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UNITED STATES DEPARTMENT OF THE INTERIOR
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GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Bulletin 868—B

KODIAK AND VICINITY ALASKA

BY

STEPHEN R. CAPPS

Mineral resources of Alaska, 1934

(Pages 93–134)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1937

For sale by the Superintendent of Documents, Washington, D. C. - - - - Price 25 cents

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KODIAK AND VICINITY

By Stephen R. Capps

ABSTRACT

Kodiak Island, although the site of the earliest white settlement in Alaska and the center of a vigorous fishing industry, is still largely unexplored, except for a strip immediately adjacent to the shores. The heavy growth of vegetation makes access to the interior of the island difficult, and few trails penetrate far from the coast. Mining activity in the past has been confined to somewhat desultory exploitation of beach sands, which in places carry gold, though some gold-bearing lodes have been staked, and a few unsuccessful attempts at lode mining have been made. What was known of the geology of the island indicated that there was a possibility that commercially valuable gold lodes might be found, and in order to stimulate prospecting the present investigation was undertaken. A topographic map covering an area of 720 square miles in the vicinity of the town of Kodiak was completed in 1932 by Gerald FitzGerald, and in 1934 the writer spent the field season in the geologic mapping of that and adjacent areas.

The geology of this part of Kodiak Island consists essentially of a great series of upper Mesozoic slates and graywackes that have a prevailing northeast strike and steep northwest dip. The apparent thickness of this series of beds is much greater than the actual thickness, for there has been much reduplication by close folding and by faulting. These rocks were intruded in late Mesozoic or early Tertiary time by granitic masses that now appear as a great and nearly continuous mass lying along the axis of the island, as outlying satellites of this mass, and as numerous dikes and sills. At a few points in this district Tertiary sandstones lie unconformably upon the Mesozoic sediments or in fault contact with them.

Kodiak Island during Pleistocene time was a vigorous center of glaciation, and from its higher mountains glaciers that almost completely covered the island pushed out to sea in all directions. The present topographic form of the island, with its glacially carved valleys and fiorded coast line, is 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 the last few years there has been a revival of interest in prospecting in this district. On several properties assessment work was being done in 1934, and prospectors were searching the hills for new discoveries. It is believed by the writer that the most promising areas for prospecting for gold lodes lie along the contact between the granitic intrusive masses and the sediments and in both granites and sediments for some distance on each side of such contacts. Some areas not plainly related to such contacts also show mineralization, but in these areas there is some indication that granitic intrusive rocks are present at depth. The placer gold in the beach deposits at many places on Kodiak and adjacent islands was doubtless derived from lodes within the islands. There is a reasonable hope that some of these gold-bearing lodes are sufficiently rich to make profitable mines.

INTRODUCTION

Location and area.—Kodiak Island lies in the north Pacific Ocean just southeast of the base of the Alaska Peninsula, from which it is separated by Shelikof Strait. It is situated between 56°40′ and 58° north latitude and 152° and 155° west longitude and is the largest of a

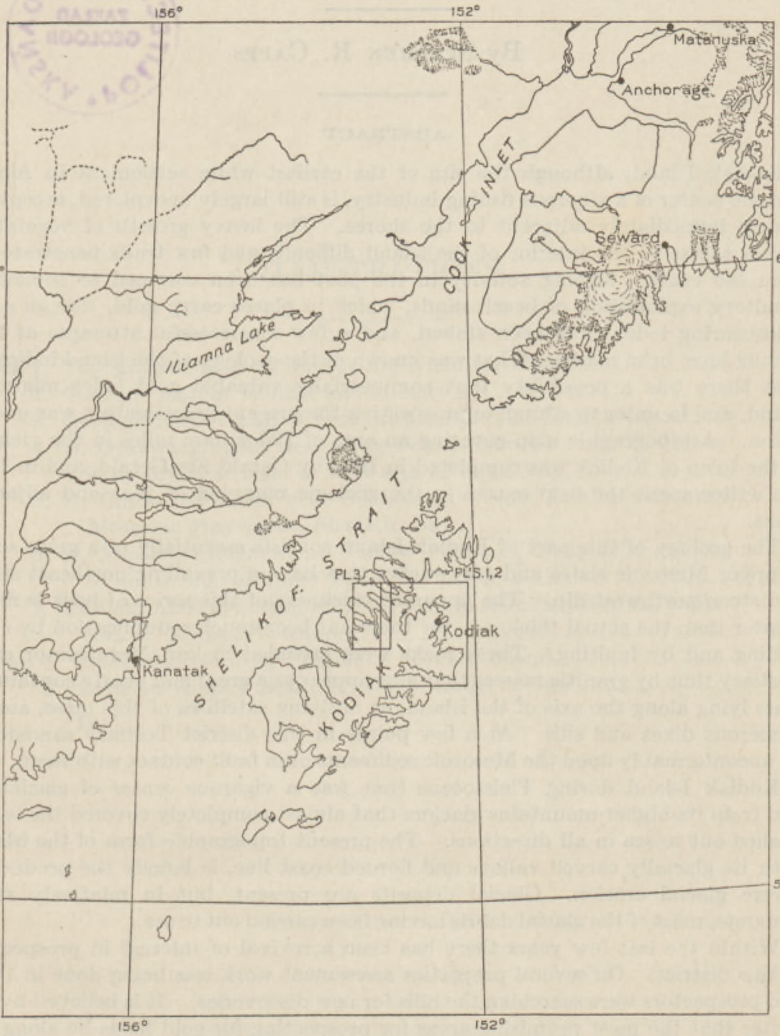


FIGURE 4.—Index map showing location of Kodiak Island.

group of islands of which Afognak, Sitkalidak, Shuyak, Uganik, Tugidak, and Raspberry are the other principal members. This group of islands, together with the Barren Islands, to the north, may be considered the southwestward continuation of the Kenai Mountains of Kenai Peninsula, for the rocks of which they are composed are similar, and their geologic structure indicates that the islands have had a similar geologic history. Kodiak Island is about 100 miles long from northeast to southwest and about 60 miles wide from northwest to southeast, but its shores are so deeply indented with bays that no point on the island lies more than 18 miles from salt water.

Figure 4 shows the position of Kodiak Island with respect to the adjacent mainland of Alaska, as well as the area described in the present report, which covers only the northeastern third of the island and parts of the smaller islands nearby.

Previous surveys.—Historically, Kodiak Island holds great interest. It is now believed by some ethnologists to lie along one of the important routes of human migration from Asia to North America, and extensive ethnologic investigations are now under way at one of the old sites of settlement on Uyak Bay, on the west coast. These investigations are still incomplete, and the conclusions reached as the results of excavations have not yet been published in final form. The written record, however, shows that this or some neighboring island was sighted by Bering on his voyage of discovery in 1741 and that by 1763 Russian trading expeditions had reached as far eastward as Kodiak Island, and the Glottof expedition wintered there.[1]

In 1783 Shelikof established a permanent post at Three Saints Bay, on the southeast coast of Kodiak Island,[2] and in 1792 the Russians moved their headquarters to Pavlosk Harbor, the present site of the town of Kodiak, which has continued to be an important trading center since that time and is the oldest continuously occupied white settlement in Alaska.

No systematic areal geologic surveys have heretofore been made of the islands of the Kodiak group, although several geologists have visited them and published reports on various phases of their geology. In 1895 Becker and Dall, of the Geological Survey, made a short visit to the island, Becker[3] being chiefly concerned with a study of the gold deposits, and Dall[4] with the coal and lignite deposits. In 1899 several geologists of the Harriman Alaska Expedition[5] studied the rocks in the vicinity of the town of Kodiak and collected some fossils there, and in 1905 this same locality was visited by Sidney Paige,[6] who also found fossils. In 1912 Martin[7] spent 2 months in studying the geology and mineral deposits of the island and compiled a geologic

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

[2] Idem, p. 224.

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

[4] Dall, W. H., Report on coal and lignite of Alaska: U. S. 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: U. S. Geol. Survey Bull. 542, pp. 125–136, 1913.

map based on his own observations and on those of the geologists who had preceded him. In 1917 Maddren [8] spent 3 weeks in studying the beach placers on the southwest side of the island. His summary statement of the general geology of the island is largely taken from Martin's report, and his own observations had to do almost entirely with Pleistocene and recent deposits. In 1932 the writer, while attached to an Alaskan survey expedition of the U. S. Navy, had an opportunity to make several airplane flights over Kodiak Island, and although no topographic map of the interior of the island was then available, and no mapping was possible, he recognized the facts that large areas in its higher and more inaccessible portions were occupied by granitic rocks and that such intrusive rocks constituted a much larger element in the make-up of the island than had previously been appreciated.

Present investigation.—In the present discussion the term "Kodiak Island" may be understood to include both that island and the numerous smaller islands which cluster about it. The study here reported covered not only a portion of Kodiak Island itself but all of Spruce and Whale Islands, parts of Afognak, Raspberry, and Uganik Islands, and all of the smaller islands in Kupreanof Strait and in Kizhuyak, Chiniak, and Ugak Bays.

As a result of the work of the geologists already mentioned, the general distribution of the rock formations on Kodiak Island had been fairly well known for some time. No systematic geologic or topographic surveys had been made, however, and the recently reawakened interest in deposits of the precious metals had created a demand for more detailed information about the island than was available. Accordingly, in 1932 Gerald FitzGerald, topographic engineer of the Geological Survey, was sent to Kodiak to map as much of the northern part of the island as time and weather would permit. In spite of a short season and unfavorable weather FitzGerald completed a topographic map covering some 720 square miles of the northeastern part of the island on a field scale of 1:180,000, and this map, published on a scale of 1:250,000 (pl. 1) is used as the base for the geologic map (pl. 2), included in this report.

The geologic work was carried out by the writer between June 27 and September 9, 1934. A 50-foot gas boat, the *Kodiak*, was chartered, captained by Wilson F. Erskine, with Seward Old as cook and helper and Larry Cope as engineer. To these men the writer owes his thanks for efficient and willing help and cooperation. 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 some detail, being traversed on foot where that was possible, or

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

Topography by Alaskan Branch
Gerald FitzGerald, Topographic Engineer
Control and shore line based upon data by U. S. Coast and Geodetic Survey.
Areas not surveyed in detail indicated by broken lines.
Surveyed in 1932

TOPOGRAPHIC MAP OF KODIAK AND VICINITY, ALASKA

Scale $\frac{1}{250000}$

5 0 5 10 15 Miles

5 0 5 10 15 20 Kilometers

Contour interval 200 feet
Datum is mean sea level

1936

where lack of beaches prevented foot travel frequent landings were made by a skiff equipped with outboard motor. Traverses were also carried inland at many places where the character of the country permitted. In reconnaissance mapping of larger areas the limitations of time forbid the running out of all geologic boundaries and the study of all rock exposures, and as a consequence it is probable that some geologic details, such as the mapping of some intrusive masses within the areas of sediments, have been overlooked. During the summer the dense growth of grass, salmonberry and rose bushes, and alder brush renders overland travel slow and difficult, and in that part of the country that lies within the zone of heavy vegetation outcrops are few, and the amount of geologic information obtainable is disproportionately small compared with the time 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, the shore lines of Ugak Bay, Chiniak Bay, Narrow and Kupreanof Straits, Viekoda Bay, and Uganik Bay and Passage cut almost at right angles across the strike of the sedimentary rocks, thus giving an exceptional opportunity to study continuous sections across those rocks. The writer realizes that more detailed studies would doubtless reveal many facts not yet recognized but believes that the portrayal of the distribution of the major rock units on plates 2 and 3 is accurate within the standards of reconnaisance mapping.

