

MINERAL RESOURCES OF THE GOODNEWS BAY REGION.

By GEORGE L. HARRINGTON.

INTRODUCTION.

The Goodnews Bay region as here considered embraces the territory lying south of Arolic River and draining into Kuskokwim Bay. It thus includes the Arolic and Goodnews river basins and the intermediate area. Some information regarding the area south of Goodnews Bay as far as Cape Newenham is also included in this paper. The surveys of this region in 1919 covered an area of approximately 1,400 square miles and extended from longitude $159^{\circ} 40'$ to 162° west, and from latitude 59° to $59^{\circ} 40'$ north. A traverse of the Yukon-Kuskokwim portage was also made. R. H. Sargent, topographic engineer, in general charge of the work, made the topographic surveys on which the geologic work north of Goodnews Bay was based. South of Goodnews Bay charts and maps of the United States Coast and Geodetic Survey were used as a base. The geologic mapping and investigation of mineral resources were done by the writer. A cook and a station assistant to Mr. Sargent completed the party.

The party left Seattle on the power schooner *Ozmo* on June 19 and made a landing in Security Cove, just east of Cape Newenham, on the evening of July 4. About two-thirds of the supplies and provisions and all other equipment were landed in the boats of the Survey expedition at the same time. The supplies were transported throughout the season by boat or by back packing. A 30-foot poling boat and a 20-foot dory, together with a 2-horsepower gasoline engine of the detachable hang-over type, were obtained at Seattle, and the poling boat was used on Goodnews River, and the dory for such shore work as was necessary. Field work ended at Kwinak (Quinhagak post office) on August 18. The return to Seattle was made by way of Bethel and the Kuskokwim-Yukon portage, Mr. Sargent with the field assistants going up the Yukon and the writer going down and continuing to St. Michael and Nome, where he spent a few days in the collection of statistics while awaiting the steamer *Victoria*. Transportation from St. Michael to Nome was afforded by the United

States Coast Guard cutter *Bear*. Seattle was reached October 19, after a 12-day trip from Nome that included stops at St. Michael, Dutch Harbor, Akutan, and Isanotski Strait.

GENERAL FEATURES OF THE REGION.

GEOGRAPHY.

Approach to this region is difficult in times of storm or fog on account of the shallowness of Kuskokwim Bay, and for this reason larger vessels must move with the tides or follow carefully the surveyed channels. A small cove just west of Security Cove affords a fair haven for small boats from easterly storms, and Security Cove is so shaped as to give protection from practically all directions. Shoals and bars off Chagvan and Goodnews bays make entrance into them difficult in rough weather, and, in addition, strong tidal currents and eddies occur at the mouth of Goodnews Bay. Traveling along the shore is done mostly in periods of calm weather or when there is an offshore breeze, the shallowness of the bay making travel in small boats particularly unpleasant in any other weather.

From Cape Newenham to the small cove west of Security Cove and from Security Cove north to Chagvan Bay there are many stretches where it is not possible to get along the beach except at very low tide, and a few where it is not possible to follow the beach even then. From Chagvan Bay to Goodnews Bay the beach is sandy, hard, and firm and may be followed on foot. The same is said to be true of the stretch from Goodnews Bay to Carter Bay, but from Carter Bay to the northern edge of Jacksmith Bay the beach is muddy and is cut by tidal sloughs, and at low tide the muddy tide flats extend out for several miles. From the north side of Jacksmith Bay to Kivinak there is another sandy beach with firm footing, although it appears likely that this beach, as well as a considerable area of the tundra back of it, is covered at extreme high tides or in times of heavy storms, as logs are often found a considerable distance back from the beach. Tidal flats occupy a considerable portion of Goodnews Bay, the sand and silt brought down by Tunulik and Goodnews rivers having partly filled its east end. Both these streams are tidal in their lower courses, and so to a lesser extent are the Arolic and Kanektok, and in ascending them advantage is usually taken of the flood tide, as there is an appreciable current on the ebb or slack tide. In their lower courses these rivers are, however, relatively sluggish and their channels are tortuous. (See Pl. VII.) Farther upstream the current quickens but is by no means uniform, as it alternately accelerates on the riffles and slackens in the stretches between. It was necessary to line the boat up some

of these riffles, and it was judged that the current was running at a rate of 7 or 8 miles an hour.

From Cape Newenham to Goodnews Bay, except for a stretch on each side of Chagvan Bay, the hills and low mountains rise almost directly from the water. North of Goodnews Bay, however, the hills recede eastward from the coast, and there are no more high hills or mountains along Kuskokwim Bay or River south of the portage to the Yukon. At Bethel the mountains lie several miles east of the river, though plainly visible on clear days. Jag Mountain, east of Cape Newenham, rising directly from the water's edge to a height of 2,291 feet, is the highest mountain along the coast, although there are a number of other mountains in the Goodnews River basin which are from 2,700 to a little over 3,000 feet in height. Most of the higher mountains are sharply jagged in outline, but those of intermediate elevation are less jagged, and the lower hills are usually well rounded, though showing a few small projecting rock points. In the southern part of the region there are numerous examples of terraced altiplanation forms on a relatively small scale, but elsewhere these terraces are rare, although not entirely absent. Their scarcity is probably due to the fact that other types of erosion have been more active and so prevented the development of these land forms.

The intermontane areas are low, flat, and broad, and numerous ponds and lakes occur in the poorly drained valleys, especially in that which connects the present valleys of the main branches of Goodnews River.

GLACIATION.

So far as was observed there are no glaciers in the Goodnews Bay region, but their former presence is made apparent by numerous topographic features such as are peculiar to glaciated regions. Near the coast there is relatively little evidence of their former presence, but this is accounted for on the hypothesis that such evidence may have been destroyed by postglacial marine inundation. In the mountains, away from the coast, many of the streams head in typical glacial cirques, in which are small lakes, and U-shaped valleys lead from these cirques to the larger tributary valleys of the main drainage systems. Erratic boulders on divides are fairly common, and faceted blocks at elevations well above the present stream channels were noted in a few places. Deposits that could be definitely classed as morainal were not seen, but it is believed that much of the material composing the unconsolidated deposits between Kuskokwim Bay and the front range of hills is of glacio-fluviatile origin. Perhaps the best example of morainal material seen was in the valley of Canyon Creek. A large stream enters Canyon Creek from the north through a deep channel cut in unconsolidated sand and gravel; a

short distance below their confluence the creek flows through a pass in the hills in a rock-cut canyon at least 75 feet deep for perhaps half a mile before crossing the wide valley of Goodnews River, into which it finally empties. The stream now flows on the south side of the pass, very close to the base of the hill on that side. Numerous small lakes, with gravel banks, lie in the pass. This lake-dotted deposit is interpreted as being a moraine that fills the preglacial valley of the creek. As the glacier retreated the stream sought the lowest place through the pass, which happened to be at one side of the deposit. Since reaching bedrock it has continued cutting until it has formed the present canyon. At the confluence of the two streams, where both are flowing through unconsolidated material, the channel is approximately in the position of the preglacial channel.

