Geology and Ore Deposits of Northwestern Chichagof Island, Alaska

DARWIN L. ROSSMAN

MINERAL RESOURCES OF ALASKA

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MINERAL RESOURCES OF ALASKA

GEOLOGY AND ORE DEPOSITS OF NORTHWESTERN CHICHAGOF ISLAND, ALASKA

By Darwin L. Rossman

ABSTRACT

The area studied includes most of the northwestern part of Chichagof Island. The work, started in 1946, is a continuation of the geologic mapping done in the adjoining Chichagof mining district by Reed and Coats. The gold-bearing zone recognized by these writers continues through the area mapped to the northern shore of Chichagof Island.

Bedded rocks ranging in age from Paleozoic(?) through Early Cretaceous were intruded by gabbro, quartz diorite, norite-gabbro, and younger quartz diorite.

The major metamorphism and deformation occurred concomitantly with the intrusion of the diorite, which is believed to have been contemporaneous with the orogeny during which the Coast Range batholith in the eastern part of southeastern Alaska was emplaced.

The oldest rocks, called the marble-gneiss sequence, probably of Paleozoic age, crop out in the northeastern half of the area. Within the mapped area blocks of rocks of this sequence are engulfed in the diorite and have been metamorphosed to gneiss, schist, and marble. Relatively unmetamorphosed, thin-bedded limestone, chert, black siltstone, and sandstone, probably the youngest rocks of the marble-gneiss sequence, crop out in a belt that extends from near Stag Bay southeast to the Chichagof mining district. These rocks underlie, unconformably(?), a massive greenstone unit, which is considered to be the oldest unit of Mesozoic age in the mapped area.

The bedded rocks of Mesozoic age consist of four major units, all in apparent conformable relation to one another. From oldest to youngest they are called: the greenstone, marble, schist, and graywacke units. The greenstone unit, probably of Triassic age, is composed of massive greenstone which is somewhat amygdaloidal in the upper part. The marble unit is composed of nearly pure marble. The schist unit is predominantly greenstone and metamorphosed siltstone but includes chert, limestone, and graywacke. The graywacke unit, of Early Cretaceous age, is dominantly graywacke with some siltstone, limestone, and, in the uppermost exposed part, greenstone. In certain areas the rocks in these units have been thoroughly recrystallized.

The igneous rocks from oldest to youngest are: gabbro, diorite, quartz diorite, the rocks associated with the nickel deposit, which include gabbro-norite and quartz diorite, and basalt. The diorite probably formed during Early Cretaceous time, and the gabbro is older. Much of the gabbro and diorite is believed to be recrystallized older rock. The oldest group of quartz diorite intrusives cuts the diorite, and is therefore younger. The quartz diorite is generally somewhat foliated and slightly metamorphosed.

The igneous rocks associated with the nickel deposits are the youngest of the major intrusive igneous rock groups. They intruded the graywacke of Cretaceous age after it had been folded to its present position.

Mafic and felsic dikes are present in almost equal proportions. They range in age from older than the diorite to younger than the youngest quartz diorite. Aplite dikes, the most abundant type, had their source in the older of the two quartz diorite intrusives. These dikes are intimately associated with most of the gold deposits in the area. Some of the pegmatite and quartz-feldspar dikes were probably formed by replacement.

A mafic rock believed to be a basalt plug crops out on the north shore of Lisianski Inlet. This body is probably the youngest igneous rock in the area.

The bedded rocks in the area constitute the western flank of an anticlinorium which has been made structurally complex by the injection of large igneous intrusive masses. Near the southwest side of the area the rocks of Mesozoic age dip steeply southwestward and strike northwestward. North of Lisianski Inlet, rocks of Paleozoic(?) age are completely surrounded by diorite.

Faults are widespread in the area. The best developed fault set strikes northwest and dips steeply to the northeast or southwest. Along many of these faults the last movement had a strong horizontal component. Generally evidence of displacement is lacking. A large fault along Lisianski Inlet appears to have caused the repetition of 5,000 feet or more of stratified rocks of Mesozoic age north of the Inlet. Quartz diorite has been intruded along it at several places. The northwestward-trending faults cut all the consolidated rocks, including the graywacke unit. A northeastward-trending fault set also cuts the rocks of the mapped area, but the set is not as well developed as the northwestward-trending set.

The northeastward-trending faults have smaller displacements than the northwestward-trending set, but are important economically because it is along them that gold-bearing quartz veins have been found.

Gold is the most important mineral commodity mined to date. The Apex and El Nido are the two largest mines in the area; gold has also been recovered from the Goldwin and Cobol properties and smaller amounts from other prospects. In addition to gold, the area includes nickel-bearing deposits at Mirror Harbor on Chichagof Island and at Bohemia Basin on Yakobi Island. The area north of Goulding Harbor contains copper. The best area for prospecting, judging from the regional geology and the number and kind of quartz veins found, appears to be along a northwestward-trending zone which extends from the head of Pinta Bay to the northern end of Althorp Peninsula.

INTRODUCTION

The area of this report is in the northern part of southeastern Alaska (fig. 39). It includes about 400 square miles on northwestern Chichagof Island, latitude 57°47′ to 58°15′ N. and longitude 135°57′ to 136°35′ W. It is covered by U. S. Geological Survey Mount Fairweather A–1, A–2, and Sitka D–7 and D–8 topographic quadrangle maps.

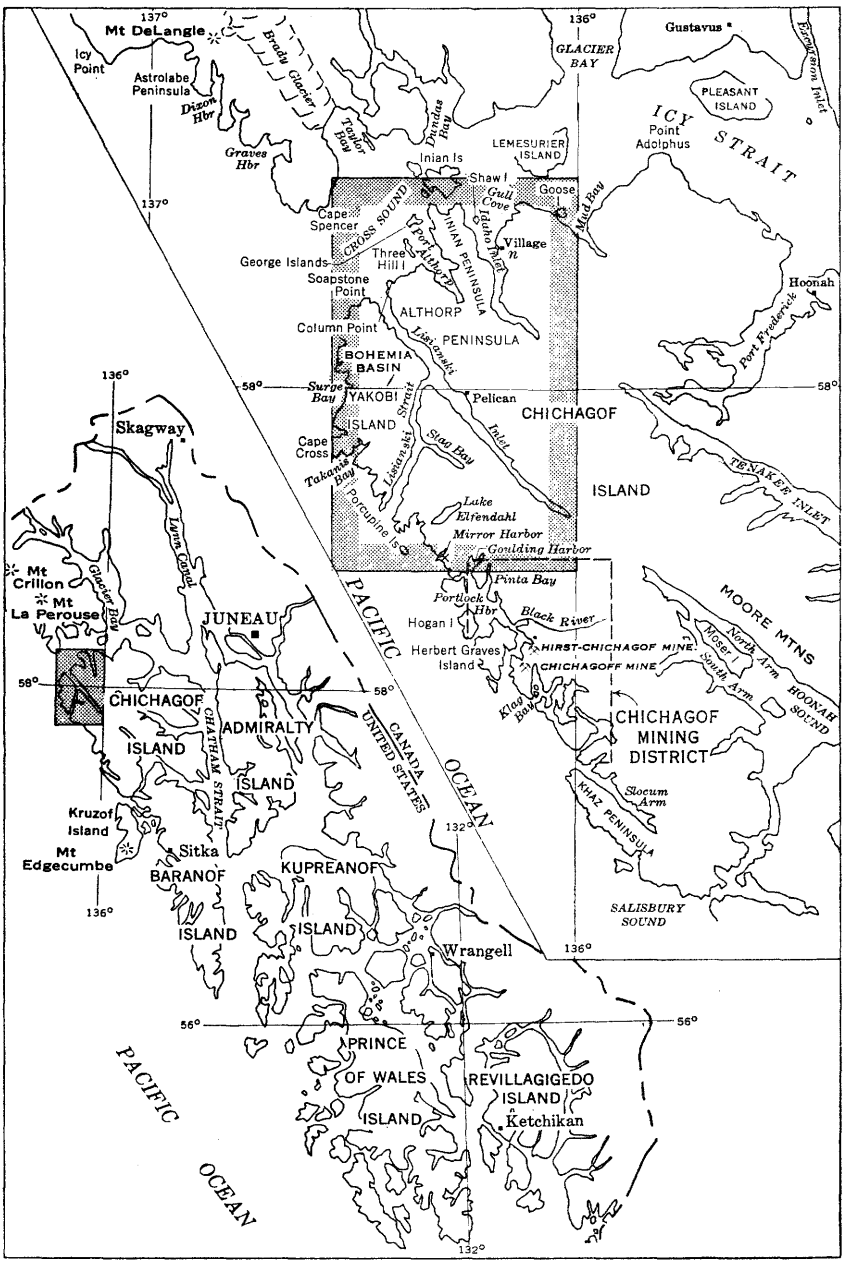

FIGURE 39.—Index map of southeastern Alaska showing location of mapped area.

The writer's geologic investigation was started in 1946 as a continuation of earlier work on the west coast of Chichagof Island by J. C. Reed and R. R. Coats (1941) of the U. S. Geological Survey.

