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KODIAK AND ADJACENT ISLANDS
ALASKA

BY

STEPHEN R. CAPPS

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KODIAK AND ADJACENT ISLANDS

By Stephen R. Capps

ABSTRACT

The Kodiak group of islands, having an area of 4,900 square miles, lie on the Pacific Ocean side of the base of the Alaska Peninsula. Although the town of Kodiak is the oldest continuously occupied white settlement in Alaska, the interior of many of the islands is still little explored and unmapped, for the heavy growth of vegetation makes inland travel difficult, and few trails penetrate far from the coast. The principal source of income for the residents is derived from the prolific salmon and herring fisheries, although somewhat desultory mining of gold from beach placers has been carried on. A few attempts to mine gold lodes have been made, with little or no success, and several gold-bearing lodes have been staked. The presence of precious metals rather widely distributed throughout this region and the increased dollar value of gold have maintained the hope that workable mines would be found, and the present investigation was undertaken for the purpose of aiding the prospector and miner in the discovery and development of such deposits. A topographic map covering an area of 720 square miles in the vicinity of the town of Kodiak was completed by the Geological Survey in 1932, and the writer spent the field seasons of 1934 and 1935 in a reconnaissance geologic study of the island group as a whole.

The Kodiak group of islands lies along the same structural trend as Kenai Peninsula, to the northeast, and there is a striking similarity in the geology of the two areas. The oldest rocks include an undifferentiated group that consists mainly of greenstone flows, tuffs, cherts, and slates and their metamorphic equivalents, probably of Triassic and Jurassic age, with minor amounts of mica schist, probably Paleozoic or older. These rocks are overlain unconformably by a tremendously thick series of slate, graywacke, and conglomerate, of late Mesozoic age, probably mainly Cretaceous. This series in turn is succeeded by a thick series of fresh-water Eocene (?) sandstones and shales, which are followed unconformably by marine Miocene or Pliocene sandstones.

The intrusive rocks consist mainly of a large mass of diorite that lies axially along the center of Kodiak Island and numerous smaller stocks, dikes, and sills of similar material. These were intruded after the deposition of the late Mesozoic marine sediments, but before the fresh-water Eocene (?) beds were laid down.

Some deformation and tilting of the Mesozoic sediments took place before the emplacement of the intrusive rocks, but during and after their intrusion further tilting and folding occurred, together with profound faulting that sliced the rocks in a northeast direction and offset the younger sediments against the older and against the dioritic intrusive masses. The greater part of the

folding and faulting was completed before Miocene time, but some later faulting and gentle folding have taken place.

During the glacial period this island group was a center of vigorous ice action, and from its higher mountains glaciers that almost completely covered the land pushed out to sea in all directions. It is even possible that at the time of greatest ice development the glaciers from the Alaska Peninsula, Cook Inlet, and Kenai Peninsula joined those of these islands, filling Shelikof Strait and lower Cook Inlet, and presented an uninterrupted ice front that extended from Prince William Sound outside of these islands to the Alaska Peninsula. The present topographic forms of the islands, with glacially carved valleys and fiorded coast lines, are largely the product of severe glacial erosion. Glacial deposits are present, but in relatively small amounts, most of the glacial debris having been carried out to sea.

Within recent years there has been a revival of interest in prospecting in this district. Several new discoveries have been made, old claims have been reexamined, and prospectors have been searching the hills for still further deposits of the metals. One small mill was in operation on a gold lode in 1935, and another plant for the recovery of gold from placer sands was in process of construction. The general geologic conditions are believed to be favorable for the occurrence of mineral deposits, and the most promising areas for prospecting for gold lodes lie along the contacts between the granitic intrusive masses and the sedimentary rocks and for some distance on both sides of such contacts. Some areas not obviously related to intrusive contacts also show mineralization, but in these there is some indication that granitic intrusives are present at depth.

So far as is known, the beach-placer deposits are not rich enough to warrant large-scale developments, but their presence indicates a bedrock source not far distant, and there is a reasonable hope that lodes sufficiently rich to justify mining will be found.

INTRODUCTION

LOCATION AND AREA

The group of islands here described, of which Kodiak Island is the largest, lies at the western border of the Gulf of Alaska, in the north Pacific Ocean between 56°30′ and 58°40′ north latitude and 150°40′ and 154°50′ west longitude (fig. 5). The group as a whole has an area of about 4,900 square miles, extends for a distance of 177 miles in a northeast-southwest direction, and at its greatest width is 67 miles wide. The following list includes the largest islands of the group, with the approximate area of each:

	Square miles		*Square miles*
Kodiak	3,588	Uganik	57
Afognak	700	Marmot	24
Sitkalidak	117	Spruce	17
Sitkinak	91	Whale	14
Raspberry	82	Amook	13
Tugidak	71	Ban	11
Shuyak	69	Aiaktalik	7

Shuyak Island, the northernmost large island of the group, lies a little more than 40 miles southwest of the nearest point of Kenai Peninsula, on the mainland, with the Barren Islands about halfway between. West of these islands, and separating them from the main-

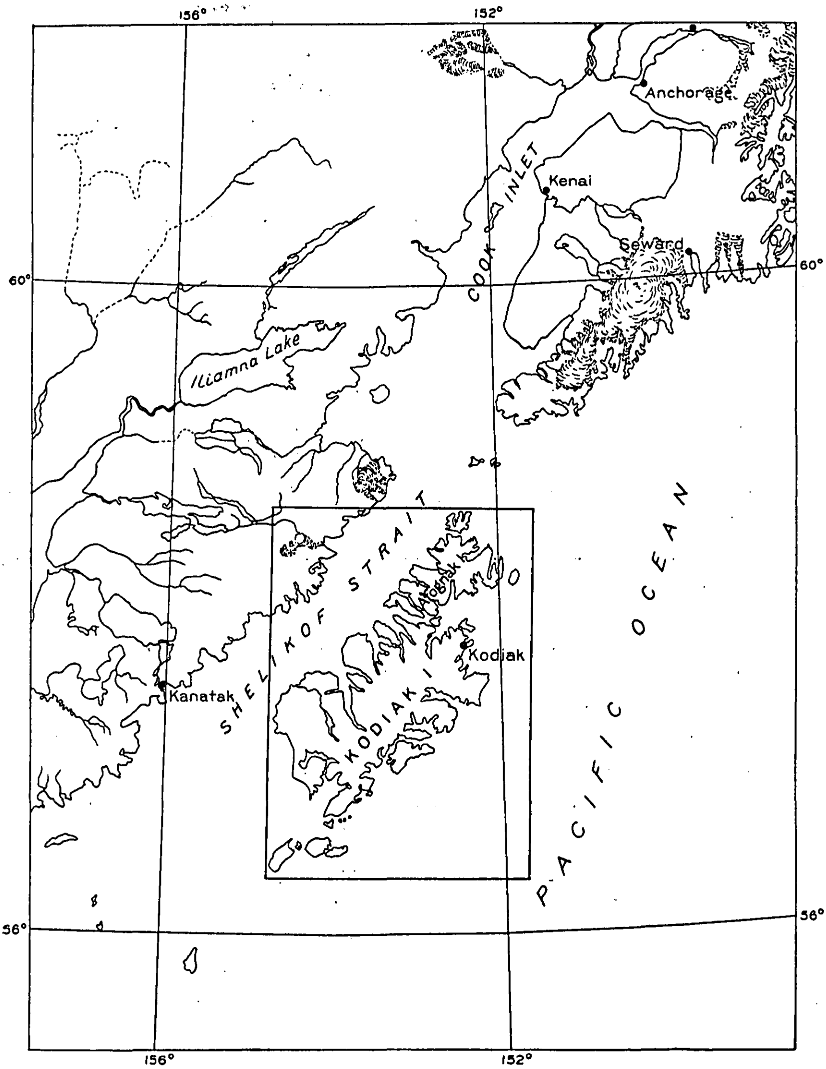

Figure 5.—Index map showing location of Kodiak and adjacent islands. The area shown on plate 2 is indicated by the rectangle enclosing Kodiak and the adjacent islands.

land of the Alaska Peninsula, is Shelikof Strait, which at its narrowest point is only 20 miles wide. The general setting of this group of islands is shown on the accompanying index map (fig. 5). In the character of its rocks and in its geologic history it may well be considered to be the southwestern continuation of the Kenai Mountains of Kenai Peninsula, whereas in these features it differs markedly from the Alaska Peninsula, which lies even closer to it. At no remote time geologically the islands of the Kodiak group were apparently all a part of a single large island that had a fairly smooth coast line.

The present intricate shore line, with its numerous deep bays, and the separation of the land mass into a great number of islands are the result of severe glacial erosion during the ice age, and the long, narrow bays and most of the narrow channels that separate the islands from one another are glacial fiords.

Although Kodiak Island was the site of the earliest white settlement in Alaska and is readily accessible by ocean vessels, its geology has until recently been little studied. This is due to the fact that the principal industry of these islands is fishing, and interest in the development of mineral resources has always been subordinate. Furthermore, although the coast line, with the many deep bays, offers excellent harbors to water craft, the rugged character of the interior and the heavy growth of vegetation make inland travel difficult, and few trails have been developed away from the immediate shore line. The numerous great Kodiak bears that range throughout this area also act as a deterrent to travel inland, and only the foolhardy venture to push into the areas of heavy brush and grass without being well armed.

PREVIOUS EXPLORATIONS AND SURVEYS

The earliest records indicate that before the coming of white men these islands supported a large native population, for their waters teem with fish, shellfish, and such aquatic mammals as seals, sea lions, and many varieties of whales, and the aborigines lived mainly on the products of the sea. Many large village sites, long abandoned, are known, and these afford an attractive field for the anthropologist, for it seems certain that this coastal belt lies along an important route of migration from northeastern Asia to the Americas. Even at the time of the arrival of the Russian fur traders the population was probably several times as dense as it is now.

Recorded history of this part of Alaska begins with the arrival of the Russian explorers and fur traders. Some island of this group was first sighted by Bering on his voyage of discovery in 1741, though he did not land. His report of the discovery of this new land and of the abundance there of pelts, particularly that of the much desired sea otter, soon led to the organization of numerous expeditions that pushed successively along the Aleutian Islands and the Alaska Peninsula. By 1763 Glottof and his companions reached Kodiak Island and spent the winter there,[1] and 20 years later the

[1] Bancroft, H. H., History of Alaska, pp. 141–147, 224, 1886.

first white settlement in Alaska was established by Shelikof in Three Saints Bay. In 1792 the Russian headquarters settlement was moved to Pavlosk Harbor, to the site of the present town of Kodiak, no doubt because of the better harbor and the presence there of spruce timber. Kodiak has ever since continued to be the largest settlement and the most important trading center in this part of Alaska and is the oldest continuously occupied white settlement in the Territory.

Until the expeditions on which this report is based no systematic geologic surveys had been made on this group of islands. The earliest published notes on the geology of this area were made by Grewingk,[2] who in 1848–49 made a reconnaissance along the coast of Alaska under Russian auspices. In 1895 Becker [3] and Dall [4] made a brief visit to Kodiak Island, Becker's chief concern being with the gold-lode deposits and Dall's with the coal and lignite resources. In 1899 the Harriman Alaska Expedition [5] made a brief visit to the vicinity of Kodiak, and a few fossils from the islands in Chiniak Bay were collected. Paige,[6] in 1905, also collected fossils from the vicinity of Kodiak.

In 1912 Martin [7] spent 2 months in studying the mineral deposits of the island and compiled a geologic map based on his own observations and on those of the geologists who had preceded him. Maddren,[8] in 1917, spent 3 weeks in an examination of the beach placers on the southwest side of the island. His condensed statement of the general geology of the island is largely taken from Martin's account, and his own studies were confined almost exclusively to Pleistocene and Recent deposits. In 1932 the writer, while attached to an Alaska survey expedition of the United States Navy, visited several points on Kodiak Island and had an opportunity to make several airplane flights over it. Although no topographic map of the interior of the island was then available and no geologic mapping was attempted, he recognized that large areas in the higher and more rugged parts of the island are occupied by granitic rocks and that granitic intrusive masses constitute a much larger element in the make-up of the island than had theretofore been appreciated.

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[2] Grewingk, Constantin, Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der Nordwest Küste Amerikas: Russ.-k. min. Gesell. St. Petersburg Verh., 1848–49, pp. 347–363, 4 pls., 1850.

[3] Becker, G. F., Reconnaissance of the gold fields of southern Alaska: Geol. Survey 18th Ann. Rept., pt. 3, pp. 1–85, 1898.

[4] Dall, W. H., Report on coal and lignite of Alaska: Geol. Survey 17th Ann. Rept., pt. 1, pp. 800–843, 1896.

[5] Ulrich, E. O., Fossils and age of the Yakutat formation: Alaska, vol. 4, pp. 125–146, Harriman Alaska Expedition, 1904.

[6] Paige, Sidney, unpublished notes.

[7] Martin, G. C., Mineral deposits of Kodiak and the neighboring islands: Geol. Survey Bull. 542, pp. 125–136, 1913.

[8] Maddren, A. G., The beach placers of the west coast of Kodiak Island, Alaska: Geol. Survey Bull. 692, pp. 299–327, 1919.

PRESENT INVESTIGATION

Of recent years, particularly since the revaluation of gold in terms of United States dollars, there has been a sharp increase in the interest shown in prospecting for both placer and lode gold deposits throughout Alaska and in the possibilities of profitable exploitation of properties already known to carry precious metals. This revival of interest extended to Kodiak and adjacent islands, where in the past considerable gold has been recovered from beach placers and where attempts have been made to mine gold-bearing lodes, and led to a demand for more detailed information than was then available concerning the general geology of the islands and the geologic conditions under which the deposits of precious metals occur there. No systematic geologic or topographic surveys had been made, although the investigations by earlier workers had given some information on the general distribution of the rock formations of this region. To meet the demand for more detailed geologic information a program was adopted by the Geological Survey that included both geologic and topographic mapping. In 1932 Gerald FitzGerald, topographic engineer, spent the summer in mapping the northeastern part of Kodiak Island. In spite of a short season and unfavorable weather he completed the topographic mapping of an area of 720 square miles on a field scale of 1:180,000, and this map has been published on a scale of 1:250,000.

In the summer of 1934 the geologic mapping of the area covered by FitzGerald was undertaken by the writer. A 50-foot gas boat, the *Kodiak*, was chartered, with Wilson F. Erskine as captain and two other men as crew. The members of the expedition lived on the boat, shifting anchorage from place to place as the work progressed. All the shore lines were studied in considerable detail, foot traverses being made where that was possible, and frequent landings being made by skiff where the rock cliffs descended directly into the water and travel alongshore was not feasible. The results of this study have already been published [9] and are included in this report.

In the summer of 1935 a reconnaissance of much of the remainder of Kodiak Island and of many of the adjacent islands of this group was carried out, the members of the expedition traveling and living aboard the *Kodiak* and working out from convenient anchorages by skiff equipped with outboard motor. Beyond the limits of the area covered by the topographic map the Coast Survey charts were used as base maps, and as those charts show topographic forms only along the immediate shore line and make no attempt to delineate

[9] Capps, S. R., Kodiak and vicinity, Alaska: Geol. Survey Bull. 868-B, 1936.

the topography or drainage away from the coast, they leave much to be desired in geologic mapping. They do, however, afford an excellent and detailed base for coastal work, and inasmuch as the present investigation was of reconnaissance character only, and the only means of travel was by boat, the accuracy of the geologic mapping is greater near the shores than in the interior portions of the islands. Plate 2 shows the geology of the area studied. Traverses inland were made on foot in many places where the character of the country permitted. In reconnaissance mapping of large areas the limitations of time prohibit the following out of many geologic boundaries and the examination of all the innumerable rock exposures, and as a consequence it is probable that some geologic details have been overlooked. For example, the position of the northwestern margin of the large granitic intrusive mass that runs from end to end of Kodiak Island is known only approximately, and some smaller intrusive bodies may have escaped notice. Similarly, it is known that many faults are present within the area of upper Mesozoic slate and graywacke. Some of these are of small displacement and of minor importance. Others doubtless are of large displacement and may be continuous for long distances, but inasmuch as they offset beds of the same group only against one another their magnitude is not known, single faults could not be traced far with confidence, and most of them have not been mapped.

During the summer grass and ferns grow densely over the mountain slopes and, together with alder, rose, and salmon berry, form thickets that not only obscure the rock formations but render travel on foot slow and laborious, so that the amount of geologic information obtainable is disproportionately small compared with the time and effort required to obtain it. On the other hand, the coast line is deeply embayed and intricate and offers excellent and almost continuous exposures in the sea cliffs. Then, too, a large number of the bays cut almost at right angles across the strike of the rock structure and thus afford an excellent opportunity to study continuous sections across the rocks. More detailed work, with an adequate topographic base map, would doubtless result in additions and corrections to the geologic map presented here, but the writer believes that the distribution of the major rock units here shown is essentially correct. He is aware that much more detailed work than he found possible is desirable in places. Outside of the protected bays it is possible to land on the shore from a small boat only in very calm weather, for at most times a heavy surf rolls in from the ocean. These outer shore lines were visited when opportunity offered, but such occasions were infrequent, and the exposed coast was examined in much less detail than the bays. It is especially regretted that more time could not be given to the complex but interesting area on Kodiak Island in the neighborhood of Kiliuda Bay and Sitkalidak Island. It is also to be regretted that the shortness of the field season and the lack of facilities for land travel prevented the examination of a considerable area of southwestern Kodiak Island, between Uyak and Olga Bays; of Sitkinak and Tugidak Islands, at the south end of Kodiak Island; and of the northern part of Shuyak Island. With these exceptions a reconnaissance examination was made of the entire group of islands.

The writer is particularly indebted to Mr. and Mrs. W. J. Erskine, of Kodiak, for unlimited hospitality offered during both field seasons, and to them and individual prospectors, cannery men, and ranchers, too numerous to name individually, for courtesies of many kinds that expedited and made more pleasant the work in this region. Wilson F. Erskine, as captain of the gas boat, gave most efficient and cordial cooperation on all occasions. The thin sections of the rocks collected in both 1934 and 1935 were examined microscopically by J. B. Mertie, Jr., and all references to mineralogic content, microstructure, and petrographic character are based on his determinations.

GEOGRAPHY

Relief.—The position of Kodiak and adjacent islands in reference to the mainland of the Alaska Peninsula and Kenai Peninsula is shown in figure 5. The dominant geologic structural features of the islands have a northeast trend, in line with Kenai Peninsula, to which their geology has a striking similarity, whereas in both lithology and structure the islands differ markedly from the Alaska Peninsula, to the west. It may, therefore, be stated that topographically, structurally, and geologically these islands are the southwestward continuation of the Kenai Peninsula, though separated from it by the accidents of erosion that have reduced much of the intervening gap below sea level. The islands are therefore to be considered as an integral portion of the great chain of mountains that borders the Gulf of Alaska on the north and west, though separated from them by some 40 miles of salt water. As a whole they are mountainous, the relief being least on the islands at the extreme north and south ends of the group and greatest in the central part of Kodiak Island. Most of the interior portions of the islands are still unsurveyed, but the coast charts show a 420-foot hill on Shuyak Island and many mountains from 1,900 to 2,546 feet high on Afognak Island. Kodiak Island is the largest and has the greatest relief, with numerous peaks along its granitic axis that rise above

3,000 feet, and near the head of Ugak and Uyak Bays mountains of more than 4,400 feet above sea level are shown. Possibly still higher mountains lie in the unsurveyed interior of the island, and there are large areas within which the mountain tops rise above 2,000 feet. Sitkinak Island, at the south end of the group, has a greatest elevation of 1,640 feet, but Tugidak Island is of low relief, much of it lying only a few feet above sea level.

The surface features of this group of islands are due largely to sculpturing by glacial ice during the recurrent stages of Pleistocene glaciation and by the local glaciers that must have persisted in these mountains until comparatively recent geologic time. Glacial deposition has also played a part in building the surface of certain areas to its present form, but within these islands glaciation was so intense and so widespread that the products of ice erosion and transportation were for the most part carried out to sea and deposited there. A discussion of the extent and the effects of glaciation is given in another part of this report, but no understanding of the present topographic forms found here is possible without an appreciation of the profound sculpturing accomplished by glaciers in past time. At the time of greatest ice accumulation only the highest peaks and ridges stood above the ice surface and so escaped smoothing, and the slopes of these elevations were sapped by ice scour and reduced to sharp ridges and pinnacles.

Coast line.—The coast line of these islands is long and intricate, characterized by a large number of deep bays with branching arms and a multitude of scattered islets. Apparently in preglacial time this island group was a single large island with a fairly regular coast line. In Pleistocene time a great glacier covered this island, and from it the ice flowed seaward along all of the preceding valleys, deepening and widening them and scouring many of them below sea level. With the wane of the glaciers these overdeepened valleys were flooded by the sea, many masses of land being entirely surrounded by water and left as islands separated by narrow channels from the main land mass. Other valleys became long, deep fiords that penetrated well in toward the heart of the islands. The distribution and location of these fiords was no doubt determined mainly by the position of preglacial valleys, though in places the ice plowed across interstream divides and altered the ancestral drainage pattern. At present the processes of erosion and deposition by streams and the powerful attack of waves on the shores are tending to reduce the irregularities of the coast line. The fiords are slowly but surely being filled; prominent headlands and exposed islands are being cut away by the waves; and bars and spits are in process of formation across many bays and inlets. The result is still far from completed, but the processes are continuous and inexorable.

Drainage.—The rivers of Kodiak and its neighboring islands are all comparatively small, for the deeply embayed coast line leaves no spot that lies more than 15 miles from the ocean. The two largest rivers are probably the Ayakulik, locally known as the Red River, and the Karluk, both of which drain the unsurveyed area at the southwest end of Kodiak Island. Both are important salmon streams and head in lakes, but it is said that neither is navigable for even shallow-draft power boats. All the other sizable streams are on Kodiak and Afognak Islands, and in ordinary stages of water, even the largest of these may be forded at favorable places with hip boots except in their lower tidal portions, though after heavy rains even the smaller ones become torrents. Nearly every one of the fiorded bays has at least one river or large creek flowing into it, and several receive the drainage from a number of such streams. The average annual rainfall of this region is over 60 inches and is rather evenly distributed throughout the year, so that the streams are large compared with the area of their basins, and their discharge is fairly constant. All flow in short, direct courses to the sea, and the drainage systems are therefore simple and of small area. In the whole region there is scarcely a human habitation that is more than a mile or two from the coast, and few valleys have even the semblance of a man-made trail leading up them, though bear trails are everywhere present. These, however, take little account of brush and other impediments to human travel, and progress up the stream valleys is slow and laborious and is possible without much trail cutting only by taking advantage of stream bars and by wading the streams where no open bars occur.