In late August and early September of the field season some time was available for a reconnaissance into portions of Viekoda, Uganik, and Terror Bays, which lie west of the area shown on plate 2. No topographic map of that area has been made, but a sketch base map (pl. 3) has been compiled from the charts of the Coast and Geodetic Survey, and on this map the areal geology is indicated by patterns. The area covered by this map adjoins to the west the area shown on plate 1.

The writer is greatly indebted to Mr. and Mrs. W. J. Erskine, of Kodiak, for hospitality while in Kodiak and for numberless courtesies, and to Nick Larionoff, of Port Nick, and Basal C. Parker, of Whale Island, for information in regard to prospecting and mining activities in the region in past years. The thin sections of the rocks collected during this investigation have been examined microscopically by J. B. Mertie, Jr., and most of the igneous rock types here listed are based upon his determinations.

GEOGRAPHY

Relief.—The general relations of Kodiak Island to the neighboring islands and to the mainland are shown in figure 4. Topographically, structurally, and geologically these islands are the southwestward continuation of the mountains of Kenai Peninsula and are properly to be considered an integral portion of the great chain of mountains that borders the Gulf of Alaska on the north and west, though separated from Kenai Peninsula by some 50 miles of salt water.

The portion of Kodiak Island here considered consists of a rugged mountain mass deeply indented by numerous bays, which give the island a very irregular outline and a long coast line compared with its area. The highest points on the island lie along the divide that separates the streams that flow to the Pacific from those that drain into Shelikof Strait; they are for the most part on mountains that are composed of granitic rocks. Altitudes of 3,800 to 4,200 feet are reached by numerous peaks around the head of Ugak Bay, and it is reported that some peaks farther south on the island are still more lofty.

The land forms of the entire island give unmistakable evidence that they have been sculptured to their present shapes through the agency of glacial ice. A discussion of glaciation on the island is given on pages 124–125, but no description of its relief and surface forms can be adequate without a recognition of the importance of glacial erosion and deposition in the development of the landscape as we see it today. Only the highest mountain ridges stood above the level of the glacial ice and so escaped smoothing. The valleys have the typical U shape in cross section, and the many deep, narrow bays are glacial fiords. In the more rugged parts of the area the dominant process was erosion and scour by the ice. In the lowlands heavy accumulations of the glacially moved debris were laid down, and it is reported [9] that the southern and southwestern parts of the island have a mild relief and include a coastal plain of considerable extent, built up largely of debris brought from the mountains by the glaciers.

Drainage.—The northern part of Kodiak Island is so deeply indented by bays that no locality in it is more than 10 miles from salt water, and consequently the streams are all short and of only moderate size. Most of the rivers flow in fairly direct courses from the higher ridges to the nearest bays, and the drainage systems are therefore simple and of small area. Even the largest streams may in ordinary stages be forded on foot in favorable places. The rivers that drain from the loftier ridges maintain a larger flow in summer than those in areas of milder relief, for the snowbanks persist longer in their basins and furnish a more constant source of water. The fairly heavy precipitation on the island (50 to 60 inches a year) yields streams that seem large in comparison with the areas of their basins. There are few large lakes in this district, and none over 1½ miles long. The only ones worthy of mention are those in the basins that drain to Saltery and Portage Bays and the next bay east of Portage Bay, on

[9] Maddren, A. G., op. cit., p. 304.

the north side of Ugak Bay; Buskin Lake, just west of St. Paul Harbor; and a lake on the low divide between upper Viekoda and Kizhuyak Bays. Within recent years the United States Biological Survey has introduced beaver to Kodiak Island, and those animals have adapted themselves promptly and multiplied rapidly, and by the building of their dams they have partly flooded the lowlands along many streams and made travel there difficult.

Climate.—The climate of Kodiak Island is influenced by the warm waters of the Japan current, which flows northeastward into the Gulf of Alaska, and is much more equable than that of inland 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, and the data are believed to be fairly representative of the climate for this district as a whole.

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 ... do	29	9.7	11.2	9.2	5.6	0.4	T	0	0	0.1	0.8	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

The extreme range of temperature is from 85° F. to −12° F. Many summers pass during which the temperature fails to rise as high as 75°, and in only 8 years out of the 46 years during which records have been kept has the thermometer 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 throughout the year, though during exceptionally cold winters ice may form on enclosed bays, particularly if they receive considerable fresh water from tributary streams.

Vegetation.—The only areas on Kodiak Island in which timber occurs are on its north end, and there only below an elevation of 1,000 feet or less. Apparently the time that has elapsed since the Pleistocene glaciers disappeared from this island has been insufficient for the trees to reestablish themselves over all the areas in which the present climate is hospitable for them, and the southward-advancing edge of the forest has at present only begun to invade Kodiak Island. Historic records and data from other sources show, however, that the edge of the forest is moving southward on the island.[10] Afognak Island, just to the north, is already well forested. By the term "forest" as used above is meant the coniferous forest, which here consists of a pure stand of Sitka spruce (*Picea sitchensis* (Bongard) Carrière). In the forest on the northeast shore of Kodiak Island and on Afognak Island spruce trees 2 to 3 feet in diameter are common and have been used extensively for local purposes. Balsam poplars (*Populus balsamifera* Linné) also occur on well-drained slopes and in the river valleys within the areas in which spruce predominates and are found farther south than the spruce, being present in small groups at least as far to the southwest as Alitak and Ugak Bays. The poplars also reach a diameter of 3 feet or more. The accompanying sketch map (fig. 5) shows the areas in which trees occur and includes both spruce and poplar.

To those unfamiliar with conditions in northern latitudes the luxuriance of plant growth in parts of Alaska seems astonishing. In this area overland travel in summer is so difficult that few people venture far from the coast. Especially in areas where timber is absent there is in most places so dense a stand of grass and berry bushes that great effort is required to push through the tangle. The commonest grass is locally known as "redtop" and in a mixed stand with ferns, fireweed, and other annual plants often grows densely to a height of 4 to 6 feet. Interspersed with the grass are such shrubs as

[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.

salmonberry, blueberry, and rose bushes. In many areas also there are dense thickets of alder brush that are almost impassable without trail cutting (pl. 4, *B*).

Agriculture and stock raising have been carried on for many years on Kodiak and Spruce Islands, as well as at other localities in this general region, but outside of the district here under discussion. Hay

FIGURE 5.—Areas on Kodiak Island in which timber occurs.

crops have been raised for many years at a farm near the mouth of the Buskin River, and wild grasses, notably redtop, beach rye, and a saltwater sedge, make excellent hay if cut at the right season and properly cured. All these grasses, however, grow in heavy, lush stands, and difficulty is often encountered in getting a sufficiently long succession of good drying days to cure hay properly. Gardens for growing quickly maturing vegetables are commonly successful, and many varieties of garden flowers flourish with surprising vigor.

Stock raising promises to be the most successful form of agriculture on this island. The abundant wild grasses afford a great supply of summer forage, and in many winters cattle do well without being fed hay or grain, though the wise stockman keeps a reserve supply of hay for use in exceptionally bad weather. Cattle, horses, sheep, and hogs have been successfully raised, though the proper breeds of hardy cattle seem to do best. Herds of cattle are maintained at several places on the island. The most severe menace to livestock is the great Kodiak bear, which at times does severe damage to herds and flocks, and until the bears can be reduced in numbers they will continue to be a hazard to stock raising. There are no other wild carnivores on the island that make trouble.

Wildlife.—Owing to the isolated position of the Kodiak group of islands it has a very meager fauna of wild animals. As the islands were completely covered by ice in late Pleistocene time, it is easy to realize that few land animals could have survived, and since the disappearance of the glacial ice the islands have been cut off from the mainland by the waters of Shelikof Strait. The only land animals indigenous to the island are the Kodiak bears, foxes, ermine, mice, and ground squirrels. Such animals as rabbits, mink, marten, lynx, land otter, beaver, black bear, and muskrat, present elsewhere throughout most of Alaska, were not native to Kodiak Island. In recent years the Biological Survey has introduced rabbits, beaver, elk, deer, and reindeer to the islands, and all seem to have multiplied and adapted themselves to the local conditions. 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. Sea otter were formerly abundant but have been exterminated.

The larger streams and the waters surrounding the islands teem with fish, and fishing is the major industry of this region. The several species of salmon, locally distinguished as king, red, humpy, dog, and silver salmon, are by far the most important, for the many salmon canneries furnish the principal employment for the people of the islands, and the fish constitute an important item in the local food supply. Herring are also packed to some extent, and valuable cod and halibut banks are found in neighboring waters. A whaling station is maintained on Sitkalidak Island, just south of the district here under discussion.

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 3 feet or more, and the Dolly Varden trout, of which great numbers that range in weight from 2 to 5 pounds each can be taken. King and silver salmon will take a lure in salt water and afford great sport to the fisherman with rod and reel.

Population.—At the time when the Russians first reached Kodiak Island the native population of that group of islands was many times larger than it is at present. A census taken by Baranof in 1795 enumerated 6,206 persons, and it was said that the Russian exploitation of the natives had then 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 United States census of 1930 the Kodiak district, which includes the Kodiak group of islands and a part of the nearby mainland of the Alaska Peninsula, contained a population in 1930 of 1,729 persons, of whom 364 were classed as white and 1,362 as natives,[11] as compared with 1,465 in 1920. In the area here under consideration the population in 1931 is given as follows, that for each village no doubt including persons living in nearby territory:

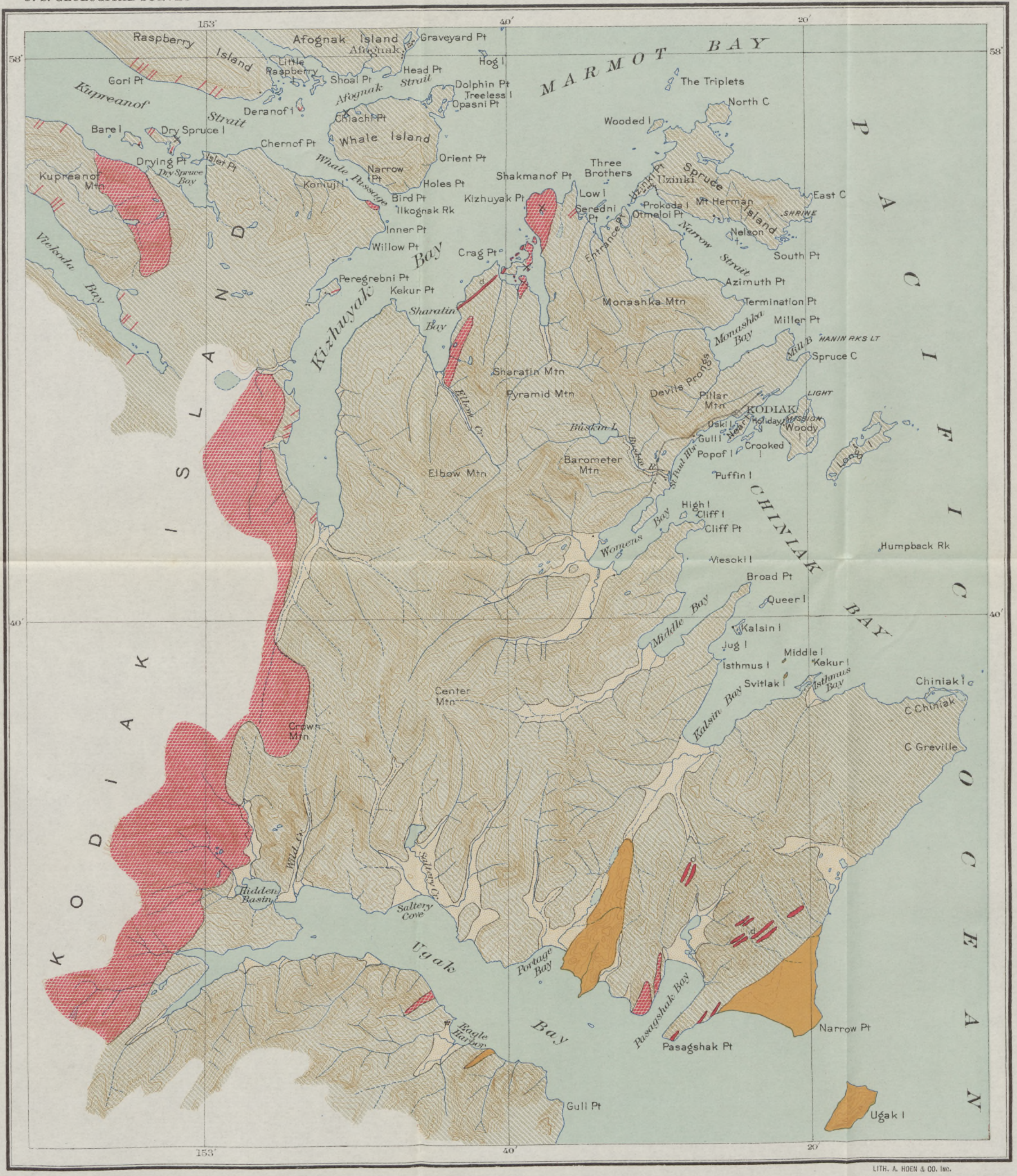
Kodiak village	442
Wood Island village	116
Uzinki village	168
Afognak village	298
	1, 024

It will thus be seen that well over half of the population of the Kodiak district is to be found within the area shown on plate 1, although that area comprises only a fraction of the area included by the census as the Kodiak district. The density of population in the Kodiak group of islands as a whole is only about one person to 2 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 of blood, many of them having a considerable proportion of Russian blood and bearing Russian names.

Routes of travel.—Kodiak Island is most easily reached from the west coast of the United States by way of Seattle, from which comfortable ships ply on a regular schedule as far west as Cordova or Seward. There passengers and freight are transferred to a smaller ship that gives local service to lower Cook Inlet and ports in the Kodiak group of islands. An occasional sailing is arranged for some vessel to go from Seattle through to Kodiak without necessitating a transfer. In summer mail, passengers, and supplies reach Kodiak from the States about once a week, but during the winter only one

[11] Discrepancy not explained.



EXPLANATION

QUARTERNARY

Present stream gravel, sand, and silt; low terrace gravel; alluvial fans; beach deposits.

TERTIARY

Moderately indurated and mildly folded sandstone of Narrow Point and Ugak Island.
(Well-indurated and steeply tilted sandstone of lower Ugak Bay and of islands off Kalsin Bay)

UNDIFFERENTIATED MESOZOIC

Slate, graywacke, and argillite
(Minor amounts of conglomerate)

LATE MESOZOIC OR EARLY TERTIARY

Granular intrusive rocks
(Mainly diorite, with some granodiorite, and gabbro at the north side of entrance of Ugak Bay)

d

Dikes and sills
(Mainly of altered diorite)

×

Gold lode prospect

Topography by Alaskan Branch
Gerald FitzGerald, Topographic Engineer
Control and shore line based upon data by U. S. Coast and Geodetic Survey.
Areas not surveyed in detail indicated by broken lines.
Surveyed in 1932

GEOLOGIC MAP OF KODIAK AND VICINITY, ALASKA

Geology by Stephen R. Capps

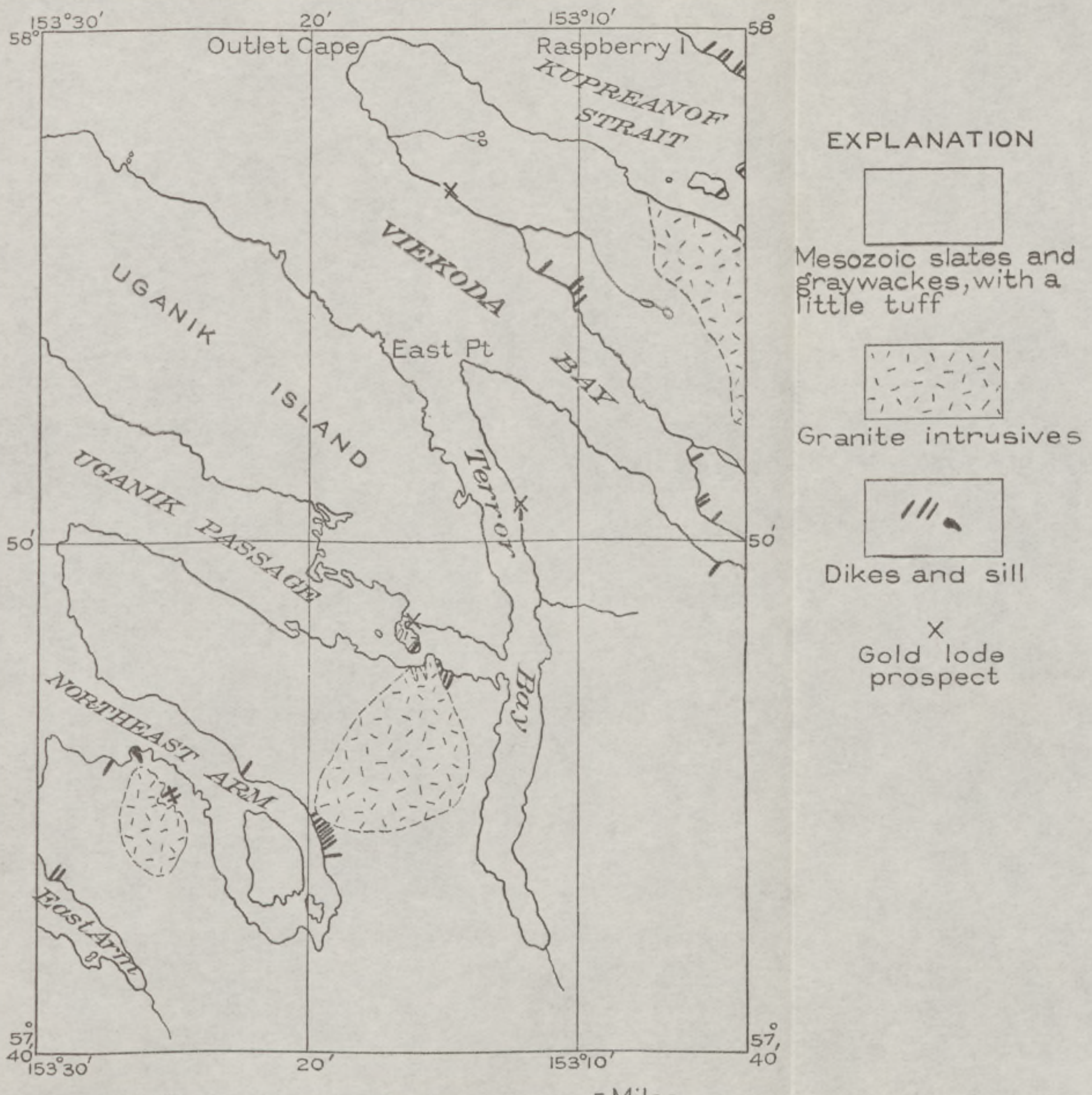
Scale $\frac{1}{250000}$

5 0 5 10 15 Miles

5 0 5 10 15 20 Kilometers

Contour interval 200 feet
Datum is mean sea level

1936



GEOLOGIC SKETCH MAP OF NORTHWESTERN PART OF KODIAK ISLAND.

sailing a month is scheduled. At irregular intervals independent vessels, operating on flexible schedules, ply between Kodiak and other Alaskan and west-coast ports.

Within the area here under discussion all settlements are on the coast, and travel is almost exclusively by boat. During the summer seagoing gas boats are operated by the salmon canneries on the island, and arrangements can ordinarily be made to go from place to place on them. There are at most settlements gas boats that can be chartered for short trips. As the chief industry of this region is fishing and as 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 of Kodiak Island is uninhabited, and roads and trails leading inland are almost completely lacking. From the town of Kodiak a road some 5 miles long and passable for automobiles has been built southwestward along the shore to a ranch on the Buskin River, and considerable work has been done on an extension of this road to the head of Womens Bay. Another road has recently been built from Kodiak to the head of Mill Bay, a distance of about 4 miles. These roads are the only roads on Kodiak Island over which cars can be taken. A few miles of poor trail, passable only on foot or on horseback, lead back from Uzinki, Afognak, and a few other places. Otherwise little or nothing has been done in this area to facilitate land travel, and large areas in the interior of the islands are unknown even to the local inhabitants.

GEOLOGY

PRINCIPAL FEATURES

The areal distribution of the geologic formations that have been differentiated in this region is shown on plate 2. The mapping of these formations was carried over the whole area during a short summer field season and is of reconnaissance character only. Much of the country is so heavily covered with vegetation that travel over it is difficult and rock exposures are not abundant. The high ridges above brush line, however, are well exposed, and the shore line offers an almost continuous exposure in sea cliffs of varying height. This shore line was examined in considerable detail, and trips inland were made at many points where the conditions of travel permitted or where geologic contacts were expected to be present. On the whole, therefore, the distribution of rock groups as here shown is believed to be fairly accurate. The determination of the age and structure of these rocks, however, is less satisfactory. Only two formations, the slate-graywacke group and the youngest of the hard-rock groups,

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of Miocene age, have been found to contain fossils that enable their age to be determined definitely. The older sediments have yielded few identifiable fossils from this region and these, although certainly Mesozoic, are not diagnostic enough to fix the age of the beds precisely. The rock group must therefore be given a place in the geologic column by correlation with similar rocks at distant points that carry the same assemblage of fossils. They are believed to be of late Mesozoic age. Furthermore, the structure of all the older sediments is highly complex. The apparently uniform northeast strike and northwest dip of these beds throughout most of the area can only be the result of duplication, for otherwise a thickness of some 40 miles of beds would be required to give the prevailing structure. Faults both large and small are numerous, but the local conditions seem to demand overturned isoclinal folding over broad areas. The oldest rocks of the island, all highly metamorphic, occur outside of the area studied, and they too are lacking in fossils and therefore are of uncertain age, though they may be Paleozoic.