It is believed that numerous changes in drainage, even of the major streams, were brought about by the glaciation of this region. The low lake-dotted pass between the forks of Goodnews River was probably the preglacial channel of that stream. The pass has been filled with gravel, as is shown by the gravel banks of the many lakelets which lie in it. These lakes differ from the lakes of flood-plain origin and from some of the lakes lying at elevations above the flood plains, practically all of which are in mossy bogs and have banks of peat or moss.

NIVATION.

Nivation, or erosion somewhat similar to glaciation but on a much smaller scale and produced by accumulations of snow, which may last from one season to another, has been an effective agent in the formation of a number of minor topographic features in this region. To nivation is attributed the abundance of small valleys of general U-shaped cross section. Such valleys were especially noted on the tributaries of Bear and Canyon creeks and also in the group of hills on the south side of Goodnews River about 20 miles from its mouth. Forms that are probably due to nivation were also observed on the slopes of the hills in the vicinity of Security Cove.

At the heads of a few of the valleys the snow banks develop cirque-like forms, one of which was observed near the granite-limestone contact in the vicinity of the glacial lake at the head of Tunulik River.

TRAVEL AND TRANSPORTATION.

In many respects this region is one of the most inaccessible in Alaska for a small expedition. For a number of years it has been necessary to come overland from the Yukon either by the portage or by way of Iditarod, or to travel in a kayak or canoe, or by a small schooner or sailing boat from Togiak. During the summer of 1919 an 800-ton schooner was placed on the run between Seattle and Bethel, and this boat made two trips and afforded the most satisfactory

freight and passenger service that has been available to the inhabitants of the lower Kuskokwim for many years. During the winter of 1918-19 there was an acute shortage of provisions, which had to be brought at heavy expense from the Yukon, on account of the failure of one of the supply schooners to bring in winter provisions. This schooner was scheduled to bring in supplies during 1919 also but had not reached Bethel when the Geological Survey party left the region in September.

Practically all supplies are landed at Bethel, although some of the smaller vessels will land supplies inside the spit at the entrance to Goodnews Bay, as well as at some points between the bay and Bethel. From Bethel supplies are brought down the river and bay by means of a launch to Kwinak and to Mumtrak, the village in the vicinity of the schoolhouse at Goodnews Bay. Supplies for the Arolic basin are brought from Kwinak either by poling boat in the summer or by dog sled in the winter and early in the spring. For the mining operations on Wattamus Creek, which flows into a tributary of Goodnews River, supplies are taken in summer up the river in poling boats or by kayaks to the landing about 3 miles from the scene of mining operations, where they are transferred to a small scow which is lined and poled up to the camp at Wattamus. In winter supplies may be brought by dog teams from either Mumtrak or Kwinak. The freight rate on general merchandise from Seattle to Bethel in 1919 was \$35 a ton, from Bethel to Mumtrak 2 cents a pound, and from Mumtrak to Wattamus Creek 5 cents a pound.

A monthly mail service was in effect from Holy Cross to Bethel and from Bethel to Kwinak during the summer of 1919. Contracts had also been let for a monthly winter service from Kwinak to Togiak by way of Goodnews Bay. In addition to the regular service thus afforded mail is put on such schooners as sail from Seattle for the Kuskokwim. A schooner, already mentioned as carrying supplies, was also intrusted with the mail and left Seattle in July, but had not reached Bethel when the Survey party left that place in September. In addition to mail service a monthly passenger service is afforded by the trips of the mail carrier from Holy Cross to Kwinak and return, his launches and boats providing the most comfortable way of crossing the portage.

CLIMATE.

A Weather Bureau station has already been established at the schoolhouse at Mumtrak. Owing to the short time during which this station has been in operation relatively few meteorologic data are yet available. During the early part of the season of 1919 the prevailing winds were westerly or southwesterly; later in the season easterly and southeasterly winds were more common. Surveys during the season were greatly hindered by stormy and foggy weather,

and on many days when it was nearly clear fog on the hills on the south side of Goodnews Bay and at the head of Goodnews River added to the difficulties of the topographic work. As a rule two or three fair days were followed by a much longer period of cloudy and stormy weather, during most of which no work could be undertaken. In spite of the considerable amount of fog and rain it seems likely that the year's total rainfall is not over 25 inches. Summer temperatures are mild, and it is probable that in general the conditions throughout the year average but little different from those at St. Michael, for which weather records are available, although it may be that periods of storms are slightly more frequent in the Goodnews Bay region. The vegetation differs but little in nature and amount in the two areas.

The snowfall during the winter does not appear to be excessive, but the snows drift badly and accumulate in sheltered spots, so that in some of the valleys it is July before the creek beds are clear. Snow was to be seen in drifts on the north sides of the mountains in gradually diminishing patches as the summer progressed, but in a number of places a small amount of snow lasts from one year to the next.

It is said that the lower Kuskokwim and the bay are usually clear of ice in the middle of May and that the river does not freeze over until about the last week of October. In late seasons ice may remain inside of Cape Newenham until the 1st of June.

VEGETATION.

From Cape Newenham to Apokak, a few miles below Eek Island, at the north end of Kuskokwim Bay, neither trees nor bushes are seen along the shore. North of the area under discussion, from Apokak to Bethel, the banks of the Kuskokwim show scrubby alders at first, followed by larger and larger alders, which are gradually interspersed with some of the larger varieties of willow. The first spruce were seen in the vicinity of Bethel, but they are said to extend for a few miles below that point. Cottonwood appears with the willows. Birch were not seen below Bethel.

Back from the beach, along streams and in sheltered valleys, there are a few willows and alders, which increase in size with the distance from the coast. At Security Cove they are not over 2 or 3 feet high on the slope of the mountains between the cove and Bristol Bay. On Goodnews River 30 miles upstream the willows are from 10 to 15 feet high. Somewhat farther up cottonwood are found along the stream. Where driftwood is not available, the alders and willows are cut and dried for fuel. In drying salmon cottonwood is preferred on account of the fact that it burns slowly and does not cook the drying fish.

