstone unit at the west end of Upnuk Lake in the Bethel quadrangle about 25 miles north of Nuyakuk Lake, and (3) fossils of probable Triassic age in calcareous lenses in altered volcanic rocks on the north side of the Eek Mountains about 50 miles west of Nuyakuk Lake.

The KCgg unit of the Gemuk group is characterized by coarse-grained clastic rocks. The unit includes rocks of Early Cretaceous and probable Late Jurassic age, which are widely exposed in the north-central part of the quadrangle and in the southeast corner. Massive-bedded, fine- to coarse-grained, well-indurated graywacke and conglomerate constitute a large part of the unit.

The composition of the graywacke is highly variable, and in many places it clearly reflects the source rock of the graywacke. Some of the more obvious varieties of graywacke that have been distinguished are volcanic graywacke, feldspathic lithic graywacke and quartz-feldspar graywacke.

Calcareous varieties of graywacke, siltstone, and conglomerate, which grade into impure limestone are common. Although this part of the Gemuk group is characterized by massive coarse-grained clastic rocks, it contains an equal or greater amount of interbedded fine-grained rocks consisting of massive varicolored siliceous siltstone, banded slaty siltstone, andesitic volcanic rocks, bedded chert, and siliceous tuff(?). Much of the graywacke, conglomerate, and siltstone is very similar to rocks in the overlying Kuskokwim group (Kks), but silty limestone, calcareous graywacke, and siltstone are more typical of the older sequence, and, in general, the older rocks are more indurated, more massively bedded, and contain less detrital muscovite mica. Bedded chert, a minor constituent of the upper part of the Gemuk group, is unknown in the Kuskokwim group.

The thickness of this part of the Gemuk group is estimated to be on the order of 5,000 to 10,000 feet. These rocks are unconformable upon older more highly deformed rocks of the Gemuk group, and in the northwest quarter of the quadrangle rocks of Early Cretaceous age are unconformable upon gneiss and schist of Precambrian age. Fossils of Early Cretaceous age (Valanginian) have been collected at several localities. No fossils of Late Jurassic age have been found in the Goodnews quadrangle, but they have been found in the Russian Mission quadrangle about 80 miles north. It is probable that rocks of Upper Jurassic age constitute part of the KCgg unit of the Gemuk group in the Goodnews quadrangle.

KUSKOKWIM GROUP

The Kuskokwim group, Kks, consisting chiefly of interbedded graywacke and siltstone with lesser amounts of pebble grit and conglomerate, crops out in the north-central part of the quadrangle and in the southeast quarter. The rocks are well indurated, are commonly light to dark gray, and weather brown. They consist primarily of angular and subrounded grains of feldspar and quartz mixed with fragments of chert, and intermediate volcanic rocks. Conglomeratic rocks in the north-central part of the quadrangle contain a large amount of schist and gneiss fragments. Detrital muscovite is prevalent in fine-grained rocks. The siltstone commonly has a blocky fracture, but slaty cleavage is well developed locally. Shaly bedding-plane parting is rare except in abundantly micaceous rocks.

The Kuskokwim group may be divided into three gross lithologic units. Rocks of the basal unit are regionally unconformable upon older rocks. They crop out in two northeastward-trending belts on the flanks of the Eek Mountains and consist of numerous zones of cobble to boulder conglomerate, graywacke, and siltstone 10 to 100 feet thick. These rocks are probably correlative with 2,000 to 3,000 feet of massive conglomerate that is exposed on the north side of the Eek Mountains a few miles north of the quadrangle. The second unit is predominantly siltstone with very little interbedded graywacke. The rocks are poorly exposed in broad northeast-trending valleys on both sides of the Eek Mountains. Intense deformation precludes a reliable estimate of thickness in these rocks, but they probably are not more than 3,000 feet thick, and they may be less than 1,000 feet. Rocks of the second unit are distinct from the coarser facies of the basal unit, but locally may be gradational into both underlying and overlying stratigraphic units. The third unit comprising thinly interbedded fine-grained graywacke and shaly siltstone is exposed along the Kulukak River in the southeast quarter of the quadrangle. Only cutbank exposures of these rocks on Kulukak River were examined in the field. The rest of the rocks mapped as Kuskokwim group in the southeast quarter of the quadrangle are identified by photogeologic study. Probably part or most of these rocks are correlative with the basal and second units of the Kuskokwim group exposed in and near the Eek Mountains. The few small exposures of the rocks of the third unit seen on Kulukak River do not permit an estimate of thickness. In the Bethel quadrangle about 40 miles north of the Goodnews quadrangle the third unit is several thousand feet thick.