Geologic fieldwork on Chichagof Island is hindered by the dense vegetation below timberline, the moist climate, and the sharp relief which renders some areas either inaccessible or accessible only with difficulty. On the other hand, rock exposures are good above timberline, along the many miles of shoreline, and along many of the streams that course down the steep mountain slopes. Rock weathering is slight and rarely masks rock textures or structures. Except in the large valley bottoms, outcrops are abundant and well exposed. Commonly the geologist can map the main geologic features, such as contacts and rock formations, with considerable confidence.

Gold is the most economically important of the known minerals of northwestern Chichagof Island, and the only one that has been profitably mined. Copper and tungsten also are present, and nickel-bearing deposits have been explored at Bohemia Basin on Yakobi Island and near Mirror Harbor on Chichagof Island. Although parts of Chichagof Island have been prospected since 1900, the interior is still largely unprospected, and ore deposits probably remain to be discovered. For example, during the course of the geologic mapping the writer found several small veins containing some free gold, although little time was spent solely in search of ore-bearing veins; however, no large vein networks, like those common in many important mining districts, were found that were not known previously, and probably no such network remains undiscovered within the mapped area.

HISTORY AND PREVIOUS INVESTIGATIONS

Chichagof Island was one of the last of the large islands in southeastern Alaska to be settled by white men, and little is known of the history of the area before 1800. The island has been known by various names. Early Russian maps show it as Sitka Island, Chicagos Island, and Tchitchagoff Island. Captain Cook sailed along the coast in 1778, and later Cape Cross was named from a cross on his chart that indicated his position on May 3, 1778 (Cook, 1785, p. 279). Cross Sound certainly was named because of its proximity to Cape Cross. Vancouver in 1794 with the ships *Discovery* and *Chatham* entered Cross Sound on returning from Prince William Sound. He spent 3 weeks mapping Port Althorp, which he named, and some of the coastline of Cross Sound nearby. Meanwhile three of his small boats under the leadership of Mr. Whidby explored Icy Strait and Lynn Canal (Vancouver, 1801, p. 211–244). On one of

his maps Vancouver showed Chichagof and Baranof Islands as King George III Archipelago. The following is quoted from the Geographic Dictionary of Alaska (Baker, 1906):

> Chichagof; island or group of islands, Alazander Archipelago. Named by Lisianski, 1805, after Admiral Chichagof. First known to the Russians as Yakobi or Jakobi, a name restricted by Lisianski, in 1805, to an island at the northwestern angle of the group, and the name Chichagof applied to the remainder. It forms the northern part of King George III's archipelago of Vancouver. The native name is Kuna or Hooniah. Variously called Chichagov, Chichagoff's, etc., and erroneously Chicagos.

A rich gold-bearing vein, later known as the Chichagof vein, was discovered in 1905, and the mining town of Chichagof was founded soon after. The town of Kimshan Cove was founded about 1917 near the Hirst-Chichagof mine. In 1919 the Apex vein was discovered near Lisianski Inlet and in 1920 the El Nido vein was found. The veins at the Cobol prospect were discovered in 1921.

In 1926 the island was photographed from the air by the U. S. Navy Department; the U. S. Geological Survey used the Navy photographs to assemble the first reliable map (Alaska topographic map 8, Chichagof-Baranof Islands, 1936).

Most of the published geologic mapping of the northern part of Chichagof Island has been done by members of the U. S. Geological Survey. The discovery of gold on Chichagof Island was first reported by C. W. Wright (1905, p. 45–46), who spent part of 1904 examining the south shore of Chichagof Island and the adjacent shore of Baranof Island. In 1905, Wright again visited Chichagof Island and made a reconnaissance survey along the western and northern shores. In 1906 he visited the claims that later became the property of the Chichagof Mining Co. During this season he examined the rocks along the northern shore of Chichagof Island, as well as parts of Yakobi Island and some of the land along Icy Strait. Wright (1907) subsequently wrote a short report on the general geology of parts of Baranof and Chichagof Islands and on the mining and prospecting activities in the Chichagof mining district. Adolf Knopf (1912) spent 3 weeks in 1909 examining the Chichagoff [sic] mine and studying the geology of the surrounding area. In 1917, R. M. Overbeck (1919, p. 91–136) spent 2 months examining the rocks along the west coast of Chichagof Island and along Peril Strait. His report describes the regional geology and ore deposits in more detail than the earlier reports. The next geologic investigation was by A. F. Buddington (1923, p. 95–105; 115–125) who spent a few days investigating mineral deposits on Chichagof and Yakobi Islands. In his reports he described several important ore deposits that had been discovered between 1917 and 1923.

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Buddington and Theodore Chapin published a bulletin (1929) in which are assembled the geologic data available at that time about southeastern Alaska. Reed (1938, p. 52–80; and 1939) visited Chichagof Island several times between 1936 and 1938 and published two reports of mining activities in the area. During the summer of 1938 Reed made a detailed investigation of the geology and mineral deposits of the Chichagoff and Hirst-Chichagof mines, and in 1939 Reed and Coats (1941) mapped the Chichagof district. This work was the first attempt at systematic geologic mapping on Chichagof Island. Although Reed and Coats mapped only about 200 square miles, many of their geologic interpretations and inferences are applicable to this report.

In 1940, Reed assisted by J. V. N. Dorr 2d (1942, p. 105–138), mapped about 5 square miles around the nickel deposits on Yakobi Island. W. T. Pecora (1942, p. 221–243) mapped the nickel deposit at Mirror Harbor in 1941. In 1942, G. C. Kennedy (Kennedy and Walton, 1946) searched Yakobi Island for nickel deposits.

PRESENT INVESTIGATION

When the present investigation started in 1946, it was planned to continue the geologic mapping of that part of Chichagof Island that lies north of Chichagof mining district and south of the valley between Idaho and Tenakee Inlets. Later, the scope of the project was increased to include all the northern part of Chichagof Island as far as longitude 135°20′ W., exclusive of the areas previously mapped by other Survey geologists.

Between June 1 and September 10, 1946, the writer, assisted by M. C. Lachenbruch and H. E. Banta as camphands, mapped about 150 square miles in the area centering around the head of Lisianski Inlet. From May to October 1947, the writer assisted by R. J. Newton, geologist, completed most of the remaining geologic mapping south of Lisianski Inlet.

Geologic mapping was continued in the summer of 1948 with the aid of R. E. Thaden and C. E. Sifton, geologic field assistants. From May 19 to June 9 the area around Stag Bay was mapped and several traverses were made on Yakobi Island. Althorp and Inian Peninsulas were mapped between June 10 and June 22. From June 23 to August 3 the area to the north and southwest of Idaho Inlet was examined. Some of the geologic features exposed along the shores of Port Althorp, the George Islands, and the Inian Islands were examined in detail during the remainder of the season to September 1.

The writer has modified and included on plate 12 geologic mapping of the vicinity of Mirror Harbor done by W. T. Pecora (1942); of

Yakobi Island by J. C. Reed and J. V. N. Dorr 2d (1942), and by G. C. Kennedy and M. S. Walton, Jr. (1946). The rock types, geology, and ore deposits of these areas have not been studied by the present writer in detail, and consequently the discussions concerning them are small. The area mapped by Reed and Coats was designated by them as the Chichagof mining district, and in this report it is referred to under the same title.

During field mapping, a base map sufficiently accurate for use in direct plotting of geologic features was not available. As an alternate method, the geologic data were plotted in the field on aerial photographs. Subsequently the data were replotted on enlarged copies of the standard U. S. Geological Survey topographic sheets.

The location of traverses was controlled largely by the geology and the terrain. Usually traverses were so spaced that contacts and rock units could be projected from one traverse to another with reasonable certainty. The average distance between traverses was about half a mile. In areas underlain by homogeneous rocks, such as diorite, the traverses were as much as a mile apart. Areas which were covered by detrital material or which were so heavily overgrown with vegetation that outcrops were virtually absent were largely unexamined.

Foliation of igneous rocks was mapped where observed, but because the traverses were spaced relatively far apart over the igneous rocks, the structural pattern shown is incomplete. Faults were mapped both in the field and from examination of aerial photographs; however, comparatively few faults have been shown on the geologic map (pl. 12) that were not observed in the field.

ACKNOWLEDGMENTS

Many residents of northwestern Chichagof Island aided the project materially. A. S. Thompson, in the fall of 1947, carried most of the party's field equipment, without charge, from Pelican to Juneau. The Pelican Cold Storage Co., under the supervision of Gene Torkilsen, helped the writer on many occasions. During the winter of 1947–48 the boats used by the writer were stored without charge by the Pelican Cold Storage Co. At times Mr. Torkilsen also provided transportation for the party. Mrs. J. H. Cann, in charge of the Apex-El Nido Mining Co., permitted the writer to map and study the property and to use many of the mine and assay maps. The U. S. Forest Service and the U. S. Coast Guard both assisted the party; their help is gratefully acknowledged.

GEOGRAPHY

Northwestern Chichagof Island is a mountainous, glaciated, coastal area. Fiords, carved by glaciers, penetrate well into the central part of

the island. Mountains rise directly from the sea in steep, nearly unscalable slopes of bare unweathered rock. Many of the streams course down the mountainsides in an almost continuous series of waterfalls. Everywhere evidence of recent glaciation is seen: In the spires and arêtes which rise above the former level of the old icecap, in the cirques which lie on every major mountain peak, in the abundant U-shaped valleys, and in other bedrock landforms sculptured by the action of glacial ice.