A collection of plants, which includes some mosses and lichens, was made during the summer. Approximately 125 species were represented in the collection, which probably comprises the most common flowering plants and grasses but should by no means be considered as completely representing the flora of the region. Wild rye is the most abundant grass at several places near the coast, and it is said that this plant seldom grows far from salt water. One of the botanically interesting localities is the warm, dry rocky southward-facing slope of Beluka Peak, on the north side of Goodnews Bay, where the yellow poppies grow abundantly and the blue forget-me-nots are somewhat less conspicuous in the floral assemblage. The wild rose was not found in the Goodnews Bay region, the first specimen seen on the Kuskokwim being at the mouth of Tuluksak River in August. It is likely, however, that the rose occurs farther down the Kuskokwim, probably being about coextensive with the spruce. One of the common grasses of the marshes was the so-called cotton grass (*Eriophorum*), the white tufts of which usually served as a warning of soft footing.

Berries are neither so plentiful nor so varied in this region as in the interior regions of Alaska, although blueberries and dwarf cranberries grow fairly abundantly in a few localities. The soft, pulpy yellow salmonberry is widely distributed, though nowhere abundant, and the dwarf arctic raspberry is rather uncommon. Red raspberries and currants were not noted.

Perhaps the plants of chief economic interest in this region are the lichens and mosses, upon which the reindeer feed. The caribou moss appears to be the most abundant. These plants cover practically the entire area, as the willows and alders together occupy relatively small areas, and many of the brushy areas contain considerable reindeer pasture. The grasses that occur very commonly in close association with alders along hill slopes and drainageways are said not to be eaten by the deer, except while they are tender, early in summer.

Agricultural operations are seldom carried on by the natives and in 1919 were limited to small gardens, in which a few of the hardier vegetables were grown. A so-called wild rhubarb was also used as a substitute for rhubarb. In general there appeared to be better soil and vegetables grew better at Bethel than at Kwinak or Goodnews Bay.

ANIMAL LIFE.

Although at certain seasons of the year various forms of animal life are abundant in this region, at other seasons parts of the region are practically deserted. There is very little large game. Bear Creek is said to have been named from a brown bear seen there several years ago. It appears likely that in former years caribou were

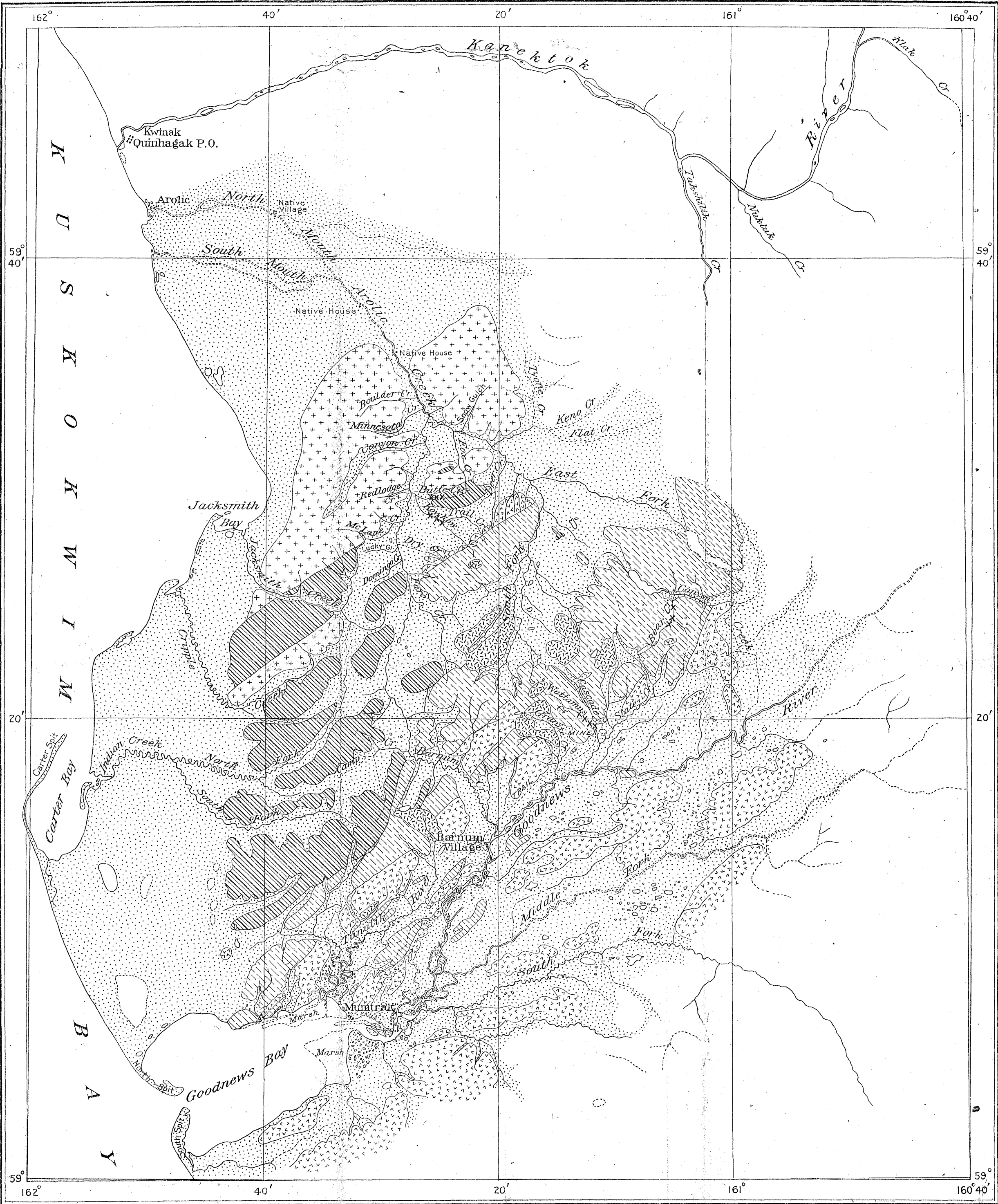
also found in this region, but if so they have been either killed or driven away and are now supplanted by the herds of reindeer (generally called deer), from which there are occasional strays. The open country, relatively free of brush and timber, and the comparative freedom from flies and mosquitoes combine to make this region especially suitable for reindeer pasture. In winter pasture is afforded on the ridges, from which the snow is blown.

Reindeer to the number of 300 or 400 are said to have been brought to the Kuskokwim about 1904, and an estimate made in 1919 placed the number then at about 15,000. Several hundred deer are owned by the Government and cared for by the Bureau of Education. Sales of female deer from Government herds may be made only to natives. A considerable number of natives are deer owners, and individuals hold from one or two to several hundred each. Several hundred deer are also owned by the Moravian mission of Kwinak and Bethel. The ownership of the remainder of the reindeer was originally vested in the Lapps, who accompanied them as herders and instructors of the natives in herding on the introduction of the reindeer into this region, the deer having been given to these herders at that time. A large part, if not most, of these have recently been purchased with a view to the commercial development of the herds and the shipping of refrigerated deer carcasses from the Kuskokwim basin.