Numerous small lakes and ponds are found scattered throughout the islands, but not many are more than a mile or so long. Litnik Lake, on Afognak Island, is said to be about 6 miles long; Karluk Lake, in southwestern Kodiak Island, is of about like size; and there are several unsurveyed lakes tributary to the Ayakulik River and Olga Bay that are from 1 to 4 miles or more long. The lakes have an important bearing on the industry of the islands, for the much sought red salmon spawns in lakes and in streams draining to and from lakes, whereas the less desirable varieties of salmon spawn in nearly every stream in the region. Of recent years beaver have been introduced to the islands, and they have readily adapted themselves to the local conditions and have multiplied with remarkable rapidity. By building dams on many streams they have not only flooded large areas in the lowlands and so made travel difficult but have made it impossible for the salmon to reach many spawning grounds that had long been so used.

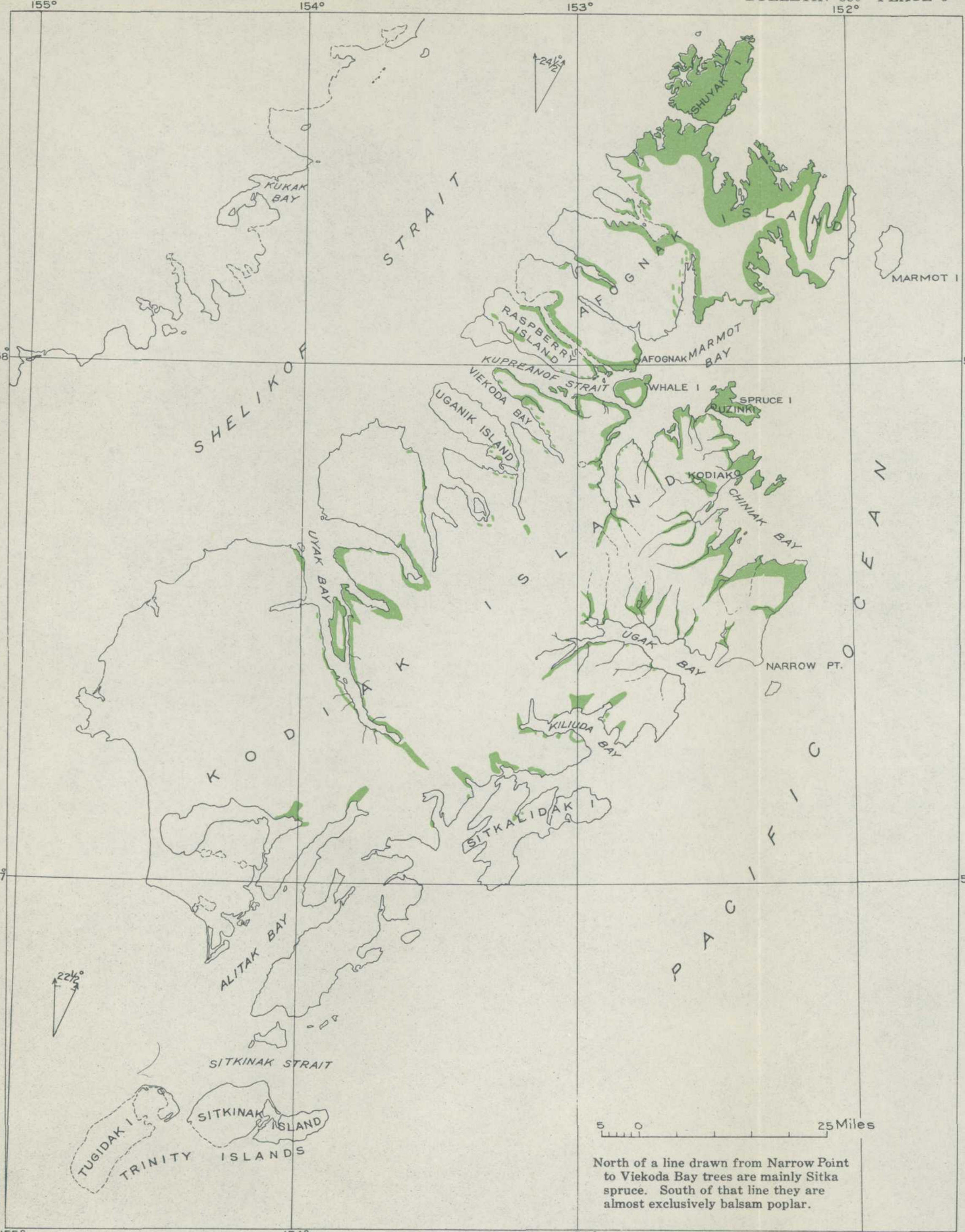
Climate.—The Kodiak group of islands lies in the path of the Japan current, which sweeps northeastward along the coast of the Alaska Peninsula into the Gulf of Alaska, and its climate is much more equable than that of island areas of similar latitude. The following table, compiled from data collected by the United States Weather Bureau, gives in condensed form the salient features of the climate at the town of Kodiak, where records have been kept more or less continuously for over 40 years. Kodiak is the only locality in the island group where such records have been collected for a continuous period long enough to yield reliable averages, and the weather there is believed to be fairly representative of the island group as a whole.

The highest recorded temperature is 85° F. and the lowest −12° F. Many summers pass in which the temperature in the shade fails to rise to 75°, and in only eight winters out of the 46 years during which records have been kept has the temperature fallen below zero. The average yearly precipitation of about 60 inches is rather evenly distributed throughout the year, though nearly half of the total falls in the last 5 months. The average of 163 days a year on which 0.01 inch or more of rain falls indicates an even larger number of overcast days. Most of the harbors and bays remain ice-free through the winter, though during exceptionally cold spells winter ice may form in enclosed bays, particularly in those that receive considerable fresh water from tributary streams.

As is to be expected, there may be a wide variation in the summer weather in successive years. In 1934, from mid-June to mid-September, there was much fine, clear weather, with light winds and calm seas. In 1935 during the same months the weather was prevailingly cloudy, with high winds and rough seas.

Weather records for Kodiak, Alaska

	Length of record (years)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Temperature (°F.):														
Monthly mean	38	29.5	31.3	33.4	36.4	43.0	50.0	54.3	54.3	49.8	42.0	35.0	30.7	40.8
Monthly mean maximum	15	34.3	36.5	38.5	42.0	47.8	56.1	60.0	59.4	55.6	47.6	39.7	35.7	46.1
Monthly mean minimum	15	24.8	26.5	28.7	31.2	37.1	43.5	47.4	48.1	43.6	36.9	30.3	26.4	35.4
Lowest recorded	46	−9	−3	2	5	20	30	32	34	26	7	−3	−12	−12
Highest recorded	36	53	60	65	61	74	82	82	85	77	66	60	61	85
Precipitation:														
Monthly mean (inches)	44	4.69	4.64	3.93	3.82	5.76	4.85	3.46	5.27	5.16	7.32	5.63	6.08	60.61
Monthly mean snowfall (inches)	29	9.7	11.2	9.2	5.6	.4	T	0	0	.1	.8	3.3	8.0	48.3
Average number of days with 0.01 inch or more		14	12	13	13	16	12	12	15	12	16	14	14	163
Winds:														
Prevailing direction		nw	nw	nw	se, w	ne	ne	ne, se	se	se	nw	nw	w, nw	nw
Average velocity (miles per hour)		13.4	10.6	8.3	9.9	7.9	7.4	5.9	6.0	7.7	8.8	8.3	9.9	8.7



MAP OF KODIAK AND ADJACENT ISLANDS SHOWING AREAS IN WHICH TREES OCCUR
1937

Vegetation.—The distribution of timber in the Kodiak group of islands is peculiar in that the northern part of Kodiak Island and all the islands north of it are well clothed with Sitka spruce trees up to about 1,000 feet or less above sea level, whereas south of Viekoda, Kizhuyak, and Chiniak Bays spruce is almost completely absent. Within a mile or so of the edge of the spruce forest fine trees 3 to 4 feet in diameter are common, and these have been used extensively for local purposes. That this unusual distribution of timber is not due to the present climate or soil is shown by the fact that within historic times the edge of the spruce forest has invaded the untimbered areas to a perceptible degree[10] and in places is advancing at the rate of about 1 mile a century. Griggs suggests that the absence of timber in many areas where conditions appear to be favorable to its growth is an inheritance from the time when Pleistocene glaciers completely erased plant life from this region, and that the reestablishment of the forest is now under way but far from completion.

Balsam poplar trees occur on well-drained slopes and in river valleys within the areas in which spruce is the predominant timber, and poplar trees are also found farther south than the spruce, being present along the valley floors and on alluvial slopes as far southward as Uyak and Alitak Bays. Poplar trees reach a diameter of 3 feet or more, but most of the large ones are decayed at the core, and this wood is little used for lumber.

The accompanying sketch map (pl. 3) shows the areas in which trees occur and includes both spruce and poplar. For all the area south of northern Kodiak Island the symbol indicates only the presence of small groves or scattered trees of balsam poplar, and many of these groves consist of medium-sized to small crooked trees.

To those unfamiliar with the rapid summer growth of plants in northern latitudes during the days of long hours of sunshine, the luxuriance of vegetation in parts of Kodiak seems astonishing. Scarcely has the snow disappeared in the spring when a lush grass, locally known as redtop, springs up and grows rapidly, often to a height of 5 or 6 feet. This grass clothes most of the lower slopes to a height of several hundred feet above sea level and in many places is interspersed with salmon berry, blueberry, and rose bushes and with brakes and other plants that together form a growth that is difficult to penetrate. There are many areas, too, where alder brush forms dense thickets (pl. 4, *A*), and these with thickets of willows make travel up many valleys slow and difficult, so that few people venture far from the coast. In such a tangle of vege-

[10] Griggs, R. F., The edge of the forest in Alaska and the reasons for its position: Ecology, vol. 15, no. 2, pp. 80–96. 1934.

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tation one is likely to have constantly in mind the possible presence of the great Kodiak bears, which range throughout this region and whose great trails through grass and brush are reminders that one may at any time unexpectedly meet a bear at close quarters. There is no doubt that this possibility prevents many persons from visiting the little-explored interior of the islands.

Agriculture and stock raising have been carried on for years in a small way at various places in this region, and there is reason to believe that these pursuits will become of increasing importance in the economic development of the islands. Such an outcome is especially desirable in this area, for at present the dominant industry is fishing, and the seasonal character of the fishing business, occupying only the warmer half of the year, makes an unbalanced year economically. One ranch, on the Buskin River 5 miles southwest of the town of Kodiak, has been operated for several years and a considerable area plowed and planted to field crops, which were used in maintaining a flock of sheep and a herd of cattle. Two other cattle ranches are maintained on Chiniak Bay and others on Kizhuyak Bay, on Kupreanof Strait, and on Spruce Island. A more ambitious stock-raising project was initiated on Sitkalidak Island, and several hundred sheep and a herd of cattle range there. At all these places it has been found that the climate is favorable and the natural vegetation adequate to support livestock. Stockmen recognize the desirability of curing hay enough to maintain their stock through severe spells of weather, but during many winters cattle will come through in good condition entirely without other feed than what they find for themselves.

The most abundant native grass, the redtop, supplies nutritious and lavish summer forage and makes excellent hay when properly cured but is worthless as winter feed when left on the stem. In many places, however, there are considerable areas of beach rye that stays green all winter, and salt-water sedge supplies excellent grazing and also makes good hay. The winters are mild enough for hardy stock to find sufficient shelter to survive in the open. The most severe menace to livestock is the great Kodiak bear. This animal hibernates during the coldest part of the winter, and stock is then free from its depredations, but during the rest of the year the stockman must be constantly on guard against it. A single bear has been known to kill or maim a dozen cattle in one night. Sitkalidak Island is fortunately free of bear, but everywhere else on the islands they are an ever-present menace, and until they are much reduced in numbers they will continue to be a severe hazard to stock raising. There are no other wild carnivores that make trouble for livestock.

Domestic gardens for quick-maturing vegetables and berries are commonly successful and supply quantities of such green stuffs as radishes, lettuce, rhubarb, onions, cabbage, cauliflower, and strawberries, and garden flowers flourish in profusion.

Wildlife.—During the glacial period this island group was the center of accumulation of local ice masses that completely covered the islands except for the highest peaks and ridges and that denuded them of vegetation and rendered them inhospitable for all sorts of land animals. It is also probable that glacial conditions lingered there much later than in lower latitudes and that postglacial time has been relatively short. Furthermore, since the shrinking and disappearance of the glaciers these islands have been cut off from the mainland by more than 20 miles of salt water. As a result, many of the wild animals common to nearby portions of mainland Alaska were not naturally present on these islands, which had a very sparse fauna of land animals. Those indigenous animals include the Kodiak bear, fox, ermine, mice, and ground squirrel. Such animals as the rabbit, mink, marten, lynx, land otter, beaver, black bear, muskrat, caribou, mountain sheep, and goats, native to Kenai Peninsula, to the north, or to the Alaska Peninsula, to the west, were missing from the island fauna, though present conditions seem to be entirely hospitable for them. In recent years the Biological Survey has introduced deer, rabbits, beaver, elk, and reindeer to the islands, and all seem to have multiplied and to have adapted themselves to conditions there. The beaver especially have found favorable conditions and have multiplied and spread with astonishing rapidity. Already many of the streams on northeastern Kodiak Island have been so blocked by a succession of beaver dams that the lowlands now consist of an almost continuous chain of ponds. Much fine grassland has been flooded and travel made difficult. Beaver pelts should furnish a welcome addition to the trapper's income when trapping these animals is permitted. Muskrats have also been introduced and are numerous in places. Many of the smaller islands are held as fur farms and are stocked with blue foxes.

The marine mammals include hair seals, sea lions, and several varieties of whales. These animals formerly supplied an important element in the diet of the natives and, with the bear, furnished the only source of red meat. Seal are still eaten to some extent. The sea otter, whose valuable fur was the main object of the Russian penetration of this territory, is now practically extinct on these islands, though it is said that an occasional pelt is illegally taken.

The waters surrounding the islands and the larger streams teem with fish, and commercial fishing is the major industry of the region, Fish also still constitute one of the main items in the diet of the inhabitants. By far the most important varieties of fish economically are the several species of salmon, locally known as king, red, humpback, dog, and silver, for these fish support the many salmon canneries of the region, and the canneries in turn furnish the principal employment for the people. Herring are also packed in several places, and valuable cod and halibut banks occur in neighboring waters. The halibut are marketed as fresh or frozen fish, and in the absence of refrigeration facilities on the islands the fish are carried to southeastern Alaska and marketed there, and the local people get little benefit from that industry. A whaling station is maintained at Port Hobron, on Sitkalidak Island, and a large number of whales are taken each year and reduced to oil, fertilizer, and other products.

The fresh-water fish are little utilized by the local inhabitants, though the streams offer a wonderful field for the sportsman. The principal game fish are the steelhead trout, which grows to a length of more than 3 feet, and the Dolly Varden trout, of which great numbers can be taken that range in weight from 2 to 5 pounds each. Silver salmon can also be taken by rod and reel in the streams during their season, and they and the king salmon can be caught by trolling with a lure in salt water. Both are great fighters. The silver salmon ranges in weight from 6 to 20 pounds and the king salmon from 10 to 60 pounds or more.

Population.—The early historic records and the many old, abandoned village sites both give evidence that the native population of the islands was many times larger before the coming of white men than it is now, and even at the time of the earliest Russian settlement there were many more inhabitants than there have been at any time since. A census taken by Baranof in 1795 enumerated 6,206 persons in this region, and it is said that the Russian exploitation of the natives had at that time already reduced the population by half. After the time of Baranof's census the decrease in population continued, though accurate statistics are not available for much of the period up to the present century. According to the census of 1930 the Kodiak district then contained a population of 1,729, of whom 364 were classed as white and 1,362 as natives, compared with a total population of 1,465 in 1920. This appears to indicate a slight increase in population during that decade, but some changes had been made in the meantime of the area included in the Kodiak district, and no close comparison is possible. The Kodiak district, as defined by the census, also includes parts of the adjacent Alaska Peninsula, so the figures here given show some 200 more persons than the actual population of the islands of this group. The population of the villages in this group of islands according to the 1930 census is as follows:

Afognak	298	Kodiak	442
Aiaktalik	30	Old Harbor	84
Alitak	86	Uzinki	168
Kaguyak	52	Wood Island	116
Karluk	192		

These figures by villages probably exclude some 100 persons scattered over the islands and not attributed to any of the villages given.

Of the total of some 1,500 persons living on these islands, more than 1,000 dwell in the four villages of Kodiak, Wood Island, Uzinki, and Afognak, all of which are within a distance of 20 miles of one another. Throughout the rest of the area the settlements are scattered and the population sparse. For a group of islands as a whole, the population has a density of only 1 person to 3¼ square miles.

Of the white population, 52½ percent are native-born and 47½ percent are foreign-born and represent many racial strains. The natives also show varying admixtures, many of them having a considerable proportion of Russian blood and bearing Russian names.

Routes of travel.—The islands of the Kodiak group are readily reached by sea-going vessels and are served by regular transportation lines from the west coast of the United States by way of Seattle, from which comfortable ships ply on a regular weekly schedule in the summer as far westward as Cordova or Seward. There passengers and freight are transferred to a smaller ship that gives local service to lower Cook Inlet ports and to the islands of this group. Calls are made regularly at the villages of Kodiak and Uzinki, and during the summer season somewhat less frequently at the salmon canneries on the west side of Kodiak Island as far south as Uyak Bay; at the whaling station at Port Hobron, on Sitkalidak Island, on the east coast; and at the herring saltery at Blue Fox Bay, on Afognak Island. An occasional sailing is also arranged from Seattle to Kodiak without transfer, with special trips to other ports if traffic warrants. Freight ships that also carry passengers call at odd times at the various settlements and canneries where cargo is to be delivered or picked up. There is also a call at Kodiak by a small steamship that makes a monthly round trip from Seward westward along the Alaska Peninsula to Bristol Bay. During the winter only a monthly service is maintained between Seattle and Kodiak.

Within this area all the settlements are on the coast, and travel is almost exclusively by boat. During the fishing season sea-going gas boats are operated by the salmon and herring fisheries located in the many bays that penetrate the islands, and arrangements can ordinarily be made to go from place to place on them. At most settlements gas boats can be chartered for special trips. As the chief industry of the islands is fishing and there is almost no travel overland, nearly everyone owns a boat of some sort and uses it for such short journeys as he makes.

The interior portions of the islands are uninhabited, and roads and trails leading inland are almost entirely lacking. From the town of Kodiak a road 5 or 6 miles long and passable for automobiles has been built southwestward along the shore to and beyond the Buskin River, and considerable work has been done on an extension of this road to Womens Bay. It is contemplated that this road will eventually be extended southward to Middle and Kalsin Bays. Another recently completed road leads from Kodiak to the head of Mill Bay, a distance of about 4 miles. Another stretch of road about 3 miles long leads from the head of Afognak Bay to an abandoned fish hatchery on Afognak Lake. These are the only roads in the region over which a car can be taken. Poor trails, passable only on foot or on horseback, occur at a few places. On Kodiak Island such trails include one up the Buskin River to Buskin Lake and one from the head of Kalsin Bay to Portage Bay; on Sitkalidak Island, from the head of Port Hobron across narrow portions of the island to bays to the southeast and southwest; from Larsen Bay to Karluk Lake, and at a few other places. There are also a few old, dim trails on Afognak Island, leading across narrow isthmuses from one bay to another. Otherwise little or nothing has been done in this region to facilitate land travel, and large areas in the interior of the islands are unknown even to the local inhabitants.

GEOLOGY

PRINCIPAL FEATURES

The general distribution of the rocks of Kodiak and adjacent islands is shown on plate 2 so far as present knowledge warrants. Earlier geologic work in this region had succeeded in determining the presence on these islands of most of the rock groups here shown, but field observations had been scattered and confined to only a part of the region, mainly on Kodiak Island itself. It was known that the bulk of the island was composed of steeply dipping slates and graywackes of probable Mesozoic age, that some older metamorphic rocks were present near the mouth of Uyak Bay and on the western shore of Kodiak Island near the Ayakulik River, that some Tertiary sedimentary rocks were present along the southeastern edge of the islands, and that a few small areas of granite were present. It had not been recognized, however, that Kodiak Island has an extensive axial core of granitic rocks and that there are many outliers of this intrusive mass; that along the northwest coast of the entire island group there is a nearly continuous belt of metamorphic rocks of a wide range of composition; that both marine and fresh-water Tertiary beds are present on the southeast coast; that the present distribution of the various formations is the result of a slicing by a series of northeastward-trending faults of large displacement; and that the island group has been the center of accumulation and dispersal of a local mass of ice that at one time almost completely covered the group of islands and was probably continuous across Shelikof Strait with the glaciers on the Alaska Peninsula.

Attention is directed to the facts that the data here presented are the result of reconnaissance work only, carried on during two field seasons of not more than 3 months each; that the area of the group of islands is 4,900 square miles; and that the highly irregular and intricate coast line is tremendously long compared with the area enclosed. To examine the 1,500 miles or so of coast line in detail was more of a task than time permitted, though the excellent cliff exposures gave large returns for the time given to them. It was impossible, however, to trace out all the contacts overland with the accuracy that is desirable, so that inland the formation boundaries are only approximate. This is particularly true of the western boundary of the large granitic mass along the axis of Kodiak Island. There is also need for a closer study of the relations and distribution of the rocks of the greenstone-schist group and some of the highly deformed Tertiary beds, particularly between Outer Right Cape and Cape Trinity, on the southeast shore of Kodiak Island. The contact along Shelikof Strait between the greenstone-schist group and the slate-graywacke group lies along a great fault that cuts a succession of inlets from Uyak Bay to the north edge of Afognak Island and is believed to be accurately mapped. The southwestern part of Kodiak Island, west of Uyak and north of Olga Bay, was not visited, and its geology is unknown.