The intrusive rocks of Kodiak Island are now known to be much more extensive than they were thought to be by earlier workers in this area. They are mainly of granitic character and are present in masses that with some interruptions extend along the central axis of the island from its north end at least as far to the southwest as the head of Uyak Bay. Associated with these larger intrusive masses are numerous dikes and sills that ramify into the enclosing rocks. The age determination of the granitic intrusives is somewhat uncertain and depends upon the validity of the correlation of the sediments which they cut. The best evidence is that they are of late Mesozoic or early Tertiary age.

The following table gives the stratigraphic sequence for this general district as it is now accepted. Some modifications will doubtless be necessary when more detailed work is done in this general region, and some of the rocks listed below, though present in other parts of Kodiak Island, do not appear in the vicinity of Kodiak and therefore are not shown on plate 2.

Quaternary:
- Gravel, sand, and silt of the present streams; beach deposits of sand, gravel, and shingle; bars and spits; tidal flats; talus accumulations; peat and impure organic deposits; soil and rock disintegration products in place; terrace and bench gravel, including some of glacial origin.
- Glacial deposits of Pleistocene glaciers.

Tertiary:
- Moderately consolidated and gently folded buff sandstones of Narrow Point. Of Miocene age.
- Dense mottled sandstone, in discontinuous areas in Kalsin and Ugak Bays, faulted and folded into older sediments. Of Tertiary age.
- Coal-bearing sediments on Sitkalidak Island and on south end of Kodiak Island. Probably early Tertiary.

Mesozoic:

Granitic intrusives as 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.

Cherts and volcanic rocks between Uyak Bay and Karluk River. Possibly of Triassic age.

Paleozoic (?) or Mesozoic:

Schist, greenstone, quartzite, and marble on northwest coast of Kodiak Island.

PRE-MESOZOIC SCHISTOSE ROCKS

Although the schistose rocks of Kodiak Island do not occur within the area here under consideration and have not been studied in any detail, nevertheless such rocks are known to be present in the region, and a brief description is necessary here in order to give an adequate presentation of the known facts. The following summary is based on reports by Martin [12] and Maddren,[13] together with some notes from other sources.

The schistose rocks of this area have been studied only on the northwest shore between Uyak Bay and Sevenmile Beach, though prospectors report the presence of such rocks on the peninsula between Uyak and Uganik Bays, on Uganik Island, and at other points immediately on the shore of Shelikof Strait. So far as known they do not extend far into the interior of the island and certainly are not present in its northeastern portion. They form a group consisting of rocks of diverse lithologic character, including fine-grained quartzite schist, crystalline limestone, and chloritic schist. Neither the thickness of the group nor the stratigraphic relations existing between its members or with associated rocks were determined. Pebbles of this group occur in the beach deposits near Cape Ikolik and may be derived from the adjacent peninsula, where schists are reported to occur, but no such rocks were observed to crop out near the beach. In his table of the geologic sequence Martin suggests a Paleozoic age for these schists, apparently on the ground that their more advanced stage of metamorphism indicates a greater age than that of the associated volcanic cherts and lavas, which are presumably Triassic. Much remains to be done in working out the stratigraphy, structure, lithology, and age relations of this oldest group of rocks in the Kodiak region.

Associated with the schists in the area between Uyak Bay and the Karluk River are cherts, lavas, and tuffs, all more or less metamorphosed, which Martin assigns with some doubt to the Triassic. Similar materials, described by Maddren, occur in the sea cliffs just west of the mouth of the Red River, near the west end of Kodiak

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[12] Martin, G. C., op. cit., pp. 128-129.

[13] Maddren, A. G., op. cit., pp. 301-302.

Island, where highly deformed and somewhat severely metamorphosed volcanic agglomerates, tuffs, and breccias have a massive bedding that strikes east and dips 40°–50° N. Though composed primarily of fragmental volcanic materials, some of the tuffaceous members contain rounded cobbles of dark-blue, finely crystalline hard, brittle limestone. The tuffaceous material in which the limestone cobbles are embedded is schistose and well foliated, especially around the limestone cobbles, to which it is firmly welded. Some members of this formation are highly silicified, and one massive member is altered to a bright-red jasperoid rock. Maddren notes the possibility that these volcanic clastic rocks of the Cape Ikolik area represent a lithologic phase of the cherts and volcanic rocks near Uyak, which are presumed to be of Triassic age. He points out, however, that their degree of metamorphism suggests that they may be more closely related in age to the schistose rocks of the island.

MESOZOIC ROCKS

DISTRIBUTION

By far the most widespread formation of this region is a group of sediments that consist mainly of slate, argillite, and graywacke, with minor amounts of conglomerate and a little chert. These rocks form the greater part of Afognak, Spruce, Whale, and Raspberry Islands and predominate on Kodiak Island as well, at least in those portions that have been studied geologically. They are the prevailing rocks in the areas shown on plates 2 and 3 of this report and except for the granitic intrusives are the only rocks that have large areal extent. They are definitely known to extend southward in the island at least as far as Uyak and Alitak Bays and probably occupy as much as three-fourths of the total area of the Kodiak group of islands. On the geologic map an attempt has been made to show the distribution of stream-deposited gravel, but most of such deposits are shallow, and under most of them the rocks of the graywacke-slate series are present at no great depth. Glacial deposits are also widespread, particularly in the areas of mild relief, but their margins are difficult to determine on account of the heavy growth of vegetation, and no attempt has been made to map them, the underlying hard-rock formations being shown instead.

This series as a whole consists of alternating bands or beds of fine-grained mudstone, now metamorphosed to argillite or slate, and coarser, impure sandstone, now indurated to graywacke. The other constituents of the series—namely, conglomerate, grit, limy argillite or argillaceous limestone, and tuff—are of only minor amount and are entirely absent over considerable areas and through great thicknesses of the series. Perhaps the most common phase of the series consists of alternating layers of slate and graywacke from a fraction of an inch to a foot or so in thickness. In places the banding is so fine as strongly to suggest seasonal varves, and in some places the gradation from coarse sand into fine mud, followed by a sharp change to sand again, is hard to explain on any other basis than that of seasonal deposition. On the other hand, the prevalent banding is on a coarser scale, with individual beds ranging from an inch or more to several feet in thickness, and in places there are beds of graywacke 100 feet or more thick, entirely free of mudrocks, and sections of argillite and slate several hundred feet thick, in which there are no beds of coarser material. Obviously these thicker beds are not the result of seasonal deposition but were produced by some different set of conditions. In both the mud-derived rocks and the graywackes there are ripple marks that indicate shallow waters at the time the sediments were laid down, and the great thickness of the series as a whole seems to demand a gradually subsiding basin of sedimentation that was filled with clastic deposits about as fast as it sank.

CHARACTER

Slate and argillite.—Although it was not possible to measure accurately the thickness of the different constituents of this group throughout the area and thus to determine the proportions of each to the others, nevertheless it is believed that in the region studied the sediments derived from muds—that is, the argillites and slates—considerably exceed in volume the coarser sediments, the graywackes and conglomerates, derived from sand and gravel beds. The first impression is likely to be that the graywackes predominate, for they are much more resistant to stream, ice, and wave erosion than the slates, and most of the prominent reefs and headlands contain more than an average amount of graywacke, whereas many of the bays and valleys have been eroded along belts where the weaker slates prevail.

The argillaceous sediments range from fairly massive argillites to slates and even to schists, though fissile slates are most abundant. In general the cleavage is somewhat wavy, but locally there are smooth-grained, even-cleaving slates that approach roofing slates in character. The materials of which these rocks are composed are of very fine grain and include particles of quartz and feldspar in a groundmass of sericite, chlorite, graphite, and clayey constituents. In places close to the larger granitic intrusive masses the materials have been recrystallized and have yielded a hard, dense rock that contains quartz, biotite, iron oxides, and cordierite in well-formed crystals with inclusions. Elsewhere black, glossy schists which are full of well-developed augen of cordierite and contain also quartz, biotite, and carbonaceous material and which might be termed "knoten schiefer" are also the product of thermal metamorphism in the near vicinity of large granitic intrusive bodies.

The cleavage of the slates is in places highly developed, so that the rock breaks readily into thin laminae and where exposed to the air soon disintegrates into thin flakes. In some places the slaty cleavage lies at a pronounced angle to the bedding, but more commonly the cleavage appears to the eye to parallel the bedding, particularly where the slate beds are thin and lie between beds of graywacke. This apparent parallelism of cleavage to bedding is probably due to extensive shearing movements between beds, the competent graywackes having resisted shearing and the entire movement having been taken up in the less competent slaty layers.

In many areas the slates are remarkable for the thoroughness with which they have been penetrated by quartz veinlets. A conspicuous type of this veining is one in which there is a tendency for tiny veinlets, ranging in thickness from hair lines to one-sixteenth of an inch, to lie roughly parallel with the foliation of the slate, yet with many branching and crosscutting veinlets forming an anastomosing pattern. In some of these rocks there is no area of slate more than an eighth of an inch thick that is free from these veinlets. In other types the quartz veinlets range in thickness from hair lines to considerable fractions of an inch, and in many places these merge into still larger, irregular veins of quartz. In these rocks the veins traverse the slate in all directions, without regard to the direction of foliation. Intimate veining by paper-thin quartz veinlets was observed in places, in beds intermediate in coarseness between slate and graywacke, but in general the intimate veining of the type described is much more prevalent in the slaty rocks than in the coarser members of the group.

In addition to the numerous fine veinlets described, the slates are in many places cut by quartz veins and bunches of considerable size, some of them reaching thicknesses of several feet. 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 it is suspected that there is some underlying granitic mass nearby that has not been exposed by erosion but that supplied the quartz to the overlying slates.

Graywacke.—Next in abundance to the argillaceous rocks in this group are the coarser sediments that fall under the definition of graywacke. These rocks are composed of impure sand and range in coarseness from argillite at one extreme to grit and conglomerate at the other. No doubt they are composed of material derived from many sources, but the presence in them of grains of quartz, feldspars, hornblende, micas, epidote, and other minerals indicate that the land mass of which they are the erosion product contained much igneous material. The rock also contains rock fragments, most common of which are particles of argillite and of graywacke.

The graywackes are dense, hard rocks, in general thoroughly indurated, so that they break with a conchoidal fracture. They vary in color from dark gray to almost black and are so much more resistant to erosion than the associated slates that on the wave-cut bluffs along the shores the graywacke beds stand out in relief as prominent plates, and in places where they occur in thick beds or where they are the most abundant rocks in the group, the differential erosion by waves has formed headlands with reefs extending out across the wave-cut platform (pl. 4, *A*).

A notable characteristic of the graywacke in this district, especially where it occurs in massive beds 10 to 50 feet or more in thickness, is the presence of disklike or spherical concretionary bodies in it. These concretions range from an inch or less to more than a foot in diameter. Most of them are approximately circular in a cross section parallel to the bedding but are thinner and of oval cross section perpendicular to the bedding. On a freshly broken surface the concretionary material is distinguished from the matrix with difficulty, if at all, but upon weathering, as the concretions are less resistant than the matrix, they 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 were observed in all parts of the area studied but seemed to be particularly abundant on Sharatin Bay (pl. 5, *B*).

During the dynamic metamorphism which this group of rocks has undergone the graywacke members have similarly been more competent than the associated argillaceous rocks. It is a common thing to see layers of fissile, thinly foliated slate lying between beds of graywacke that are still massive and not at all schistose. In places, however, where shearing has been especially severe, the graywacke may contain secondary micaceous minerals and show a parallel cleavage, though the degree of schistosity is even there less than in the associated slates.