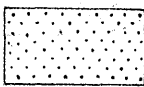
Fish are fairly plentiful in the streams in this region. Salmon are the most abundant, although the run of the various species of salmon in 1919 was said to be much below normal. Grayling, several varieties of trout, and whitefish are also taken. In winter the natives are said to catch a small blackfish from the lakes in the tundra for use as food.

Rabbits do not appear to be plentiful, but it is reported that they seem to be increasing in number. The list of more common furbearing animals includes white and red foxes, mink, and muskrat. Squirrels are caught in great numbers, and the skins are used locally in the manufacture of parkas and other garments. The skins of the reindeer are used both for garments and for sleeping bags and robes. The hair on skins of the reindeer fawn is much finer than that of adults, and these skins are used in making a better grade of garments. Dams or other signs of the presence of beaver were not observed by members of the Survey expedition.

Ducks and geese of several species breed in considerable numbers along the streams and in the marshy places, but cranes are relatively scarce. Curlew and plover were frequently seen on the broad, low ridges, snipe and sandpipers were seen along the shores of the streams, and gulls and terns were seen in large numbers along the rock shores, where, with the cormorants, they appear to nest. Hawks and owls appeared to be somewhat uncommon. A number of smaller land



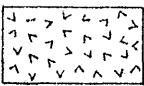
EXPLANATION



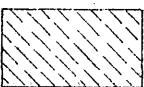
Quaternary sands, silts, and gravels of alluvial, fluvio-glacial, and marine origin



Tertiary(?) granitic and andesitic rocks



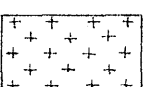
Mesozoic(?) basaltic intrusives, flows, and tuffs. May include small amounts of sedimentary rocks



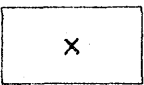
Mesozoic(?) sandstones, slates, argillites, cherts, and graywackes, with some included flows and tuffs of basalt and some granitic intrusives



Carboniferous(?) limestone with some red and black slates



Pre-Carboniferous(?) greenstones; altered acidic and basic igneous rocks, including also some areas of metamorphosed sedimentary rocks



Placer gold

GEOLOGIC SKETCH MAP OF GOODNEWS BAY REGION, ALASKA

Geology by G. L. Harrington

Scale 1:250,000
5 0 5 10 Miles

birds were observed, including but one robin. Four birds seen at a distance were believed to be magpies. Ptarmigan were observed at several places, and it is said that in the last year or two they have increased considerably in numbers, although not yet as abundant as they were several years ago.

INHABITANTS.

In the region between Cape Newenham and Kwinak, the white population was about 25 in 1919. The native population of the same region was probably about 250, including the residents at Kiniginogimut, a village on the largest stream emptying into Chagvan Bay, at Mumtrak, on Goodnews Bay; at Kwinak; and at a small village at the north mouth of Arolic River, as well as a number of single families and individuals scattered over the area. Most of these natives were at Kwinak and Mumtrak, where native schools have been established. The natives are all of Eskimo stock.

GENERAL GEOLOGY.

CHARACTER OF THE ROCKS.

In the Goodnews Bay region the rock units as mapped (Pl. VII) are relatively few in number but nevertheless include a considerable range of types. The sedimentary rocks comprise limestone, argillite, sandstone, and conglomerate, and the metamorphosed equivalents of most of these. A considerable variety of igneous rocks are also found, including basalt flows, dikes that were taken in the field to be andesites, and intrusive granites, with some massive intrusives that are probably intermediate in composition between the granite and the basalt and that have been included with the granites on the map in this report. In addition to these rocks, some of which have suffered deformation, there is a considerable area of more strongly metamorphosed igneous rocks, apparently of a basic type. A large part of the region is covered by unconsolidated deposits of alluvial, glacio-fluvial, and marine origin. It appears likely that most of the unconsolidated deposits were formed by more than one agency.

Limitations of transportation and of time prevented detailed geologic work, and a lack of outcrops increased the liability of error in mapping. As the entire area was covered in a field season of 45 days, during much of which the weather was such as to prevent work, it will readily be seen that there were many square miles which it was necessary to map from a distance on the basis of similarity of lithologic appearance, with regional trends as an additional help in delimiting the different rock units.

Search was made during the season for fossils in the sedimentary beds, but without success, so that no definite age assignment of the rock units can be made. Only the relative age could be determined,

and correlations must be founded on data obtained from fossiliferous beds of similar lithology in regions to the north.

It is believed that the areal distribution of the sedimentary and associated igneous rocks, which have been assumed to be of Mesozoic age, is represented with fair accuracy on the map. The distribution of the limestones and of the metamorphic rocks has been plotted from more meager data and therefore is probably less accurate in detail, nevertheless it is felt that the map represents the distribution of these rocks approximately.

STRUCTURE.

The geologic map indicates the general northeasterly trend of the rocks of the region, and the elongation of areas of consolidated rocks surrounded by areas of Quaternary unconsolidated gravels and sands, mainly in the direction of the strike. Variations of strike occur, however, from nearly east to north, but the strikes are mainly in the northeast quadrant. Where other strikes were seen, they appear to have been produced in the relief of local stresses incident to the major deformation. The dips are mainly steep—from 60° to vertical. Apparently southeasterly dips are prevalent. It is assumed, from the differences in degree of metamorphism, that the rocks on the west side of the region are the oldest. With the younger rocks lying to the east, the general structure of the Goodnews River valley is considered to be synclinal, with the eastern limit of the syncline not exposed in the region, unless the metamorphic rocks of Cape Newenham are considered to mark it. Faulting and minor folding are of common occurrence. The folding is especially noticeable in the area of slates, and the faulting in the more arenaceous rocks and in the basaltic tuffs and flows.

SEDIMENTARY ROCKS.

Limestone and the metamorphosed argillitic rocks associated with it are the oldest sedimentary rocks observed in the region. Some of the limestone beds are 100 feet or even more in thickness, but for the most part the series, as observed, is made up of a number of beds from 10 to 50 feet thick, separated by considerable thicknesses of slate or phyllites. Some schistose rocks seen on the western edge of the region are probably to be considered as the metamorphosed equivalent of these beds. Quartzites were also observed in one place in the series. Locally, basic igneous rocks appear to be intercalated with the upper portion of the limestone and argillite series, but probably many of these are intrusive. The limestones are mainly dark gray but weather nearly white. Abundant white talus débris from the limestone beds gives them an undue prominence and in places conceals the talus and surface of the associated rose-bed and dark-gray slates. Nodular cherts were observed in some of the limestone beds, and other beds are reticulated with quartz and calcite