Although the islands of this group are the structural southwestward continuation of the Kenai Mountains of Kenai Peninsula, and the dominant elements of the geology are similar, nevertheless there are also considerable differences between the two provinces. In both the preponderant rock group consists of slates and graywackes, probably in the main of upper Mesozoic age, highly metamorphosed, generally of steep dip, much faulted and folded, and largely devoid of fossils. To the west of these rocks throughout the island group, and locally on the east of them as well, there is an older series that includes ellipsoidal lava, crumpled cherts, limestone, and argillaceous sediments, all in various degrees of metamorphism and alteration and lying unconformably below the slate and graywacke or separated from them by faults. On the islands these materials seem to be locally more highly altered than on Kenai Peninsula and include greenstone schist, schist composed of greenstone and shaly and sandy sediments intricately kneaded together, crumpled cherts, limestone, and locally even mica schists. Though their contact with the slate-graywacke group is in most places along profound vertical faults, they are evidently older and are correlated with the Triassic and Jurassic of Kenai Peninsula, though the mica schists may be older still.

Next younger than the slates and graywackes in this region and unconformably above them are fresh-water or subaerial Tertiary beds that include sandstone, shale, and conglomerate, generally well indurated and steeply dipping and locally much crumpled, crushed, and contorted. These beds contain numerous carbonaceous bits of plant remains and even thin coaly streaks, though identifiable leaves have been collected at only one locality. They are tentatively correlated with the Eocene fresh-water sedimentary rocks of Cook Inlet.

Still younger than the fresh-water Tertiary beds and probably lying unconformably above them are marine sandstones that have been recognized only at Narrow Point, on the west coast of Kodiak Island. These beds consist of gently folded and moderately indurated buff sandstones that carry a marine Miocene or Pliocene fauna. They are the youngest consolidated rocks of the region.

Granitic masses were injected into the rocks of this region after the slates and graywackes were laid down, but before the deposition of the Tertiary beds. The granite is now exposed as one long, narrow body that extends along the axis of Kodiak Island for almost its full length and as many smaller satellitic masses that by their distribution suggest that not far below the present surface the granites are more extensive than at the surface. The granites are of late Mesozoic or early Tertiary age.

The latest geologic event of major importance on these islands was the accumulation, during Pleistocene time, of an ice mass that extended in all directions to the borders of the island group, completely submerged the lower-lying areas, and left only a few of the highest peaks and ridges projecting above its surface. Erosion by this glacier or by possible Pleistocene predecessors of it deeply affected the topography of the region by rounding and smoothing the overridden surfaces, deepening and straightening the valleys, and scouring out deep fiords that, on the retreat of the ice, left the land mass cut into numerous islands and furrowed by deep bays. The present topography has been altered from the form given it by glacial ice only in a minor way, stream erosion having accomplished little and the attack of waves on the exposed coast line having only fairly begun.

Positive evidence of the age of the rock formations in this island group is scanty, fossils having been found at only a few localities and in only three formations. The age assignments given to the other rock groups are therefore based in part on somewhat long-distance correlation with the rocks of Kenai Peninsula. Nevertheless the structural features here are so directly in line with those on the peninsula, and the rocks are so similar in lithology, structure, and relations to one another that the age assignments are given with a considerable degree of confidence.

The following table gives the stratigraphic sequence for this region as it is now accepted. No doubt future work will modify this stratigraphic column, especially by the subdivision of some groups into smaller, more sharply defined units, but that will be possible only by much more detailed study than has yet been given. The discovery of additional fossils would also be of great aid in more closely defining the age of the rocks in which they may be found.

Quaternary:

Gravel, sand, and silt of the present streams; beach deposits of sand, gravel, shingle, and boulders; bars and spits; tidal flats; talus accumulations; peat and impure organic deposits; soil and rock-disintegration products in place; terraces and bench gravel, some of glaciofluvial origin; volcanic ash.

Glacial deposits of Pleistocene glaciers.

Unconformity.

Tertiary:

Moderately consolidated and gently folded buff marine sandstones of Narrow Point, of Miocene or Pliocene age.

Unconformity.

Sandstones, shales, and conglomerattes of southeastern coast of Kodiak Island and adjacent islands, in general highly inclined and locally greatly folded, crumpled, and distorted. Contain carbonized plant remains and coal seams. Of probable Eocene age. These rocks also include massive, dense mottled sandstones of Kalsin and Ugak Bays and Port Hobron.

Unconformity.

Mesozoic:

Granite intrusives as irregular masses, stocks, dikes, and sills, cutting youngest Mesozoic sediments. Of late Mesozoic or early Tertiary age.

Graywacke, slate, and conglomerate, the dominant formation throughout the Kodiak group of islands. Probably Cretaceous and older.

Unconformity.

Greenstone schist, knotty schist of greenstone and associated sedimentary rocks; ellipsoidal greenstone; crystalline limestone; contorted cherts and argillaceous sedimentary rocks; volcanic tuff; mica schist. Mainly of early Mesozoic age, though probably containing some older materials.

MESOZOIC AND OLDER ROCKS

GREENSTONE-SCHIST GROUP

CHARACTER AND DISTRIBUTION

The oldest rocks that have been recognized in these islands are here grouped as an undifferentiated assemblage of rocks of a great variety of lithologic types, in varying stages of metamorphism, but generally characterized by the presence of basic lavas and tuffs and of knotty chert-slate schists and for the most part highly altered by dynamic metamorphism. For the sake of simplicity in terminology, these rocks are here referred to as the greenstone-schist group, from their most conspicuous phase, although the group includes also chert, little-altered basic lavas, moderately to highly metamorphosed sedimentary rocks of various types, and locally even mica schists. It may be stated at the outset that this group probably contains rocks of a considerable range in age and certainly of a wide range of materials, and that it is only because the demands of reconnaissance mapping prevented a more detailed study of them that the group was not subdivided into members on the basis of lithology.

On the northwest side of the islands the rocks of this group extend in a southwestward-trending belt from Shuyak Island, on the north, along the northwestern edges of Afognak, Raspberry, Uganik, and Kodiak Islands, at least as far as the southwest entrance to Uyak Bay and probably to the extreme western edge of Kodiak Island, and the continuity of this belt is broken only by the numerous bays and straits that cross its course. It seems certain that the belt is actually continuous across these narrow arms of the sea from headland to headland of one island after another. Southwest of Uyak Bay it continues into the unmapped portion of southwestern Kodiak Island, probably entirely across it to the west coast, for Maddren[11] describes rocks in the sea cliffs just west of the mouth of the Red [Ayakulik] River, on the west coast of Kodiak Island, as including highly deformed and somewhat severely metamorphosed volcanic agglomerates, tuffs, and breccias, with cobbles of hard, brittle blue limestone. The tuffaceous material in which the limestone cobbles are embedded is schistose and well foliated, especially around the cobbles. Some members of the formation are highly silicified, and one massive member is altered to a bright-red jasperoid rock. Maddren notes the possibility that these rocks may belong to the same group as the rocks at the mouth of Uyak Bay, and his description might well be applied to many localities in the areas

[11] Maddren, A. G., op. cit. (Bull. 692), pp. 301–302.

here mapped as belonging to the greenstone-schist group. This correlation is also supported by the trend of the great fault which borders the western belt of greenstone schist on the east and which, if projected southwestward from Uyak Bay, would pass to the east of the area studied by Maddren. Whether or not all the area northwest of the projection of this fault and including the coast line from Uyak Bay to and beyond Cape Ikolik is composed of rocks of the greenstone-schist group is not known, but it appears almost certain that the belt of these rocks is continuous to the southwest coast of Kodiak Island. As mapped, the belt has a length in a southwesterly direction of over 100 miles and a maximum width of 11 miles. It doubtless extends still farther both northeast and southwest, and it widens to the northwest an unknown distance beneath the waters of Shelikof Strait. The eastern border of the belt is a great vertical fault that deviates but little from a northeast direction, and that from Uyak Bay to Raspberry Strait, a distance of about 50 miles, is an almost straight line. North of Raspberry Strait the fault has a slight convexity toward the east, but its general trend remains about the same to the point where it extends out into the sea near the north end of Afognak Island. South of Uyak Bay the trend of the fault apparently veers slightly toward the south.

Originally the rocks of which this group is composed were ellipsoidal basaltic flows and tuffs, with which were interbedded and associated clayey and impure sandy sediments, limy shales, thin-bedded to massive limestones, and thin layers of chert, separated by argillaceous layers. Mica schists were also locally present. Where least altered and stretched, the cherty members of the group consist of distorted and crumpled beds in which bands of chert a small fraction of an inch to an inch thick alternate with argillaceous materials in such a way that from half to two-thirds of the total thickness is composed of chert and the rest of slate (pl. 4, *B*). The slaty material is black, and the chert is prevailingly gray to black, so that the rocks are of somber appearance. In places all these rocks are now present with little evident alteration. Thus on the north side of Sitkalidak Strait for several miles southwest of Left Cape there are exposures of greenstone that still exhibit the original ellipsoidal structure of these effusive rocks. Locally bodies of slate and graywacke rocks of the next younger group are enclosed in the greenstone schist. Toward the top of this group in many places there seems to be a gradual transition from highly metamorphic rocks to less altered materials, and in such places it was found difficult or impossible to determine sharply the boundary between this and the next younger group of rocks. In other words, the severe dynamic metamorphism seems to have been somewhat local and to have been most intense in the vicinity of the bordering faults and also to have affected the rocks on both sides of the fault contact, so that the greenstone-schist rocks were placed in juxtaposition with highly metamorphosed phases of the younger rocks, thus rendering the exact determination of the fault plane difficult except where the rocks on opposite sides of it are of different lithologic character.

Notwithstanding the fact that some phases of this rock group closely resemble certain phases of the overlying slate-graywacke group, there are nevertheless certain aspects of the greenstone schist that are characteristic and distinctive. A common phase especially well developed along the Shelikof Strait side of the islands was in the field termed "knotty" schist. These knotty schists are easy to recognize in the field but are difficult to describe, for they include a wide variety of facies, all of which are so highly altered and so full of secondary minerals that their original character is obscure. Apparently some phases of the knotty schist were derived from thin-bedded cherts and slates which under profound dynamic metamorphism were so stretched and crushed that the brittle cherty layers were broken into fragments, and these fragments are now scattered indiscriminately through the slaty mass. Other phases appear to have been originally basic tuffs with interbedded clayey sediments later squeezed and stretched so that fragments of basic lava lie scattered through a matrix of obscure origin, now greatly altered. A considerable number of specimens from this group of rocks contain lime carbonate, either as a limy constituent of the original sediments or as tiny calcite stringers and veinlets introduced later. In the amount of calcareous material present the rocks range from those containing a mere trace to decidedly limy schists and at a few localities to pure crystalline limestone.

The basic lavas present also vary widely in degree of metamorphism. Little-altered phases in which the original ellipsoidal structure is plainly evident occur at Ghost Rocks, in Sitkalidak Strait (pl. 5, *A*), and fresh-appearing amygdular lavas were seen in Kiliuda Bay. Locally the greenish lava flows contain local patches of dense, fine-grained bright-red rock, the borders of which are so irregular that it is apparent that they represent local oxidation of the iron-bearing minerals in the greenstone. The areas in which the greenstone flows are only slightly altered are, however, exceptional, for in general the flows have been sheared and stretched, and secondary minerals have developed. On Hogg Island, at the mouth of Bluefox Bay, there are well-bedded tuffs composed of fragments of fine-grained felsitic lava, glassy lava, chert, and crystals of andesine. The general aspect of this tuff is dacitic.

On Kodiak Island, 2 miles north of the entrance to Uyak Bay, a shore-cliff exposure shows a massive gray crystalline limestone bed about 150 feet thick, striking N. 50° E. and dipping 60° NW., separated from a 30-foot bed of similar limestone by basaltic tuff and greenstone schist. These are the only occurrences of massive limestone seen on the islands, though many of the sedimentary rocks are more or less calcareous.

At a few localities in these islands mica schists are associated with rocks of the greenstone-schist group. In these schists metamorphism is farther advanced than in most of the associated rocks, and they are probably older than the greenstones, though so closely infolded and deformed with them that time was not available to map them separately. Thus in Malina Bay, Afognak Island, 2 miles east of the south entrance of the bay, there are well-developed quartz-mica schists in which thin laminae of quartz are separated by layers of glistening muscovite. Accessory minerals include hornblende in an advanced stage of chloritization, chlorite (possibly derived from biotite), albite, titanite, apatite, and pyrite. These rocks are thoroughly schistose and closely resemble the pre-Cambrian Birch Creek schist of interior Alaska. However, the associated Mesozoic rocks are so highly metamorphosed that it seems unsafe to correlate the mica schists of these islands with the Birch Creek schist or to assume a very great age for them, and in the lack of positive evidence of their age they are here tentatively included with the greenstone-schist group. On both the north and south sides of Paramanof Bay, Afognak Island, and on Ban Island in that bay there are highly siliceous mica schists consisting of contorted laminae of quartz separated by thin layers of muscovite scales and containing accessory calcite and chlorite. These rocks are more siliceous and less micaceous than those of Malina Bay, but the differences seem to be mainly in the relative abundance of quartz and mica and not in degree of metamorphism. At both places they occur in areas composed dominantly of greenstone schist and are here mapped with it, although very likely older than the greenstones.

Throughout the thickness of the greenstone-schist group of rocks there are present rocks of sedimentary origin, including argillite and slate, graywacke, chert, water-laid tuff, and limestone, all metamorphosed along with the associated basic layers. These sedimentary rocks, particularly the slates and graywackes, increase in relative abundance in comparison with the igneous rocks as the higher portions of the group are approached, and it may be frankly stated that the boundary between this rock group and the adjacent slate-graywacke group has in places been drawn somewhat arbitrarily, for the resemblance is so close between the less deformed rocks of the older group and the more deformed rocks of the younger group that their separation was not everywhere possible in reconnaissance mapping.

STRUCTURE AND THICKNESS

The rocks of the greenstone-schist group vary greatly from place to place in the amount of metamorphism which they have suffered, ranging from little-altered pillow lavas, tuffs, breccias, cherts, slates, and graywackes to the highly schistose equivalents of all these rocks. Their structure also shows equally great variation, ranging from monoclinal dips in some places to highly involved and contorted structure elsewhere. In general the rocks exposed on the southeast shore of Kodiak Island and on Sitkalidak Island are less metamorphosed and of simpler structure than those on the northwest border of the island group, though in places even there the rocks are not greatly deformed and have only moderate dips. Wherever exposed the greenstone-schist rocks have been greatly faulted, those on the northwest coast of the islands being separated from the younger slate-graywacke series by a profound fault that extends through the entire island group. On the southeast coast also the surface distribution of the greenstone schists has been largely determined by northeastward-trending faults that have sliced the rocks into a series of blocks. These faults stand nearly vertical, with the downthrow invariably on the southeast side and a general high dip to the northwest. Near the faults the metamorphism of the bordering rocks is greater than elsewhere, and probably the stresses developed along these faults were in part at least the cause of the more complex structure there.

Little detailed information was obtained concerning the thickness of this rock group other than that as a whole it must be many thousands of feet thick. Nowhere was the base of these rocks seen unless the mica schists of Malina and Paranaof Bays, on Afognak Island, are the base, and there the structure is so involved that no sequence of rocks was determined. Complex folding and crumpling, known faults of great displacement, and the probable presence of many other unrecognized faults have produced a geologic puzzle that can be solved only by much more detailed work than has yet been done.

AGE AND CORRELATION

The scarcity of fossils in all the rocks of these islands except those of Miocene or Pliocene age makes it necessary to place great reliance on lithology for correlation. Fortunately a somewhat similar section on Kenai Peninsula near Seldovia and Port Graham was studied by Martin,[12] who found determinable fossils in it and was therefore able to give the rocks a definite age assignment. These localities lie along the strike of the rocks of the Kodiak group of islands, are a part of the same geologic province, and are separated from the islands by a distance of only 50 miles. Martin's description of the rocks on the southwest end of Kenai Peninsula so accurately describes also the greenstone-schist rocks of the Kodiak group of islands that there can be little doubt of the correlation between the islands and the mainland. Martin, however, was able to subdivide the rocks he examined into smaller units, and from some of these he obtained fossils. He describes green and dark-red ellipsoidal lavas with associated tuffaceous beds and cherts that aggregate over 3,000 feet in thickness, overlain by Upper Triassic cherts. He provisionally assigns them to the Triassic, or at the earliest to the latest Paleozoic. The Upper Triassic rocks include limestone, chert, and tuffaceous materials, conglomerates and breccias, from which fossils were collected, notably *Halobia superba* Mojsisovics and *Pseudomonotis subcircularis* Gabb, both of Upper Triassic age, but with the *Pseudomonotis* beds apparently younger than those carrying *Halobia.* Martin also describes contorted cherts from the same district, the age of which is uncertain but which he was inclined to believe lie above the Upper Triassic limestones and tuffs but are also of Upper Triassic age. Above all these rocks he found tuffs and volcanic agglomerates with interbedded sandstone, shale, and limestone with a probable aggregate thickness of 2,000 or 3,000 feet. These beds carry a marine fauna of Lower Jurassic age.

By comparison of the greenstone-schist group of Kodiak and adjacent islands with the rocks at Port Graham and Seldovia, described by Martin, the following facts seem evident:

1. The quartz-mica schists of western Afognak Island have no counterpart on Kenai Peninsula. Their advanced stage of metamorphism indicates a greater age than that of the associated beds, and they are probably Paleozoic or even older.

2. The ellipsoidal greenstone flows and associated tuffs and breccias of southeastern Kodiak Island and the probably equivalent but more highly metamorphosed greenstone schists on the northwest border of the island group bear a remarkably close resemblance to similar rocks on Kenai Peninsula. They have yielded no fossils but appear to underlie Upper Triassic beds and are considered to be of Triassic age, or possibly in part late Paleozoic.

[12] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: Geol. Survey Bull. 587, pp. 52–61, 1915.

3. This group contains limestone, chert, tuffaceous materials, and breccias that correspond closely to the description of Upper Triassic beds carrying *Halobia superba* and *Pseudomonotis subcircularis* on Kenai Peninsula and that are probably of the same age.

4. Contorted cherts in this group correspond closely with those on Kenai Peninsula that Martin thinks probably overlie the other Upper Triassic rocks but are also of Upper Triassic age.

5. Tuffs and agglomerates with interbedded sedimentary rocks that occur in these islands, particularly those of Hogg Island, on Bluefox Bay, resemble rocks near Seldovia that bear Lower Jurassic fossils.

In conclusion, therefore, it appears likely that the greenstone-schist group contains rocks that include schists of Paleozoic or possibly even pre-Cambrian age, greenstones that may range from Carboniferous to Triassic, and cherts and tuffs of Lower Jurassic age. The group as a whole, however, is believed to be mainly of Mesozoic age. Many rock types were recognized in the field, but the limitations of reconnaissance mapping and the complexity of the structure prevented the separation of this group into its constituent parts, a difficult task that should, however, be attempted when time and funds become available.

SLATE-GRAYWACKE GROUP

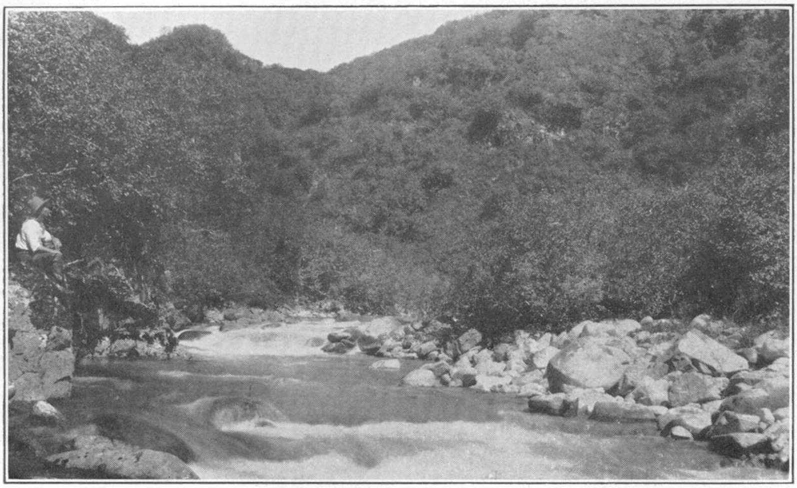
GENERAL CHARACTER

The most prevalent formation in the Kodiak group of islands consists of a group of rocks composed mainly of slate, argillite, and graywacke, with minor amounts of conglomerate and a little altered tuff. These rocks occur in a wide southwestward-trending belt that extends centrally throughout the length of Afognak and Kodiak Islands and that includes all or part of many of the adjacent islands. This belt is bordered on the northwest by a great fault that brings the slate-graywacke group into contact with the greenstone-schist group, and on the southeast the rocks are in either depositional or faulted contact with the greenstone-schist group or with younger Tertiary beds. The slate-graywacke belt is interrupted by large and small intrusions of granitic materials and by dikes and sills that are offshoots of the larger intrusive masses.

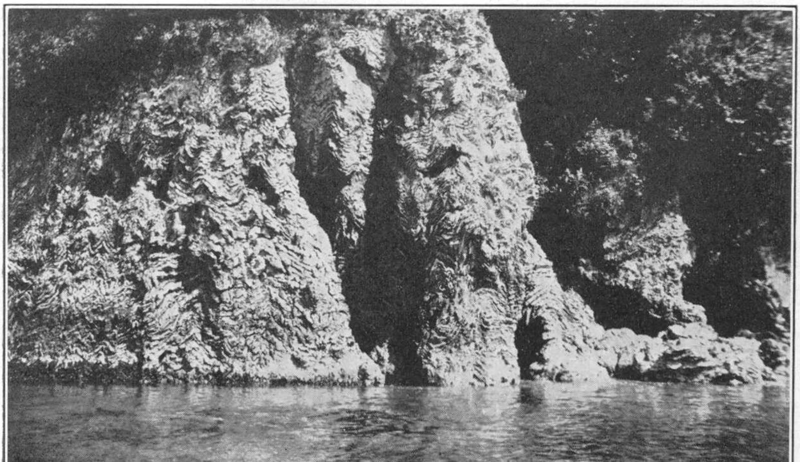
There is little doubt that these rocks can for the most part be correlated with similar rocks on Kenai Peninsula, where also the most prevalent rocks are slates and graywackes. The slates and graywackes of Kenai Peninsula have been described by Johnson,[13] and those in the vicinity of the town of Kodiak by Capps.[14] As a

[13] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: Geol. Survey Bull. 587, pp. 113–119, 1915.