The graywackes, by their resistance to fracturing, have been much less receptive hosts to the infiltration of quartz veinlets than the slates. Where quartz veins are abundant in these rocks they are likely to cut the graywacke at all angles and in all directions, without the tendency toward parallelism that is shown by the veinlets in the slates, where the veinlets tend to follow the planes of foliation. In the lack of such foliation the veins followed any irregular cracks that were open to them, and the quartz tended to form fewer but larger veinlets in the graywacke.

The larger granitic intrusive masses have profoundly altered the graywackes near their margins, yielding dense, hard contact rocks which have a metallic ring when struck with a hammer and in which enough secondary pyrite has been developed to give the rocks a rusty-red color on weathering. Some of these rocks have a faint reddish-brown to purple cast and by slight color variations still show the original bedding of the rocks. Contact metamorphism has completely recrystallized the rock, which now consists of an aggregate of quartz, biotite, iron oxides, and well-formed crystals of cordierite.

Conglomerate.—Conglomerate beds of various types and thicknesses are present in the slate-graywacke series throughout the district, though forming only a small fraction of 1 percent of the series as a whole. No sharp distinction can be drawn between graywackes and conglomerates, for many of the graywackes carry scattered pebbles and fragments of rock, and all the conglomerates contain slate and graywacke beds and lenses in which few pebbles are present.

Perhaps the commonest type of conglomerate is that which consists mainly of pebbles of black argillite in a matrix of graywacke. Conglomerate of this kind was noted on Kalsin and Jug Islands, in Kalsin Bay, where there are beds a few feet thick in which most of the argillite pebbles are only a fraction of an inch in diameter, though some as large as 4 inches were seen. Toward the head of Kalsin Bay, on the west shore, a conglomerate bed at least 30 feet thick contains well-rounded pebbles that reach 6 inches in diameter, though most of them are much smaller. There the pebbles in a dense graywacke matrix are composed mostly of black to green chert, black argillite, and quartz, though there are many acidic intrusive rocks present, including porphyries and granite.

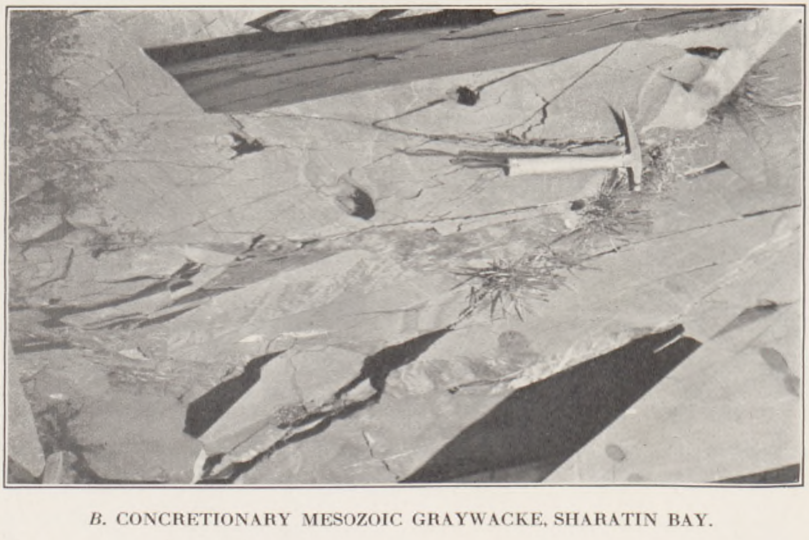
In Narrow Strait, half a mile south of Azimuth Point, irregular beds of conglomerate are present in the slate and graywacke series. They range in texture from rocks in which the pebbles are one-eighth of an inch or less in diameter to coarser bands and lenses that carry pebbles as much as 2 inches across. The most abundant pebbles are of black argillite and quartz, though chert and various igneous rocks are represented. These conglomerates are so firmly indurated that when broken they fracture across the pebbles and matrix alike.

The thickest conglomerate noted in this district occurs on the west shore of Kizbuyak Bay at the base of the peninsula that terminates in Peregrebni Point, where throughout a stratigraphic thickness of 300 feet there are alternating beds of graywacke and conglomerate. The conglomerate beds range in thickness from 2 to 15 feet and in coarseness from rocks in which the pebbles are of pea size to coarser rocks in which the pebbles average 2 inches in diameter and reach a maximum of 6 inches. The pebbles are composed of argillite, quartz, chert, and siliceous dike rocks, named in order of abundance, but include little or no granitic material. The conglomerates are distorted and somewhat sheared and are cut by many tortuous quartz stringers.

A. GRAYWACKE BEDS NEAR CRAG POINT, SHARATIN BAY.

B. HEAVY ALDER BRUSH AT HEAD OF WEST ARM OF UGAK BAY.

A. CONTORTED SLATES NEAR SHAKMANOF POINT.



B. CONCRETIONARY MESOZOIC GRAYWACKE, SHARATIN BAY.

. As a whole, the conglomerates of this series are believed to be intraformational and of no great stratigraphic significance. They lie in the midst of a thick series of argillaceous and arenaceous materials that were laid down in shallow water and are believed to be the result of local conditions that permitted the deposition of lenticular masses of coarser materials. Up to the present time it has been impossible 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 wide areas.

Tuff.—About 4 miles northwest of the head of Viekoda Bay there are outcrops of a rock that in the field was considered to be a mixture of light-green chert with a dark-green altered material that could not be identified in the hand specimen. Later study of thin sections of these rocks showed them to be made up of 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 and recemented by a network of veinlets of coarser calcite and quartz. Shadowy outlines suggest ghosts of preexisting feldspar crystals. These rocks are believed to represent original lava or tuff, probably basic, now largely replaced by chlorite, quartz, and calcite. In the field they show highly complex close folding, though they are interbedded with ordinary slates and graywackes that are somewhat less severely deformed. The altered tuff occurs in a band some 50 feet thick, and its general strike is northeast and its dip about 45° NW., parallel with and probably conformably with the associated slates and graywackes. No similar rocks were seen elsewhere in the district studied.

STRUCTURE AND THICKNESS

Although the slate-argillite-graywacke-conglomerate group in this district is in general highly metamorphosed, with slates more abundant than argillites and with minor folds and wavy structure prevalent over wide areas, nevertheless there is a major structure that is so persistent and so uniform as to be remarkable. This dominant general structure has an isoclinal dip to the northwest and a north-northeast to northeast strike. To be sure, there are local variations from this general structural trend, with beds striking east, north, or even northwest, but departures from the normal structure occur only in small areas and in many of these are due to the injection of intrusive masses that have thrown the adjoining sediments into irregular attitudes.

Upon this major northeast strike and northwest dip have been imposed many minor folds that locally may obscure the dominant trend of the rocks. Individual observations taken on small exposures

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mean little, for although the prevailing northeast strike may be apparent, any possible dip may be found on portions of the smaller subsidiary folds. The amplitude and the length from crest to crest of these minor folds range from a few hundred feet to fractions of an inch, and in a few places intricate distortion has thrown the sediments into a maze of small crushed, broken folds (pl. 5, *A*). Yet even in those places the prevailing major structure can be detected if the exposures are of large enough area.

Finely cleaving slates of even foliation and cleavage perfect enough to furnish roofing slates occur at many places, and where they are interbedded with more massive graywacke beds the foliation lies almost but not quite parallel to the bedding planes. Faulting of the sediments is common, and many gulches and gaps in the beach cliffs are developed along fault planes. The prevailing strike of the faults is parallel to the general structure—that is, north-northeast—and the prevailing dips are usually steeper than that of the bedding, but many faults were observed striking in other directions and with all possible dips. There is also abundant evidence of faulting parallel to the bedding, and the incompetent mudrocks have in the aggregate taken up a tremendous amount of movement parallel to the bedding during the development of their slaty cleavage. In so monotonous a succession of beds there is little evidence of the amount of displacement on these faults, though the extensively developed slickensides and the amount of sheared materials on some of them indicate faults of large throw. There is no definite clue as to the amount of sliding between beds that has taken place.

Surface observations of structure of the slaty rocks must be made with discernment, if reliable information is to be obtained, for on even slight weathering the thinly foliated rocks open along the cleavage planes and then become flexible, so that they are very susceptible to surface creep. Exposures along the beach cliffs show many places in which the surficial portion of the slates has crept so much as to obscure its normal attitude completely.

No definite statement can be made as to the thickness of this great group of sediments. From Cape Chiniak, at the eastern point of the island, to Cape Uganik, on the shore of Shelikof Strait, is a distance of 57 miles at right angles to the structure of the beds, and except for the interruption of a granitic intrusive mass some 6 miles wide in the center of the island, the entire 57 miles is composed of sediments of this group that have an average northwestward dip of at least 45°. If this were considered to be a normal sequence of beds, the calculated thickness would be more than 36 miles. Obviously, however, this is not a reasonable assumption. It is known that the beds have been folded, severely in places, and it is quite possible that closely compressed folds are present. Furthermore, there is no way of calculating the amount of repetition of beds that may have taken place through faulting. Numerous faults of unknown displacement are present. Nevertheless, even when these facts are borne in mind it seems necessary to believe that so wide a section of rocks, with a vertical relief of as much as 4,000 feet, must have been formed from a series of beds that as deposited was many thousands of feet thick, for nowhere in the district studied do the underlying older rocks appear at the surface.

AGE AND CORRELATION

The recognized methods by which the geologic age of a group of sedimentary rocks may be determined are (1) the finding in the rocks of fossilized organic remains, either plant or animal, whose age range is known; (2) the discovery of diagnostic fossils in rocks both above and below the strata in question, thus limiting their age to the time between the two known horizons; (3) the tracing of the beds in question into adjacent areas where condition 1 or 2 is met; or (4) correlation on the basis of lithologic similarity, structure, or some special characteristics with similar rocks of known age elsewhere. The last method is the least satisfactory of the four but must be relied on for at least a tentative age determination when the other methods fail. On Kodiak Island direct evidence of the age of the graywacke-slate-argillite-conglomerate group was obtained at only a few places, for so far it has yielded determinable fossils only from Chiniak and Izhut Bays. The absence of fossils in the more highly metamorphosed members of this group is not surprising, for during their folding, shearing, and recrystallization any organic remains that they might originally have contained would have been destroyed. But in certain of the less altered members, such as the argillites and massive graywackes, alteration has not proceeded far enough to destroy all organic traces if these had every been present, and it seems necessary to assume that these rocks, as originally laid down, were almost devoid of such animals as could have left shells behind them. The only younger rocks of the island whose age is pretty definitely known are the sandstones at Narrow Point, of Miocene age, described farther on in this report. These sandstones are quite certainly younger than the graywacke-slate-argillite-conglomerate group, for they are less well indurated, are only mildly folded, are little altered, and overlie the older group unconformably. The positive evidence is therefore that the older group is of pre-Miocene age.

In 1899 the geologists of the Harriman Alaska Expedition collected fossils from Woody and Pogibshi Islands in Chiniak Bay near the town of Kodiak, and these fossils were identified by Ulrich [14] as including a marine invertebrate that he called *Inoceramya concentrica;*

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

some worm tubes identified as *Terebellina palachei;* and a number of fucoids (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[15] also collected similar fossils near Kodiak, and on their evidence no change was made in the age assignment of the rocks. In 1912 Martin[16] collected a fossil from 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.