The major peaks rise to altitudes ranging from 3,000 to 3,600 feet. Most peaks are snow covered and in one of the highest a small glacier remains, sheltered from the sun by the steep headwall of a deep cirque. The topography is controlled by the underlying rock. The softest and most easily eroded rocks form the lowest and most subdued landforms, and the hard resistant rocks form the mountains and upland areas.

Vegetation is dense. Gravel-filled valleys and the more gentle mountain slopes are heavily timbered. Moss hangs from the trees, and in heavily wooded areas it forms a thick mantle over the ground and fallen trees. Except in the thickest forest, undergrowth is dense, and a tangle of fallen trees, brush, and other plants covers much of the area below 2,000 feet in altitude. Below timberline, talus-covered slopes and old landslides and snowslides are covered with an almost impenetrable growth of salmonberry bushes and gnarled alders. Above timberline little brush is found and the mountains are covered with heather and other small plants such as lupine, Indian paintbrush, and grasses and sedges. Low flat areas are covered with muskeg, a type of swamp formed by mosses and grasses decaying into a peatlike mass.

Trails are quickly obliterated by vegetation and those which where found were nearly impassible. Access to much of the country below timberline was most easily achieved by following the stream beds.

Pelican, Elfin Cove, and the village on Idaho Inlet are the only permanent settlements within the mapped area. The largest village, Pelican, has a permanent population of several hundred persons. It is on the north shore of Lisianski Inlet, 14 miles southeast of Cross Sound. The principal industry centers around a cold-storage plant and a salmon cannery. The town also has a sawmill, one or more restaurants, and several grocery stores. Elfin Cove is a small fishing village in a sheltered harbor on the west coast of Inian Peninsula. The unnamed village on the east side of Idaho Inlet, 3½ miles southeast of Shaw Island, consists of several families. Shaw, Inian, George, Three Hill, and Porcupine Islands have been used in the past as fox farms.

The climate of northwestern Chichagof Island has a marked influence upon the country and upon the human activities within it. The most important feature is the rainfall, which is heaviest in October,

decreases sharply in November, and gradually diminishes each month until the end of June. The rainfall normally increases progressively each month thereafter until November. Several graphs that show the variation in precipitation and temperature have been prepared from records published by the United States Weather Bureau's climatological data (1941–46) (fig. 40). There is a marked difference in the total rainfall at points separated by only a few miles. In general, the areas most exposed to winds from the ocean are the warmest and wettest. All the weather stations are outside the mapped area, with the exception of the station at Gull Cove. The station at Cape Spencer is on the north side of Cross Sound. Gustavus is on the north side of Icy Strait a few miles east of the entrance to Glacier Bay. Radioville is on a small island at the south edge of the Chichagof mining district (fig. 39). The weather station at Sitka on Baranof Island is about 80 miles from Pelican. It is the only weather station listed whose data are possibly not directly applicable to the weather of Chichagof Island. It is thought, however, that the weather on northern Chichagof Island is sufficiently similar to that at Sitka to warrant inclusion of the climatological data from Sitka.

Cross Sound receives a great deal of cold glacial melt water from Brady Glacier and from Glacier Bay. The moist air, warmed by contact with the ocean, upon sweeping over the cold water of Cross Sound has its moisture condensed into fog, which often besets the adjacent land but does not reach far inland. The top of the fog usually does not exceed 2,000 feet in altitude.

GEOLOGY

The northwestern part of Chichagof Island is underlain almost entirely by highly recrystallized rocks of Mesozoic and Paleozoic age, and by extensive bodies of igneous rock that are dominantly dioritic in composition. Within the mapped area, the regional trend of the rocks is northwest, parallel to the axis of an anticlinorium that involves most of the bedded rocks in the north end of southeastern Alaska (Buddington and Chapin, 1929, p. 315–316). The thick succession of rocks of Mesozoic age that crops out in the southwestern part represents the eastern flank of a geosyncline to the west of the anticlinorium. These rocks of Mesozoic age consist mainly of greenstone, slate, schist, and graywacke. The anticlinorial core lies to the east on the eastern part of Chichagof Island and in the central part of the Glacier Bay area. The exposed rocks are dominantly limestone and argillite. The only rocks believed to be of Paleozoic age within the mapped area are now highly recrystallized sedimentary rocks that crop out as isolated bodies within the diorite (pl. 12).

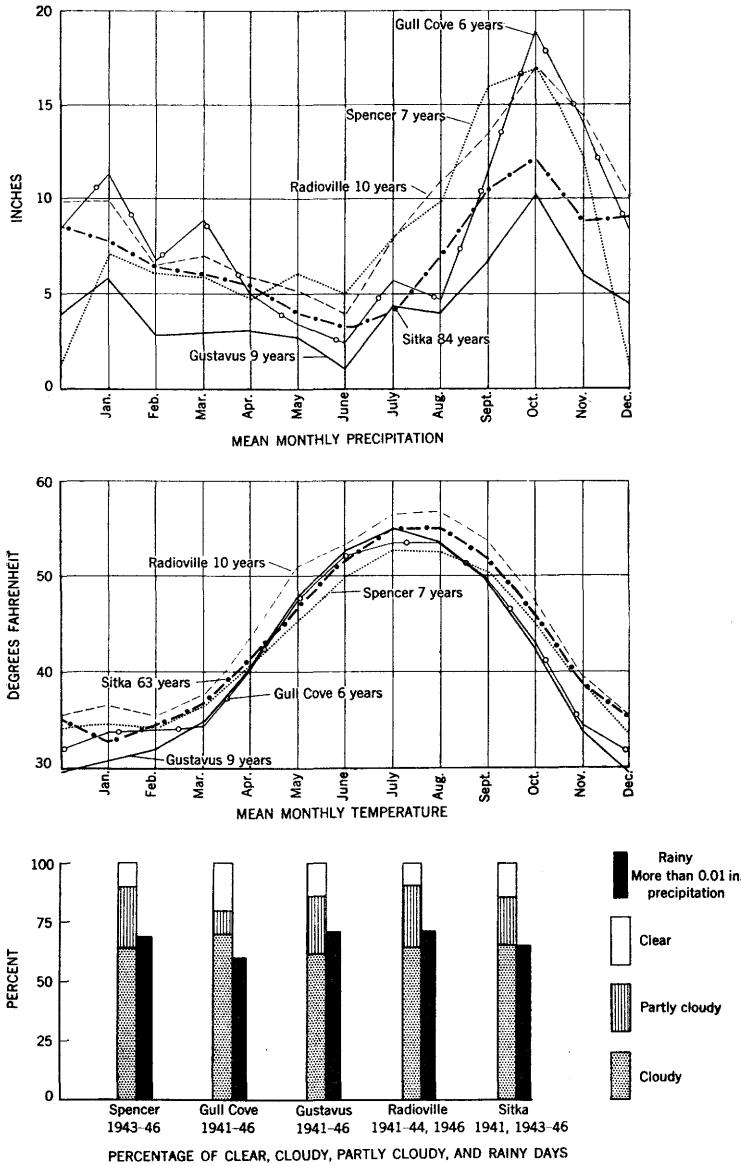

FIGURE 40.—Climatological data on northwestern Chichagof Island, Alaska.

The main period of intrusion probably took place during the later part of Early Cretaceous time. The dioritic body itself consists of multiple injections of magmas which were dioritic in composition. Probably the intrusions were related to the major structures in the area. The magma was widely intruded into the Coast Range of Alaska and Canada, and the diorite occurs as an elongate tongue which

extends as far south as southern Baranof Island. From its areal distribution it seems to die out to the south. To the north, the tongue of diorite is exposed in a wide irregularly shaped band almost continuously as far as the head of Glacier Bay. Beyond this point the geology is unknown, but from examination of existing geologic maps, it is reasonable to assume that this body joins the main Coast Range batholith somewhere within a few tens of miles north of the boundary between southeastern Alaska and Canada.

Within the mapped area, and as far north as the head of Glacier Bay, the diorite has almost everywhere been intruded along the contact dividing the rocks of Mesozoic and Paleozoic age. The reason for this is not fully understood. The main period of intrusion was followed by small but widely distributed intrusions of quartz diorite. Still later, the rocks now cropping out adjacent to the Pacific Ocean were intruded by a magma of gabbroic or noritic composition. This cycle was also followed by intrusions of quartz diorite.

Some of the gold-bearing quartz veins on Chichagof Island appear to be related to the older of the two quartz diorite intrusive rock groups. At places, such as Mirror Harbor on Chichagof Island and Bohemia Basin on Yakobi Island, the norite contains nickel along its marginal parts.

BEDDED ROCKS

MARBLE-GNEISS SEQUENCE

DISTRIBUTION AND GEOLOGIC RELATIONS

The oldest rocks found on the northwestern part of Chichagof Island are a thick sequence of metamorphosed sedimentary rocks which will be referred to in this report as the marble-gneiss sequence. Except for a small area adjacent to the greenstone unit south of Lisianski Inlet, the rocks mapped as belonging to the marble-gneiss sequence are enclosed within a younger crystalline rock having the texture and mineral composition of diorite; consequently the bedded rocks have been so thoroughly metamorphosed that most of the original structures commonly found in sedimentary rocks have been obliterated. At a few places the original rock grains are preserved, and a few crushed and recrystallized fossils have been found, although none were sufficiently well preserved to be identified. Most of the rocks in the sequence are either gneiss, marble, or schist. A small area northeast of Lisianski Inlet contains sedimentary rocks that are somewhat less metamorphosed and consist of thin-bedded limestone, chert, and graywacke.