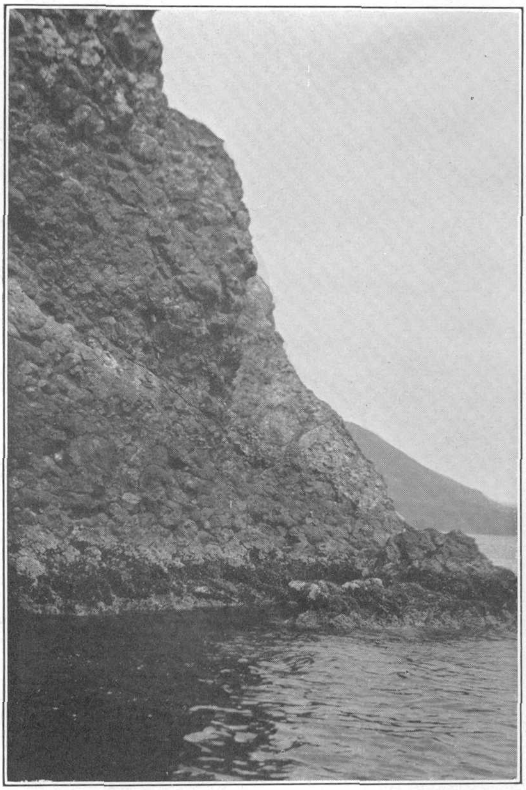
[14] Capps, S. R., Kodiak and vicinity: Geol. Survey Bull. 868–B, pp. 109–112, 1937.



A. DENSE BRUSH AT HEAD OF UGAK BAY, KODIAK ISLAND.

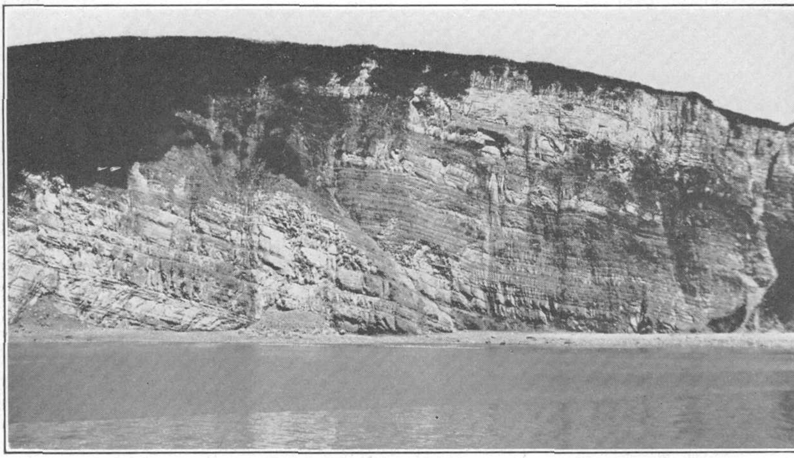


B. CONTORTED CHERT AND SLATE, SITKALIDAK STRAIT, KODIAK ISLAND.

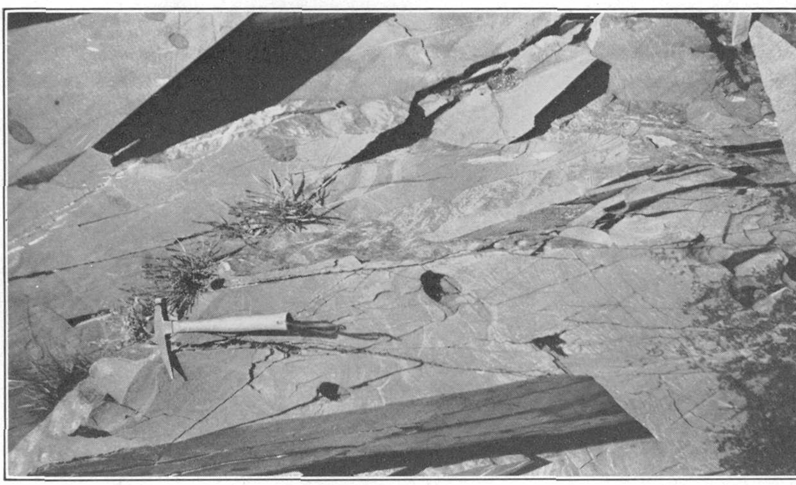


A. ELLIPSOIDAL GREENSTONE, GHOST ROCKS, SITKALIDAK STRAIT.

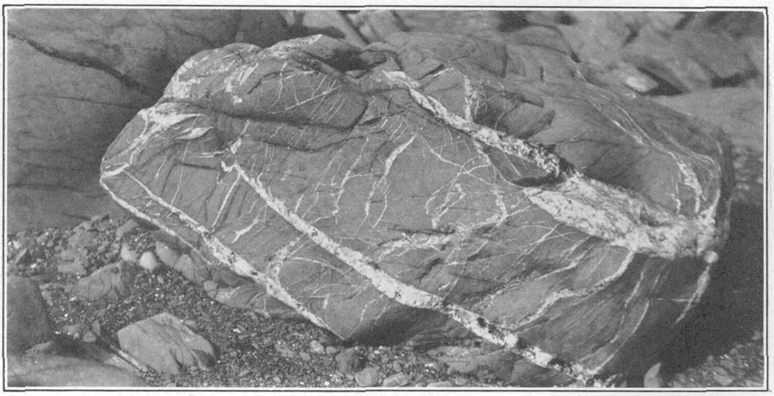
B. INTERBEDDED SLATE AND GRAYWACKE, IZHUT BAY, AFOGNAK ISLAND.



A. INTERBEDDED SLATE AND GRAYWACKE, ZACHAR BAY, KODIAK ISLAND.



B. CONCRETIONARY GRAYWACKE, SHARATIN BAY, KODIAK ISLAND.



A. QUARTZ VEINS IN GRAYWACKE, TONKI BAY, AFOGNAK ISLAND.

B. CONTORTED SLATE AND GRAYWACKE NEAR DIORITE CONTACT, SHAKMANOF POINT, KODIAK ISLAND.

group they include an undifferentiated aggregation of metamorphosed detrital sedimentary rocks, composed mainly of alternating bands of fine-grained mudstones, now metamorphosed to argillites or slates, and coarser, impure sandstones, now indurated to graywackes (pls. 5, *B*, and 6, *A*), with lesser amounts of conglomerate, grit, limy slate, and altered tuff. These less abundant constituents form only a very small fraction of the group and are entirely absent over considerable areas and through great thicknesses of the series. The most prevalent phase consists of an alternation of thin bands of slate and graywacke, from an inch to a foot or more in thickness. In places the banding is so fine as to suggest seasonal varves, and in some such rocks the gradation from coarse sand into fine mud, followed by an abrupt change to coarse sand again, is difficult to explain on any other basis than that of seasonal deposition. In general, however, the prevalent banding is on a coarse scale, with individual beds ranging from an inch to several feet in thickness, and in places there are massive graywacke beds 100 feet or more thick, entirely free from argillaceous rocks, and sections of argillite or slate several hundred feet thick, in which there are no beds of coarser material. Certainly these thicker beds are not the result of seasonal deposition but must have required many years for their accumulation. In both the mudstones and the sandy phases there are ripple marks that indicate shallow-water conditions during their deposition, and the great thickness of the series as a whole seems to demand a gradually subsiding basin of sedimentation and a fairly constant supply of rather uniform sediment that filled the basin about as fast as it sank.

The degree of metamorphism which these sedimentary rocks have undergone is fairly uniform throughout this region, though there is a great difference in the way the different rock types have been affected by the stresses that have been applied to them. The most obvious general structure is a northeast strike and a fairly steep monoclinal dip to the northwest, though there are local variations in both strike and dip. It is evident, however, that other processes than simple tilting have been involved, for an estimate of the vertical thickness of the group, based on the assumption of simple tilting with no duplication of beds, gives a thickness that is greater than seems reasonable. Many faults of undetermined displacement are known to be present, and locally there is evidence of isoclinal folding, so that it seems clear that in any section measured across the islands there is reduplication of beds. The graywacke beds are highly competent and rigid, whereas the argillaceous beds are incompetent and yield readily to shearing stresses. As a result the argillaceous beds have generally a well-developed slaty cleavage, most

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of the slippage between beds during periods of folding and tilting having been taken up by them, the graywacke beds meanwhile having remained massive and showing little secondary cleavage.

SLATE AND ARGILLITE

Although no attempt was made to obtain an accurate measurement of the proportion of argillaceous to arenaceous rocks in the slate-graywacke series of these islands, nevertheless the impression was gained that slates and argillites considerably exceed the graywackes in volume, and this in spite of the facts that through their greater resistance to erosion the graywackes stand out from the slates in high relief along the wave-cut cliffs and that most of the prominent headlands and reefs in the region these rocks occupy owe their presence to resistant graywacke beds.

The argillaceous strata range in character from fairly massive argillites without prominent cleavage to fissile slates and even to slaty schists, the commonest phase being a fissile slate with somewhat wavy cleavage. Locally slates that cleave into thin, flat plates occur, and some approach roofing slates in the perfection of their cleavage. They range from gray to black, are generally of fine grain, and include particles of quartz and feldspar in a groundmass of sericite, chlorite, graphite, and clayey minerals. Where penetrated by thin dikes and sills of acidic intrusive rocks the slates show little or no contact metamorphism, but for some distance from the margins of larger granitic intrusive masses the slaty materials have been recrystallized into hard, dense contact rocks that contain quartz, biotite, iron oxides, and cordierite in well-formed crystals. At other places black, glossy schists, full of well-developed augen of cordierite and containing also quartz, biotite, and carbonaceous material, are the results of less severe contact metamorphism.

Although somewhat massive argillites without pronounced secondary cleavage occur in places, the argillaceous rocks in the main have a well-developed slaty cleavage and break readily into thin laminae. Where exposed to weathering these slates disintegrate much more readily than the associated graywackes and break down into soft, flaky material that is easily removed by erosion, leaving the graywacke beds in high relief. The bedding of the slates is generally recognizable as a banding in layers of slightly different color and lies parallel with that of the included graywacke. The cleavage, however, in many places crosses the bedding at considerable angles, terminating abruptly at the graywacke beds. The relation of the angle of cleavage to the bedding seems to depend upon the amount of slipping or shearing that has occurred between beds. If that movement has been great, the cleavage may approach parallelism to the bedding, and in general it is closely parallel to the bedding where thin beds of slate and graywacke alternate. The absence of secondary cleavage in graywackes that are interbedded with highly fissile slates indicates that during deformation most of the movement has been taken up by the slaty layers.

In many places in this region the slates have been penetrated by quartz veinlets in a remarkably intimate manner. Some rocks show a close network of tiny quartz veinlets ranging in thickness from hair lines to one-sixteenth of an inch, the veinlets showing a tendency to lie parallel to the foliation of the slates, but many of them cutting across the foliation to form an anastomosing network throughout the rock. This injection of quartz veinlets is in places so thorough that no area of slate more than an eighth of an inch thick is free from them. Elsewhere the quartz veinlets range in thickness from hair lines to considerable fractions of an inch, and these may merge into still larger, irregular quartz veins. The larger veins traverse the slate in all directions, though tending to follow the planes of bedding. Intimate veining by paper-thin veinlets and by coarser veins occurs in fine slates, in beds of intermediate coarseness, and in graywackes, but in general the finer-grained rocks seem to have been more easily penetrated, perhaps because they fracture more easily and so allowed the quartz-bearing solutions more ready access.

In addition to the common type of intimate injection by multitudes of very thin quartz veins, there are places where larger veins and irregular bunches of quartz many feet in maximum thickness cut both slates and graywackes, either parallel to or crosscutting the bedding, and some of these carry gold. In general the presence of abundant quartz veins in the slates is an indication of nearness to granitic intrusive masses, and in some places where this relation cannot be proved by direct observation it is suspected that some underlying granitic mass, not exposed at the surface, has supplied quartz-bearing solutions that have penetrated the nearby sedimentary rocks.

GRAYWACKES

The proportion of graywacke to slate in this group varies greatly from place to place. In some localities graywacke beds form much the greater part of the group and are separated from one another by only thin slate layers. Elsewhere the slates may be equally preponderant over the graywackes. The graywackes, as seen in the hand specimens, are light- to dark-gray impure sandstones, ranging in induration from moderately hard to very hard rocks that approach quartzites in appearance and in coarseness from fine-grained argillaceous rocks at one extreme to grits and conglomerates at the other. They differ from normal sandstones and quartzites in that instead of being composed wholly or largely of quartz they contain, in addition to quartz, angular to partly rounded grains of various feldspars, pyroxene, epidote, and biotite and fragments of a wide variety of rocks, including slate, chert, lavas, and intrusive materials. It is apparent that the land mass from which these sediments were derived was subjected to mechanical disintegration, as well as to chemical decomposition, and detrital materials resulting from both these processes were delivered to the basins of sedimentation. The prevailing dark color of the graywackes is due in part to carbonaceous material but in part also to the inclusion of fragments of dark-colored minerals and rocks. In places shale fragments are conspicuous by their abundance, and certain beds contain scattered slate and argillite pebbles which, where abundant, form conglomerates of slate pebbles in a graywacke matrix. The graywackes in many places are calcareous and locally are cut by veins of calcite and quartz.

Within small areas individual graywacke beds may be persistent for some distance, but as a rule they are lenticular and interfinger at their edges with other slate and graywacke beds, so that even thick, massive graywacke strata cannot be continuously traced for any great distance. Certain of the more massive graywacke beds in this region are characterized by the presence of spherical or disk-shaped concretionary bodies, ranging from an inch or less to more than a foot in diameter (pl. 6, *B*). These concretions tend to be circular in a cross section parallel to the bedding but lenticular in a section at right angles to the bedding. When freshly broken the concretionary material is distinguishable from the matrix with difficulty, if at all, but on weathering the concretions prove to be less resistant than the matrix, have a somewhat different color, lose their cementing material, become sandy, and disintegrate, leaving depressions and cavities in the graywacke to attest their former presence. Concretionary graywackes of this type are present throughout the island group and may be of some value in working out the complex structure that prevails.

There is everywhere evidence that the graywackes have been more resistant to deformation and metamorphism than the associated argillaceous rocks. Commonly fissile, thinly foliated slate bands lie between beds of graywacke that are still massive and entirely free from secondary cleavage. In some localities, however, where shearing has been unusually severe, the graywackes contain secondary micaceous minerals, have been partly recrystallized, and show a secondary cleavage, though the degree of schistosity is much less than in the associated slates.

The graywackes, by their resistance to fracturing, have been much less receptive hosts to the infiltration of quartz than the slates, and quartz veins are much less abundant in them. Where abundantly present the quartz veins are likely to cut the graywacke in all directions in an irregular anastomosing network, without the tendency toward parallelism that is shown by the veinlets in the slates, for in the slates the veinlets tend to follow the planes of foliation, and such planes are generally lacking in the graywackes, in which the quartz tends to form fewer and larger but more devious veins (pl. 7, *A*).

The larger granitic intrusive masses have by contact metamorphism profoundly altered the graywackes near the contacts, yielding dense, hard contact rocks that have a metallic ring when struck with the hammer and that contain enough pyrite to give red, brown, and purple colors on weathering, the original bedding being discernible in slight color variations in the different layers. These contact rocks are completely recrystallized at the contacts and now consist of an aggregation of quartz, biotite, iron oxides, and cordierite crystals. As distance from the intrusive mass increases the contact effects become rapidly less evident, and a quarter of a mile or so from even the larger intrusives there is little apparent contact metamorphism.

CONGLOMERATE

Conglomerate beds are present in the slate-graywacke group throughout the region and show a great range in thickness and in character, though forming only a minute fraction of the series as a whole. Perhaps the commonest type consists of scattered pebbles of black argillite or slate in a graywacke matrix. The pebbles may be rather scantily distributed, so that the rock might be called a pebble-bearing graywacke, or they may be so abundant as to form typical conglomerates. In those rocks in which the pebbles consist almost exclusively of black argillaceous materials the pebbles show a tendency to be flat and disk-shaped, as if the strata had resulted from the cementation of a sandy shingle beach. No sharp distinction can be drawn between pebbly graywackes and unquestioned conglomerates, for all intermediate stages occur. Slaty pebbles as much as 6 inches in diameter were seen, though most of them are much smaller.

The thickest conglomerate noted in this group of rocks occurs on the west shore of Kizhuyak Bay at the base of Peregrebni Peninsula, Kodiak Island, where through a stratigraphic thickness of 300 feet there are alternating beds of graywacke and conglomerate. The individual conglomerate beds range in thickness from 2 to 15 feet and in coarseness from rocks in which the pebbles are of pea size to coarse conglomerates containing pebbles as much as 6 inches in diameter. These pebbles include a wide variety of rock types, among which, in the order of their abundance, are argillite, quartz, chert, and siliceous dike rocks, but little or no granitic material is present. The conglomerates are distorted and somewhat sheared and are cut by many tortuous quartz stringers and veins.

As a whole, the conglomerates of this region are believed to be intraformational and of no great stratigraphic significance. Some of them are known to be lenticular and to grade into graywackes, and none are known to be continuously present over large areas. They occur at various horizons in a very thick series of argillaceous and arenaceous materials that were deposited in shallow water, and probably they are the result of local conditions that caused the deposition of lenticular bodies of coarser material. In the work so far done it was not found possible to correlate the conglomerates that were observed at widely separated localities, and it is considered to be unlikely that as deposited they were continuous over large areas.

TUFF

The only place within the slate-graywacke group of beds in which rocks that were definitely identified as volcanic tuff occur is about 4 miles northwest of the head of Viekhoda Bay. In the field these rocks were considered to be a mixture of light-green chert with a dark-green altered mineral that could not be identified in the hand specimen. Thin sections of this rock studied under the microscope prove it to be a very fine grained material consisting of a groundmass of chlorite, calcite, and quartz, in proportions of about 50, 30, and 20 percent, respectively, fractured into fragments and recemented by a network of veinlets of coarser calcite and quartz. Shadowy outlines suggest ghosts of preexisting feldspar crystals. These rocks probably represent original basic lava or tuff, now largely replaced by chlorite, quartz, and calcite. In the field they show highly complex close folding, though they are interbedded with normal slates and graywackes that are somewhat less severely deformed. The altered tuff occurs in bands some 50 feet thick, and its general strike is northeast and its dip is about 45° NW., in accord with the structure of the associated sedimentary rocks. No similar rocks were seen elsewhere in the slate-graywacke series of this region.

STRUCTURE AND THICKNESS

There is abundant evidence that the slate-graywacke group has suffered from severe regional metamorphism that included monoclinal tilting, folding, faulting, and locally intricate contortion and crumpling, yet much the greater number of exposures give the impression of simple monoclinal tilting, with the strike northeast and the dip 30°–70° NW. To be sure, there are some departures from this apparently simple monoclinal tilt, with local strikes to the east, north, or even northwest, and a few small areas in which the average dip is to the southeast, but such departures are notable for their rarity and are due to local cross folding, to highly localized crumpling, or to the intrusion of igneous masses that have thrown the adjacent sedimentary rocks into irregular attitudes (pl. 7, *B*). Over considerable areas, too, there are gentle wavy folds, with, however, the general trend of strike and dip parallel to the dominant structure. Individual observations of strike and dip taken on small exposures are therefore of little value, for, although any possible dip may be found on small, subsidiary folds, these folds may be only unimportant details in the general picture. The amplitude and the length from crest to crest of these subsidiary folds range from a few hundred feet to a fraction of an inch, and in a few places intricate distortion and crumpling has thrown the beds into a maze of crushed and broken folds, yet even there the prevailing major structure can be detected if the exposures are of large enough area. Caution must be exercised in accepting the apparent structure in partly weathered outcrops, for on weathering the slates incline to split into thin flakes, the beds thus weathered are weak, and surface creep on slopes may give the exposed edges of strata a very different structure from that in underlying unweathered beds.

The apparent simple monoclinal tilting so generally prevalent is in many places deceptive, for close scrutiny may reveal closely appressed folds with parallel limbs, resulting in a duplication of beds that would not be suspected if the sharp bending at the crest or trough of the fold were not visible. How extensive duplication of this kind may be is not known, for the monotony of the group, with an almost complete absence of key beds that can be continuously traced, and the lenticular character of the various beds all make a deciphering of the structural details too difficult and too time-consuming to be possible in reconnaissance studies.

Faulting is prevalent throughout the region, and pronounced zones of weakness along faults have been generally attacked by streams and now appear as gulches. Where similar alternating slate and graywacke bands occur on both sides of these faults it may be impossible to estimate the amount of displacement, though wide bands of gouge and slickensides indicate that many faults are of considerable magnitude. At some places, however, where contrasting formations are brought into contact by faults, it is certain that the displacement has been great. Thus, along the great nearly vertical fault that extends from the north side of Afognak Island southwestward throughout the length of this island group, with a probable continuous length of 120 miles, and that brings the rocks of the greenstone-schist group into contact with those of the slate-graywacke group, there is a vertical displacement that must be as great as 2,400 feet and may be much more. Several faults of similar magnitude are known on the southeast shore of Kodiak Island between Chiniak and Alitak Bays, where Tertiary rocks or beds of the slate-graywacke group are faulted into contact with one another or with the still older greenstone-schist rocks. In all these faults that have been definitely recognized and mapped the fault plane stands nearly vertical and strikes northeast, and the side to the northwest has moved upward compared with the southeast side. It therefore seems safe to assume that in the many other northeastward-striking faults of the region in which the relation of the two sides was not clear the northwest side is the upthrown side. There are also many other faults striking in various directions and with all possible dips. Some of these cut the bedding, but every slaty bed is in itself evidence of slipping parallel to the bedding planes, and the incompetent rocks have in the aggregate taken up a tremendous amount of movement parallel to the bedding during the development of their slaty cleavage. Only those faults whose course was definitely traced are shown on the accompanying geologic map, for in the monotonous succession of beds in which they occur it was generally impossible to trace them continuously for any distance, and bedding faults are almost universally present.