Other evidence as to the age of this group of sediments comes from their correlation on the basis of structure and lithology with the rocks that make up most of Kenai Peninsula and the Chugach Mountains of Prince William Sound. The dominant rock group of Kodiak Island strikes north-northeast, directly in line with Kenai Peninsula, where a great thickness of remarkably similar argillites, slates, and graywackes strikes in the same direction and has prevailingly steep dips. There too the sediments are cut by granitic intrusives and are largely barren of fossils. In the region of Turnagain Arm Park[17] has obtained from these rocks several collections of fossils that were determined to be of Cretaceous age and probably Upper Cretaceous. From this evidence, therefore, it is known that Cretaceous rocks are included in this group. In view of the very great thickness of the group, however, and of the fact that fossils have been obtained from only a part of it, the assumption that the entire group is of Cretaceous age seems unsafe at this time. Quite possibly beds of both Upper and Lower Cretaceous age may be present, as well as sediments of even older Mesozoic age. For the present, therefore, it seems best to assign these rocks on Kodiak Island to the Mesozoic, leaving for the future the more accurate determination of their age limits and their subdivision.

TERTIARY ROCKS

DISTRIBUTION AND CHARACTER

Rocks of Tertiary age occur on Narrow Point, at the north entrance to Ugak Bay, and are reported also at other localities outside the district here described—for example, on Sitkalidak Island, which lies adjacent to the southeast coast of Kodiak Island; on the southern

[15] Paige, Sidney, unpublished notes.
[16] Martin, G. C., unpublished note.
[17] Park, C. F., Jr., The Girdwood district, Alaska. U. S. Geol. Survey Bull. 849–G, pp. 393–394, 1933.

portion of Kodiak Island; and on the Trinity Islands, just south of Kodiak Island. A few other small areas in the district here discussed are occupied by rocks (described below) that are tentatively considered to be of Tertiary age.

Narrow Point is a bold headland which is exposed to the open ocean and against which a heavy surf breaks almost constantly, so that for weeks at a time it is impossible to land on the point 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 writer was therefore fortunate in finding one day calm enough to permit a landing for a short time near the southern point of the cape and in obtaining a close view of the southward-facing cliffs from a small boat. This headland for a distance of about 3 miles in a northwesterly direction from the cape is composed of rather massive fine-grained gray to buff sandstone. (See pl. 6, *A*.) 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 upon close scrutiny. The sandstone is well cemented and stands in steep 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 on weathering. One bed a foot or so thick was so full of fossil shells that it approached a limestone in composition, although the shells were embedded in a sandy matrix. Locally the sandstone contains spherical concretions that reach a maximum diameter of 3 feet.

At several other localities in this district there are sandstones that are here tentatively classified as of Tertiary age, though no fossils were found in them. On the north side of Ugak Bay, just east of Portage Bay, the shores for a distance of more than 2 miles are composed of massive sandstone. This area and a small islet off the mouth of Portage Bay and a wedge of sandstone just east of Eagle Harbor, all alined along the same structure, are believed to be parts of a single geologic unit. Remarkably similar sandstones were also found on Svitlak, Middle, and Kekur Islands, in the mouth of Kalsin Bay, and these islands likewise lie along the projected strike of the sandstones of Ugak Bay. At all these localities the sandstones are rather massive, so that their bedding is indistinct. All have a greenish cast, are more thoroughly indurated than the rocks of Narrow Cape, and contain fairly coarse fragments of slate. Those on Kekur Island contain rounded concretionary bodies from a fraction of an inch to several inches in diameter. A thin section cut from a specimen collected on Svitlak Island showed a fragmental rock composed largely of angular to subangular grains of minerals derived mainly from granitic rocks. In addition there were particles of rhyolitic rocks, chert, and slate, and secondary chlorite, sericite, epidote, and calcite were recognized. All these sandstones show more metamorphism and chemical alteration than the sandstones of Narrow Point, which are fresh and little altered.

STRUCTURE AND THICKNESS

The sandstones of Narrow Point, as exposed on its south shore, are mildly folded and form two shallow synclines separated by a low anticline. These folds strike about northeast. The steepest dips observed were at the south tip of the point, where the beds dip 38° NW., but the average dips are not more than 15° or 20°. No faults were observed, and apparently a stratigraphic thickness of about 1,000 feet of beds is exposed. The contact of these sandstones with the slate-graywacke series to the northwest is not exposed, but the relation is either one of faulting or an unconformable overlap of the sandstone upon the much more steeply tilted slate-graywacke beds.

The structural relations of the sandstones on the islands at the mouth of Kalsin Bay are not known. In Ugak Bay, however, the sandstones are much faulted and dip at steep angles. In general appearance they seem younger than the adjacent slate-graywacke beds, but how much of their present position is due to faulting and how much to infolding with the slate-graywacke rocks is not known.

AGE AND CORRELATION

Fossils collected at Narrow Point were submitted to W. P. Woodring, of the Geological Survey, who reports as follows:

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 Pliocene age. Fossils of similar aspect described by Grewingk [18] and Dall [19] were referred by Dall to the Miocene, but they may be Pliocene. *Mytilus middendorffii* 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

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

[19] Dall, W. H., Correlation papers—Neocene: U. S. 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.

from the Yakataga region is said to be of Oligocene age.[20] 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, is also 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.[21]

The collection above described was the only one obtained from the sandstones of Narrow Point, but it rather definitely fixes their age as Miocene or Pliocene. The age of the other sandstones from Ugak Bay and the islands of Kalsin Bay is, however, less certain. Their structure is more complex, they have been more severely folded and faulted, and they show a greater degree of chemical alteration than the sandstones of Narrow Point. Whether this more advanced metamorphism is due to greater age or to the fact that the beds occur in an area of more severe deformation is not known. Their structural relations to the adjacent Mesozoic rocks suggest an age greater than that of the Miocene or Pliocene beds of Narrow Point, as does also their greater induration and alteration. On the other hand, they are less metamorphosed and apparently younger than the associated Mesozoic sediments. For the present all that can be said is that they are probably Tertiary and of Miocene age or older.

INTRUSIVE ROCKS

CHARACTER AND DISTRIBUTION

Considerable areas along the rugged mountain axis of Kodiak Island are composed of granitic rocks, which are really much more extensive than has heretofore been supposed. An earlier generalized geologic map of the island [22] shows only two small masses of intrusive rock, both on the coast, but in 1932 the writer made several flights over the island by airplane, and although no adequate map was available on which to plot his observations, he noted that much of the rugged ridge that forms the main north-south divide of the island is composed of granitic rocks that occur as fairly large masses and as smaller outlying bodies. During the present investigation several of these granitic bodies were mapped in whole or in part, and the completed map of the island will eventually show that granitic rocks are abundantly present. Associated with them are numerous dikes and sills, and the impression given is that much of Kodiak Island is underlain by a great intrusive body from which many small projections extend upward into the overlying sediments, and that

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

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

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

erosion has so far exposed only the projecting apophyses of a much larger, concealed mass.

It is not surprising that earlier casual geologic examinations of the shores of this island overlooked the extent of the intrusive rocks, for these rocks 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. The development of normal stream valleys in preglacial time was naturally most rapid in belts of easily eroded rocks, and the slates and graywackes were much more easily carved than the harder intrusive rocks. Later on the stream valleys were occupied by glaciers through a succession of glacial advances, and the ice widened and deepened the depressions in the softer rocks, leaving the more resistant intrusive rocks as the prominent ridges forming the drainage divides. Within the district here discussed the coarser-grained granitic rocks of this kind can be observed at the shore line only at the head of the central arm of Ugak Bay; on the south shore of Ugak Bay, 2 miles northwest of Eagle Harbor; on Kizhuyak Point; in Sharatin Bay; on the north slope of Kupreanof Mountain; and at the narrows of Uganik Passage, although at a number of other places they occur within a mile or less of the shore. Numerous dikes and sills of the same general composition but of different texture were seen in the shore cliffs at many places. In places these dikes and sills are abundant within a few miles of the larger granitic masses but are absent at greater distances from them. This spatial relation and the similarity in composition indicate a common source of origin, and there seems to be little reason to doubt that they represent penetrations by the granitic magma through cracks and along bedding planes into the overlying sediments to a considerable distance beyond the front of the main body of invading magma. Considered as a group, these rocks are predominantly mica-quartz diorites, but some contain as much as 30 to 40 percent of potash feldspars. The more alkaline phases might be described as granodiorites. Some approach monzonites in composition. One dike rock is a muscovite granite.

By far the largest body of granitic rock mapped is that which forms the main north-south divide of the island and extends from the upper part of Kizhuyak Bay southward at least to the head of the basin drained by Ugak Bay. Its southern and western limits lie in unmapped areas and are not known. This granitic mass is at least 27 miles long and is in places more than 5 miles wide. It has a known surface area of at least 60 square miles, and its actual area may be several times that large. This mass is of medium to coarse texture and is prevailingly of gray color, owing to a white background of quartz and white feldspar flecked with biotite and in places with hornblende. Four thin sections cut from specimens collected in the headward basin of Ugak Bay were quartz diorite or mica-quartz diorite and contained quartz, andesine, biotite, iron oxides, and apatite. Two of the specimens also showed hornblende, and one showed secondary chlorite and sericite. Two other specimens were collected from this same mass some 20 miles north of Ugak Bay, on the west side of Kizhuyak Bay. One of these might be classified as muscovite granite and contained quartz, orthoclase (some of which is graphically intergrown with quartz), a little plagioclase, and muscovite. The other was a mica granodiorite containing quartz, both plagioclase and orthoclase feldspar, with the plagioclase dominant, biotite, and muscovite.

It cannot now be stated with assurance whether this intrusive mass represents a single period of intrusion, with considerable variation in the composition of the magma from place to place, or more than one period. The area occupied by the intrusive rock is rugged, the lower slopes are heavily covered by vegetation, and much more detailed work than has been given to it will be required to answer the many questions that might be raised in regard to the sequence of events at this place.

On the south shore of Ugak Bay, 2 miles northwest of Eagle Harbor, a small body of granular intrusive rocks cuts the Mesozoic sediments in a belt about half a mile wide. Its southward extension was not mapped in detail. This rock yielded three specimens, two of which proved to be biotite granodiorite containing quartz, orthoclase, microcline, plagioclase, biotite, apatite, and iron oxides, with a few specks of pyrite. The feldspars, particularly the plagioclase, are much sericitized, and the biotite is almost completely altered to chlorite and epidote. The third specimen was a quartz diorite containing quartz, andesine, some orthoclase, much almost colorless hornblende, biotite altered to chlorite, iron oxides, and apatite.

In the northern part of this district, at Kizhuyak Point and on 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 rock, none more than a few square miles in area, and of related intrusive rocks that fall under the definition of mica granodiorite. These rocks are of fairly coarse grain, are gray, and contain quartz, orthoclase, much sericitized plagioclase, chloritized biotite, muscovite, and apatite. One specimen of a rather fine-grained pinkish rock from a small islet just south of Larson Island was a muscovite granite composed of quartz, orthoclase, albite, muscovite, and a few grains of chloritized biotite.