veins. Overlying the limestones is a thick series of argillite sandstone and graywacke, locally metamorphosed to slate and quartzite. The best exposures were observed on the north shore of Goodnews Bay at Beluka Peak and eastward toward the mouth of Tunulik River. At Beluka Peak the rocks are fine-grained, dense, somewhat siliceous argillites of a general gray-green color, which ranges through several shades from nearly white to a slaty drab. These argillites are much shattered and fractured, so that they seldom break along bedding planes. They show much minor faulting, with a lateral displacement across the bedding which may amount to but a few inches or may be several feet. Some bedding planes are slickensided and are thus apparently planes of movement. Calcite veinlets appear along many of the openings produced by movement and also are to be noted in the fractured argillites, some of which are calcareous. There is a thickness of 700 feet or more of argillites underlying a 300-foot bed of sandstone, which grades into a 100-foot conglomerate bed. Alternating and intergrading sandstones and conglomerates to a total thickness of 700 or 800 feet lie above the first conglomerate. The larger pebbles of the conglomerate are mainly red cherts, of which some of the flat, elongated boulders are 2 feet in maximum dimension, but the greatest diameter of the rounded cobbles is little over 1 foot. Green and black siliceous argillite pebbles are also present in these conglomerates. The cementing material is fine green, gray, and black sand.

To the east along the beach from the conglomerates there is an abrupt change in strike from N. 50° E. to N. 25° W., and the rocks are of finer grain, black argillites being succeeded by lighter-colored siliceous argillites which do not have the greenish tinge of those at the western edge of Beluka Peak. The lighter-colored argillites are much netted with fine calcite veins and strike about N. 5° E. These rocks are succeeded by a red and green fine-grained chert or tuff, much like that in the vicinity of Arctic Island, on the lower Yukon near Russian Mission, which extends for several hundred feet to the east, and give way in turn to a series of basaltic tuffs and flows that crop out for 1,500 feet along the beach.

Although most of these rocks have an easterly dip, the dip is very steep, and in addition there has been considerable faulting, so that while it is believed that, as already stated, younger rocks lie successively toward the east, there appears to be a possibility that at Beluka Peak the rocks are successively younger toward the west, the beds being overturned, and, therefore, that the sequence is from the red and green cherts or tuffs and black slaty argillites through the sandstones and conglomerates to the greenish argillites, and that the pebbles of red chert in the conglomerate were derived from the chert or tuff series.

East of the basalt tuffs and flows argillite and basalt alternate in several wide bands, the next to the last of which, consisting of basalt, extends for 6,000 feet along the north shore of Goodnews Bay, to the mouth of Tunulik River. From the strike and dip of the flows, where observable, it has been calculated that this band represents a thickness of at least 2,400 feet.

At a number of places along the beach on the north side of Goodnews Bay small dikes, from a few inches to 5 feet in width, cut the basalt and the sedimentary rocks just described.

Elsewhere in the area outcrops of sedimentary rocks were observed, but these were of small extent, and usually but few data, aside from the strike, could be obtained from these isolated outcrops. They exhibited all the phases already described, from black slaty argillites to conglomerates, and included at numerous places fine-grained feldspathic graywackes, which were not always readily separable from the basalts. Cherty rocks appeared to be more abundant elsewhere than on Goodnews Bay, especially between Wattamus and Bear creeks.

IGNEOUS ROCKS.

Between Cape Newenham and Chagvan Bay occur altered igneous rocks of a number of types, with minor amounts of slate. The igneous rocks appear to be mainly basic rocks, almost entirely altered to chlorite and serpentine. Some of the serpentine is apparently the source of a white kaolin or asbestos, said to be obtained from a narrow band between Cape Newenham and Security Cove and used as a white paint by the natives. The basic rocks have been cut by later intrusives which appear somewhat more siliceous. North of Cripple River, and again north of Jacksmith Creek, acidic intrusives appear in close association with the limestone.

The basaltic rocks, which may include some andesite intrusive masses and flows, are widely distributed throughout the valley of Goodnews River, and include tuff, thin-sheeted ellipsoidal flows, and thicker and more massive flows. Their occurrence with the argillites and sandstones and their relation to those rocks have already been noted. At Red Mountain the suggestion of columnar structure seen from a distance was considered as showing the probability that the rocks there are also basalt.

This series of rocks is intruded by a number of small batholithic granite masses at the head of Tunulik River, at the head of Granite Creek, on Olympia Creek, and on Arolic River. It is very probable that there are many other intrusive masses in the mountains that extend northeastward and form the divide between the Goodnews and Arolic drainage basins. The andesite dikes seen on the north shore of Goodnews Bay are not improbably related in origin to the intrusion of the granites.

The last major deformation of the region and the present structure were probably caused by the intrusion of the granites, which are also assumed to have produced the auriferous mineralization. Later movements have taken place, but not in such a manner as to produce folding.

TERTIARY AND QUATERNARY GEOLOGIC HISTORY.

It is to the cycle of events occurring within the Tertiary and Quaternary periods that the region owes its present topographic form. To these events also are attributed the unconsolidated deposits now found so extensively over the region. It may be assumed that the intrusion of the granites and the consequent elevation of the land surface occurred at the end of the Cretaceous period or during early Tertiary time. This uplift resulted in a range which extended from what is now the mouth of Kuskokwim Bay northward to Kuskokwim River. The highest peaks of this range were undoubtedly many hundred feet higher than the present crests, and its western front was also far to the west of its present position and faced an open sea much deeper than the present Kuskokwim Bay and Bering Sea, with only a few if any islands in what is now the Yukon-Kuskokwim delta region.

The wave erosion caused the shore line to retreat gradually eastward until it reached approximately its present position. In the meantime the debris from the rapidly cutting streams had been carried to the sea and there transported to form the offshore deposits which shoaled up the waters in late Tertiary time. Mature topographic forms with wide valleys were developed by the beginning of the Quaternary period. During early Quaternary time there appears to have been much extravasation of basaltic lavas in western Alaska. None of these relatively recent lavas are known in this region, though they appear to occur on Bristol Bay and on the lower Yukon in the vicinity of Russian Mission, as well as farther south in the Ingakslugwat Mountains, in the delta region, and still farther south on Nelson and Nunivak islands. It is extremely probable that these outpourings of lava in other regions were marked by changes of level in this region, so that there appears to have been subsidence in the vicinity of Goodnews Bay. In view of the fact that the area probably then stood somewhat higher above the sea than at present, the subsidence that took place appears to have amounted to at least 300 feet. Probably soon after partial emergence glaciation in the region reached a maximum. Glaciers filled many of the interior valleys but appear not to have reached the sea except in a few places, as in the valley of Goodnews River and possibly also by way of Chagvan Bay. With the retreat of the glaciers a great amount of glacial debris was deposited in the streams, which were taxed to their limits

to transport the material to the sea. Their task appears to have been made easier by further elevation of the land surface, but at the first opportunity their load was dropped, and thus was built up the widespread frontal tundra-covered gravel coastal plain which now lies between the mountains and Kuskokwim Bay and River. Some of the materials laid down in the upper portions of some of the streams, where their valleys were marine embayments, are now being reworked and transported to the sea. Examples of such reworked material are afforded by high gravels overlain by silts in the valley of Goodnews River. In verification of this hypothesis as to the mode of origin of the frontal apron of the mountains, it may be pointed out that the indentation of the shore line called Jacksmith Bay is opposite a stretch of mountains from which no large streams flow; while on either side the shore line has been extended westward through deposition by streams. At the present time the westward advance of the shore line seems to be practically at a standstill, and it is probable that in this particular embayment, owing to the fact that the shore is made up of fine silt and peaty material and is unprotected by a gravel beach, as it is to the north and south, the shore line is shifting slowly eastward. Streams entering the other bays are filling them and extending the land area, obtaining their débris through all the forms of erosion prevalent in subarctic climates, including mechanical disintegration by frost, nivation, and soil flows, as well as normal transportation by running water.