No accurate estimate of the thickness of this group of rocks is possible from the data now available. From Cape Chiniak, at the eastern extremity of Kodiak Island, to the great fault near the northwest end of Raspberry Island the distance across the strike of the beds is 52 miles, and except for the interruption of a small granitic mass half a mile wide in Sheraton Bay, the entire distance is occupied by sediments of this group that have an average northwestward dip of 45° or more. If this were considered to be a normal sequence of beds the calculated thickness of the section would be 39 miles, a figure obviously too large and not justified by observational data. It is known that the beds are folded, in places isoclinally, and that involves duplication of strata of an unknown amount. Further, it is known that the rocks are cut by numerous faults of unknown displacement which also bring about reduplication, so that in any section across the island group beds of the same age are probably encountered many times. Nevertheless, even with these facts thoroughly recognized there seems to be no escape from the conclusion that so wide a belt of steeply dipping beds, with a vertical relief of as much as 4,000 feet and with no older rocks brought up by faulting through a distance of nearly 40 miles, must have been formed from a series of beds that as deposited was many thousands of feet thick. No more accurate figure can yet be given.

AGE AND CORRELATION

As no determinable fossils have been found in the rocks that underlie the slate-graywacke group in the Kodiak Island group, as only a few collections of fossils have been obtained from this group, and those all from Chiniak and Izhut Bays, and as the only younger fossiliferous formation is of Miocene or Pliocene age, it must be admitted that the determination of the age of this group of rocks is still a matter of some uncertainty. Nevertheless, there are methods of approach to the problem that throw considerable light upon it and can be relied upon with some confidence. The recognized methods by which the geologic age of a sedimentary bed or a group of beds may be determined are (1) the finding in the rocks of fossilized remains of plants or animals whose age range is known; (2) the discovery of diagnostic fossils in rocks both above and below the rocks in question, thus limiting their age to the time between the two known periods of deposition; (3) the tracing of the beds in question into adjacent areas where condition 1 or 2 is met; (4) correlation on the basis of similarity of lithologic character, structure, or some special characteristics with rocks of known age elsewhere. Where the other methods fail the least satisfactory method of correlation—that upon lithologic and structural similarity—must be relied upon for a tentative age determination. In this region direct evidence of the age of the slate-graywacke group was obtained at only two general localities. The prevailing absence of fossils in these rocks, especially in the more highly metamorphosed members of the group, is not surprising, for during their folding, shearing, and recrystallization any organic remains that they might have originally contained would have been destroyed. But certain members of the group, such as argillites and massive graywackes, are little altered—certainly not so much that all fossil traces would have disappeared if any had been present originally. It therefore seems necessary to assume that the waters in which these sediments were deposited were almost devoid of such animals as could have left shells behind them. The only fossils that have been found in this group of rocks were collected near the town of Kodiak and at Izhut Bay, and in both areas the fossiliferous strata lie in the midst of a very thick and much deformed and faulted group of beds whose stratigraphic position in the group is not known.

In 1899 the geologists of the Harriman Alaska Expedition collected fossils from Woody and Pogibshi (Near) Islands, in Chiniak Bay near the town of Kodiak, and these fossils were identified by Ulrich [15] as including a marine invertebrate that he called *Inoceramya concentrica;* some worm tubes identified as *Terebellina palachei;* and a number of fucoids, or primitive plants. Ulrich concluded that these fossils were of early Jurassic age, ascribed the rocks in which they occur to the Yakutat formation, and correlated the slates and graywackes of Kodiak Island with similar rocks in Prince William Sound. In 1905 Paige [16] also collected similar fossils near Kodiak, and on their evidence no change was made in the age assignment of the rocks. In 1912 Martin [17] found a fossil at the head of Whale Cove, Izhut Bay, that was identified by T. W. Stanton as an indeterminate echinoid from a formation not older than Jurassic. Since that time, however, fossils of the same type as those found at Kodiak have been collected from various places in the Chugach Mountains and the Alaska Range, and the modern interpretation is that Ulrich's *Inoceramya concentrica* is identical with *Inoceramus*, and that the age of the containing beds is Cretaceous, and possibly Upper Cretaceous. The only other formations of these islands which have yielded fossils and whose age is therefore pretty definitely known are the fresh-water Tertiary beds of the southeastern coastal region, of Eocene or younger age; the marine sandstones of Narrow Point, eastern Kodiak Island, of Miocene or Pliocene age; and some Pleistocene beach deposits of southwestern Kodiak Island. These beds are all definitely younger than the slate-graywacke group, for they are less indurated and overlie the older group, probably unconformably. The positive evidence available therefore indicates that the group is pre-Miocene and probably pre-Eocene. It seems equally certain that this group of beds is younger than the greenstone-schist group, already described, which is believed, on the basis of lithologic and structural similarity, to correspond to beds on Kenai Peninsula that range from late Paleozoic or Triassic age to Jurassic. The slate-graywacke group itself bears a striking resemblance in composition, structure, and degree of metamorphism to a great series of rocks on Kenai Peninsula that lies directly along the strike of this island group and that consists of remarkably similar argillites, slates, and graywackes, is largely devoid of fossils, and is cut by granitic intrusions. From these rocks, in the region of Turnagain Arm, Park [18] in 1931 obtained

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[15] Ulrich, E. O., Fossils and age of the Yakutat formation: Alaska, vol. 4, pp. 125–146, Harriman Alaska Expedition, 1904.

[16] Paige, Sidney, unpublished notes.

[17] Martin, G. C., unpublished notes.

[18] Park, C. F., Jr., The Girdwood district, Alaska: Geol. Survey Bull. 849–G, pp. 393–394, 1933.

several collections of marine invertebrate fossils that were determined to be of Cretaceous age, and probably Upper Cretaceous. These are now believed to be the correlatives of the marine shells from Chiniak Bay. It therefore appears that on Kodiak and adjacent islands the group is also in part of Cretaceous age, and this ties in well with the probable Jurassic age of part of the underlying greenstone-schist group and the probable Eocene age of the overlying fresh-water sediments. It is by no means certain, however, that all the rocks of this group are of Upper Cretaceous age. Even when every allowance is made for repetition of beds by close folding and by faulting, there seems to be no escape from the conclusion that a tremendous thickness of sediments, to be measured in thousands of feet, is included in this group. Possibly some Jurassic beds are included, and possibly both Lower and Upper Cretaceous sediments are represented. The determination of the exact age limitations of this great group of beds must await further field studies and the discovery of other and more diagnostic fossils in them.

TERTIARY ROCKS

Rocks of Tertiary age that include sandstone, shale, and conglomerate are present in a belt along the southeast margin of the island group from Chiniak Bay at least as far as Cape Trinity and Aiaktalik Island and almost certainly to Sitkinak and Tugidak Islands also. Within this belt, however, these rocks are not exposed continuously but occur as irregular patches on the headlands and outlying islands or as narrow belts or wedge-shaped masses bordered on the northwest by faults. They include two distinct groups of sedimentary rocks—the older and more widely distributed consisting of sandstone, shale, and conglomerate that, so far as known, were all deposited in fresh water and are of Eocene (?) age, and the younger composed almost entirely of marine sandstone of Miocene or Pliocene age.

EOCENE (?) SEDIMENTS

DISTRIBUTION AND CHARACTER

Sandstones, shales, and conglomerates that are obviously younger than the Mesozoic slates and graywackes with which they are associated are present in discontinuous areas in Kalsin, Ugak, Kiliuda, and Kaguyak Bays, at Dangerous Cape and Cape Trinity, and on Ugak, Sitkalidak, Two Headed, Geese, Aiaktalik, and probably Sitkinak and Tugidak Islands. They include sediments which vary widely in lithologic character, structure, and degree of metamorphism but which have in common certain characteristics that appear to justify grouping them together, for all, so far as known, were laid down as fresh-water sediments or as estuarine deposits. It should be stated, however, that the time available for their study in the field and the prevailing weather conditions did not permit as thorough an examination of these beds as was desirable. For the most part they occur along a coast which is exposed to the open ocean and on which a heavy swell breaks almost constantly, so that landings from a small boat can be made only under conditions that are rarely met. Tugidak and Sitkinak Islands are surrounded by foul waters and extensive kelp fields and have not harbors even for moderate-sized boats, so that no chance was offered to land on them. Under these conditions it is possible that the rocks here mapped as of probable Eocene age may include also some later beds.

An excellent section for the study of these rocks is found in the almost continuous sea cliffs along the east end of Sitkalidak Island between McDonald Lagoon and Cape Barnabas, where a great thickness of beds of this formation occurs. For the most part fairly hard sandstone and black shale predominate, though locally conglomerate is present in considerable amount. A partial, roughly measured section along the east shore of Tanginak Bay was as follows, though in the steeply dipping and folded beds there was no certainty as to which was the top and which the bottom of the sequence:

Section on east shore of Tanginak Bay, Sitkalidak Island

	Feet
Sandstone	250
Concealed	200
Sandstone and conglomerate	200
Conglomerate	100
Contorted sandstone and shale	100
Thin-bedded sandstone and shale	75
Mildly contorted shale with some sandstone	180
Thin-bedded sandstone and shale	100
Highly contorted shale	180
Thin-bedded sandstone and shale	270
Contorted shale	90
Thin-bedded sandstone and shale	30
Mainly shale, with some sandstone and grit	300
Total	2,075

In this section the beds for the most part have a northeast strike and a steep monoclinal dip to the northwest, but locally there is intense folding, crumpling, and faulting (pl. 8, *A*).

East of this section, along the north shore of Sitkalidak Island, the strike of the beds ranges from N. 20° E. to due east and averages about north-northeast and the dips are prevailingly steep, predominantly to the northwest but locally to the southeast. At the prominent cape 1¼ miles northwest of Cape Barnabas there is an exposure of several hundred feet of massive sandstone in plates 6 inches to 20 feet thick, with little or no shale. Some beds contain scattered pebbles of black shale, but no true conglomerates were seen. A careful examination of these beds failed to reveal any signs of marine fossils, though carbonaceous imprints of sticks were found.

Similar beds were seen on Ugak Island, at Dangerous Cape, and on the southwest shore of Sitkalidak Island. At Two Headed Island this formation is composed of thinly interbedded sandstone and shale, striking northeast and dipping 20°–45° SE. Cape Kaguyak and the southeast shore of Kaguyak Bay are composed mainly of platy sandstone in beds 7 to 50 feet thick, striking northeast and dipping 45°–85° NW.

The sandstones of this formation that were examined in thin section consist of subangular to rounded grains, largely derived from granitic rocks, of quartz, orthoclase, microperthite, biotite, and some fragments of slate, chert, etc. The conglomerates contained pebbles of a wide variety of materials, among the most abundant of which were graywacke, chert, limestone, and granitic rocks. Many of the sandstones show ripple marks, and a common characteristic of the formation is the presence of small nodules of coal, plant fragments now altered to coal, or, more rarely, lenticular coaly seams as much as 1 inch thick. No coal beds of commercial size were seen, but it is reported that on Tugidak Island there is a coal bed over a foot thick, and that both Tugidak and Sitkinak Islands are composed largely of shales and sandstones of this formation.

At several localities the structural relations seem to show that the basal portion of the formation was deposited unconformably upon the Mesozoic slates and graywackes, and the basal Tertiary sandstones there have certain peculiarities. Thus along the southeast shore of Port Hobron and on Sitkalidak Lagoon, on Sitkalidak Island just west of Pivot Point, Kiliuda Bay; at Portage Bay in Ugak Bay; and at Svitlak, Middle, and Kekur Islands, in Kalsin Bay, the sandstones, which tend to have a greenish cast, are more or less fractured, and the tiny fractures are filled by thin gray-white filaments of a material composed of carbonates and zeolites. In places the sandstones are thick and massive, with the bedding difficult to determine. Some are full of angular fragments of slate as much as half an inch in diameter and of bits of rhyolite and chert, as well as such secondary minerals as chlorite, sericite, epidote, and calcite; and some contain numerous spherical or discoid concretions several inches in maximum diameter. The fact that these basal sandstones all occur not far from major fault zones may account for their fractured condition and for their degree of metamorphism.

STRUCTURE AND THICKNESS

The present distribution of the Eocene (?) beds in this region has been brought about by a series of profound northeastward-bearing faults that were accompanied by steep tilting to the northwest (pl. 8, *B*), and by local folding and even contortion. One of these faults has been traced from Kalsin Bay southwestward across Ugak and Kiliuda Bays and may be continuous to the southwest with the fault that enters Sitkalidak Island at Amee Bay; another crosses Narrow Point and the mouth of Ugak Bay, passes behind Dangerous Cape through Boulder Bay, and may be continued to the southwest by the fault that crosses Sitkalidak Island, through McDonald Lagoon and Rolling Bay, and even farther to Kaguyak and Alitak Bays; still another fault croses Sitkalidak Island along Port Hobron and Sitkalidak Lagoon. Doubtless there are still other faults in this region that have not been recognized. All these faults have a northeast strike and are nearly vertical, and in all likelihood they are related in time to the great vertical fault that separates the greenstone-schist group on the western border of the island group from the slates and graywackes. The faulting was accompanied by local severe folding, distortion, and alteration, particularly in the areas close to the faults.

Apparently there were two periods of movement along at least some of the faults in post-Eocene time, one preceding and one following the period of deposition of the Miocene or Pliocene beds at Narrow Point, for along the fault that separates these beds from the slates and graywackes the Miocene or Pliocene beds are only mildly folded and little altered, whereas along the southwestward continuation of this same fault on Sitkalidak Island the Eocene(?) beds are steeply dipping and locally much crumpled and contorted.

It is difficult to make a reliable estimate of the thickness of beds so intricately deformed and cut by faults. The partial section measured on Sitkalidak Island seems to show a thickness of over 2,000 feet and includes only part of the total thickness of the formation there. The basal sandstone on the north side of Ugak Bay, though possibly repeated by folding and faulting, is nevertheless to be measured in many hundred if not in thousands of feet. It therefore seems certain that these fresh-water Tertiary beds aggregate several thousand feet in thickness. No more accurate figure can now be given.

AGE AND CORRELATION

The age determination of this formation is based on rather scanty evidence, which, however, is satisfactory as far as it goes.

The fresh-water sediments lie with apparent unconformity upon the slate-graywacke group, which is believed to be in part of Cretaceous age. They are believed to be overlain, with probable unconformity, by marine Miocene or Pliocene sandstones and are thus evidently of early Tertiary age. The only identifiable fossils that have been found in them were collected on the Trinity Islands by a member of the Coast and Geodetic Survey in 1932 and were identified by Roland W. Brown, who wrote as follows:

Two species of plants are represented in this material—*Sequoia langsdorfii* (Brongniart) Heer and *Corylus americana* Walter. These indicate an age not earlier than Eocene in Alaska but may occur in deposits of later age.

In general lithologic character these beds resemble rather closely the Kenai formation of Cook Inlet in those places where the Kenai has undergone equally severe deformation. To be sure, one characteristic of the Kenai formation is the presence in it of coal beds in some abundance, but workable coals seem to be lacking in the Kodiak region. Nevertheless, the beds there contain coaly fragments and thin seams, and a thicker bed is reported from the Trinity Islands. Like the Kenai formation these beds are of fresh-water origin, and all the evidence points to a similar age. It therefore seems probable that at least some of this formation is the time equivalent of part of the Kenai, and that all of it is of pre-Miocene Tertiary age. For the present the Eocene(?) age of the formation is accepted.

MIOCENE OR PLIOCENE SANDSTONE

DISTRIBUTION AND CHARACTER

Marine sandstones of Miocene or Pliocene age have been recognized in this region in only one locality—at Narrow Point, at the north entrance of Ugak Bay, eastern Kodiak Island, and along the shore for about 4 miles north and 4 miles west. Narrow Point is a bold headland which is exposed to the open ocean and against which a heavy surf breaks, so that for weeks at a time it is impossible to land from small boats. Furthermore, the sea has cut this cape into nearly vertical cliffs, and in places no beach is exposed even at low tide. The examination of these rocks, upon which this description is based, was made during a brief visit on a day when for a short time the surf was moderate enough to permit a landing through it at a point near the southern tip of the cape, and the cliffs west of the cape were examined from a boat that kept just outside of the surf. The headland for a distance of 4 miles west of the cape is composed of fine-grained gray to buff sandstone. In places the bedding is easily recognizable, though elsewhere the sandstone is so massive that the bedding can be discerned only with difficulty and is more easily determined from a distance than close at hand. The sandstone is fairly well indurated and stands in nearly vertical cliffs, though it is rather friable under the hammer. Some beds are slightly more resistant to erosion than others and stand out in mild relief upon weathering. One bed a foot or so thick was so full of fossils that it approached a limestone in composition, although the shells were embedded in a sandy matrix, and elsewhere imperfectly preserved sandy casts of fossils occur in the sandstone. A rather general characteristic of the formation is the presence in most of the beds of spherical sandy concretions that reach a maximum diameter of 3 feet. The sandstone is by no means a pure quartz sandstone but when freshly broken has a gray color and contains, besides quartz, fragments of feldspar, ferromagnesian minerals, fragments of slate, and some clayey material. Upon weathering it takes on a light-buff color.

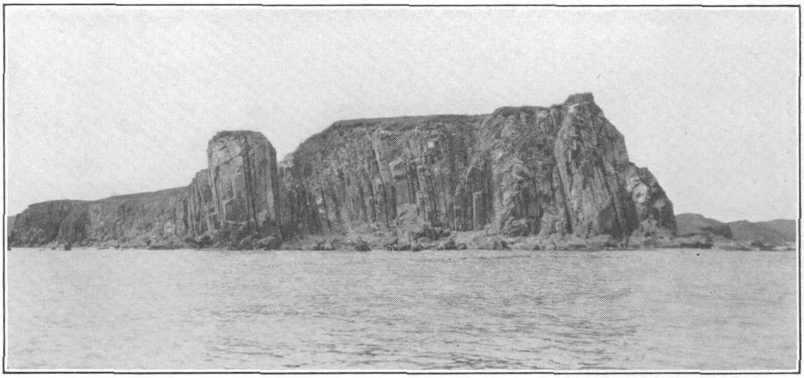
STRUCTURE AND THICKNESS

As exposed in the cliffs that extend from Narrow Point westward for a distance of 4 miles, the sandstones are seen to be mildly folded (pl. 9, *A*) and to lie in two shallow synclines separated by a low anticline. The folds strike northeast, and the steepest dips, at the south tip of the point, are 38° NW., though the average dips are not more than 15° to 20°. No faults were directly observed, and apparently a stratigraphic thickness of about 1,000 feet of beds is exposed. The contact of the sandstones with the slate-graywacke series to the northwest is not exposed, but inasmuch as that contact lies along the northeastward extension of the fault that lies just west of Dangerous Cape and crosses Sitkalidak Island, it seems probable that these sandstones are dropped against the slates and graywackes by a fault. If, however, that fault is the same as the one that cuts Sitkalidak Island, the effect of the fault and of the accompanying deformation upon the Narrow Point marine beds was much less than upon the adjacent Eocene (?) sediments on Sitkalidak Island. Possibly movement along the fault has been recurrent, and therefore the folding of the younger beds has been less severe because they have been subjected to less vigorous and fewer periods of deformation. As the contact between the sandstones and the slate-graywacke beds has not been seen, the possibility must also be considered that it is one of depositional overlap, with a strong angular unconformity between.

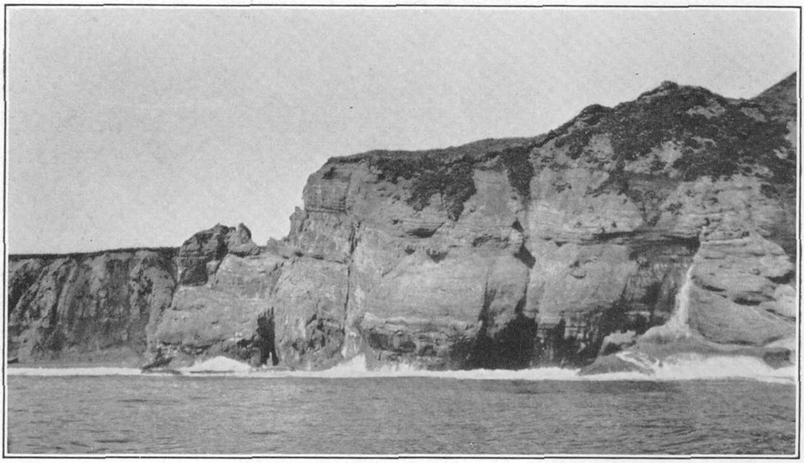
AGE AND CORRELATION

The age of the marine sandstones of Narrow Point is determined as Miocene or Pliocene by W. P. Woodring, on the basis of a single fossil collection. Woodring reports as follows:

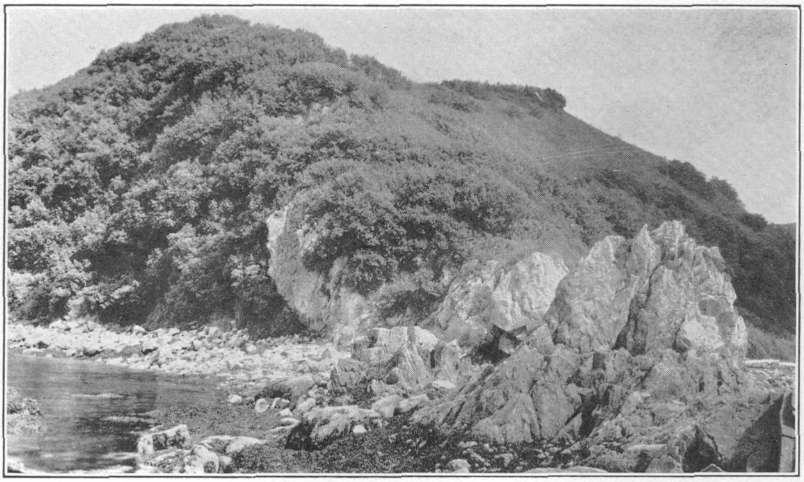
A. FOLDED AND FAULTED EOCENE (?) SANDSTONE AND SHALE, SITKALIDAK ISLAND.