The largest mapped area of bedded rock that belongs to the marble-gneiss sequence is an arcuate belt extending from the head of Lisianski

Inlet to the entrance to Idaho Inlet. It has a known length of 25 miles, but may be much longer. The north end is concealed beneath Icy Strait and the south end extends beyond the mapped area. The strata have a general northwesterly trend, parallel to the long direction of the rock mass. The beds in the central part of the belt dip about 45° NE., but at both ends the dip is steeper and in most places is vertical.

Other rocks that probably belong to the marble-gneiss sequence crop out south of Lisianski Inlet in three discontinuous bodies which have a pronounced elongate shape. The northernmost two are surrounded by foliated crystalline dioritic rock. The southernmost is in contact with greenstone and quartz diorite on the southwest side and with diorite on the northeast side. The strata in the southern body are complexly folded. The strike is generally to the northwest, parallel to the long axis of the body, but the dip is highly variable. In places it is nearly flat, an unusual structural feature in this area where most of the stratified rocks dip at high angles. The strata in the central body either dip steeply to the northeast or to the southwest or are vertical; those in the northern body dip steeply northwestward.

A few masses of rock of the marble-gneiss sequence lie in the diorite in the area between Idaho Inlet and Mud Bay. These strata trend northwestward and most dip steeply to the northeast.

Little is known of the true sequential order of the strata. Between Lisianski Inlet and the entrance to Idaho Inlet the beds structurally uppermost are probably those farthest to the southeast. Of the rocks found south of Lisianski Inlet, those farthest to the southwest are probably the youngest. The rocks north of Lisianski Inlet could not be correlated with those to the south, and the two groups may not be equivalent in age.

PETROLOGY

The most common rock types composing the marble-gneiss sequence, listed in order of decreasing abundance, are gneiss, marble, amphibole hornfels, and slightly metamorphosed sedimentary rock.

Gneiss.—Gneiss is widely distributed in all the large rock masses included in the marble-gneiss sequence. The light-colored gneiss ranges from a variety made up of quartz, feldspar, and mica, to a darker variety composed predominantly of hornblende and pyroxene. Quartz is not entirely absent, even in the most mafic types.

The light-colored gneiss commonly is in contact with diorite. Although this may be only a fortuitous relationship, it suggests that metamorphism by the diorite has had a tendency to transform more than one type of sedimentary rock into gneiss. The largest single body of this gneiss crops out on the divide between Meadow and Marble Creeks, about 5 miles north of Pelican. Light-colored gneiss also

forms an ill-defined elongate zone along the east side of the marble-gneiss sequence of rocks east of Idaho Inlet and crops out over several square miles south of the head of the inlet.

In outcrop typical light-colored gneiss is a medium-grained foliated rock. The foliation is accentuated in places on weathered surfaces by quartz-rich lenticles about one-fourth inch wide and several inches long. The appearance of the rock varies from place to place owing to changes in mineral composition, grain size, texture, and to a lesser extent to alteration. Banding in the gneiss is due to alternating layers that differ in grain size and in relative proportions of included minerals. These differences between bands probably reflect compositional differences between beds of the original sediments from which the gneiss was derived. The banding may have been accentuated by a process of segregation during metamorphism. Within the gneiss, bands of rock that are nearly identical to the diorite are common within a few hundred feet of the diorite-gneiss contact. This rock may have been injected, but no evidence of injection could be found, and the writer believes that it represents thoroughly recrystallized beds.

The minerals common in the light-colored gneiss are listed below:

Mineral	Light-colored gneiss (range in percent by volume)	Specimen of typical light-colored gneiss (percent by volume)
Feldspar (albite through andesine)	30–60	50
Quartz	15–40	40
Hornblende	5–20	6
Biotite	1–10	3
Chlorite	5–20	1.6
Magnetite	0–3	0.1
Pyrite	0–1	0.3

Feldspar appears fresh in the hand specimen, but in most thin sections it is seen to be partly saussuritized. Quartz is unaltered. In many places two ages of quartz are present. Hornblende is usually a green or, more rarely, a blue-green type, and it commonly has unaltered cores and chloritized margins. Locally hornblende is replaced by biotite.

Dark-colored gneiss is more widely distributed than is the light-colored gneiss and is present in all the larger rock bodies of the marble-gneiss sequence. Small internal structures common in sediments have not been observed and have undoubtedly been obliterated by metamorphism. Listed below are the most common minerals found in the dark-colored gneiss. The percentages shown as indicat-

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ing the range of the amount of the mineral in the rock are those which can be expected in normal specimens of the dark-colored gneiss.

Mineral	Dark-colored gneiss (range in percent by volume)	Specimen of typical dark-colored gneiss (percent by volume)
Feldspar (andesine to labradorite)	20–60	30
Quartz	5–30	16
Hornblende	10–80	45
Biotite	0–15	Tr.
Clinopyroxene	0–50	5
Epidote group minerals	0–10	1
Chlorite	1–20	2
Apatite	0–2	Tr.
Sphene	Tr.–2	0.2
Garnet	0–25	.1
Magnetite	0–5	.2
Pyrite	0–5	.3

As seen in thin section, hornblende crystals appear to have increased in size during metamorphism, first growing between grains of plagioclase and quartz and later, as metamorphism continued, engulfing many of the original grains within the large new crystals of hornblende. Most of the hornblende is bright green in thin section, but in some of the thin sections the hornblende has a bluish hue in certain orientations.

The plagioclase is generally saussuritized or chloritized and the well-developed twinning is largely masked by alteration. In many crystals, the alteration is more extensive in one of the sets of twins than it is in the other, and even where twinning is no longer visible because of alteration, the position of the twins is clearly shown by the preferential alteration. In some thin sections the borders of the hornblende and biotite can be seen to be altered to chlorite. Some of the dark-colored gneiss contains pyroxene near augite in composition, its distribution being controlled by the composition of the original rock. As a rule, the pyroxene shows little chemical interaction with adjacent grains of other minerals, and probably it is in fairly good chemical equilibrium with its environment. In other thin sections, however, pyroxene has been partly recrystallized to hornblende, but this is probably due to retrogressive metamorphism rather than to lack of chemical equilibrium of the pyroxene to its environment. There is little evidence to indicate that the pyroxene was segregated into discrete layers. Sphene is locally an abundant constituent of the dark-colored gneiss. It ordinarily is confined to specific bands and probably is one of the original minerals of the rock.

Marble.—About 15 percent of the marble-gneiss sequence is composed of marble. Little is found south of Lisianski Inlet, but the

rocks of the marble-gneiss sequence which crop out north of Lisianski Inlet contain as much as 40 percent. Between Lisianski Inlet and the head of Idaho Inlet the sequence contains many beds, some as much as 50 feet thick, that are almost entirely of marble. Several large bodies of marble and other strata lie within the diorite between Idaho Inlet and Mud Bay. Apparently the original limestone was not as easily changed in texture and mineral composition as were most of the other sedimentary rocks of the area. Consequently in many localities outcrops looking like igneous rocks contain parallel layers of marble. This feature is typical of much of the area mapped as well as of the Glacier Bay area to the north which lies in the same geologic province. The writer believes that the presence of this marble is evidence that much of the rock mapped as diorite is actually a recrystallized older sedimentary rock.

Most outcrops of marble are similar in appearance. The rock is gray, blue gray, or tan. Above timberline exposed surfaces are fluted and pitted by solution. In areas containing marble, underground drainage is well developed, and locally small caves have formed.

The marble has a granular texture, and ordinarily it is composed of 90 to 98 percent calcite. The grain size depends upon the degree of metamorphism, large crystals of calcite having formed where the rock was subjected to high temperature. For example, northwest of Tarn Mountain adjacent to an intrusion of diorite, crystals in the marble are as much as 3 centimeters in diameter; normally the crystals range from ½ to 3 millimeters in diameter.

Other minerals in the marble are feldspar, pyroxene (diopside), epidote, quartz, garnet, chlorite, graphite, hornblende, pyrite, magnetite, and wollastonite. The marble undoubtedly contains some dolomite but none was recognized in the thin sections examined. Where it is in contact with light-colored igneous rock, the marble is commonly replaced in part by garnet, pyroxene, and in a few places by magnetite.

Schist.—A small amount of schist is included in the marble-gneiss sequence. Biotite schist and hornblende schist occur in almost equal amounts. The hornblende schist resembles the dark-colored gneiss in mineral composition and differs from it only in the degree to which preferred orientation of minerals have been formed. The largest known body of biotite schist is about 1,000 feet thick and extends from Mineral Mountain 6 miles north to a point north of Wedge Mountain. This band lies structurally below the lowest mapped marble and is separated from it by several hundred feet of gneiss. Biotite schist crops out north of Idaho Inlet at several places near the contact of the marble-gneiss and the diorite and a few small bodies of schist are scattered throughout the gneiss in the same area.