The Kuskokwim group includes rocks ranging in age from late Early Cretaceous (Albian) to middle Late Cretaceous (Coniacian). Fossils of late Early Cretaceous (Albian) age occur in rocks of the basal unit of the Kuskokwim group in the Bethel quadrangle about 20 miles north of the Goodnews quadrangle. No fossils have been found in rocks of the second unit. Fossils of middle Late Cretaceous (Coniacian) age occur in the third unit where it is exposed on Kulukak River. In the Bethel quadrangle about 45 miles north of the Goodnews quadrangle, fossils of early Late Cretaceous (Cenomanian) and middle Late Cretaceous (Coniacian) age occur in the third unit.

BASALT

Black and dark-gray olivine basalt flows, QTb, crop out in the lower valley of Togiak River. The rock is fine grained, finely porphyritic, and vesicular. The tops of some of the flows are marked by coarse scoria, curved gas tubes 2 to 3 inches long, and pahoehoe structure. Good columnar jointing occurs locally. The flows appear to be essentially horizontal. The chief rock-forming minerals are small subhedral grains of pyroxene and olivine and small laths of labradorite. The crystalline minerals are embedded in brown isotropic glass. The mineral grains and glassy matrix show little or no secondary alteration, and the rock looks fresh in hand specimen and thin section.

The thickness of the flows is unknown, but in most places they are probably less than 300 feet thick. The northernmost large exposure of lava, which is south of the westward-flowing part of Togiak River, is bounded on the north and east sides by a steep scarp 120 to 150 feet high. The face of the scarp is at one place about half a mile south of exposures of sedimentary rocks of probable Cretaceous age. These sedimentary rocks are overlain by poorly consolidated, limonite-cemented boulder conglomerate of late Pliocene or Quaternary age. No boulders of basalt were found in the conglomerate. Probably the lava overlies the conglomerate.

The lava may be of late Pliocene or early Pleistocene age. It was extruded after the Togiak River had cut its wide valley to about its present depth and before the earliest known period of glaciation. Boulders of vesicular basalt, which were deposited by the oldest and most extensive glaciers, are common on the mountains east and west of lower Togiak Valley up to an altitude of about 3,000 feet above sea level.

A possible source for at least part of the lava is the isolated mountain west of the headwaters of Negukthlik River. The nearly level flat top of the mountain is about 1,000 feet above the surrounding valley. Apparently, the mountain consists entirely of fine-grained basalt flows interbedded with a large amount of brecciated pumice and scoria. The fact that the flows apparently dip 15 to 25 degrees indicates that the flat top of the mountain is not formed by a single near-horizontal flow. Ice-deposited erratic boulders are widespread on top of the mountain. The origin of the mountain is not known, but it probably is of volcanic origin rather than an erosional remnant.

Comparable, predominantly basaltic volcanic rocks that are probably about the same age as those in Togiak Valley, crop out along Kwethluk River in the Bethel quadrangle about 75 miles northwest and in the Yukon-Kuskokwim delta region (Harrington, 1918, p. 47-48).

UNCONSOLIDATED QUATERNARY DEPOSITS

Silt deposits, Qs, consisting of light- and dark-gray silt and sandy silt cover much of the Bering Sea coastal plain in the western part of the quadrangle. The deposits extend north of the quadrangle for about 150 miles where they underlie much of the Yukon-Kuskokwim delta. They form a plain of moderate microrelief that rises gently up toward the mountains to an altitude between 100 and 150 feet above sea level. The plain is incised by several large through-flowing streams and is characterized by a general lack of vegetation other than moss and lichen, a fretwork of small consequent streams, and countless large and small thaw lakes. In the vicinity of Kanektok River, the scars of broad, shallow outwash channels indicate that the silt is older than the oldest known ice advance down Kanektok Valley. The plain is separated from areas of reworked silt (Qrs) and flood-plain deposits (Qf) by steep outward-facing scarps 10 to 50 feet high. The unit was mapped mostly by photogeologic methods.

The deposits probably thicken westward, away from the mountains. A well drilled at Bethel about 60 miles north of the quadrangle showed that the silt is at least 450 feet thick and that it becomes sandier with depth and contains pebbles and wood fragments. The deposits are probably of nonmarine fluvial origin but may include eolian and marine members. They range from Pleistocene to Recent in age. Mammoth remains are reported (Spurr, 1900, p. 132) from the deposits in the Bethel quadrangle.