B. STEEPLY DIPPING EOCENE (?) SANDSTONE, CAPE KAGUYAK, KODIAK ISLAND.



A. GENTLY FOLDED MIOCENE OR PLIOCENE MARINE SANDSTONE, NARROW POINT, KODIAK ISLAND.



B. DIORITE SILL CUTTING SLATE AND GRAYWACKE, SHARATIN BAY, KODIAK ISLAND.

13372. Kodiak Island, Alaska, southwest shore of Narrow Point at mouth of Ugak Bay; S. R. Capps, July 12, 1934:

Neverita?
Opalia?
Neptunea?
Undetermined small gastropod.
Mytilus middendorffi Grewingk.
Cerastoderma cf. C. nuttalli (Conrad).
Chione aff. C. securis (Shumard).
Tellina?
Macoma cf. M. brota Dall.
Pseudocardium aff. P. densatum (Conrad).
Mya cf. M. "intermedia Dall".

These fossils are of Miocene or Piocene age. Fossils of similar aspect described by Grewingk[19] and Dall[20] were referred by Dall to the Miocene, but they may be Pliocene. *Mytilus middendorffi* is a striking extinct species already recorded from the south coast of Kodiak Island and also from Unga Island by Grewingk. *Chione* aff. *C. securis* appears to be closely allied to a species found in the Miocene and Pliocene of the Pacific coast of the United States. A form of this species from the Yakataga region is said to be of Oligocene age.[21] The hinge of the species listed as *Pseudocardium* aff. *P. densatum*—the most abundant species in the collection—is inaccessible, but its affinities seem to be reasonably certain. This genus, which is extinct, also is found in the Miocene and Pliocene of the Pacific coast of the United States but appears to be represented in beds referred to the Oligocene.[22]

The Miocene or Pliocene age of the Narrow Point sandstones is therefore accepted. It is quite possible that a detailed examination of the Tertiary deposits southwest of Narrow Point, here mapped as of Eocene (?) age, may result in the discovery in them of some marine Miocene beds, but the assignment here given represents the state of present knowledge.

INTRUSIVE ROCKS

CHARACTER AND DISTRIBUTION

The central axis of Kodiak Island is occupied by a granitic mass that is some 70 miles long, averages about 8 miles wide, and has an area of about 550 square miles. In addition, there are many outlying satellites of granitic material on Kodiak and the adjacent islands. An earlier generalized geologic map of this island group[23]

[19] Grewingk, Constantin, Beitrag zur Kenntniss des orographischen und geognostischen Beschaffenheit des Nord-west-Kuste Amerikas: Russ.-k. min. Gesell. St. Petersburg Verh., 1848–49, pp. 347–363, 4 pls., 1850.

[20] Dall, W. H., Correlation papers—Neocene: Geol. Survey Bull. 84, pp. 238–242, 252–259, 1892; Neozoic invertebrate fossils: Alaska, vol. 4, pp. 101, 111–120, pl. 10, Harriman Alaska Expedition, 1904.

[21] Clark, B. L., Fauna of the Paul and Yakataga formations (upper Oligocene) of southern Alaska: Geol. Soc. America Bull., vol. 43, p. 815, 1932.

[22] Clark, B. L., and Arnold, Ralph, Fauna of the Sooks formation, Vancouver Island: California Univ., Dept. Geol. Sci., Bull., vol. 14, p. 153, 1923.

[23] Martin, G. C., Mineral deposits of Kodiak and neighboring islands: Geol. Survey Bull. 542, pl. 5, 1913.

shows only two small masses of intrusive rock, both on the coast, but in 1932 the writer made several airplane flights over the islands, and although no map was available on which to plot his observations he noted that much of the rugged ridge that forms the main northeast-southwest divide of Kodiak Island is composed of a large mass of granitic rock and that there are also numerous smaller outlying bodies of similar material. During the investigations of 1934 and 1935 the outlines of the main granitic mass were mapped (pl. 2) except for a portion of its northwest margin, and the general shape and position of a large number of other intrusive masses were determined. Associated with the larger intrusive bodies there are numerous dikes and sills of similar materials, and from these and the abundance of quartz veining in many places where no intrusive rocks occur at the surface the impression is given that the prevalence of granitic intrusives at depth is much greater than it is at the surface; that much of the region is underlain by a great intrusive body from which many smaller projections extend upward into the overlying formations; that erosion has so far exposed only the upward-projecting apophyses of a much larger, concealed mass; and that as erosion proceeds the areal extent of the granitic masses will increase.

When the geologic map of this region (pl. 2) is examined, it does not seem surprising that in the earlier, more cursory studies of the shores of these islands the large part played by granitic instrusive rocks in their make-up should have been overlooked, for they reach the shore line at comparatively few places. This is not a fortuitous happening but is due to the superior resistance of the granitic rocks to erosion, as compared with the more easily eroded sediments and schists. The development of normal stream valleys in preglacial time naturally took place more rapidly in belts of easily eroded rocks, and the alternately banded slates and graywackes, the foliated greenstone schists and tuffs, and the thin-bedded cherts and slates were much more easily carved by streams than the harder intrusive rocks. Later in their history, during glacial time, the stream valleys were occupied by glaciers through a succession of advances, and glacial erosion widened and deepened the depressions in the softer materials, leaving the more resistant intrusive rocks as prominent ridges forming the drainage divides, or as bold headlands. Within the region here described the larger bodies of coarser-grained granitic rocks can be observed at the seacoast only at Kizhuyak Point, the head of Sheratin Bay, and at Kupreanof Mountain, on northern Kodiak Island; at Uganik Narrows and the headlands between Uganik and Uyak Bays, on western Kodiak Island; and at Alitak Point, Deadman Bay, Kaiugnak Bay, Three Saints Bay, and the head of the central arm of Ugak Bay, on southern and southeastern Kodiak Island; and at Malina and Paramanof Bays, on Afognak Island. A rough calculation shows that, although granitic rocks occupy over 13 percent of the area of this island group, less than 4 percent of the shore line is bordered by them.

Numerous dikes and sills, most of which are only a few feet thick but which in places reach thicknesses of as much as 150 feet, of the same general composition as the larger intrusive masses, though of different texture, were seen in the shore cliffs at many places (pl. 9, *B*). They are abundant within a few miles of some of the larger granitic stocks, whereas near others they are rare or lacking. Thus, in Kupreanof Strait and Viekroda Bay, near the Kupreanof Mountain stock, and in Uganik Bay, near two small stocks there, sills and dikes are plentiful. A persistent group of sills runs in a south-southwest direction across Spiradon, Zachar, and Uyak Bays, and their grouping at least suggests that some of these sills, which are only a few feet thick, may be continuous for 10 or even 20 miles. They are not related to any visible body of granitic rock, but their presence arouses the suspicion that they may have their origin in such a mass that has not yet been uncovered by erosion. Both in strike and in dip these sills and dikes show a strong tendency to follow the bedding planes of the slates and graywackes into which they are intruded, but some dikes cross the bedding planes at various angles, and many of the sills here and there depart from the bedding planes for short distances.

The close spatial relationship of many dikes to larger granitic masses, as well as the similarity in chemical composition, indicates a common origin, and it seems certain that the dikes and sills represent offshoots of the granitic stocks that have penetrated along bedding planes and through cracks into the adjacent and overlying stratified rocks for considerable distances beyond the front of the main body of invading magma. Thin sections of several dikes and sills showed them to include mica-quartz diorite, granodiorite, muscovite granite, rhyolite, sodic rhyolite, and rhyolite porphyry.

The great elongate granite mass that occupies the central axis of Kodiak Island is apparently continuous from Kizhuyak Bay on the north to Alitak Bay on the south. Its southeastern border and a part of its southwestern border have been traced with a fair degree of accuracy, but its northwestern border lies in a rugged, unmapped area and is known only approximately. This great stock is 70 miles long and apparently has an average width of about 8 miles. The topography developed on its surface by streams and by glacial ice is the most rugged found in this region, and the highest peaks reach elevations ranging from 3,000 to over 4,000 feet, in places rising to heights of over 3,000 feet within less than a mile of the seacoast. This mass is composed for the most part of coarse- to medium-grained gray diorite, whose color is due to a white background of quartz and white feldspar, flecked with darker minerals. Thin sections cut from samples of this rock, collected at various places throughout its extent, show that it is predominantly quartz diorite, which characteristically consists of more or less sericitized plagioclase, quartz, and biotite, in places altered to zoisite. Two specimens collected in Kizhuyak Bay showed a somewhat different composition. One was a muscovite granite containing quartz and orthoclase, some of which was graphically intergrown with quartz, a little plagioclase, and muscovite. The other was a mica granodiorite containing quartz, both plagioclase and orthoclase with the plagioclase dominant, and biotite and muscovite.

The smaller granitic bodies on the northwest coasts of these islands are also mainly quartz diorite. In a locality near the north end of Ban Island, in Paramanof Bay of Afognak Island, the quartz diorite is much crushed, faulted, and slickensided, and there seems to be a complete gradation between normal quartz diorite and crushed glossy-black slickensided material that looks like serpentine and that under the microscope shows rock fragments replaced by clinozoisite and serpentine.

The small, narrow intrusive mass that crosses Sitkalidak Strait just west of Amee Bay is a fine-grained diorite containing plagioclase and leached hornblende and biotite. That on the south shore of Ugak Bay, 2 miles northwest of Eagle Harbor, is in part a biotite granodiorite containing quartz, orthoclase, microcline, plagioclase, biotite, apatite, iron oxides, and occasional specks of pyrite, and in part a quartz diorite containing quartz, andesine, some orthoclase, much almost colorless hornblende, biotite altered to chlorite, iron oxides, and apatite. On the northern part of Kodiak Island, at Kizhuyak Point, and the islands just southwest of it, on the east shore of Sharatin Bay, and at the southeast entrance of Whale Passage there are small masses of granitic rocks that include gray mica granodiorite of fairly coarse grain, made up of quartz, orthoclase, plagioclase, much sericitized and chloritized biotite, muscovite, and apatite, and muscovite granite composed of quartz, orthoclase, albite, muscovite, and a few grains of chloritized biotite.

On both sides of the shallow bay at the northeast entrance to Ugak Bay, Kodiak Island, there are intrusive dikes and sills that are much more basic than any of the other intrusives noted. They are of fairly coarse grain, of dark-gray color, and in thin section prove to be gabbro, with labradorite feldspar, augite, iron oxides, and such secondary minerals as sericite, chlorite, calcite, epidote, quartz, and pyrite. They were mapped only near the shore but extend an unknown distance inland beneath the vegetation-covered slopes.

Doubtless there are within the region other bodies of intrusive rock which lie in the unmapped interior of the islands and which the writer did not see. Erratic boulders were seen here and there on the beaches, and some of these were of intrusive rocks that differed in character from any that were observed in place. As will be shown, it is quite possible that some of these erratics were brought to the islands by glacial ice from sources on the mainland to the west and north. Just west of Cape Alitak an extensive beach stretches northwestward, formed of materials swept along shore from that direction by currents and waves. On this beach there is a great variety of igneous rocks of types that have not been recognized in place in this region. They may possibly have come from some unknown source within the island group, but it seems more likely that they were carried eastward from the Alaska Peninsula by glacial ice that in Pleistocene time reached across Shelikof Strait to Kodiak Island.

STRUCTURE AND AGE

The granitic intrusive rocks and the associated dikes and sills were injected into the early Mesozoic greenstones, cherts, and sedimentary rocks as well as into the upper Mesozoic slates and graywackes that are probably in part of Upper Cretaceous age, and all these rocks where in contact with large intrusive masses show contact-metamorphic effects. Although many of the contacts show that faulting has taken place since the intrusive solidified, nevertheless at many localities it is evident that both the larger stocks and their offshoots as dikes and sills were injected into sedimentary rocks that are as young as Upper Cretaceous. The intrusive rocks are, as a rule, much less affected by faulting, folding, and dynamic metamorphism than the stratified host rocks, and in places the rather straight boundaries of the invading magmas cut across the tilted and folded stratified beds in such a way as to show conclusively that a part, at least, of the regional metamorphism had been accomplished before the intrusive rocks were injected. On the other hand, neither the earlier Tertiary sedimentary rocks of Eocene (?) age nor the Miocene or Pliocene sedimentary rocks were seen to be invaded by intrusive materials. These facts, therefore, appear to limit the age of the granitic intrusives to the period after the Upper Cretaceous beds were deposited and before the presumably Eocene terrestrial materials were laid down. The Eocene (?) strata are in general steeply tilted and locally crumpled and contorted, and if the very late Mesozoic or very early Tertiary age of the granitic intrusions, as determined, is accepted, the deformation of the Tertiary sedimentary rocks must have occurred after the intrusive bodies were in place. The comparative freedom of the granitic masses from regional metamorphism is therefore to be attributed to their greater rigidity or competence, as compared with the less competent bedded sedimentary rocks, and the granitic stocks may well have acted as buttresses against which the more yielding bedded rocks were compressed and along which accumulated stresses were taken up by faulting rather than by folding or tilting. The occurrence of a general period of granitic intrusion in these islands at about the end of Mesozoic time corresponds well with the known facts in the Kenai and Chugach Mountains of Prince William Sound, and also in the Alaska Range, where large granitic stocks cut rocks of probable Upper Cretaceous age and where Tertiary sedimentary beds are comparatively free from such intrusions.

QUATERNARY DEPOSITS

PREGLACIAL CONDITIONS

As none but reconnaissance geologic studies have been made in the Kodiak region, only a few general facts are known concerning the detailed happenings there in Pleistocene time, but it seems reasonable to presume that the history of this region in regard to past climates has been similar to that of other portions of the Pacific coast region of Alaska. Such records as are at hand indicate that for a long time during the Tertiary period the coastal region had a temperate climate somewhat warmer than that of today. By the end of Tertiary time the present mountains in the Kodiak area were outlined, most of the pronounced crustal folding and faulting had been completed, and the general relations of land and sea were about as they are today, though differing greatly in detail. The mountain masses had been attacked by the agencies of normal erosion, and the streams had cut deep valleys from the mountains to the sea, giving a complete drainage pattern and reducing the uplands to a stage of youthful maturity. The valleys, however, being stream-eroded, bore the evidences of their origin and were narrow-floored, V-shaped in cross section, and bordered by steep ridges that rose to rugged interstream divides. At its mouth on the coast each stream had built a delta composed of the detritus removed from its basin, or, if wave erosion was too severe for deltas to be built out into the ocean, the detritus was distributed along shore by waves and currents as beaches, bars, and spits. The coast line was then relatively smooth, in contrast to the deeply embayed shore of today, and it is likely that instead of a group comprising a great number of islands, a single elliptical land mass extended continuously from Shuyak Island on the north to Tugidak Island on the south.

GLACIATION

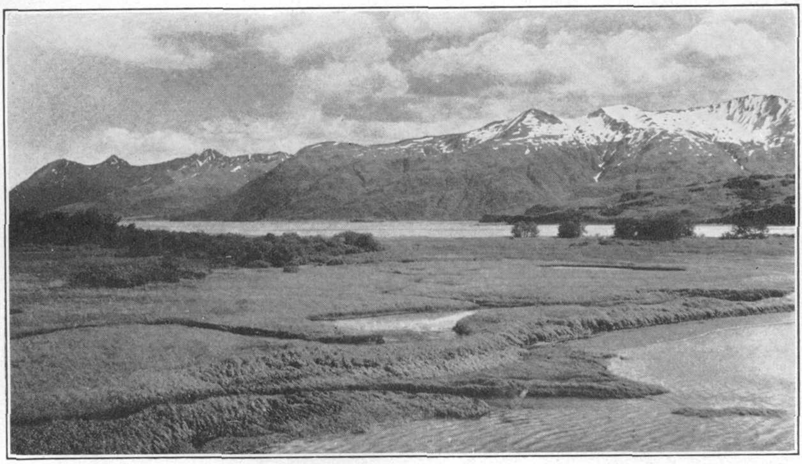
Pleistocene time, or the glacial epoch, began with a gradual worldwide change in climate that had dramatic effects upon much of the Northern Hemisphere. There is still a considerable divergence of opinion as to the causes for this climatic change, but whatever the cause, there certainly was a lowering of the mean annual temperature that permitted the accumulation over great areas of more snow each winter than melted away during the following summer, with the result that the snow fields gradually thickened, became ice, and ultimately formed glaciers. Much is still to be learned concerning the succession of events in this region during the glacial epoch, as only reconnaissance geologic studies have so far been made, and considerable areas within the region have been examined only hastily or not at all. By analogy with other parts of the continent, where more details are known, it seems reasonable to suppose that these islands also were invaded repeatedly during Pleistocene time by glacial ice, the periods of heavy ice accumulation and advance alternating with periods of milder climate and ice withdrawal, and the last ice advance probably to be correlated with the Wisconsin stage of glaciation in the United States.

At first, under a slowly cooling climate, the ice accumulation took place in the protected valley heads of the higher mountains, but later, as the climate became more severe, it reached lower and lower altitudes. In this way great numbers of small, separate ice tongues were formed, which, as they grew larger, extended down their valleys, joined other tributary ice streams to form many-branched trunk glaciers, and eventually widened, thickened, and lengthened until they reached the sea and pushed out into it for some distance. In this region adjacent valley glaciers of this kind, although perhaps separated at their heads by steep, ragged ridges that projected above the ice surface, in their lower courses overflowed the interstream ridges and joined one another to form a continuous ice mass which entirely covered the islands except for the few summit ridges in the higher mountains. This series of events was probably repeated several times during the Pleistocene epoch, ice accumulation and widespread glaciation being succeeded by times of milder climate or by interglacial stages during which the glaciers melted away in part or completely, and these in turn being succeeded by renewed glaciation.

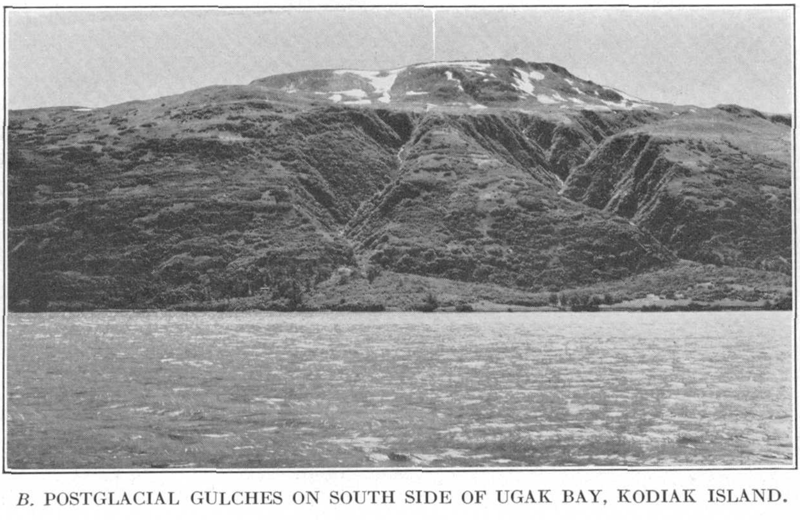
The sculpturing effect of the repeated glacial invasions upon the surface forms of the land was profound. Glacial cirques with steep walls were formed in the valley heads, and the lower valleys, filled with slow-moving glaciers shod with abundant rock fragments, were ground and rasped into broad, deep troughs, from which overlapping spurs and other irregularities were removed. The few ridges and peaks that projected above the glacier surfaces were steepened and sharpened by the attack of the ice upon their bases, and those that were overridden by the glaciers were smoothed and rounded (pl. 10, *A*). The lower valleys of many of the main drainage lines were eroded below sea level, so that the retreat of the ice left fiords, deep inlets, and straits, and many bodies of land, cut off by ice erosion from the mainland mass, remained as islands around it.

Just how much of the glacial sculpturing of the landscape as we see it today is due to erosion by ice during the last great ice advance, and how much was accomplished during earlier glacial invasions, is not known. Glacial deposits on the islands are abundant and widespread, but none so far examined can be definitely attributed to a glacial advance earlier than the last, and the erosive action of the last glaciers was so profound that it removed much of the evidence of the work of its predecessors. Except for the highest peaks and ridges these islands were completely covered by glacial ice that originated locally and that flowed seaward in all directions from the central mountain highlands, and at least during Wisconsin time the entire island group was occupied by a continuous center of glaciation, the straits and bays that separate and indent the islands being all ice-filled, and the glaciers, pushing out to sea, forming a continuous ice shelf that presented an uninterrupted ice cliff entirely around this island group.