ECONOMIC GEOLOGY.

HISTORY OF MINING.

A summary of the history of mining in the Goodnews Bay region has been given by Maddren¹ in connection with his report on the results of field work in 1914. In his discussion he considers the entire valley of the lower Kuskokwim, including the Goodnews Bay region:

This region appears to have been neglected as a field for prospecting during the early years of the gold excitement that centered in the Klondike and spread along various tributaries of the Yukon. It was not until the Nome boom, in Seward Peninsula, reached its height during 1900 that further attention was directed toward the Kuskokwim region. One of the results of the rush of people to that district was the movement of a small number of men from Nome to the region about the mouth of the Kuskokwim during the summer of 1900, and they prospected in that vicinity for several years. Placer gold was discovered at several localities in the vicinity of Goodnews Bay, and productive mining on a small scale was undertaken on Butte Creek, in the basin of Aalalik [Arolic] River near the settlement of Quinbagat [Kwinak], and has been carried on for the last 10 years or more.

During the winter of 1900-1901 a typical dog-sledge stampede to the Kuskokwim Valley was made by a considerable number of men from Nome. The

¹ Maddren, A. G., Gold placers of the lower Kuskokwim: U. S. Geol. Survey Bull. 622, pp. 299-301, 1915.

movement was based on vague rumors of the discovery of placer gold on a stream designated "Yellow River," but the location of this stream in the Kuskokwim Valley does not appear to have been even approximately fixed.

From 1901 and 1902 there appears to have been some mining done on the Arolic, but with the failure to find bonanzas the majority of the stampedeers left this field, and it was not until 1906 that there was another influx. Maddren continues:

The discovery of placer gold on the headwaters of Innoko River in 1906 caused a considerable movement of prospectors from Nome up Kuskokwim River the following year. It is estimated that several hundred persons left Nome for the Innoko diggings by way of the Kuskokwim River during 1907. Most of them arrived at their destination after various delays and risks due to unsatisfactory transportation, especially across Bering Sea and into the mouth of the river. A few of these persons, however, did not go all the way to Innoko district but stopped at various points along Kuskokwim River and turned their attention to prospecting some of its tributaries.

The "mosquito flotilla" that came up the Kuskokwim in 1906 and 1907 made it appear to the traders and missionaries at Kwinak and Bethel as if they were no longer on the outskirts of civilization, with but one or two yearly boats bringing supplies, but were on one of the world's commercial highways.

Each influx of prospectors was encouraged by the finding of gold in the streams they prospected, but after working for a time most of them failed to develop profitable ground and left. However, a small production by a few men continued to be made yearly on Butte Creek, and some mining was done on Fox and Snow gulches and on Trail, Kowkow, and numerous other creeks. An estimate of \$100,000 for the total production to 1919 was based on an estimate of \$70,000 for Butte Creek and \$30,000 for the streams named, all of which flow into the Arolic or one of its tributaries. Of the \$30,000 a considerable proportion came from Kowkow Creek. The first production of gold on this creek was made in 1913, and a number of claims on it have been held ever since.

Practically every white man in the region has had at some time during the last three years an interest in one or more claims in the Arolic basin. Some have utilized these claims to get a grubstake on which to prospect during the spring, and in 1917 a party of three or four men were engaged in prospecting on Bear Creek, which flows into Canyon Creek, a tributary of Goodnews River, when a native reindeer owner and herder called Wattamus (apparently a corruption of his baptismal name Bartimeus) reported to one of the miners that he had found gold on a stream about 8 miles to the south. Several claims were staked on this new creek, which was named Wattamus after the discoverer. After staking, the owners of Discovery claim and the two claims above and the two below

Discovery pooled their interests, and these five claims have since been held as a unit. Later comers staked ground above and below the Discovery group. A notable production was made during 1917 on the Discovery group of claims, and in 1918 considerable mining was done. The total production for the two years was about \$35,000, thus giving an approximate total for the district, prior to 1919, of \$135,000.

In addition to the streams above mentioned as having been producers, many others have been prospected. Some of the streams in the vicinity of the granite masses showed fine gold but not in sufficient amount to warrant the undertaking of mining, and for the most part titles to claims have been allowed to lapse.

GOLD PLACERS.

GENERAL FEATURES.

There are in general two types of placers in the Goodnews Bay region. Those of the Arolic basin are mostly in wide gravel-filled valleys in the group of low hills in the vicinity of Butte Creek or between these hills and the surrounding hills or mountains to the south, east, and northwest. The placers of the Goodnews Bay drainage basin, on Wattamus and Bear creeks, are in much more sharply incised valleys in the mountain masses. The Arolic placers probably represent concentration from older valley fillings, glacio-fluvial or marine sediments; the others represent the concentration of gold by erosion of bedrock since glaciation, in the bottoms of glacial valleys.

The streams that yielded gold in 1919 were Kowkow, Wattamus, and Bear creeks, the first in the Arolic Basin, the others in that of Goodnews Bay. In the Arolic Basin title to claims in Butte and Trail creeks is held pending future developments and operations. A number of claims in addition to those worked are also held on Kowkow Creek. On Wattamus Creek several claims are held below the Discovery group with a view to the possibility of developing dredging ground.

MINING CONDITIONS.

Inasmuch as the placer ground is shallow, open-cut mining is the method in use. An effort is made to groundsluice off as much of the overburden as possible, usually within a foot or two of bedrock, before shoveling in. At times there is a shortage of water for groundsluicing, but this difficulty is partly overcome in various ways. On Wattamus Creek a dam has been erected to impound water which is used for "splashing." On Kowkow Creek ditches bring the water from the forks of the creek. It is said that more mining could be done on Butte Creek were water available, but the necessity of constructing ditches to bring water will mean one or two seasons of dead work before mining can be done with other than Butte Creek water.