The relation of the various minerals to each other and the unusually large number of minerals in the rock indicate that minerals in the biotite schist were in the process of readjustment when the main period of metamorphism ceased. The following minerals were noted in thin section: hornblende, feldspar (two ages), quartz (two ages), biotite, chlorite, sphene, apatite, pyrite, and epidote. All except apatite and sphene are present in appreciable amounts. Most of the biotite schist contains quartz which was introduced at the time of maximum metamorphism. In places the quartz is so plentiful that it occurs along foliation planes as bands and lenses. In a few places, such as near the peak of Mineral Mountain, quartz bands several feet thick have formed. The introduction of quartz appears to have unbalanced the chemical equilibrium of the rock. In most thin sections examined, quartz replaces most of the original minerals, and probably was an important factor in the formation of new ones. Hornblende and biotite typically are partly altered to chlorite.

The biotite schist contains two ages of feldspar. The older is the more altered and is replaced by the younger. Generally, opaque minerals are not abundant, but in a few places the biotite and hornblende schists contain a considerable amount of pyrite. A band of amphibolite schist on the ridge 1 mile southeast of Mineral Mountain contains as much as 10 percent pyrite.

Amphibole hornfels.—Part of the rock mapped as belonging to the marble-gneiss sequence is a dark-colored, fine-grained rock which is called amphibole hornfels in this report. The term "hornfels" as used herein simply means a metamorphosed rock that is so fine grained that the individual grains cannot be recognized with the unaided eye. Amphibole hornfels and subordinate coarser grained amphibolite cover several square miles on the northern part of Chichagof Island. One mass of amphibole hornfels crops out near the top of the ridge east of the village on Idaho Inlet. The same rock crops out along Trail River and 2 miles southeast of Pyramid Mountain.

Unless the marble-gneiss sequence is overturned, the amphibole hornfels constitutes the uppermost rock unit of the marble-gneiss sequence between Lisianski and Idaho Inlets. The amphibole hornfels appear to rest conformably on the rest of the marble-gneiss sequence, but the relationship is obscured because of the complex rock structures and the lack of good exposures. Probably the amphibole hornfels was originally a mafic volcanic rock.

The amphibole hornfels is composed mainly of hornblende and plagioclase, generally andesine. Commonly the hornblende constitutes 50 to 70 percent of the rock by volume and the plagioclase 20 to 40 percent. Two to 10 percent quartz was found in all the thin sections

examined. Pyroxene, commonly diopside, may compose as much as 10 percent of the rock. Most of the pyroxene is partly altered to hornblende, and the writer believes that a fairly large proportion of the pyroxene has been completely altered to hornblende. Accessory minerals common in the amphibole hornfels include apatite, sphene, and magnetite. As a rule, chlorite and epidote alteration is not extensive. The feldspar is saussuritized, and some of the hornblende crystals are partly replaced by chlorite around the margin of the crystals.

Slightly metamorphosed sedimentary rocks.—Sedimentary rocks that are believed to be the youngest in the marble-gneiss sequence crop out in an elongate belt in the area southwest of Stag Bay. They extend about 8 miles from a point 1½ miles north of Pinnacle Peak to Otter Lake. Similar rocks crop out along the same line of strike from a point near the outlet of the Goulding Lakes to the valley of Black River in the Chichagof mining district. The rocks in this belt are the most highly folded of any found in the mapped area. The regional strike is generally northwest, but the dip is highly variable. One peculiar structural feature of the sedimentary rocks is the low angle of dip. Dips as low as 20° are common in these rocks but are not found at any other place in the area mapped. The cause or significance of the flat dips remains unexplained.

The sedimentary rocks probably underlie the greenstone unit. The writer believes that the contact between them is unconformable because the underlying rocks are more highly deformed than is the younger greenstone, and because the contact is irregular, suggesting that it is an erosional surface. The sedimentary rock succession is in contact with igneous rock everywhere within the mapped area, and the relation between this sedimentary rock and lower bedded rocks is not known.

The slightly metamorphosed sedimentary rocks include three main lithologic units: an upper unit consisting of thin-bedded chert interbedded with black shale, a middle unit composed mainly of thin-bedded limestone, and a lower unit consisting of sandstone and siltstone. The upper unit, the chert, ranges in thickness from 20 to 500 feet. In outcrop it is thin bedded, and individual strata average about 2 inches in thickness. The upper part of the unit contains only chert, but the lower part contains some graphitic shale interbedded with the chert. The chert is composed mainly of fine-grained quartz and in places it contains small flakes of sericite. The quartz is equigranular and commonly has sutured borders. The crystals range from 0.003 to 0.03 millimeter in diameter. Probably the chert has been slightly metamor-

phosed. The rock unit stratigraphically below the chert consists of thin-bedded limestone interstratified with thin siliceous beds; it is about 700 feet thick. In outcrop the thin-bedded limestone is white, gray, or tan and consists of beds 1 to 6 inches thick. In a few places, particularly near the top of the unit, the thin-bedded limestone is interlayered with graphitic shale. A few unidentifiable fossil fragments were found in the limestone where it crops out on Big Chief Mountain.

The lowest unit in this succession of sedimentary rocks consists of sandstone and siltstone, and is estimated to be between 500 and 1,000 feet thick. The upper part is conformable with the overlying limestone and the lower part grades into gneiss which is in contact with igneous rock. This lower unit has not been examined in detail because the rocks are poorly exposed and crop out in relatively inaccessible areas. The rock in outcrop is a moderate yellowish to dark brown. Beds range from less than 1 foot to 6 feet in thickness. Most of the rock is fine grained. Quartz and feldspar are the most common minerals.

Several bodies of greenstone lie stratigraphically below the sandstone-siltstone section, but are separated from it by igneous rock. The igneous rocks containing the greenstone crop out intermittently in a narrow zone that extends from Stag Bay to Goulding Lake. The greenstone is perhaps correlative with the amphibole hornfels that crops out north and east of Idaho Inlet and is described above.

AGE AND CORRELATION

No fossils sufficiently well preserved to be identified have been found in the marble-gneiss sequence, and the age of the sequence remains unknown. Moreover, because its structure is confused by major intrusive bodies, the relationship of the marble-gneiss sequence to formations of probable Mesozoic age is imperfectly understood.

The marble-gneiss sequence lies structurally below rocks of Mesozoic age, and does not resemble any part of that section; furthermore, the marble-gneiss sequence is more highly metamorphosed than the rocks of Mesozoic age; thus, the marble-gneiss probably is older than the rocks of Mesozoic age. The marble in the diorite east of Idaho Inlet is probably correlative with the limestone of Silurian age (Buddington and Chapin, 1929, p. 80) which crops out on the north side of Tenakee Inlet. A similar limestone also mentioned by Buddington and Chapin, which is known to have been deposited in Silurian time, crops out in Glacier Bay.

GREENSTONE UNIT

DISTRIBUTION AND GEOLOGIC RELATIONS

The oldest bedded rock recognized by Reed and Coats (1941, p. 14–19) in the Chichagof mining district was called by them the greenstone-schist sequence. They recognized two lithologic units, to which they referred as the upper and lower parts. The lower part consists of sedimentary and volcanic rocks; the upper, of metamorphosed lava. The upper part is in fault contact with a similar rock, called by them "the greenstone formation." Additional mapping by the writer of the same sequence of rocks farther northwest shows that there is no fundamental stratigraphic break between the greenstone formation as mapped by Reed and Coats and the upper part of their greenstone-schist sequence. The lower part of their greenstone-schist sequence is lithologically different from the upper and, in addition, the contact between the upper and lower parts may be unconformable. The writer believes that lower part of the greenstone-schist formation as mapped by Reed and Coats is correlative with the rocks mapped as the uppermost beds of the marble-gneiss sequence (pl. 12). In this report the name greenstone-schist is not used. Rocks mapped by Reed and Coats as the lower part of the greenstone-schist formation are included in the marble-gneiss sequence, and the greenstone formation and the upper part of Reed and Coats' greenstone-schist formation make up the greenstone unit of the present report.

The greenstone unit crops out in a belt extending northwestward from the northeastern corner of the Chichagof mining district to a point 1½ miles northwest of Lake Elfendahl. The average width of outcrop is about 2 miles. The average thickness is probably about 9,000 feet. The greenstone is conformably overlain by marble. Another area containing rocks similar to those of the greenstone unit extends in a linear belt from a point 4 miles north of Pelican to the north edge of the largest of the Inian Islands. This belt is bordered on the east by younger diorite and on the west by marble which may be equivalent to the marble unit south of Lisianski Inlet. Between the head of Port Althorp and the Inian Islands the rocks which are probably equivalent to the greenstone unit have been recrystallized to amphibolite.

The rock included as part of the greenstone unit north of Lisianski Inlet is correlated with the greenstone unit south of Lisianski Inlet, solely on the basis of similarity in rock type and in the order of succession of the several rock units. Some of the recrystallized rock found on the Inian Peninsula appears to be derived from stratified sedimentary rock. In this respect the rock mapped as part of the greenstone unit north of Lisianski Inlet differs from the greenstone

unit south of the inlet; the latter is made up almost entirely of massive and schistose greenstone and amygdaloidal greenstone.

PETROLOGY

The more common rocks in the greenstone unit may be conveniently subdivided into massive and schistose greenstone, amygdaloidal greenstone, massive and schistose amphibolite, and banded amphibolite. The schistose varieties of greenstone and amphibolite occur in much smaller amounts than the massive greenstone and amphibolite; all these rocks are derived from older rocks of mafic composition. The massive greenstone and amphibolite are derived from basaltic lava flows and the banded amphibolite from bedded mafic sediments or interbedded mafic sediments and volcanic rocks.