Kupreanof Mountain, on the south side of Kupreanof Strait, lies within an area of about 10 square miles of mica-quartz diorite much like that found in the great mass that extends southward from

Kizhuyak Bay. Similar bodies of quartz diorite also occur between Uganik Passage and the Northeast Arm of Uganik Bay, and also between Northeast Arm and East Arm, where a quartz diorite mass forms a prominent mountain.

Numerous dikes and sills cut the Mesozoic sediments, particularly in the vicinity of the larger diorite and granodiorite masses. Most of them are thin, ranging from a few inches to a few feet in thickness. They are conspicuous in the steep, bare shore cliffs, where their light color contrasts with the somber shades of the sediments into which they are intruded, but few of them could be traced inland beneath the vegetation-covered slopes above the cliffs, and the linear extent of most of them is not known. The largest dike in this district is the one that extends southwestward from the intrusive mass of Kizhuyak Point across several small islands and behind Crag Point to Sharatin Bay, a distance of 4 miles. This dike strikes northeast and dips about 50° SE. At its northeast end, near the diorite mass of which it is an offshoot, it is about 150 feet thick, but on Sharatin Bay it has thinned to 50 feet. It is finer-grained than the diorite of Kizhuyak Point and shows fewer dark-colored minerals.

Dikes and sills are particularly abundant on the west side of upper Kizhuyak Bay, on Raspberry and Dry Spruce Islands, in Viekoda Bay, in the narrows of Uganik Passage, and on the Northeast Arm of Uganik Bay. At all these localities the relation of the dikes to nearby large masses of granitic intrusive rocks is evident, and in places the dikes and sills can be traced directly into the diorite masses. In chemical composition the dikes and sills were probably much like the parent intrusive bodies at the time they were injected, though of finer grain, owing to their more rapid cooling. Thin sections cut from several of them show that they are much more altered than the coarser diorites and granodiorites, with the feldspars and dark minerals generally altered to calcite, chlorite, sericite, and other secondary products.

At the northeast entrance to Ugak Bay, on both sides of a shallow bay, intrusive rocks that occur as dikes and sills are much more basic than any of the intrusives already described. They are of fairly coarse grain, are dark gray, 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 shores but extend an unknown distance inland beneath the heavily vegetation-covered slopes.

STRUCTURE AND AGE

The intrusive rocks were injected into the Mesozoic sedimentary beds, as is shown by the fact that they cut across the bedding at all angles, and in places they have profoundly altered the host rocks by contact metamorphism. The intrusive rocks, however, particularly those of dioritic types, are much less affected by faulting, folding, and dynamic metamorphism than the sediments into which they were intruded, for uncrushed, massive dikes and sills lie in contact with much crumpled and highly fissile slates. It is therefore evident that a large part of the dynamic metamorphism to which the sediments were subjected had been completed before the injection of the dioritic intrusives. The gabbros of lower Ugak Bay appear to be more crushed and folded than the dioritic rocks and may be somewhat older, though this may be a local condition only.

As all these intrusives cut sediments that are believed to be of Mesozoic age and probably include beds of Upper Cretaceous age, it is evident that the intrusive rocks are at least as young as Upper Cretaceous. No intrusives were observed in the Miocene sandstones of Narrow Point or in the sandstones of Ugak and Kalsin Bays, which are also believed to be of Tertiary age. The evidence from this region, therefore, indicates an age for the intrusives somewhere between the Cretaceous and the Miocene. Elsewhere in the coastal mountains of Kenai Peninsula and Prince William Sound granitic intrusives cut Mesozoic rocks but are absent in the coal-bearing Tertiary beds, now assigned to the Eocene. This indicates a period of intrusive activity at about the end of Mesozoic or the beginning of Tertiary time, and for the present the intrusive rocks of northern Kodiak Island are considered to be of that age.

QUATERNARY DEPOSITS

PREGLACIAL CONDITIONS

No detailed studies have been made of the series of events that occurred on Kodiak Island during Pleistocene time, but from what is known of past climates of the Pacific coast region of Alaska in general, it seems safe to assume that Kodiak Island had a somewhat similar history. Thus it is believed that for a long time during the Tertiary period this region had a temperate climate, somewhat warmer than that of today. By the end of the Tertiary the present mountains had been formed, most of the pronounced crustal folding and faulting had been completed, and the general outlines of the islands were as we see them today, though in detail they presented a very different appearance. The rugged mountain masses had been attacked by normal streams and had been reduced to a stage of youthful maturity. Deep valleys, radiating from the central mountains, had been cut so as to give a complete drainage pattern, but the valleys, being stream-cut, were narrow-floored and walled with steep ridges that rose to narrow, rugged interstream divides. It is probable that instead of the present deeply embayed coast line the outline of the island was much smoother, with the streams flowing to the outer coast, each of them having developed a delta or a shoal area built up of the detritus brought down during the development of its valley. Many of the present small islands that now border Kodiak Island were then part of it, and it is likely that Afognak and Kodiak Islands were then a single larger island.

GLACIATION

Pleistocene time, or the glacial period, was introduced by a change in climate that was world-wide and that witnessed the development of glaciers over enormous areas in the Northern Hemisphere. Whatever may have been the ultimate cause of this development of glacial ice, there was in this region a lowering of the mean annual temperature so that more snow fell in the mountainous areas during the winters than melted away during the succeeding summers. As a consequence of this accumulation of snow, glaciers formed, at first only in the heads of protected valleys on the slopes of the higher mountains, but later, as the climate became more severe, at lower and lower altitudes. Thus a multitude of individual glaciers were formed, and as they grew they gradually extended down their valleys. Tributary ice streams joined in the larger valleys to form many-branched trunk glaciers, and the trunk glaciers widened, thickened, and lengthened until they reached the sea and pushed out into tidal waters to some distance. This series of events was repeated several times during the Pleistocene, epochs of ice accumulation and severe glaciation being succeeded by epochs of milder climate, or interglacial stages during which the glaciers melted away in part or altogether. These repeated glacial invasions had profound effects upon the topography of the island. Cirques were formed at the valley heads, the glacier-occupied valleys were broadened and deepened by ice scour, overlapping spurs and irregularities were ground away, and broad glacial troughs were formed. Such ridges as projected above the ice surface 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. The lower valleys of many of the main drainage lines were eroded below sea level, so that on the retreat of the glaciers deep inlets and bays were left.

The succession of events on Kodiak Island during the glacial epoch has not been worked out in detail. Just how much of the glaciated topography as we see it today was due to the erosive action of the ice during the last great glacial advance and how much of the sculpturing was accomplished during earlier ice invasions is not known. Indeed, at the present time no deposits that can be definitely attributed to a glacial advance earlier than the last have been found. During the last ice advance, which doubtless is to be correlated with the Wisconsin stage of glaciation in the United States, the development of the glaciers was so great that evidences of earlier advances were for the most part obliterated or buried. Except for the highest peaks and ridges Kodiak Island was completely buried by glacial ice that originated locally and that flowed seaward in all directions from the central mountain ridges. At the time of its greatest development Kodiak and Afognak Islands formed a continuous center of glaciation, Marmot Bay and Afognak, Narrow, and Kupreanof Straits all being ice-filled, and this glacial center was completely surrounded by ice cliffs that projected into the sea. All the present bays were occupied by great ice streams, and it is even possible, though not yet proved, that glaciers from this island center pushed westward into Shelikof Strait and there joined eastward-flowing glaciers from the Alaska Peninsula, thus connecting these islands with the mainland.

After the climax of the Wisconsin stage of glaciation was reached the climate again slowly became milder and glacial melting was more rapid than ice accumulation, so that the ice began to thin and the edges of the glaciers began to melt backward. More and more of the higher ridges appeared above the level of the ice, and the fringing islands and outermost capes emerged as rocky headlands, separated by the still great valley glaciers that flowed out of the many bays. With continued melting these valley glaciers retreated back into their basins, large areas in the regions of mild relief were freed of ice, and those valley troughs that had been eroded below sea level became arms of the sea.

At the present time the progress of deglaciation on these islands is almost complete. A single small glacier about half a mile long survives in the headward basin of Ugak Bay, on the sheltered north slope of a 4,000-foot mountain, but few spots have the necessary altitude and protection from the sun to allow glaciers to exist under present climatic conditions. Considerable areas within the higher mountains of the island are still unmapped and unexplored, and it is possible that a few other small glaciers persist, but there are no glaciers of noteworthy size on the island.

GLACIAL DEPOSITS

Although the ice withdrawal from this region is virtually complete, there is still left abundant evidence in the topography of its former presence, and morainal material and outwash gravel are widely distributed in the lower portions of the island. By far the greater portion of the rock waste removed by the glaciers from the highlands was carried out to and deposited in the sea, so that it is not now available for examination, but throughout the district here described, except on the highest and steepest ridges, there are traces of morainal material. Where the relief is steep glacial deposits occur only in patches, and there usually only in thin sheets. In the lowlands, however, such as the lower slopes of the main valleys and on the capes and peninsulas of moderate relief, there is generally a layer of glacially derived waste, either unassorted morainal material or gravel deposited by the streams that drained from the ancient glaciers. The luxurious grass lands and brushy areas 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 glacial clay a few feet thick, but locally, as at the village of Uzinki, there are exposures of 20 to 30 feet of blue glacial till. All the exposures of morainal materials examined were blue and almost completely unoxidized. This lack of weathering testifies to their comparative youth, and they were without doubt laid down by the glaciers of the latest (Wisconsin) glacial stage. These glacial and glacial-outwash deposits are of great economic importance, for they form the soils upon which the luxurious growth of grass, brush, and forest now flourishes. There has been too little time since the disappearance of the glaciers for residual soils, formed by the chemical and mechanical disintegration of bedrock, to accumulate in sufficient amount to furnish a general soil covering over the island.

Since the last withdrawal of the glacial ice normal processes of erosion have been resumed by the streams, which have been engaged in the process of developing gradients fitted to their volume and load. Many small lakes have been partly or completely filled; overdeepened portions of the old glacier floor have been aggraded; and the great quantities of gravel, sand, and silt supplied by the waning glaciers and by postglacial stream erosion have been distributed along the valley floors and deposited in the heads of the bays, to form extensive shoal areas. Each bay head into which a large stream empties has now an extensive delta in progress of building, and shoals, exposed at low tide as broad mud flats, extend far out from the mouths of the streams. In general the amount of postglacial stream cutting in hard rocks has been small, but in places sharply incised gulches have been eroded into slopes that were left smooth by the latest glaciers (pl. 6, *B*).

Concurrently with the slow filling of the bays with detritus brought from the land by the streams, there is a steady attack by the waves on the many prominent capes and headlands. This encroachment on the land by the sea is naturally most rapid at those places where there is least protection from the full force of the storm waves, and already a well-developed wave-cut platform, backed by a sheer rock cliff, can be recognized at many places on the coast. Indeed, the outer shores of Kodiak and the neighboring islands are everywhere characterized by steep rock cliffs standing above a wave-cut rock platform. This process, together with the filling of the bays and the growth of sand spits and bars along the coast, will eventually result in a much smoother and less indented coast line than exists at present.