The conditions of snowfall and the time of melting of the snow vary on the different creeks, but it is late in June or even July before the creeks are sufficiently free of snow and frost to permit ground-sluicing, which it is aimed to do while the water is abundant. The later part of September is as late as mining can usually be carried on, although in favorable years the mining season may extend into October. Most of the auriferous stream gravel as well as the barren gravel overburden lies within the reach of circulating water, and operations are therefore not impeded by the necessity for thawing. However, large granite boulders in the gravels on the upper claims of Wattamus Creek are a very real detriment to mining. It is probable that such boulders will also be found on the upper courses of other streams heading from either side against the Arolic-Goodnews divide.

Most operations are conducted on a partnership basis, but the Discovery group of claims on Wattamus Creek were being worked by about 10 or 11 men. Wages in 1919 were \$6 and board for an 8-hour day. Labor is difficult to procure, for a number of the permanent residents have ground of their own which they work more or less intermittently, and as this district is off the main highway of Alaska travel, the Yukon, there is little opportunity of obtaining labor from the drifting class of miners.

As no power plants were in operation in 1919 and there is no necessity for thawing, fuel was required only for camp purposes. It was obtained by gathering and stacking alders and less preferably willows, which were used after a period of drying. In the vicinity of the camp both alders and willows are found in sufficient numbers to meet immediate needs.

There is no spruce timber in this region nearer than Bethel, so that lumber for sluice boxes must be obtained from the sawmill at that place or by whipsawing drift logs from the upper Kuskokwim found on the beach, chiefly in the vicinity of Carter Spit. Spruce, however, is not wholly satisfactory, and whenever possible lumber is obtained from the States. Cottonwood grows on the upper Goodnews River; and cottonwood poles, together with a few large alders or willows, are sometimes used to make the trestles of the sluice boxes.

ORIGIN OF THE PLACERS.

The principal rocks throughout the region are those of sedimentary origin, including sandstone, quartzite, slaty or argillitic rocks, chert, and limestone. Associated with the sediments are lava flows, in large part basaltic. These rocks are intruded at a number of places by granitic and related acidic rocks. It is believed that these intrusives have caused most of the auriferous mineralization of the sedimentary rocks. Quartz veins are not uncommon, but they are mainly narrow and of small extent, so that quartz pebbles and cobbles are rather rare. It is believed that some of these veinlets carried the gold from which

the placers were derived. This hypothesis accords well with the known facts with respect to Wattamus Creek and to some of the other streams that head against granite areas and are reported to carry gold but not in quantities sufficient to pay for mining.

No acidic igneous rocks were observed in the immediate vicinity of the placers on Bear Creek, nor were pebbles of this type of rock observed in the gravels in the cut on this stream. It would thus appear that the placer gold is derived mainly from veinlets that were probably related in origin to the intrusive granite found elsewhere in this region. So far as known, the placer ground on this creek is all of low grade, and those who worked on it in former years report that they could not make wages on it.

Some massive intrusives occur in the Kowkow Mountains, south of Kowkow Creek, and between the crest of the ridge and Kowkow and Trail creeks there is much quartz veining in the severely fractured rocks. No gold was observed by the writer in any of the quartz veins. Between Kowkow and Butte creeks the bedrock is covered by a mantle of unconsolidated gravels which is locally as much as 75 feet thick. A few outcrops of shattered limestone appear, however, rising slightly above the gravels. Associated with the limestone at the head of Butte Creek are andesitic rocks which are apparently intrusive and which may have had an influence on the occurrence of the gold.

The valleys of Wattamus and Bear creeks were once occupied by glaciers, and any preglacial concentrations of gold were swept out and disseminated in the valley of Goodnews River. The present gold placer deposits of those streams are concentrations of the gold contained in the rocks which have been cut down by erosion since the glaciation. Erosion has been rapid since the retreat of the glaciers and has consisted of rapid mechanical disintegration by frost, assisted by soil flows, which have carried the disintegrated rock from the slopes to the bottoms of the valleys. Thence it is removed by the normal processes of stream transportation so far as the streams are competent to transport the soil and rock débris.

For the deposits worked in the Arolic basin the mode of the later concentration into workable placers is not so readily apparent, as the physiography of that area involves other factors in addition to those concerned in the concentration processes on Wattamus and Bear creeks, and the history of the area has by no means been completely deciphered. It was not possible to determine whether the accumulation of the placers on Butte and Kowkow creeks was preglacial or postglacial, although the so-called gumbo bedrock on Kowkow Creek resembles a reworked till. As has been stated in the consideration of the geologic history, the land surface once stood at a higher level than at present, was then depressed, probably 300 feet or more below the present surface, and was then reelevated to approximately

its present position. The maximum glaciation possibly occurred shortly after the period of maximum inundation and before reelevation to the present level was completed. During the period of these earth movements deposits of gravel were formed by normal stream erosion, by the deposition of glacial débris, by wave action along beaches, and by combinations of these three processes. On reelevation of the surface to approximately its present position, normal stream erosion was resumed in the gravel deposits, and in places the underlying bedrock was cut. The Arolic deposits are therefore due to stream concentration from bedrock and from the probably auriferous gravels that had been previously accumulated.

MINING OPERATIONS.

During the summer of 1919 all the creeks on which mining was being done were visited, and some notes were made as to details of mining methods and other features in connection with the operations.

WATTAMUS CREEK.

Placer gold was discovered on Wattamus Creek early in the summer of 1917 by a native who was herding reindeer in the vicinity. He reported the discovery to a group of miners on Bear Creek, who returned with him and staked Discovery claim and Nos. 1 and 2 above and 1 and 2 below Discovery, including one claim for the native. Interests were pooled on these claims, and the native and one of the original stakers have since sold out to the Discovery Mining Co., the shareholders of which include Charles Thorsen and Jack Wilkins, who were among the original group of owners. Joe Jean has purchased the shares of some of the others. A number of other claims were staked above and below the original group, but little work has been done on any of these except "No. 3 above." On the discovery of paying ground, work on Bear Creek stopped and operations were transferred to Wattamus Creek, where during the fall of 1917 gold to the value of more than \$10,000 was produced. In 1918 work was continued, chiefly on Discovery claim, and the production was more than \$20,000, making a total for the two years of about \$35,000.

In 1919 work was being done on three claims by two plants. The Discovery Mining Co. employed 10 or 12 men, about equally divided between claims Nos. 1 above and 1 below Discovery, and Ryan & Wickert worked "No. 3 above." In addition to the claims that are being worked, a number of other claims are held, and some of those below the Discovery group were prospected during the winter of 1918-19 with a view to dredging operations.