Massive and schistose greenstone.—The massive greenstone is so fine grained that individual grains usually cannot be seen with the unaided eye. In fresh exposures the rock is generally dark green, but locally it may be dark red or purple. Weathered surfaces are lighter shades of green or gray. South of Lisianski Inlet the rock is massive; bedding and smaller-scale structures within the beds are rare. Under the microscope the original rock-forming minerals appear altered; some are unidentifiable. The common minerals are hornblende, quartz, epidote, clinozoisite, chlorite, pyroxene, pyrite, and magnetite. Hornblende is in part an original mineral, and in part is formed from pyroxene. Quartz makes up 20 to 50 percent of the rock, a much higher percentage than would be suspected from examination of hand specimens. The greenstone is cut by a myriad of thin white veinlets which range from paper-thin seams to as much as several millimeters in thickness. The veinlets are largely prehnite and lesser amounts of quartz, chlorite, and calcite.

The greenstone schist is mainly derived from the massive greenstone by intense and widespread shearing stresses. It is difficult to estimate the volume of the greenstone schist, but probably it composes one-tenth of the greenstone unit. The greenstone schist contains tremolite or actinolite, quartz, and feldspar, plus small amounts of chlorite and epidote. In all thin sections of the greenstone schist examined, the minerals apparently are less altered and more nearly in chemical equilibrium than the minerals in the massive greenstone. The most common feldspar is albite or sodic oligoclase.

Amygdaloidal greenstone.—A specimen of amygdaloidal greenstone was taken from the top of the highest hill about 1 mile due north of Pinta Bay. The groundmass of the rock is fine grained and consists of altered pyroxene, chlorite, clinozoisite, epidote, and a small amount of quartz and feldspar. The largest grains in the groundmass are pyroxene crystals which have a maximum length of 0.1 mm. Feld-

spar is present as ragged, widely scattered grains. It is highly saussuritized, and probably much more feldspar was in the original rock than can now be recognized. Fractures, some of which contain veinlets, cut the rock in all directions. The most common vein minerals are prehnite and chlorite.

The amygdules, the largest of which are 1 inch in diameter, are composed of quartz and scattered crystals of epidote. They contain some clinozoisite that apparently formed from epidote. Under high magnification the quartz shows needles of a pale green amphibole, probably actinolite, and undulatory extinction.

Massive amphibolite.—Most of the greenstone unit mapped on Inian Peninsula is metamorphosed to a massive or banded amphibolite. Locally the massive amphibolite is sheared to schistose amphibolite. In outcrop massive amphibolite is dark green to gray. Its texture ranges from granoblastic to coarsely porphyroblastic. The average grain size of typical massive amphibolite ranges from 0.5 to 3 millimeters. In places, however, the average grains of amphibolite are no larger than 0.03 millimeter whereas in other areas the rock contains crystals several inches long. A few hornblende crystals are more than 2 feet long, but these are uncommon. The essential minerals of the amphibolite are hornblende and feldspar. Other common minerals are quartz, chlorite, clinozoisite, magnetite, sphene, pyrite, and apatite. In a few places biotite or pyroxene makes up an appreciable part of the rock.

Hornblende is in all the rocks examined and commonly is the most abundant mineral. It is irregular in shape and most grains have deeply embayed borders. In most of the rock the hornblende may include grains of quartz, feldspar, pyroxene, epidote, or older hornblende. Individual hornblende crystals have been observed which contain 20 to 50 grains of other minerals.

Plagioclase feldspar is nearly as abundant as hornblende. It ranges from albite to labradorite in composition, but in most of the rock it is sodic andesine. The albite appears to have formed by metamorphism. Other feldspar in the amphibolite is saussuritized and a few grains contain needle-shaped crystals of amphibolite.

Quartz has two distinct modes of occurrence. Some of it is in the form of rounded grains that were part of the original rock. These rounded grains are usually cloudy and high magnification shows numerous inclusions, many of which are small crystals. The other form of quartz is clear and usually has lobate contacts against other minerals, suggesting that it replaces them. Commonly it occurs as veinlets.

Epidote, like quartz, is of diverse form and of several ages. The oldest is found as grains embedded in hornblende and in the centers of younger epidote crystals. Epidote veinlets are common. One

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specimen from the south side of Inian Island shows epidote abundant in the wall rock near an epidote-bearing veinlet. The amount of epidote decreases away from the veinlet, which suggests that the epidote replaced the rock in which it now occurs.

Nearly all the massive amphibolite contains fine-grained crystals of chlorite as incrustations surrounding hornblende crystals and as irregular masses between other mineral grains. Sphene is uniformly distributed throughout the rock. Normally it is in euhedral crystals which show well-developed preferred orientation with their long axes parallel. Medium-grained amphibolite contains crystals of sphene averaging about 0.2 millimeter in diameter.

Pyroxene is lacking in much of the amphibolite, but locally it is abundant. Normally rocks containing pyroxene are those in which the feldspar content is low. In several localities near marble beds, the amphibolite contains a green, highly pleochroic pyroxene belonging to the diopside-hedenbergite-acmite isomorphous series. The optical properties of the pyroxene indicate that it has an approximate composition of $Di_{25}He_{60}Ac_{15}$.

Amphibolite generally contains little or no biotite. Where the rock contains secondary quartz, however, as much as 15 to 20 percent biotite may be present. Usually rock containing biotite resembles diorite texturally. The biotite apparently formed from hornblende or from chlorite which in turn formed from hornblende. Retrogressive metamorphism has affected most of the biotite-bearing rocks, as is indicated by the occurrence of chlorite around the margins and along the cleavage planes of the biotite crystals.

Banded amphibolite.—The banded amphibolite differs from the massive amphibolite in that it is made up of alternating light-colored and dark bands. Most is derived from rocks of the greenstone and schist units and is best shown on Inian Peninsula and the Inian Islands. Its distribution is characteristically irregular and is not differentiated on the geologic map. The largest body of banded amphibolite crops out on the east side of the Inian Peninsula and extends from the northern tip southward for 2½ miles. Another body of amphibolite extends northward from the north shore of Salt Chuck Bay on the west side of the Inian Peninsula for about 1 mile. The rocks in both of these bodies of banded amphibolite grade into massive amphibolite along the strike. Smaller masses of banded amphibolite are found on the Inian Islands. In outcrop, the contrast in color between the bands is marked and gives rise to a distinctive rock type. In the well-banded amphibolite, the light bands contain almost no dark minerals, and the dark bands contain few light-colored minerals. The dark bands are the same in texture and mineral composition as the massive amphibolite. Generally the light bands are narrower than the dark bands within any one rock group. Feldspar

and quartz are the main minerals in the light bands, and feldspar is about four times as abundant as quartz. The texture resembles that of normal diorite. Under the microscope the contact between bands is seen to be gradational, although it appears sharp in the hand specimen. Small irregular-shaped grains of hornblende occur throughout the light bands but are most plentiful near the contacts. The distribution and shape of these grains suggest that they are unreplaced remnants of larger crystals.

The banded amphibolite occurs in the same geologic province and has undergone the same type and degree of metamorphism that the massive amphibolite has undergone. The banding is undoubtedly due to the character of the original sediment. The fact that the hornblende in the light-colored bands has probably been replaced by feldspar and quartz suggests that metamorphic segregation has taken place. The writer believes that metamorphism has accentuated the contrast in mineral assemblages of the bands, and that, at least locally, the light-colored bands have become lighter in color through replacement of the dark minerals.

MARBLE UNIT

DISTRIBUTION AND GEOLOGIC RELATIONS

South of Lisianski Inlet a band of marble separates the greenstone from the overlying schist formation; apparently both contacts are conformable. The same rock unit has been described by Reed and Coats (1941, p. 22–24) under the section on limestone. This marble band ranges from 200 to 1,000 feet in thickness, as compared to its maximum thickness of 1,500 feet in the Chichagof mining district. Within the mapped area, the marble unit extends from the head of Goulding Harbor to Lake Morris, where it presumably is cut off by the stock at Lake Elfendahl. The unit thins northward and is present north of Lake Elfendahl as small discontinuous bodies. An isolated body that crops out on the south side of Cub Mountain may be part of the marble unit. A marble-bearing sequence too small to map crops out near the magnetite deposit on the east flank of Mount Hill. These small bodies may belong to the marble unit or they may simply be small beds or lenses of marble in the overlying schist unit.

North of Lisianski Inlet a narrow discontinuous band of marble extends from a point 1 mile north of Pelican to the north edge of the largest of the Inian Islands. Other similar masses crop out southeast of the head of Lisianski Inlet. All these may belong to the marble unit.

The marble north of Lisianski Inlet has an average thickness of about 100 feet. The southern part of the band dips east and is prob-

ably overturned. The northern part dips steeply in either direction or is vertical. In places the marble pinches out or is offset by faults. As the marble cannot be traced across the head of Port Althorp, some doubt exists as to whether the band on the Inian Peninsula is a continuation of the band to the south; however, both parts lie along the same line of strike.

In outcrop the marble is light gray to nearly white. On exposed surfaces the rock is deeply etched and fluted by solution. In timbered areas the characteristic hummocky karst topography indicates the presence of the marble even where it is covered. Underground drainage is common, and few streams cross the marble except near sea level.