Glacial drift, Qd, consisting of unsorted and poorly sorted deposits of sand, gravel, and boulders comprising various types of ice-contact and glaciofluvial deposits are widespread in the Goodnews quadrangle. Small areas of glacial outwash, alluvium, and colluvium are included with the unit. The thickness of the deposits ranges from a thin veneer to at least 100 feet. The unit is mapped chiefly from aerial photographs on the basis of topographic expression. Older deposits farthest from the source areas are commonly highly modified and difficult to recognize. Younger deposits generally show typical swell and swale glacial topography and are easily recognized on the ground and on aerial photographs. The age of the deposits probably ranges from early Wisconsin to Recent.

Outwash deposits, Qo, consisting of poorly sorted to well sorted sand and gravel with some silt and boulders, form terraces and outwash fan-plains. The deposits are recognized on aerial photographs by their relationship to end and recessional moraines and by their well-drained surface scarred by numerous abandoned stream channels. They are generally progressively younger toward their source area and are contemporaneous with associated moraines. The thickness ranges from a thin veneer to more than 150 feet.

Reworked silt, Qrs, consisting of reworked silt, sandy silt, and bog deposits, underlies a plain that is transitional with or slightly above areas of flood-plain alluvium of Recent age (Qf) and separated from higher plains of older silt deposits (Qs) by an erosional scarp 10 to 50 feet high. Areas of reworked silt form part of the Bering Sea coastal plain in the northwest corner of the quadrangle. They are more extensive farther north in the vicinity of the Kuskokwim River where they underlie several thousand square miles of the coastal plain and the Yukon-Kuskokwim delta. The surface of the plain formed by these deposits is characterized by countless large and small thaw lakers, lack of brush or tree cover, and lack of stream scars and oxbow lakes. In the Bethel and Russian Mission quadrangles to the north, "islands" of older silt deposits (Qs), which rise sharply above the plain, indicate that the plain is an erosional surface formed by the dissection and almost complete removal of the upper part of the older silt deposits (Qs). The unit was mapped mostly by photogeologic methods.

Colluvium, Qc, consists chiefly of frost-rived rubble but locally includes small amounts of bog deposits, flood-plain alluvium, terrace deposits, glacial gravels, and windblown silt. The deposits are best developed on the rounded slopes of unglaciated mountains in the western part of the quadrangle where they merge and interfinger with other kinds of unconsolidated deposits near the base of the slopes. The unit was mapped mostly by photogeologic methods.

Flood-plain alluvium, Qf, (locally includes some beach deposits) consists of mud, silt, sand, gravel, and boulders forming the flood plains of present-day streams. The deposits are incised a few feet to a few tens of feet below the surface of older unconsolidated deposits and bedrock benches.

INTRUSIVE ROCKS

Intrusive igneous rocks in the Goodnews quadrangle consist of dikes, sills, and small stocks of mafic rocks (Tm); numerous stocks of granitic rocks (Tg); small rhyolite dikes (Tr); and small intrusive bodies of ultramafic rocks (Tu). The age of most, or all, of the intrusive rocks is thought to be Tertiary, because in the Bethel quadrangle to the north similar rocks intrude volcanic and sedimentary rocks as young as middle Late Cretaceous age. Some of the mafic intrusive rocks (Tm) seem to be genetically related to the granitic rocks, as they are closely associated with them and are similar in composition to mafic facies of the granitic rocks. However, some of the mafic rocks are intruded by the granitic rocks and are therefore older. In Hagemeister Island quadrangle a few miles south of Goodnews quadrangle, both basalt and rhyolite intrusive bodies are well exposed in the sea cliffs on the east side of Togiak Bay. The basalt intrudes the rhyolite. The relative age of rhyolite and the granitic rocks was not determined in the Goodnews quadrangle as the two rocks were not found in contact. A single contact examined in the Bethel quadrangle suggests that the rhyolite is younger than the granitic rocks. However, Cady (Cady and others, 1955, p. 71-73) concluded that the rhyolite is older than the granitic rocks in the Central Kuskokwim region northeast of the Goodnews quadrangle.

Granitic rocks, Tg, form numerous intrusive stocks, which range in size from less than a square mile to at least 50 square miles. Some of the stocks are nearly round in plan; others are elongate with their long dimension oriented north or northeast parallel to the regional strike. Contacts of the stocks commonly dip outward indicating that the stocks are probably more extensive at depth. The stocks consist primarily of medium-grained, light- to dark-gray quartz monzonite, but they range in composition from granodiorite to granite and contain minor amounts of gabbroic, diabasic, and aplitic rocks. They are surrounded by metamorphic aureoles of hornfels formed by recrystallization of sedimentary and volcanic rocks.