There is an interesting speculation, supported by some field evidence, as to whether or not Shelikof Strait and lower Cook Inlet were ever so completely filled with ice that the Kodiak center of glaciation was connected by a continuous glacier with the mainland of the Alaska Peninsula, on the northwest, and with Kenai Peninsula, on the north. Both of those regions supported great glaciers during Pleistocene time, and both even now contain large and vigorous glaciers. It is known that from both thick, vigorous ice streams pushed out to sea, as they did from the Kodiak group of islands. Shelikof Strait, which separates the islands from the Alaska Peninsula, is 20 miles wide at its narrowest point and has an average width of about 26 miles. Its waters are of only moderate depth, the deepest sounding being 162 fathoms and most of the water between Afognak Island and the mainland being less than 100 fathoms deep. To the north of the islands, between them and Kenai Peninsula, the maximum depth of water is 112 fathoms, and in most of the area the depth is less than 100 fathoms. Lower Cook Inlet is even shallower. The glacial topography of northwestern Kodiak and Afognak Islands gives abundant evidence that ice moving northwestward from them had a thickness of at least



A. GLACIATED SLATE AND GRAYWACKE MOUNTAINS OF UPPER UGAK BAY, KODIAK ISLAND.



B. POSTGLACIAL GULCHES ON SOUTH SIDE OF UGAK BAY, KODIAK ISLAND.

2,000 feet where it entered Shelikof Strait. The mountains on the Alaska Peninsula are much higher, today support large glaciers, and no doubt at the time of greatest ice development sent much larger glaciers into the strait than those coming from the islands. From what is known of the Antarctic ice shelf, it seems reasonable to believe that at the height of glaciation ice from the islands joined that from the Alaska Peninsula, filling Shelikof Strait, or even that ice from the mainland pushed eastward to the islands, while at the same time the glaciers from Cook Inlet and from southern Kenai Peninsula pushed southward to the islands. The writer does not conclude that ice from the mainland completely surmounted the mountains of the islands, but only considers the possibility that these islands stood as a local center around and along the flanks of which the glaciers from the mainland flowed. Field evidence that supports such a speculation was found on the east end of Afognak Island. There the two arms of Tonki Bay occupy glacial valleys that are continuous southward across the peninsula, that of the western arm extending through a low gap to Marmot Bay, and that of the east arm, less marked, reaching King Cove on Marmot Strait. Evidence that both of these depressions are glacially eroded is afforded by glacial striae, morainal material containing typically faceted and striated boulders, and characteristic glacial topography. These valleys are bordered on the east and west by ridges from 1,200 to 1,900 feet high, and these ridges are glacially smoothed and rounded to their summits. All these features are characteristic of many fiords and valleys throughout the island group, but at Izhut Bay there is no local highland that could have supplied so thick a mass of ice. Furthermore, the direction followed by these valleys and the direction of ice movement in them, as indicated by glacial striae, is almost north-south, parallel to the margin of the island group and at right angles to the direction that would be expected if the ice that flowed through the valleys had originated locally. The severity of glaciation in these valleys of moderate relief, far removed from a likely local source of glaciation, and its trend at right angles to the expected direction of local ice movement suggest that the valleys were occupied by ice that flowed east and south from Cook Inlet and Kenai Peninsula and overrode the lower flanks of the islands.

Corroborative facts that suggest that ice from the Alaska Peninsula pushed eastward across Shelikof Strait to these islands is afforded by the fiord-like character of Kupreanof Strait, the low pass from Shelikof Strait through to Onion Bay, Raspberry Strait, Malina Bay, and Afognak Lake; the low divide between Paramanof Bay and Danger Bay; and Shuyak Strait. All these iceways lie in country which was completely surmounted by glacial ice during the time of maximum glaciation but which was scarcely of high enough relief to be the source of such vigorous local glaciers. Their direction is what would be expected if a thick glacier flowed eastward from the high mountains near Cape Douglas, pushed across Shelikof Strait, and overrode the islands north of Kupreanof Strait.

Another line of evidence indicates the possibility that the mainland glaciers reached Kodiak Island. Just west of Alitak Point, on the southwest shore of that island, there is an extensive sand and gravel beach, built of materials that were derived from the wave erosion of Pleistocene deposits to the northwest. On these beaches there is a great assortment of pebbles of volcanic rocks, that, so far as known, do not occur in place in these islands. These pebbles include fine-grained aphanitic lavas and a wide range of porphyritic lavas, rocks of types that are present in the volcanic regions of the Alaska Peninsula. It is admitted that a part of southwestern Kodiak Island has not been examined geologically, and there is a possibility that volcanic rocks of the types referred to are present there, but that possibility is believed to be remote. Maddren [24] described extensive Quaternary deposits on southwestern Kodiak Island, composed of glacial till and glaciofluvial outwash, that he believed had been derived from the unexplored interior of the island. There seems to be no doubt of the glacial origin of these beds, but the presence in them of an assortment of rocks not known locally at least suggests that the materials may have been brought by glacial ice from the Alaska Peninsula.

Whether or not these surmises that these islands were tied to the mainland by glacial ice in Pleistocene time are correct, nevertheless there can be no doubt that the island was the site of an extensive local center of glaciation, and even if this center was once a part of the mainland ice sheet, it became separated during the waning stage of glaciation and thereafter persisted as a local center. In it, as it shrank in turn, the ice streams in adjacent valleys separated from one another and became distinct, individual valley glaciers, continuing for a long time the erosion and sculpturing of their basins. The present glacial features are therefore much what they would have been if there never had been a connection between the local ice cap and the mainland glaciers. Most of the striae and erratic boulders left by the mainland ice would, in any event, have been removed by the lingering glaciers of local origin. The evidence for determining the former extension of mainland glacial ice to these islands is therefore difficult to obtain, and the matter

[24] Maddren, A. G., op. cit., pp. 305–311.

cannot yet be considered conclusively settled. The problem of recurrent glaciations on the islands during Pleistocene time also remains to be worked out. It is assumed that the blue, unoxidized till seen at so many places on the islands is of Wisconsin age, for elsewhere in Alaska the last widespread glaciation has been rather definitely correlated with the Wisconsin. There is little hope that the glacial deposits here can be ascribed to a definite stage in the Pleistocene on paleontologic grounds, for such fine discriminations can scarcely be made between faunas many of whose components are living today. In 1917 Maddren collected fossils from what he believed to be a Pleistocene beach deposit at the mouth of the Red [Ayakulik] River, on southwestern Kodiak Island. These fossils were examined by William H. Dall, who reported as follows:

The specimens are rolled and broken fragments, and the assembly indicates a colder temperature than that now normal to the locality. So far as they can be identified the species are:

Pecten (Chlamys)islandicus Muller.
Monia macroschisma Deshayes.
Tellina lutea Gray.
Macoma middendorffii Dall.
Venericardia crebricostata Krause.
Venericardia crassidens Broderip and Sowerby.
Mya intermedia Dall.
Chrysodomus sp., fragment.
Boreatrophon sp., fragment.
Balanus sp., fragment.

Dall made no comment on the age of this collection and apparently accepted Maddren's age determination of the beach as Pleistocene. Another collection by Maddren from a point 3½ miles north of the Red [Ayakulik] River, from a beach that he considered to be Pleistocene, contained 10 species of shells that Dall reported to be of species now living in the vicinity.

Still another collection of plant remains was obtained by George H. Whitney at Uganik Bay, Kodiak Island, from a calcareous sinter, and was examined by F. V. Coville, who identified one plant as *Salix sitchensis*, now living in the area, and the other as a *Betula* or an *Alnus*, and reported the material to be comparatively recent and certainly not older than Pleistocene. More accurate age determinations for the glacial deposits of the region must therefore await much more detailed field studies than have so far been made.

After the climax of the Wisconsin glacial stage was reached the climate again slowly became milder, the average yearly snowfall was less than the average melting, and the glaciers began to shrink, both in area and in thickness. More and more of the higher mountains began to appear above the ice surface, interstream ridges and divides were bared, and the central ice mass was broken up into a large number of individual valley glaciers, each of which found its way to the sea, but between which rocky headlands were exposed on the coast. With continued melting the separate glaciers shrank back into their basins, large areas in the regions of mild relief were freed of ice, and those glacial troughs that had been eroded below sea level became straits or fiords, extending deeply into the land mass or cutting it up into a great number of islands.

It is believed, however, that in these islands valley glaciers lingered in favorable places for a long time after the ice had disappeared entirely in lower latitudes, and that the time since the final disappearance of some of the glaciers is very short compared with post-Wisconsin time in the Great Lakes region. Indeed, a single small glacier about half a mile long still survives in the headward basin of Ugak Bay, on the sheltered north slope of a 4,000-foot mountain, and other small glaciers may persist in the little-explored and unmapped interior of Kodiak Island. The present topographic forms of the region are therefore due in considerable part to erosion by valley glaciers that persisted long after the decline of the greater Wisconsin glaciers was well under way.

GLACIAL DEPOSITS

Although glacial deposits are widely distributed throughout the islands, especially in the low-lying areas of gentle relief, nevertheless the bulk of this material is surprisingly small compared with the enormous volume of rock that was removed during the glacial excavation of the many valleys, fiords, and straits and the rounding of all surfaces except the very highest peaks and ridges. This comparative paucity of glacial debris on land is to be explained by the fact that during most of their existence and during the period of their most vigorous erosion the glaciers pushed out to sea and there deposited their rock waste in places that are not now available for direct observation. An examination of the coast charts of this region shows a broad, shallow platform surrounding the islands on the south, east, and north, with many thousand square miles of bottom above the 100-fathom line, but dropping off sharply on the east to depths of 1,000 to 3,000 fathoms. This platform is no doubt, in part at least, an accumulation of glacial detritus and suggests that the Wisconsin glaciers pushed out some 50 miles to sea southeast of these islands. The great eastward bulge of the under-water platform east of the mouth of Cook Inlet, known as Portlock Bank, suggests that it was a dumping ground for the rock waste brought out to sea by a former great glacier from Cook Inlet.

On land, in these islands, more or less glacial debris is to be found everywhere except on the highest and steepest ridges, where the relief is steep, or on the high rounded ridges, where morainal material is present only as scattered boulders or as a thin sheet of till. In the lowlands, however, such as the lower slopes of the main valleys and on capes and peninsulas of moderate relief, there is generally a layer of glacially derived material, either unassorted morainal stuff or outwash gravel deposited by streams that drained from the ancient glaciers. The luxuriant areas of grass and brush so generally found up to altitudes of 1,000 feet or more are for the most part underlain by glacial debris. Commonly the sea cliffs, cut into bedrock, show a surface layer of a few feet of glacial till, and locally, as at the village of Uzinki, there are exposures of 20 to 30 feet of glacial till, composed of scattered boulders and fragments of rock in a matrix of sticky blue clay.

The most extensive and thickest areas of glacial deposits are to be found in the relatively flat country along the south and southwest shores of Kodiak Island. The peninsula that terminates at Cape Trinity is such an area, but its margins are wave-cut cliffs in hard rock, and exposures of the material on the rolling surface are not good. Better opportunities for observing the character of the glacial deposits are offered by the lowlands between Cape Alitak and Cape Ikolik, for there the sea cliffs are cut in unconsolidated Pleistocene materials. Near Low Cape the glacial plain is 6 miles wide, stands from 30 to 300 feet above sea level, and exhibits on its surface a rolling, hummock and kettle topography, dotted by large and small lakes. Farther north, near the mouth of Ayakulik (Red) River, the bluffs were examined in some detail by Maddren,[25] for he believed that the glacial materials there were the source of the placer gold now occurring on the beach. Maddren describes the deposits as unconsolidated Quaternary materials exposed in sea bluffs from 25 to 250 feet in height and also extending some distance out to sea as a wave-cut platform. The bluffs are composed of typical till, with a considerable proportion of stream-washed gravel and sand in some sections. The till is unoxidized and gray. In general the bluffs consist of a basal member of till overlain by outwash gravel and sand, though some sections consist wholly of till, and some chiefly of gravel and sand. One section showed two till members separated by a beach deposit containing marine shells, indicating an elevation of 30 to 50 feet at this place since the beach was formed. The beach deposit also contained rounded boulders of lignite, the bedrock source of which is not known.

The glacial material on southwestern Kodiak Island and the beach gravel derived from it contain many types of rock that are not known to occur in place in this region. This suggests the pos-

[25] Maddren, A. G., op. cit., pp. 305–308.

sibility that the glacial material may have come, in part at least, from the Alaska Peninsula, to the northwest.

Somewhat similar thick deposits of glacial till and outwash are present on the west shores of Kodiak, Uganik, and Afognak Islands—at Sevenmile Beach, just west of Uyak Bay; north of Uyak Bay between Chief Point and Cape Kulink; just east of Miners Point, at the south entrance to Uganik Bay; near Cannon Lagoon, Uganik Bay; south of Cape Uganik on Uganik Island; and 4 miles northeast of Raspberry Cape. At all these places the waves have attacked thick deposits of glacial till and gravel, and some placer gold has been concentrated from them on the beach. Practically all the placer gold that has been mined in this region has been found under such conditions.

Still another extensive area of glacial deposits is known to lie in the unmapped region of southwestern Kodiak Island and to occupy a broad lowland that reaches from the foot of Karluk Lake to Shelikof Strait at Sevenmile Beach.

No opportunity was offered to the writer to visit Sitkinak and Tugidak Islands, but it is reported that Tugidak Island is of low relief, and its surface is largely covered with unconsolidated deposits, probably morainal material dropped by the great glacier that emerged from Alitak Bay.

POSTGLACIAL EROSION AND DEPOSITION

As soon as the first rock ridges were bared by the shrinking of the glaciers with which they had been covered, postglacial erosion began on them, and it has since continued. In the larger stream valleys, however, as soon as the glacier tongues began to withdraw, there was still a flood of waters from the melting ice fields, and the torrential streams carried down and deposited great quantities of glacial outwash, in places burying the valley floors to some depth. Later on, as the glaciers shrank still farther and the amount of debris supplied by them diminished, the earlier glacial outwash gravel was entrenched and now appears as terraces along the valley sides. With still farther shrinkage and almost complete disappearance of glaciers from these islands normal processes of erosion and deposition have been resumed. The streams, however, in occupying valleys that had been profoundly broadened and deepened by the ice, flowed over beds that were no longer adjusted in gradient to their volume and load. Locally the valleys had been overdeepened, and these places became lakes. Elsewhere ridges of rock or moraine lay athwart the valleys, and through these the streams began to cut canyons. Tributary streams, now flowing from hanging valleys, plunged in waterfalls or rapids down into the main valleys, and in these rapid stretches erosion was vigorous and gorges were developed (pl. 10, *B*). The task of rivers to adjust the slope and width of their beds to the volume of water, to the load of debris carried, and to the character of the material over which they flow is never completed, but in this region, so recently freed from an ice cover, it is only begun, and the glacial aspect of the landscape has as yet been little altered. The start so far made is visible in occasional sharp, rock-cut gulches on the hillsides, a canyon here and there cut through rock or into moraine or outwash, or partly filled small lakes. At the head of each bay into which a moderately large stream empties, a delta is now in process of building, and shoals, exposed at low tide as broad mud flats, now extend far out from the mouths of these streams.

Concurrently with the slow filling of the bays with detritus brought from the land by streams, there is a steady attack by waves on the many prominent capes and headlands. This encroachment of the sea upon the land is most rapid where the coast is exposed to the full force of the storm waves, and a well-developed wave-cut platform, backed by sheer rock cliffs, is to be found at many places on the outer shores of the islands. This process, together with the filling of the bays and the growth of spits and bars along the shore, is already resulting in a smoother coast line, though it is still far from completion.

In the present investigation no attempt has been made to map the unconsolidated deposits in those areas in which the bedrock is covered by thin deposits of talus, soil,. glacial materials, or stream gravel, the purpose being to show the distribution of the rock formations wherever their character could be determined with reasonable certainty. In those areas where fairly extensive deposits of these materials occur, however, an attempt has been made to map them (pl. 2). Where shown, the alluvial deposits are confined almost exclusively to the valleys of the major streams, and particularly to those whose valleys were overdeepened by glacial scour and so served as catchment basins for retaining the detritus brought down by the streams since the glacial ice retreated. No doubt the lower portions of many of these broad valleys were embayments of the sea when first bared of glacial ice but were later filled by delta deposits and have since been aggraded by stream-laid gravel, sand, and silt. This filling process is still actively in progress. In the region as a whole, however, the volume of stream gravel is surprisingly small—a fact that is to be explained by the relatively small size and steep gradient of the streams and the comparatively short time that the streams have had to carry on their processes since their valleys were vacated by glacial ice.

At the base of steep cliffs talus accumulations are forming, particularly below the ragged and pinnacled diorite peaks between the heads of Uyak and Three Saints Bays, and in many protected bays steep streams from the bordering ridges have been able to build out alluvial fans into tidewater.

Extensive and well-developed beaches are not common in this region. By far the greatest part of the shore line of these islands is bordered by wave-cut rock cliffs below which there is only a narrow beach, composed of coarse boulders, that is covered at high tide, and at many places the cliffs descend directly into the sea with no intervening beach. In protected bays into which the larger streams empty there is commonly a beach across the seaward face of the delta, and here and there a hook has been built across a bay to enclose a lagoon. The only extensive beaches occur in those coastal areas of low relief where the shore cliffs are composed of unconsolidated and easily eroded glacial and glaciofluvial materials, and by far the best developed of these is the continuous beach that stretches from Cape Alitak northwest to and beyond the Ayakulik River. This beach, for 4 miles north of Cape Alitak, is constructional and consists of a bar that encloses Alitak Lagoon. North of that lagoon it lies on a shallow, wave-cut shelf of glacial till, above which rise the bluffs of glacial clay and gravel from which the beach material was derived. Similar though less extensive beaches are found below bluffs of glacial materials on the shore of Shelikof Strait at Sevenmile Beach; between Chief Point and Cape Ugat; on Uganik Island south of Cape Uganik; and on Afognak Island halfway between Raspberry Cape and Raspberry Strait. On all these beaches some placer gold has been mined.

VOLCANIC ASH

In the spring of 1912 a dramatic event in the history of this part of Alaska occurred when Katmai Volcano, on the Alaska Peninsula to the west, exploded violently, covering an east-west belt in the central part of these islands with volcanic ash and pumice to a depth of several feet. This eruption and its manifestations and results have been described in great detail by a series of publications of the National Geographic Society, which has sponsored several expeditions to the region. At the time of the explosion it seemed that the part of the Kodiak group of islands that lay to the leeward of the volcano had been rendered uninhabitable, and the towns of Afognak, Kodiak, and Uzinki lay in the zone of deepest ash fall. On the south end of Kodiak Island and on the northernmost islands of the group the ash fall was less severe. On northern Kodiak Island the grass and lower vegetation were completely buried, water supplies were polluted, many buildinngs were crushed in, wild animals and birds were destroyed, the waters of the ocean for miles were covered by an unbroken mass of floating pumice, and the fishing industry, which was almost the only support of the people, was temporarily ruined. The recovery of the region from the ash fall was, however, almost as spectacular as the disaster itself. Vegetation soon pushed through the ash or reestablished itself upon it, first in the lower lands and later at progressively higher altitudes. By 1935, 23 years after the explosion, little was to be seen of its results on casual inspection. To be sure, any excavation through the ground cover of vegetation revealed the presence of the ash, now compacted to a layer a foot or so thick. In many spruce thickets ash may still be found clinging to the trunks and lower branches, and on the higher slopes of the mountains, above the zone of abundant vegetation, there are still patches of bare ash that from a distance might easily be mistaken for snow banks.

One notable result of the ash fall is to be found in the rapid filling of the heads of many shallow bays into which drain the larger streams from the region of deepest ash burial. Great quantities of the light, easily eroded ash have been carried down by the streams and deposited in the sheltered waters of the bays. For example, in the head of Viekhoda Bay the coast charts, surveyed before the eruption, show depths as great as 4 fathoms in places that are now bared at ordinary low tides, and many other bays have much more extensive shoal areas at their heads than they did before the Katmai eruption.

MINERAL DEPOSITS

GOLD PLACERS

During the past 40 years considerable beach-mining for placer gold has been carried on at various places in the region, but all these operations have been conducted on a rather small scale and with simple equipment. In addition to the gold recovered, the beaches have also yielded a small quantity of plantinum metals. Several of the beach placer deposits were visited in 1917 by Maddren,[26] who states that their production up to that time was variously estimated at $50,000 to $150,000. Later estimates obtained from men who had been engaged in mining on those beaches indicate that the estimates given by Maddren are too low, and since that time mining in a small way has been carried on intermittently. No records are available, however, upon which to base a reliable estimate of the total production from the beach-placer operations. During the last 20 years only

[26] Maddren, A. G., The beach placers of the west coast of Kodiak Island, Alaska: Geol. Survey Bull. 692, pp. 299–318, 1919.

desultory mining has been done, and this by parties consisting of only a few men. Experience has shown that after severe storms from certain directions the waves concentrate gold and other heavy minerals into a well-defined strip along the beach, and that with favorable weather and at certain stages of the tide this streak of concentrates can be collected and sluiced at a profit. Favorable conditions occur so infrequently, however, that the rewards achieved are likely to be small. The beaches yield an occasional grubstake to those who are shrewd enough to recognize a favorable combination of conditions when it arises and are familiar enough with the beaches to pick the most likely locations.

All the beach placers that have been mined are in areas where the storm waves have attacked extensive deposits of unconsolidated glacial till and outwash gravel, and the gold deposits are believed to be the result of concentration by the waves of large quantities of unconsolidated material whose gold content was small. The beaches that have yielded practically all the gold that has been recovered so far are known locally as the Red River Beach, on southwest Kodiak Island; Sevenmile Beach, just west of the mouth of Uyak Bay; Miners Point Beach, at the south entrance of Uganik Bay; Uganik Beach, on the northwest end of Uganik Island; and Raspberry Beach, on western Raspberry Island. In all these places some prospecting has been done to determine whether or not the bluffs back of the beaches contain sufficient gold to justify mining, but so far no paying ground has been found in them. In 1935 two or three men were mining and prospecting on Raspberry Beach, and it is reported that three or four men were on Red River Beach.

For several years reports have been current that the low-lying valley between Onion Bay and Raspberry Beach was underlain by gravel carrying sufficient gold to justify the installation of a dredge. A large block of claims had been staked, and in the summer of 1935 arrangements were made to prospect the ground by drilling. After a short drilling campaign the results were found to be unpromising, and the enterprise was abandoned.

ALASKA WESTWARD MINING CO.

An interesting development was in progess during the summer of 1935 near Cape Alitak, at the southwestward extremity of Kodiak Island, where a mill was under construction to treat wind-blown dune sands for their gold content. The bedrock of Tanner Head, of which Cape Alitak is the tip, is composed of quartz diorite, separated by Rodman Reach from the Mesozoic slates and graywackes to the northwest. From Cape Alitak a narrow barrier beach of sand and small pebbles stretches northward for 4 miles to connect with the

Pleistocene till and gravel bluffs that form the coast line northwestward to and beyond the Ayakulik River. These bluffs are attacked by the storm waves, and as the prevailing winds are from the northwest the material derived from them is carried southward along shore by waves and currents, which have formed the barrier beach that lies outside of Alitak Lagoon. This beach contains a great variety of pebbles that are foreign to Cape Alitak, and indeed many of them are of rock types that are not known on the parts of Kodiak Island that have been studied. Whatever their ultimate bedrock source may be, they certainly came from the Pleistocene bluffs of the southwest shore of Kodiak Island. The south end of the barrier beach rests against the north side of Cape Alitak, about half a mile east of its extreme tip. At that point the end of the cape is connected to Tanner Head only by a low, narrow neck of land. In that vicinity there is a considerable accumulation of dune sand, blown onto the cape by the northwest winds that sweep along the barrier beach, and these sands, being derived from the gold-bearing beach deposits of the Ayakulik River district, also carry some fine gold. For several years claims have been staked on the gold-bearing dune sands of Alitak Point, and a small amount of gold has been recovered from them. The sands also contain a large amount of magnetite.