The marble band exposed north of Lisianski Inlet does not closely resemble the marble unit south of Lisianski Inlet, probably because it has undergone relatively more intense recrystallization. In places on the north end of the Inian Peninsula the marble is pale red or reddish orange and is cut by anastomosing stringers of a pale-green mineral.

PETROLOGY

Most of the limestone which originally made up the marble unit has been recrystallized to marble. Farther south, correlative rocks are less recrystallized and are considered to be limestone (Reed and Coats, 1941, p. 22–24). Calcite is the dominant mineral, but magnetite, pyrite, quartz, and feldspar are present locally. Garnet and wollastonite have developed where the marble has undergone intense thermal metamorphism. Some of the marble is dolomitic, but the relative abundance of dolomite is not known. It is recognized on weathered surfaces where it stands out in relief as riblike ridges or as single crystals. So few of these structures were found that dolomite is believed to be rare.

Magnetite deposits have formed in a few places along the contact of the quartz diorite and the marble. One such deposit crops out 1 mile south of the entrance to Stag Bay; another crops out on the west-central part of the Inian Island group (pl. 12). The mineral assemblage is the same in both deposits. The richest specimens contain 70 to 80 percent magnetite. In the hand specimen a bright green pyroxene, hedenbergite, is visible, and in thin section quartz can be seen as small grains and irregular masses.

AGE AND CORRELATION

The marble south of Lisianski Inlet is part of the same band that extends across the Chichagof mining district and that has been assigned somewhat doubtfully to the Upper Triassic by Reed and Coats

(1941, p. 24). The limestone cropping out on Inian Peninsula, Althorp Peninsula, and at the head of Lisianski Inlet is correlated with the marble band south of Lisianski Inlet on the basis of lithologic similarity and by its relations to the overlying and underlying stratified rocks which resemble the schist and greenstone formations, respectively. It should be pointed out that these bedded rocks are correlated with the schist and greenstone units south of Lisianski Inlet solely on the basis of lithologic similarity and order of succession. Stratigraphic relationships between the marble and overlying schist units indicate that there is little difference in age between them; the schist is regarded as being of Jurassic age, and the marble unit is also tentatively assigned a Jurassic age.

SCHIST UNIT

DISTRIBUTION AND GEOLOGIC RELATIONS

The schist is one of the thickest and most widespread rock units on northwest Chichagof Island. It extends from Cross Sound to the eastern boundary of the Chichagof mining district. Undoubtedly it extends much farther southeast, probably at least as far as central Baranof Island. Rocks that are probably equivalent to the schist unit crop out north of Lisianski Inlet. These rocks extend northward from a point near Pelican to the Inian Islands. Subsequent mapping by the writer shows that similar rock crops out north of Cross Sound in a belt that lies along the east side of Taylor Bay and Brady Glacier. This belt is about 14 miles long and is in places as much as 2 miles wide. Another belt of rocks which probably are part of the schist unit crops out southeast of the head of Lisianski Inlet.

The thickness of the unit probably exceeds 9,000 feet but is difficult to determine accurately because of the abundant small-scale folds and crumpling generally common in the schist. The contacts at both the top and bottom appear to be conformable, but the rocks have undergone deformation that is sufficiently intense to have destroyed the evidence of an unconformity either at the contacts or within the unit.

PETROLOGY

Originally the schist unit consisted mainly of tuff, a few lava flows, and tuff interbedded with sedimentary material. Interstratified with these beds were carbonaceous shale, fine-grained carbonaceous graywacke, chert, and some limestone. In general there are more massive graywacke and more greenstone in the rocks of the schist unit in the Chichagof mining district than there are in correlative rocks in the area of this report. The rocks of the schist unit have all been metamorphosed, and the most common is a greenstone interstratified with

a graphitic schist. In a few areas where the metamorphism has been relatively intense the schist unit has been metamorphosed to an amphibolite or to a crystalline schist.

Interbedded greenstone and graphitic schist.—Greenstone interbedded with graphitic schist crops out south of Lisianski Inlet in a wide but intermittent zone that extends from Mount Hill south to Goulding Harbor. The same zone continues southeast across the Chichagof mining district. To the northwest the same rock crops out in a zone which extends across Yakobi Island. North of Lisianski Inlet the same type of rock crops out in an area that lies between Cross Sound and a point on Lisianski Inlet almost opposite Miner Island.

The mineral assemblage in the greenstone of the schist unit resembles that in the greenstone of the greenstone unit. The common minerals are: augite, epidote, and labradorite. Pyrite, magnetite, and chalcopyrite are common locally. Rocks in the cliffs on the south ridge of Cub Mountain, as well as those in several mountains lying between Stag Bay and Goulding Harbor, are rust stained from the oxidation and leaching of pyrite. Chalcopyrite is particularly abundant in an area extending several miles northwest of Goulding Harbor.

The greenstone is extensively altered by low-grade metamorphism. Chlorite, zoisite, epidote, and prehnite are the most common minerals. Laumontite, a calcium-bearing zeolite, is sparsely but widely distributed in the rock. Original pyroxene is usually chloritized. The metamorphosed rock contains abundant unaltered crystals of new actinolite or tremolite. In places alteration of the original feldspar has resulted in the formation of albite and epidote.

The graphitic schist interbedded with the greenstone commonly consists of quartz and lesser amounts of epidote, clinozoisite, and graphite. Biotite and chlorite are present locally, particularly where the rock has undergone a high degree of thermal metamorphism. Graphite appears to be abundant in the outcrop and in the hand specimen, but under the microscope was found in only small amounts.

The interbedded greenstone and graphitic schist are incompetent, and because of this they are usually highly intermixed. Commonly, bedding is completely destroyed. Under the microscope the rock appears highly comminuted and most minerals are shattered or show evidence of strain. Reed and Coats (1941, p. 25) recognized the lack of competence of the rock and attributed thinning of the schist unit in the central part of the Chichagof mining district to lateral migration of the rock by plastic flow. The writer has noted several areas where the rocks of the schist unit exhibit this characteristic of flowage. The most notable examples occur on Three Hill Island, the western

tip of the George Islands, and along the contact of the diorite and the schist unit on Althorp Peninsula south of Lacy Cove.

Greenstone schist.—Greenstone schist derived from volcanic rocks is present in a few places within the greenstone unit. The largest known mass of schist crops out along the shores of Lisianski Strait south of the junction of the strait and Stag Bay. Other masses crop out on the north shore of Lisianski Inlet near Cross Sound.

In outcrop the greenstone schist is usually some shade of green. Foliation is well developed. The shearing stresses that developed the schist destroyed any older structures, such as bedding, which may have existed. The greenstone schist is ordinarily composed of fibrous amphibole set in a matrix of quartz, feldspar, and a fine-grained amorphous material. The average grain size is about 0.02 millimeter and, consequently, identification of the mineral constituents is difficult. Common minerals in a few specimens include epidote, actinolite, chlorite, quartz, albite, and clinozoisite. Other minerals found locally include augite, hornblende, and sodic amphibole. Magnetite and sphene are common accessory minerals. Most of the quartz is interstitial, but in places vague outlines of rounded quartz grains are still discernible.

Feldspar is lacking in most of the greenstone schist, but in places it is abundant. Reed and Coats (1941, p. 27) describe one specimen from the Chichagof mining district which contains 20 percent albite.

The feldspar usually shows either a complete lack of twinning or only simple albite twinning. Zoning of the albite has not been observed, and if present, it is rare. Greenstone schist that contains albite also contains abundant epidote and clinozoisite.

Limestone.—Most of the limestone in the schist unit lies in the upper third of the section. Several beds have been mapped in the area east of Mirror Harbor, and a few small lenticular masses were discovered south and west of Lake Elfendahl. Limestone in the schist unit is similar in color and composition to that in the marble unit but is generally less metamorphosed. In a few places the limestone contains irregular masses of quartz which probably are the remains of silicified fossils.

AGE AND CORRELATION

No new data regarding the age of the schist unit were obtained during the course of the geologic mapping. Reed and Coats (1941, p. 29–30) give almost all that is known concerning the age of the greenstone unit:

> The fossils on which rests the age assignment of the schist and the older bedded rocks of the district were collected from a large boulder in Goon Dip River in the canyon at the northeast foot of Goon Dip Mountain. No fossils

were found in any of the limestone in place. From its position the boulder could have come from either the limestone to the east or from the large limestone lens in the schist on Goon Dip Mountain but it seems much more likely that the boulder came from the large limestone lens. On the assumption that it came from the lens, the formation, because of the inadequacy of the fossils, is somewhat doubtfully assigned to the Triassic period.

The fossils were studied by John B. Reeside, Jr., who reports as follows on the specimens submitted:

"This lot contains a coralline type in the form of ovoid masses. Most of the fine structure has been destroyed by recrystallization, and close identification is not possible. The Paleozoic paleontologists think that it is not a Paleozoic type. It suggests in some respects an Upper Triassic form placed by J. P. Smith in the genus *Heterasteridium;* in others it suggests forms placed by Smith in the genus *Spongiomorpha.* I am strongly inclined to believe it referable to the Upper Triassic but cannot definitely prove the case either way on this material alone."

One lot of the several collected by an employee of the Hirst-Chichagof Mining Co. on Kruzof Island in 1938 was reported by Reeside as "dark-gray limestone with many silicified corals. The silicification has destroyed most of the smaller details, but the forms present seem to include a *Theocosmilia* like *T. norica* Frech, as figured by Smith; an *Isastrea* like *I. parva* Smith; and a third form that may be a species of *Spongiomorpha.* The only fauna of this type that I know is from the Upper Triassic."