ALLUVIUM AND BEACH DEPOSITS

In the present investigation no attempt was made to map the superficial deposits in those areas in which the bedrock is covered by talus slopes, soils, and even the thinner glacial deposits, the purpose being to show the distribution of the rock formations wherever their presence could be determined with reasonable certainty. In areas where fairly extensive alluvial deposits occur, however, an attempt has been made to map them (pl. 2). Such alluvial deposits are confined almost exclusively to the valleys of the major streams, particularly to those whose valleys were overdeepened by glacial scour and so served as favorable basins for catching and retaining the detritus brought down by the streams after the glacial ice retreated. No doubt many of these broad valleys were embayments of the sea when first bared of glacial ice, but later they were filled by delta deposits and still later aggraded by stream-laid gravel, sand, and silt. This filling process is still actively in progress. In a few protected bays short, steep streams from the bordering mountain ridges have been able to build out alluvial fans into the bays, such as those on the south side of upper Ugak Bay and on the east side of Kizhuyak Bay.

Extensive beach deposits are almost entirely lacking in this part of Kodiak Island. The rocky shores descend steeply into fairly deep water, and the material cut from the cliffs by the erosion of the waves is quickly carried out and deposited in the sea. There are few places where one can walk along the beach for any considerable distance at high tide, for at short intervals there are steep cliffs or headlands below which no beach is exposed.

VOLCANIC ASH

A dramatic event in the history of this part of Alaska occurred in 1912, when Katmai Volcano, on the Alaska Peninsula west of Kodiak Island, exploded violently, covering the northern part of the island with volcanic ash and pumice to a depth of several feet. At the time it seemed that the island had been rendered uninhabitable. The grass and lower vegetation was completely buried, water supplies were polluted, wild animals and birds were destroyed, and the fishing industry, the commercial mainstay of the inhabitants, was ruined (pl. 7). The recovery of the region from the ash fall was, however, almost as spectacular as the disaster itself. Vegetation soon pushed through the ash and reestablished itself upon it, first on the lower lands and later at progressively higher elevations. In 1934, 22 years after the explosion, only a keen observer would notice its results. To be sure, any excavation through the vegetative ground cover reveals the presence of the ash, now compacted to a layer a foot or so in thickness, and on the higher slopes of the mountains, above the zone of abundant vegetation, there are still patches of bare ash to be seen. One notable result of the ash fall is recognizable in the rapid filling that has occurred in the heads of many shallow bays into which the larger streams drain. 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 Viekoda Bay, where the coast charts, based on surveys before the eruption, show as much as 4 fathoms of water, the flats are now bare at low tide, and the shoal areas at the heads of many other bays are much more extensive than they were before the Katmai eruption.

MINERAL DEPOSITS

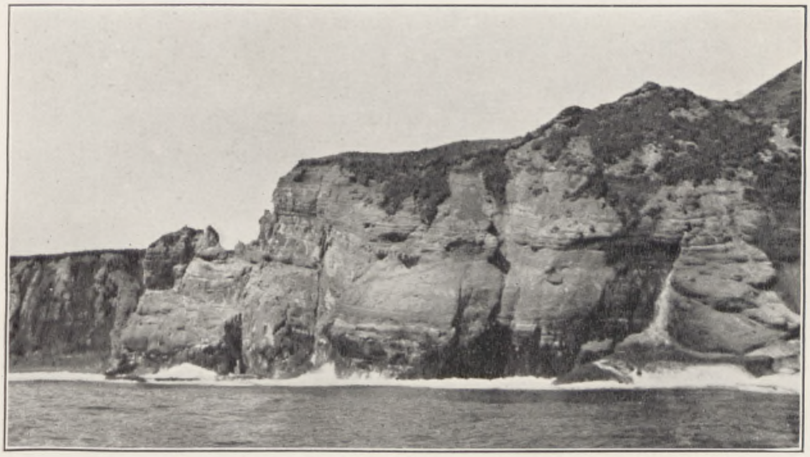
GENERAL CONDITIONS

There are no mines in the area here described that were productive in 1934. For many years certain beaches on the western and southwestern coasts of Kodiak Island have been worked intermittently for placer gold, with which is recovered a very small proportion of the metals of the platinum group. These placer deposits were visited in 1917 by Maddren,[23] 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 mined extensively on those beaches suggest that the figures given by Maddren are too small. No records are available, however, upon which to base a reliable estimate of the total production from the Kodiak beaches. During the last 20 years only desultory operations have been carried on, and the annual production has averaged only \$1,000 or some such amount.

All the beach placers occur at localities where the waves have attacked extensive deposits of glacial till and outwash gravel, and the beach-placer deposits are believed to be the result of concentration by waves of vast quantities of unconsolidated material, the gold content of which was very small. Nevertheless the presence of even small amounts of gold in glacial deposits that were derived from somewhat local sources on this group of islands indicates that gold mineralization has occurred on the islands and that it may have been localized in places into lodes that are yet undiscovered.

Attempts have been made from time to time to develop gold-lode mines on Kodiak Island, but all these attempts have been short-lived and have ended in failure. These failures are not to be taken as evidence that no worth-while lodes exist there, but they reflect on

[23] Maddren, A. G., The beach placers of the west coast of Kodiak Island, Alaska: U. S. Geol. Survey Bull. 692, pp. 299-319, 1919.



A. MIOCENE SANDSTONE AT NARROW POINT.

B. POSTGLACIAL GULCHES ON SOUTH SIDE OF UPPER UGAK BAY.

KODIAK, ALASKA, IN AUGUST 1912, SEVERAL MONTHS AFTER THE EXPLOSION OF KATMAI VOLCANO.

The thick covering of volcanic ash is everywhere apparent.

the judgment or the management of those men who undertook their development. With the present increased price of gold there has been a stimulus to renewed prospecting, and it is possible that this will result in the discovery of profitable properties. The general geographic situation is good, for freight rates to and from any portion of the island should be reasonable, and the numerous bays and harbors offer excellent sites for shipping facilities.

All the prospects examined occur in or within a few miles of some one of the granitic intrusive masses, and their mineralization is believed to be genetically related to these intrusives. The abundant quartz veining in the Mesozoic sediments seems also to be related to the granitic intrusive rocks, though that relationship is less well established. There seems to be more secondary silica in the sediments that lie near the borders of the intrusive stocks than elsewhere, though quartz veins and veinlets are common throughout the district. Most of these veins show little or no mineralization, however, and the lack of mineralization in general but its presence in a few veins suggests that there has been more than one period of vein formation. In one large quartz vein on Kizhuyak Point the outer portions of the vein are almost barren of metallic minerals, though the center portion in places shows abundant sulphides. This relation indicates that at this place a period of quartz deposition with little metallic content was followed by a later period of injection by quartz accompanied by sulphides. Elsewhere in the district no evidence of the relation between the unmineralized and mineralized quartz veins was seen.

PROSPECTS

Womens Bay lode.—A group of claims was staked many years ago on a lode on Kizhuyak Point and has since been restaked several times and by various persons. This property is most easily approached from the small bay, locally called "Womens Bay" (not to be confused with Womans Bay, southwest of Kodiak), that lies between Shakmanof Point and Kizhuyak Point. It is reported that this lode was first staked in 1906 and that most of the development work was done in that and the next few years. The lode lies at an elevation of about 600 feet and was formerly connected with the beach at the head of Womens Bay by a trail through timber and thick brush, but the trail is now so overgrown as to be almost obliterated. The lode is a great quartz vein cutting diorite. It strikes N. 60° W. and dips about 75° SW., is readily visible for about 600 feet along the strike, and is said to have been traced for 1,800 feet and to maintain its direction and thickness for that distance. It ranges in width from 12 to 14 feet. The developments consist of a shaft on the top of the ridge and said 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 the small bay. The adit is said to be 152 feet long. It is now badly caved and inaccessible, and the shaft has no ladders and is 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 were introduced. At the shaft the sulphide streak lies somewhat nearer the footwall than the hanging wall, is about 18 inches thick, and consists of rather heavy sulphide material 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. Assays taken some years ago are said to have shown an average of $2 to $3 to the ton in gold, at the old value for that metal, and some silver, but more recently several assays are reported to have shown an average of $8.40 to the ton in gold at the present value. One assay, made in the Geological Survey, of a portion of the heavy sulphide ore showed no gold and 1.19 ounces of silver to the ton. Persistent rumors had been circulated that this ore contained important 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 at a profit with gold at its present price. If, however, as is suspected, the samples assayed were taken only from the portions of the vein that carry the most abundant sulphides, then the amount of ore in sight is small, and it remains to be proved that sufficient ore is present to justify considering the deposit as more than a prospect, particularly as only moderate values have so far been found.

Kizhuyak lode.—Between Kizhuyak and Crag Points, on Kizhuyak Bay, is a group of small islands, the largest locally known as Larson Island, that lie across the mouth of a bay referred to locally as Anton Larson Bay. Through these islands and onto Kodiak Island south of them extends a narrow projection of the diorite mass of Kizhuyak Point, and along the eastern edge of this projection there are several localities in which quartz veins carrying sulphides are present and which show conspicuously the rusty stains that result 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 southeast of Larson Island, and on the small peninsula of Kodiak Island, still farther south, It has been called the Kizhuyak lode.

Developments on this lode include an adit 33 feet long driven north from the beach in a little bight on the southeast 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 and about 150 feet in elevation above this adit. This lode is said to have been first located in 1903 or 1904, and the work on it has been done at different times since by various persons. There has been no production from it.

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 showed on assay gold 0.14 ounce and silver 0.74 ounce 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 lode 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 sediments. There are many quartz veins a fraction of an inch to 4 inches thick, forming a lode which is locally 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 an elevation of about 150 feet, a small open cut, now slumped, shows quartz in irregular bunches and veins cutting diorite. In spots the quartz is heavily mineralized with pyrite and arsenopyrite 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 values. 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.

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.

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 to 40 feet in 1903 but was so wet that it was abandoned. Later an adit was driven from the high-tide level S. 60° W. for a distance of 95 feet, and 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 others strike northwest. Some of the quartz veins are in places as much as 18 inches thick, but as exposed in the cliffs they are irregular in thickness, and many pinch out within a short distance. The adit was driven into the sea cliff at a place where the quartz veins and irregular bunches are most abundant, but at its face only a few quartz stringers are present. In the crosscut there is 1 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-developed 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 the quartz, and that several tons of it was shipped to a mine in Uyak Bay and milled there. No statistics of production are available, but the fact that the enterprise was abandoned indicates that the tenor of the quartz was too low to be profitable.

Baumann & Strickler prospect.—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 edge, strikes a little west of north, dips gently eastward, and cuts slates of Mesozoic age. At the time of visit it had been developed only by a few open cuts but was said to have been traced for 200 to 300 feet. As exposed, the vein consists 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 is a dike 6 inches thick that lies 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 surfaces 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 a high gold tenor have been obtained, and it was reported that a small prospecting mill was to be installed on the property in the spring of 1935.

Brenneman prospect.—It is reported that some 20 years ago F. R. Brenneman drove a 60-foot adit on a quartz vein in Viekoda Bay, 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. The claim is said to have been patented, but no development work has been done on it for many years. It was not visited by the writer.

Mayle prospect.—Some prospecting has been done by Harry Mayle and his partner on Uganik Island, at the north end of the neck of the peninsula that restricts Uganik Passage. The prospect lies at the contact of diorite with a hard, dense contact-metamorphosed phase of the slate-graywacke series. Two short adits, one 10 feet and one 6 feet long, have been driven into the bluff at the high-tide level, and another 50 feet above them is 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 so far developed, shows no well-defined single vein but consists 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.

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