Albite rhyolite, Tr, forms two small tabular intrusive bodies east of Togiak River. The rock is light to medium gray, fine grained, and porphyritic. Rhyolite is not very common in the Goodnews quadrangle, but east of Togiak Bay south of the quadrangle it forms numerous intrusive bodies. In the Bethel quadrangle it forms numerous small stocklike intrusive bodies as well as dikes and sills.

Mafic rocks, Tm, chiefly gabbro and diabase, constitute small stocklike bodies, dikes, and sills. The proximity of some of the mafic intrusive rocks to the granitic rocks suggests that the two may be genetically related.

Ultramafic rocks, Tu, consisting of serpentinized dunite, forms two, small, apparently tabular dikelike intrusive bodies in the western part of the quadrangle; one body is about 8 miles southeast of Jacksmith Bay and the other about 3 miles north of Goodnews Bay. A third small body of ultramafic rock is indicated by abundant serpentine float in a small area about a mile south of the great south bend of Kanektok River near a small body of intrusive diabase; however, the serpentine body is concealed by frost rubble. Numerous ultramafic bodies crop out in Hagemeister quadrangle to the south.

STRUCTURE

Major structural elements in the Goodnews quadrangle trend northeastward. The broad belt of rocks of Precambrian age in the northwestern part of the quadrangle crop out at or near the axis of a small geanticline that plunges gently northeastward. The geanticline formed as early as Late Jurassic or Early Cretaceous time.

Most, or all, of the broad area southeast of the geanticline as far as Togiak River is downwarped relative to the geanticline. It was compressed into broad anticlinorial and synclinorial folds in Late Cretaceous or early Tertiary time. The folds plunge gently northeastward and appear to merge toward the southwest in a broadly upwarped area in the vicinity of Goodnews Bay. The position and size of these large folds are deduced more from the outcrop pattern of the rocks than from the attitude of the bedding, because the broad warps are superposed upon a thick section of rocks that had previously been severely deformed. The Eek Mountains and the mountains drained by Nukluk and Takshilik Creeks are formed on a well-defined anticlinorium that is strongly asymmetric northwest. A second rather poorly defined anticlinorium trends northeastward from the vicinity of Quigmy River to the headwaters of Narogarum River. In the northcentral part of the quadrangle these two large upwarps are separated by a broad synclinorium that widens toward the northeast into the Bethel quadrangle where it includes rocks as young as middle Late Cretaceous (Coniacian) age.

Near the southern edge of the quadrangle east of Togiak River the rocks strike generally northeast about parallel to the regional strike. The rocks are severely deformed, but no large-scale folds comparable to those recognized west of Togiak River have been found here. The two small areas underlain by rocks of Late Cretaceous age are probably dropped fault blocks.

Farther north the rocks strike generally northwest, but in the Bethel quadrangle the strike swings back to N. 5°-10° E. and continues for at least 30 miles. These rocks apparently form the southern and western flank of a broad arcuate anticlinorium that wraps around the southwestward-plunging end of the Alaska-Yukon geanticline (Cady and others, 1955, p. 89-90, pl. 2).

Most of the faults in the quadrangle have been mapped from the study of air photos. Their straight linear traces probably indicate that they dip steeply. Many of the faults trend northeastward roughly parallel to the axes of the major folds, and these faults probably are closely related to the folding of Late Cretaceous or early Tertiary age. However, the Togiak-Tikchik fault or fault zone may have been active in Quaternary time, as the trace of this great fault is marked by offsets in unconsolidated alluvial deposits in the central Kuskokwim region about 60 miles north of the quadrangle (Cady and others, 1955, p. 92-93, pl. 8).

No evidence indicating relative movement on the Togiak-Tikchik fault has been found in the Goodnews quadrangle where the trace of the fault is almost everywhere covered by surficial deposits. In the Bethel quadrangle the rocks west of the fault are upthrown so that greenstone of Permian age rests upon sedimentary rocks of Early Cretaceous age. Some of the mafic intrusive is part of the same belt of greenstone that crops out in the northeast corner of the Goodnews quadrangle. The fault dips 60°-70° NW. where it cuts the greenstone.