In 1935 a group of these claims was purchased by the Alaska Westward Mining Co., and in July of that year a mill was in process of erection. The mill, to be operated by a 65-horsepower gas engine, included a bin from which an endless bucket conveyor was to carry the sand to a hopper, which in turn was to feed a centrifugal bowl separator, the waste to be discharged onto the beach through a flume. A tractor equipped with a scraper was to move the sand to the ore bin. At the time of visit the machinery was all on the ground, the mill building partly finished, and the milling equipment in process of installation. It was expected that the plant would be in operation in a few weeks. No word has been received at this writing as to the success of the enterprise, but if those dune sands should prove to be minable at a profit the operation will be unique, for, so far as is known to the writer, wind-blown sands have not elsewhere been found to contain gold in profitable amounts.

GOLD LODES

Prospecting for gold lodes in this group of islands has been carried on intermittently for the last 40 years or more, some development work has been done at many places, and at a few localities mining has been carried on to some extent. Yet, as most of the earlier attempts have long been abandoned, it is now difficult to learn anything about them, and even the locations are unknown to most of the present residents. Those prospects whose location could be determined were visited, and a brief description of each is given here. The fact that most of the attempts to develop gold-lode mines in this region have been unsuccessful should not be taken to prove that workable gold lodes do not exist here. Adequate prospecting and sampling in advance of attempts to start milling ore, the selection of the right equipment for reducing the type of ore present, and proper financing and management are almost as necessary for the successful development of a mine as the finding of a sufficiently large and rich ore body, and failure in any one of these items may bring disaster to an enterprise. With the increased price of gold there has been a stimulus to renewed prospecting, and there is a real possibility that this may result in the discovery of profitable properties. The general geographic location of the region is such that freight charges should be reasonable; the numerous protected bays and inlets offer protected harbors for shipping facilities; and the mild winters and abundant rainfall give many opportunities for the local development of water power for mine operations.

In general it may be said that the gold-bearing veins of this region are similar in type to veins found in many parts of the world that are related in origin to granitic intrusive rocks, and there seems reason to believe that this genetic relationship holds for the Kodiak group of islands. Such veins may occur in the granitic bodies themselves but are more commonly found in the invaded rocks, within a few miles of the contact. They are characterized by a quartz gangue carrying the sulphides arsenopyrite, pyrite, sphalerite, chalcopyrite, and galena, with the two first-named most abundant, as well as varying amounts of gold and silver. In most such veins the value of the precious metals far exceeds that of the copper, lead, and zinc.

As far as could be learned, all the gold lodes of this region occur within a few miles of a granitic intrusive mass, or of dikes that are offshoots from such a mass. In places, too, granitic intrusives may be even nearer, beneath the surface, than they appear on the areal map.

UYAK BAY PROSPECTS

Brief references to gold lodes in the Uyak Bay area were made some years ago by Becker,[27] whose map showed the Calaveras, Dan, and Bear prospects, on the west side of the bay south of Larsen Bay; the Lake prospect, on Carlsen Point; and the Wanberg & Boyer property, on the point between Zachar and Spirodon Bays. All the Uyak Bay lodes occur in the vicinity of acidic dikes that cut the

[27] Becker, G. F., Reconnaissance of the gold fields of southern Alaska: Geol. Survey 18th Ann. Rept., pt. 3, pp. 80–81, 1898.

Mesozoic slates and graywackes, and the number and persistence of these dikes suggest that an unexposed granitic mass may lie beneath the surface at no great depth and may be the source both of the dikes and of the quartz veins. Becker's descriptions are as follows:

Several small prospects exist on Uyak Bay, Kodiak Island. * * * The Bear, Dan, and Calaveras claims lie close together, the first two on what is supposed to be the same vein and the last on a second, nearly parallel vein. The country rock is a carbonaceous schist or slate, and the fissures cut the cleavage. The Bear vein strikes N. 25° W. (true) and dips in a southwesterly direction at 40°. In width it varies from a few inches to about 6 feet and averages perhaps 2½ feet. The quartz is usually solid but is not entirely free from included schist fragments. A number of fine outlying parallel stringers accompany the vein. The sulphurets are arsenopyrite and pyrite, the former preponderating. Free gold is easily panned from the croppings, and some extraction has been effected with an arrastre, but I was not able to ascertain the yield or tenor.

The Dan is about 500 yards from the Bear and on its strike, but the deposit has not been traced through the heavy timber. The vein is about 2 feet in width and contains the same sulphurets. The mispickel here is well crystallized, and the general appearance of the quartz is good. No work is in progress, and scarcely any has been done. The Calaveras lies to the northeast of the Dan, on a similar vein of the same strike. It is about 20 inches wide and shows pyrite, mispickel, and galena.

The Lake claim is about 4 miles north of the Bear and on the east shore of the bay. The vein at this point strikes N. 70° E. (true) and dips 80° to the southward, cutting the slate, which is here manifestly of sedimentary origin. The vein is only a foot wide, and the only sulphuret observed in it was a very little mispickel. The vein lies on one of a double series of joints forming a nearly rectangular system. On the shore below the vein is a neat illustration of the mechanism of jointing. The partings cross both sandstone and shale. In the sandstone the joints are from one-fourth to one-half inch wide and filled with quartz, but in the shale the same cracks are so narrow as to be scarcely visible, although sometimes carrying quartz. Evidently the shale yielded far more prior to rupture than did the sandstone.

The Wanberg & Boyer is 10 miles north of the Bear and near the entrance to Uyak Bay. The prospect is on a veinlet 7 inches wide, striking about N. 55° E. (true) and dipping to the southeast at 65°. It lies in sedimentary schist and conforms nearly in strike, less nearly in dip. Nearby excellent glacial modeling and scratches were observed.

AMOK GOLD MINING CO.

The most serious attempt at gold-lode mining that has been made in this region was that of the Amok Gold Mining Co., whose property lies on the east shore of Uyak Bay, east of Amook Island. The property is now idle, the underground workings full of water and inaccessible, and the mill dismantled. It was visited in 1912 by Martin,[28] who wrote as follows:

Several quartz veins, all of which are reported to be gold-bearing, cut the country rock, which is black slate having a well-defined cleavage. The general

[28] Martin, G. C., op. cit. (Bull. 542), pp. 132–133.

strike of the cleavage is N. 15° E. (magnetic) and the dip is 75° NW. The bedding of the slate is much disturbed and difficult to recognize, but at one point a strike of N. 35° E. (magnetic) and a dip of 47° NW. were observed. A small intrusive mass of sill-like habit cuts the slates. This rock was determined as keratophyre.

The principal vein outcrops approximately parallel to the shore, striking N. 45° W. (magnetic) and dipping 80° SW. It is said to average 3 feet thick, with a maximum of 5 feet, and is composed of quartz with a small proportion of pyrite, no other constituents being visible to the naked eye. The number and persistence of the larger veins are uncertain, but the slates are cut by a multitude of minute quartz veins, some of which pass into zones of multiple fracturing in which there are aggregate bodies of quartz of considerable magnitude. Most of these veins are parallel to the cleavage, though a few cut across it at various angles, some of which are as great as 90°.

The underground developments consist of an adit 210 feet long, a shaft 130 feet deep, two drifts 130 and 50 feet in length, and several surface prospects. Two mills, of 5 and 10 stamps, respectively, several hundred feet of pipe line furnishing water under high pressure for power, and other outside improvements have been installed. The mills have not yet run.

A quartz vein outcropping on the beach near the present workings of the Amok Gold Mining Co. was mined by Mr. Wanberg several years ago. It is said that he took out about $8,000 in 3 or 4 years with an arrastre.

Matson's ledge is about one-half mile south of the Amok Gold Mining Co.'s property and consists of a 6- to 10-inch quartz vein striking N. 55° W. (magnetic) and dipping 60° SW. The country rock is slate and fine-grained graywacke, whose bedding (?) or cleavage strikes N. 10° E. (magnetic) and dips about vertical. A short adit and several open cuts were the only improvements seen on this property.

The present resident on the Amok Gold Mining Co.'s property, W. J. Hughes, reports that the 5-stamp mill, erected about 1906, was burned and replaced in 1912 by a 10-stamp mill, which produced only a few hundred dollars' worth of gold. Mining was discontinued for many years after 1913 but was resumed in 1926–27. The ore then mined was found to be of too low grade to be profitable, and the property has since been idle.

Martin [29] also gives the following brief account of a prospect on Afognak Island:

At a prospect on Malina Bay, Afognak Island, there is said to be a quartz vein 14 feet wide carrying gold and little silver. The vein is said to occur at the contact of slate with granite and diorite and to be cut by a porphyry dike.

According to information received from another source, an adit 140 feet long was driven several years ago on a gold- and silver-bearing vein at the mouth of the second creek inside the entrance to Malina Bay on the north shore. This locality may or may not be the same as that mentioned above.

MOYLE PROSPECT

Some prospecting has been done by Harry Moyle and his partner on Uganik Island at the north end of the neck of the peninsula that

[29] Martin, G. C., op. cit. (Bull. 542), pp. 133–134.

restricts Uganik Passage. The prospect, which was visited in August 1934, is at the contact of diorite with a hard, dense contact-metamorphic phase of the slate-graywacke series. Two short adits, one 10 feet and one 6 feet long, had been driven into the bluff at the high-tide level, and another 50 feet above them was 18 feet long. Assays from the upper adit showed only small values, but tests of ore from the lower workings are said to have showed gold and silver ranging from $7.60 to $11.67 a ton. The lode, as developed at that time, showed no well-defined single vein but consisted of bunches and stringers of quartz of irregular trend and rusty color, with some unoxidized pyrite. No production has yet been made from this property.

BRENNEMAN PROSPECT

It is reported that some 20 years ago F. R. Brenneman ran a 60-foot adit on a quartz vein in Viekoda Bay, about 4 miles southeast of Outlet Cape. This vein is said to have carried visible free gold and to have shown a thickness of as much as 2½ feet in the tunnel. The claim is said to have been patented, but no work has been done on it for many years.

BAUMANN & STRICKLER MINE

In the summer of 1934 W. E. Baumann and Ernest Strickler located a quartz vein on the east shore of Terror Bay, about halfway between East Point and the entrance to Uganik Passage. The vein, which crops out at the water's edge, strikes a little west of north, dips gently eastward, and cuts Mesozoic slates and graywackes. At the time of visit, in August 1934, it had been developed only by a few open cuts but was said to have been traced for 200 to 300 feet along the strike. As exposed, the vein consisted of 2 to 8 inches of quartz bordered both above and below by a reddish gouge an inch or two thick. Immediately above the upper gouge was a dike 6 inches thick that lay parallel to the vein throughout the distance through which they had been uncovered. Dike, vein, and gouge all show pronounced evidence of movement, and all lie along a zone in which faulting has taken place before and since the intrusion of the dike and the deposition of the quartz. The vein matter shows pronounced grooving and slickensides on both its outer surfaces, and the quartz itself is sheared into thin layers, each of which shows grooving parallel to that on the outer surface of the vein. The quartz is white, with some dark spots and flecks, and contains rusty spots from the oxidation of pyrite. Free gold, some occurring as coarse colors, may be seen with the naked eye in many specimens. Assays showing high gold tenor have been obtained. It is reported that a small prospecting mill was installed on the property in 1935 and that the ore milled yielded satisfactory returns.

DRY SPRUCE ISLAND PROSPECT

A quartz lode was located on the northeast point of Dry Spruce Island by Jack Fields in 1902, and an attempt was made to develop it during the next few years. It is said that a shaft was sunk to a depth of 30 or 40 feet in 1903 but was so wet that it was abandoned. Later an adit was driven from high-tide level S. 60° W. for a distance of 95 feet, and at 25 feet from the entrance a crosscut was driven westward for 10 feet. The sea cliffs at the portal show slate, much crumpled and faulted, striking northeast and dipping steeply northwest, cut by a reticulating network of quartz veins and bunches that for the most part have a nearly vertical dip and a northeast strike, though some strike northwest. Some of the quartz veins are in places as much as 18 inches thick, but as exposed in the cliffs they are very irregular in thickness and direction and may pinch out within a short distance. The adit was driven into the base of the sea cliff at a place where the quartz veins and bunches were most abundant, but at its face only a few quartz stringers are present. In the crosscut there is a foot of quartz on the hanging wall and about an equal amount on the footwall. The quartz is white and vesicular, with many small vugs lined with well-formed quartz crystals. It is slightly rusty in places but in the main shows little mineralization. It is reported that some very high assays were obtained from this lode and that several tons of ore from it was shipped to the Amok Gold Mining Co., of Uyak Bay, and milled there. No statistics of production are available, but the fact that the enterprise was abandoned indicates that the returns were too low to be profitable under the conditions then prevailing.

WHALE ISLAND PROSPECT

Many years ago an attempt was made by Alex. Friedland and his partners to develop a mine on Whale Island, a short distance east of Chiachi Point. At present all that remains of this venture is a shaft near the beach, now full of water, that was sunk on a quartz vein cutting Mesozoic slate and graywacke, and the ruins of an arrastre and water wheel at a creek nearby. A few pieces of white quartz in the arrastre indicate the type of rock that was milled. It is said that the tenor of the quartz was found to be too low for profitable mining, and that little gold was produced.

WOMENS BAY LODE

A group of claims on Kizhuyak Point, reported to have first been staked in 1906, have since changed ownership several times. The property is most easily approached from the small bay, locally called Womens Bay, that lies between Shakmanof Point and Kizhuyak Point, and it is commonly referred to as the Womens Bay lode. The lode lies at an elevation of about 600 feet and is connected with the beach at the head of Womens Bay by a trail through timber and thick brush, long overgrown but said to have recently been cleared out. The lode is a great quartz vein cutting diorite. It strikes N. 60° W. and dips about 75° SW., is readily visible on the surface for about 600 feet along the strike, ranges in thickness from 12 to 14 feet, and is said to have been traced for 1,800 feet and to maintain its direction and thickness for that distance. In 1934 the developments, most of which are said to have been carried out in the years immediately following the discovery, consisted of a shaft located at the top of the ridge and reported to be 22 feet deep and an adit several hundred feet southeast of the shaft, driven from the valley wall of the stream that flows to Womens Bay. The adit is said to be 152 feet long. At the time of visit in 1934 it was caved and inaccessible, and the shaft had no ladders and was partly filled with water.

The vein consists for the most part of milky-white quartz with some small diorite horses. It is distinctly banded parallel to the walls and is jointed parallel to the banding. The bulk of the quartz shows little mineralization, and this almost barren quartz was apparently introduced first. Later the vein was reopened, and sulphides and quartz of a second generation came in. At the shaft the sulphide-bearing streak lies somewhat nearer the footwall than the hanging wall, is about 18 inches thick, and consists of rather heavy sulphides and quartz, but within a short distance along the strike in either direction the sulphide-bearing portion of the vein thins out to a width of 4 to 6 inches. The metallic minerals visible to the naked eye are arsenopyrite, pyrite, chalcopyrite, sphalerite, galena, and minor amounts of the oxidation products of these minerals. It is hardly to be expected that oxidation has extended deeply into the vein, for its outcrop has been glacially smoothed and rounded, and an unknown but probably considerable thickness of it has been eroded away. Assays taken several years ago are said to have shown an average of $2 to $3 a ton in gold at the old value for that metal and some silver. More recent assays are reported to have shown an average of $8.40 a ton in gold at the present value. Just how the samples for assay were taken, or how large a portion of the vein they represent, is not known. One assay, made in the Geological Survey, of a portion of the heavy sulphide ore yielded no gold and 1.19 ounces of silver to the ton. Persistent rumors have been circulated that this ore contains commercial quantities of tin, but the sample tested showed no significant tin content, if any, and spectroscopic tests for platinum gave negative results.

So far as the writer could learn, no adequate sampling of this vein as a whole has been done. If the reported assays were averages for the whole vein, it is possible that the lode might be mined profitably with gold at its present increased price. If, however, as is suspected to be the case, the assays were taken mainly from the portions of the vein that showed the most abundant sulphides, then the amount of ore in sight is small, and it remains to be proved that there is sufficient ore to justify operating a mine, particularly as only moderate values have so far been found.

KIZHUYAK LODE

Between Kizhuyak and Crag Points, in Kizhuyak Bay, is a small group of islands, the largest of which is known locally as Larson Island, that lie across the mouth of Anton Larson Bay. Through these islands and onto Kodiak Island, south of them, there extends a narrow projection of the diorite mass of Kizhuyak Point, and at several localities along the eastern margin of this projection there are quartz veins carrying sulphides and showing a conspicuous rusty color that results from the oxidation of the sulphides. This belt of mineralization was noted especially on the southeast point of Larson Island, on a small islet just to the southeast, and on the adjacent small peninsula of Kodiak Island. It has been called the Kizhuyak lode.

This lode is said to have been first located in 1903 or 1904, and some work has been done on it at different times by various persons, though there has been no production from it. The developments include an adit 33 feet long, driven northward from the beach in a little bight on the southeastern point of Larson Island; a small open cut on the hill about 500 feet northeast of the adit and about 100 feet vertically above it; a 10-foot adit driven southward from the beach on Kodiak Island along the strike of the lode; and a small open cut on the ridge some distance south of this adit and about 150 feet higher.

The adit on Larson Island is driven on a quartz vein in diorite that strikes N. 14° W. and dips 78° W. The face shows 36 inches of white vein quartz that in places is heavily mineralized with sulphides, mainly pyrite and arsenopyrite, and their oxidation products. Several tons of the sulphide ore has been stacked at the mouth of the adit. A grab sample of this material assayed 0.14 ounce in gold and 0.74 ounce in silver to the ton. Tests for tin and platinum gave negative results. The open cut on the hill to the north, now partly filled in, shows some rusty quartz cutting diorite. The exposure is poor but serves to indicate a continuation of the zone of mineralization to that point.

Along the strike of the zone to the south, on Kodiak Island, the beach cliffs show extensive mineralization in the diorite near the contact with slates and graywackes and also in the sedimentary rocks. There are many quartz veins a fraction of an inch to 4 inches thick, forming a lode which is in places heavily mineralized with arsenopyrite and pyrite and which is rusty red with iron oxides. The full width of the mineralized zone could not be determined, as it was partly covered by soil and vegetation. A 10-foot adit has been driven from the high-tide line southward into a zone of quartz stringers cutting diorite. Several hundred feet still farther south, in line with the workings already described and at about 150 feet above sea level, a small open cut, now slumped, shows quartz in irregular bunches and veins cutting diorite. In places the quartz is heavily mineralized with arsenopyrite and pyrite and is discolored with iron oxides and a greenish stain, probably derived from the arsenic in the arsenopyrite.

The various workings described, together with other exposures along the same general trend, demonstrate the presence of a zone of strong mineralization that extends along the strike for at least three-quarters of a mile. The assays so far made indicate only moderate tenor. No systematic sampling of the lode has been carried out, and too little work has been done to demonstrate either the extent of the zone, or whether parts of it carry enough precious metals to justify the hope that a mine might be developed here.

BARLING BAY PROSPECTS

About 3 miles west-northwest of the village of Old Harbor, on Kodiak Island, and 1 mile north of the head of Barling Bay, is a large group of gold-lode claims, staked in 1933 and 1934 and owned by Fred Hinton, R. E. Krauter, Charles Cook, and Nels Christiansen. Three distinct quartz veins, known as the Brown Bear, Old Harbor, and Silver Queen lodes, are said to have been found on the property. The developments include a cabin and blacksmith shop at the head of an alluvial fan on a steep creek that emerges from a southward-trending gulch half a mile northwest of the head of Barling Bay; a trail from the cabin up the gulch to the outcrop of the Brown Bear lode; a 40-foot tunnel driven to intersect a quartz vein on the east side of the gulch some distance below the Brown Bear vein; and open cuts on the Brown Bear vein at the point where the creek crosses it. Some small open cuts and pits are also said to have been excavated at various places on all three veins.

The Brown Bear lode is considered to be the largest, most persistent, and most promising lode on the property. It crops out on both sides of the sharp gulch where it was discovered and is said to have been traced in northeast and southwest directions from the point of discovery for a distance of several miles. Open cuts have been made on it on both sides of the gulch. The country rock is composed of slate and graywacke that have a general though variable strike to the northeast, and the bedding is wavy, so that the dip ranges within a short distance from 90° to 15° SE. The vein, of massive white quartz, tends to follow the wavy bedding of the slates and graywackes and is therefore irregular in strike and dip. On the west side of the gulch a nearly vertical dike about 8 feet thick and striking about north cuts the slates and graywackes, and between the dike and the vein there is apparently a fault that cuts off the dike to the south and the vein to the north, for the vein seems to terminate abruptly in that direction. The relations were difficult to make out, for the open cut had slumped and the exposures were not good. From the fault the vein follows an irregular course to the south and east, across the creek, and disappears on the east gulch wall beneath the overburden and vegetation there. The total exposed length of the vein at that place was about 90 feet. Near the dike and the fault the vein shows nearly 15 feet of shattered and crushed quartz containing specks and bunches of sulphides, mainly arsenopyrite and pyrite. Another section showed three bands of quartz 18 inches, 30 inches, and 6 feet thick, separated by bands of oxidized slate and graywacke 30 and 18 inches thick. Both the quartz and the intervening sedimentary rocks showed some sulphides. The vein matter is said to assay several dollars a ton in gold and silver.

The Old Harbor vein is said to crop out in the same gulch at an elevation of about 1,000 feet, to average 5 feet in thickness, and to have been traced for 3,000 feet along the strike. More development work will be required before the persistence and average content in precious metals of these veins can be determined.

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