The width of the so-called pay streak varies greatly; it is probably not over 20 to 30 feet on "No. 3 above" but more than 100 feet

below the Discovery group. Some of the small gulches appear to have greatly enriched the main pay streak, and in a few places there is some rich ground at the sides above the creek level. The value of the gold in the pay streak runs from 25 cents to \$2.50 per square foot of bedrock. The gold is reported to assay \$16.40 an ounce.

All mining is done by open-cut methods. The material is ground-sluiced to remove 2 to 5 feet or more of barren soil and gravel, leaving from 1 to 2 feet of gravel to be shoveled into the boxes, the larger boulders being rolled to one side. Where the bedrock is loose and friable slate or sandstone, about 6 inches of that is mined also. The bedrock consists mainly of slaty argillite, sandstone, chert, and basalt. The gravels are predominantly of these rocks but contain also pebbles of conglomerate and of a dark-colored porphyritic rock with varying amounts of granite. The granite pebbles increase in size and amount toward their source, at the head of the creek. Below Discovery claim there are relatively few boulders more than 18 inches in diameter; on claim "No. 1 above" they are 3 to 4 feet in greatest dimension but are not so numerous as to constitute a serious impediment to mining. On "No. 3 above" the granite boulders are still larger and more numerous.

From the data at hand it is estimated that the total production of this creek will probably be little over \$250,000, unless the lower claims are worked by dredges, for it is doubtful whether the claims below "No. 2 below" can be worked profitably by hand. Boulders would probably seriously interfere with dredging operations above Discovery claim. It is not likely that the ground above "No. 3 above" will pay wages if worked.

BEAR CREEK.

Apparently the first claims on Bear Creek were staked in 1916, although they may have been staked at the time of the early rushes to the Arolic in 1900, 1901, and 1906-7. Little if any work was done until 1917, when a few men were working there. Some of these men working claim "No. 1 above" report that they did not make wages and left for Wattamus when gold was found on that stream. In 1919 two men were working on claim No. 2 above Discovery, the first work that had been done on that claim.

This stream flows into Canyon Creek, a tributary of Goodnews River, and should not be confused with the Bear Creek in the area at the head of the Tuluksak, on which some mining has also been done, nor should the Canyon Creek into which this stream flows be confused with the Canyon Creek that lies between Kanektok River and the Tuluksak-Aniak region.

At the head of this creek a dark-gray fetid limestone appears in the bed of the creek. This limestone appears to grade into slaty cal-

careous argillites. Sandstones, grit, and conglomerate, as well as chert and some basic fine-grained igneous rocks, are also found within the basin of the stream. The rock is not exposed in the bed of the creek where mining was being done, but the gravels are made up of boulders, cobbles, and pebbles of conglomerate, sandstone, limestone, and dense argillite, with a little chert. Some of the boulders are much weathered to a light-yellow rock. They were probably basalts originally. Overlying 2 to 5 feet of gravel is 2 to 3 feet of black, tough clayey muck, over which the stream flows with but little cutting. Some of the gravels are iron stained and partly cemented.

When the creek was visited, August 11, 1919, a cut 15 by 50 feet had been groundsluiced off. The cut was made diagonally across the creek bed, to cut the pay streak, if there was one. No boxes had yet been put up, so that it was not possible to determine the gold tenor of the gravels from the clean-ups. However, two or three pans taken along the base of the gravels each gave only a few very small colors, and it is doubtful whether the cut paid wages.

AROLIC BASIN.

The first mining in the Arolic Basin was done in 1900 or 1901, but little gold was produced until after 1906. The production has come chiefly from Butte Creek. Since work was started on Kowkow Creek in 1913 the yearly production from that stream has probably about equaled that from Butte Creek and in some years has exceeded it. In 1918 a power scraper was operated on Kowkow Creek. In 1919 but one claim was being worked in the Arolic basin, three partners operating on claim No. 1, above Discovery, on Kowkow Creek. Several other creeks in this basin have been prospected, but their entire production is negligible.

Where mining was being done in 1919 about 6 or 7 feet of overburden was being moved. The upper 1 to 3 feet consists of soil, moss, and peat and overlies 3 to 4 feet of nearly black, reddish, or blue-gray uncemented gravel, which, in turn, overlies 8 to 15 inches of rather fine gravel, containing a little clay. This bottom layer is tightly packed and requires considerable picking to loosen, but it breaks up readily in running water. The excavation is carried to a false bedrock, called "gumbo" on Kowkow and Butte creeks, which is a tight clay that contains a very small amount of gravel and somewhat resembles a glacial till. The depth to bedrock is not known. On Butte Creek the depth below the "gumbo" is said to be 15 to 25 feet. The gravels are mostly of local origin and consist of argillite, basalt, sandstone, and some coarser-grained acidic igneous rocks. On Butte Creek limestone gravel is also found. The Kowkow gold is said to assay \$17.60 an ounce, and that from Butte Creek somewhat higher.

CONCLUSIONS.

The original deposition of the gold in fissures associated with quartz was probably genetically related to the intrusion of the late Mesozoic granites into the sedimentary and earlier igneous rocks, which range from Paleozoic to probably late Mesozoic in age.

From the original deposits the gold has been eroded by streams and other agencies, not including glaciation, and has been concentrated in placers by some streams, mainly those in the vicinity of the granites.

Glacial erosion has removed most of the gold-placer deposits and has scattered the gold widely over a considerable area in amounts not suitable for profitable mining.

Postglacial concentration has been effected by some streams in connection with the erosion of the rocks containing auriferous veins. In other streams the placers appear to be, at least in part, the result of reconcentration from glacial, fluvio-glacial, and marine deposits. In a general way, both types of deposits may be found in the vicinity of the granites.

COAL.

No coal is known in the Goodnews Bay region, although natives have brought in to the school teachers and others at Mumtrak reports of "a mountain of coal" south of Goodnews Bay. These reports have not been verified, and it appears likely that the supposed coal is a dense black chert or fine-grained black basalt. Small seams of coal are reported to occur on Hagemeister Island and on the beach near the mouth of Kulukak River, on the north side of Bristol Bay. Coal of good quality in thick beds is also said to occur north of the Goodnews Bay region, on Eek River, near what is known as the island mountain, described as an isolated low mountain rising well above the surrounding flats and forming a conspicuous landmark. The occurrence of this deposit seems to be well authenticated.

ASBESTOS.

Along the shore between Cape Newenham and Security Cove there are said to be exposed thin seams or veins of a white material, which is believed to be asbestos of the very short-fibered variety produced by the weathering of serpentinous rocks. It appears to be weathered almost to a clay, so that its commercial possibilities appear small. The natives occasionally obtain small amounts from this deposit and, mixing it with seal oil, use it as a white paint for their kayaks and bidarkas. A red paint obtained near by is believed to be hydrous iron oxide precipitated from water seeping through pyritiferous slate or argillite.