MINERAL RESOURCES AND OCCURRENCES

GOLD

Placer gold has been mined at numerous places in the Goodnews quadrangle in the past half century, but at present there is no reported gold-mining activity. Most of the mines were in the Arolic River basin and on the south side of the mountains at the head of Arolic River. The early history and production of some of these mines were reported by Harrington (1919, p. 220-227). Intermittent mining activity on some of the streams continued until about 1942 when the placers were either mined out or the rising cost of operation forced the mines to close. The most recent mining has been done on upper Wattamuse Creek by about six men who operated a small mine from 1953 to 1955. A small amount of gold has been mined on Rainy and Trail Creeks, both of which are near the north edge of the quadrangle. Both of these mines ceased operation about 1941 after 2 or 3 years activity. The location of many of the mines and prospects indicates that mineralization associated with intrusive bodies of granitic rocks is the primary source of the gold. The small placer deposits on Rainy and Trail Creeks, which are at some distance from outcropping granitic rocks, were probably formed by secondary concentration of glacial gravels.

PLATINUM

A few ounces of platinum were reportedly (Smith and others, 1927, p. 52) recovered in gold placer operations on Kowkow and Butte Creeks east of Jacksmith Bay. The platinum was probably derived from mafic intrusive rocks in Island Mountain south of these two streams.

QUICKSILVER

Lode deposits of cinnabar, an ore mineral of mercury, have been found near the north edge of the quadrangle on Arsenic Creek and near the headwaters of Amugiak Creek about 6 miles east of Mount Oratia. The cinnabar on Arsenic Creek is closely associated with small sill-like intrusive bodies of hydrothermally altered diabase. About 2,000 pounds of cinnabar concentrates were reportedly produced from a placer gold mine on Rainy Creek, to which Arsenic is tributary, a few hundred yards below the lode deposits (Rutledge, 1948, p. 3). The cinnabar deposit east of Mount Oratia was examined by E. M. MacKevett of the U. S. Geological Survey who reports (oral communication, 1957) that weak cinnabar mineralization occurs for several hundred feet along a northwestward-trending shear zone in quartz monzonite. The cinnabar is associated with stibnite, ore mineral of antimony, and the arsenic minerals, orpiment and realgar.

ZINC

Sphalerite, ore mineral of zinc, occurs in a vein 12 to 15 inches thick on the west bank of Togiak River about 3 miles above the mouth of Pungokepuk Creek. The vein is exposed over a length of about 25 feet in recrystallized pillow lavas. Diorite, which crops out on the east bank of the river, probably caused recrystallization of the rocks near by. The sphalerite, which is coarsely crystalline and nearly black, constitutes an estimated 30 percent of the vein. The dark color of the sphalerite indicates that it contains a high percentage of iron. Minor amounts of pyrite and chalcopyrite are associated with the sphalerite. The chief gangue mineral is quartz. This is the only known sphalerite in this part of Alaska.

COAL

Local inhabitants report that a coal bed several feet thick is exposed on the Ungalikthuluk River in the southeast corner of the quadrangle. The writers have not seen the coal and do not know its exact location. It may be in the Hagemeister Island quadrangle to the south.

SUGGESTIONS FOR PROSPECTING

Systematic search for lode deposits of gold and cinnabar should be guided by the fact that the gold is associated with granitic and rhyolitic intrusive bodies and that quicksilver in this part of Alaska is almost always associated with small altered intrusive bodies of mafic rock.

The search for placer gold deposits should be guided by what is known about the origin of gold, generally, and by what is known about the mode of occurrence of the deposits that have been mined in the Goodnews quadrangle. Placer gold deposits are commonly on streams that flow through, or head in, mineralized areas associated with intrusive bodies of granitic or rhyolitic rocks. They are better developed where prolonged and undisturbed stream erosion has produced a broadly rolling land surface. Most of the Goodnews quadrangle has been heavily glaciated; the combined erosion of alpine glaciers and numerous large fast-flowing streams, which were rejuvenated by uplift, has destroyed most of the mature land surface that characterized the quadrangle in pre-Pleistocene time. Many of the placer deposits that may have formed in pre-Pleistocene time have been destroyed. Those that remain owe their existence to special circumstances.

The known placer deposits in the quadrangle are of two types: placer deposits of pre-Pleistocene age that were preserved from glacial erosion, and placer deposits of late Pleistocene and post-Pleistocene age that were formed by the reconcentration of glacial drift. Deposits of pre-Pleistocene age are likely to be preserved in glaciated areas on the downstream side of mountains that were high enough not to be overridden by glacial ice. The placer deposits in the Arolic River Basin on Kowkow, Butte, and Domingo Creeks are probably of pre-Pleistocene age but were not destroyed in Pleistocene time because they are near the periphery of the glaciated area and were protected from glacial erosion by Island Mountain. Pre-Pleistocene placer deposits may also be preserved in the valleys of pre