The rocks from the Chichagof district and those from Kruzof Island have not been correlated in the field, but they are in the same general structural and lithologic belt.

From the above it is evident that little positive evidence is known concerning the age of the schist unit. The writer has carefully examined the contact of the schist and graywacke in the Chichagof mining district as well as in the area of the present report. At no place has a suggestion of a disconformity or unconformity been found. Furthermore, the schist graywacke contact shows a gradation in rock type indicating that the change in environment of sedimentation and source areas was gradual. Overbeck (Reed and Coats, 1941, p. 35) collected fossils from Slocum Arm that may be of Late Jurassic age. Reed and Coats are inclined to believe the rocks containing the fossils belonged to the graywacke formation. This area has not been geologically mapped, however, and certain rocks in the schist unit are lithologically similar in appearance to those in the graywacke unit. Furthermore, if the fossils did come from the graywacke and are Jurassic in age, then the underlying formation is either Jurassic or older.

The present writer believes that no great difference in age is indicated between the uppermost rocks of the schist unit and the lowermost rocks of the graywacke unit and, in consideration of the above, tentatively regards the schist unit as being of Jurassic age.

GRAYWACKE UNIT

DISTRIBUTION AND GEOLOGIC RELATIONS

The youngest consolidated bedded rock that has been recognized on Chichagof Island is a thick, dark-colored sequence. Apparently the rocks crop out along the full length of the west coast of Chichagof Island. Similar rocks crop out at Cape Spencer to the north and on Baranof and Kruzof Islands to the south. The regional strike is northwest, and the dips, usually steeper than 45°, are to the southwest. The succession is called the "graywacke formation" by Reed and Coats (1941, p. 33–35), and the name "graywacke unit" is used in this report to refer to this sequence.

The unit has a maximum outcrop width of 2 miles and extends in a continuous band from Dry Passage to Lisianski Strait. The total thickness of the graywacke unit and its relations to overlying rock are unknown. Although extensively intruded by igneous rock, the graywacke succession is structurally simple. From Dry Passage to Islas Bay the rocks strike uniformly northwest and dip about 65° SW. Between Islas Bay and Lisianski Strait, the graywacke is split into two limbs by the stock at Lost Cove. The southern limb maintains the northwest strike and southwest dip as far as Lisianski Strait. The northern limb has a more northerly strike and steeper dips.

The graywacke appears to rest conformably on the schist unit. Reed and Coats (1941, p. 31–32) were of the opinion that an unconformity might exist between the two although they found no positive evidence of one. The writer has examined the contact at many places, both in the Chichagof mining district and in the area included in this report. Where the contact was observed the two units grade without apparent unconformity into one another. Although greenstone fragments resembling rocks of the greenstone and schist units do appear in the graywacke, the fragments may have come from a locality outside the area mapped, where uplift may have exposed the underlying rocks. Some greenstone is also interbedded with the graywacke. The gradational contact between the greenstone and graywacke units seems to indicate that they are conformable in the area included in this report.

PETROLOGY

The graywacke unit is made up mainly of massive and shaly graywacke. Lenses of greenstone, however, are common, particularly in the upper part of the unit. The amount of greenstone in the graywacke unit increases from the southeast to the northwest, and the graywacke unit on Yakobi Island at the south end of Lisianski Strait

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contains at least 30 percent greenstone. Chert is present in small amounts. Conglomerate is virtually absent, although present farther south in the southeastern part of the Chichagof mining district.

In outcrop the graywacke shows distinct bedding. Differences between beds are due to variations in color or in grain size, or to a combination of both. Beds range from less than an inch to 30 feet in thickness; most, however, are between 6 inches and 3 feet thick. Beds persist for considerable distances, and lateral thinning or thickening is generally unobservable in outcrop.

A much thicker section of graywacke crops out in the Chichagof mining district (Reed and Coats, 1941, p. 30–35) than in the area mapped by the writer. The graywacke in places is metamorphosed, and muscovite, andalusite, pale red garnet, and staurolite have formed. Andalusite is found in the rocks over several square miles; the greatest concentration is along a northwestward-trending zone extending from Sea Level Slough to the outer part of Islas Bay.

In weathered outcrops, light-colored crystals of andalusite usually stand out in relief. Crystals range from less than one-half inch to 4 inches in length and from 0.1 inch to 1 inch in diameter; the average crystal is perhaps one-fourth inch in diameter and 1½ inches in length. The abundance of crystals varies from place to place; on some outcrops only one crystal may be present in several square feet of surface, and at another place as many as 100 crystals may occur within a single square foot. Adjacent beds may vary in the amount of andalusite. In general the shaly graywacke contains the highest concentration of crystals. As the degree of metamorphism must have been very nearly the same for all beds in any one local area, it appears that the difference in amount of included andalusite is due to a difference in the composition of the original beds.

The graywacke in contact with the stocks at Mirror Harbor, Lost Cove, Ilin Bay, Urey Rocks, and the Porcupine Islands has been recrystallized. Within the aureole or zone of contact metamorphism, biotite was the first new mineral formed; this was followed closely by new feldspar. Hornblende is the most important mafic mineral. The new feldspar is free of inclusions, and twinning is well developed. This is in marked contrast to normal feldspar found in the graywacke, which is turbid, full of inclusions, and shows little twinning. Garnet, andalusite, and light-colored mica are sparse in the recrystallized rock.

AGE AND CORRELATION

No new information regarding the age of the graywacke was found by the writer during the course of mapping the northwestern part

of Chichagof Island. Reed and Coats (1941, p. 35) have summarized the existing knowledge as follows:

No fossils have been found in the graywacke formation within the Chichagof mining district. The graywacke sequence is abundant along the west coasts of both Chichagof and Baranof Islands. The Wrights believe the graywacke possibly to be Permian, and Knopf thought it might be Late Jurassic or Early Cretaceous.

The fossils collected by Overbeck from Slocum Arm almost surely came from the formation herein called graywacke. Although Overbeck assigned a probable Upper Jurassic age to the formation on the basis of those fossils, he was careful to cite the paleontologist's report, in which it was indicated that the distinction between Upper Jurassic and Lower Cretaceous was in this case not satisfactory.

If the fossils in some of the lots collected by an employee of the Hirst-Chichagof Mining Co. on Kruzof Island and in the Chichagof district came from the same formation as the graywacke in the Chichagof mining district, as is believed probable, then the Lower Cretaceous age of the formation appears to be certain.

The doubt as to the age designation of the formation arises because the rocks at Kruzof Island and in the Chichagof district are not definitely known to be in the same formation and because of the possibility, which, however, appears remote to the authors, that the formation as mapped includes both Upper Jurassic and Lower Cretaceous rocks.

UNCONSOLIDATED SEDIMENTS

Unconsolidated sediments are not abundant on Northwestern Chichagof Island; they consist of moraine, alluvium, and volcanic ash. The glacial moraine is widely but thinly scattered over most of the mapped area. Remnants of lateral moraines can still be found in sheltered niches along the valley walls and along the sides of the fiords. Above timberline, terminal moraines are generally below the cirque basins, and erratic boulders are scattered over most of the upland surface. There are a few boulders and in places a thin veneer of apparently glacially derived detritus on the coastal plain on the west side of Chichagof Island.

The scarcity of morainal material on Chichagof Island probably is due to the manner in which the glaciers receded. During the period of maximum glaciation the ice was nearly 3,000 feet thick over most of the area. The main source of the ice was in the Fairweather Range to the north and in the high mountains lying north and east of Glacier Bay. The ice moved southward and westward from these mountains, sweeping over much of the northern part of Chichagof Island. Probably this ice was then relatively clean, as is the ice in the glaciers which form in these areas today. At the period of maximum glaciation the ice front extended well into the sea and the ice on Chichagof Island was cut off from its source in the high mountains as the re-

duced volume of ice was channeled to the ocean through Icy Strait and Cross Sound. This left a large cap of stagnant ice covering most of Chichagof Island with no adequate source to maintain itself; consequently this thick mass of ice ablated over a relatively short period of time without leaving thick accumulations of glacial detritus in the form of marginal or terminal moraines.

The larger streams contain alluvium which in places may be several hundred feet thick. Many of the streams have formed deltas where they enter the bays and inlets. The delta at the outlet of Lisianski River has filled the inlet from shore to shore for distance of more than a mile. Other streams flowing into Lisianski Inlet as well as those streams entering Stag Bay and Idaho Inlet have formed deltas of comparable size. Mud Bay contains the largest deposit of unconsolidated material on northern Chichagof Island. This bay, which was originally at least 3 miles long and about 1 mile wide, has been almost completely filled. In some respects the material in Mud Bay differs from the deltaic deposits at the heads of the fiords. The bay was not a fiord and may never have been very deep; there is also a strong suggestion that some of the material which fills the bay may have been deposited by a glacier occupying the area of the present Icy Strait.

Volcanic ash, presumably from the crater of Mount Edgecumbe, which is about 60 miles to the southeast, once covered most of the northwestern part of Chichagof Island. Probably the ash covered the area with a layer that, upon compaction, was about 6 inches thick, but most of it has been removed and can now be found only in a few spots that are well sheltered from erosion. The remaining ash is gritless, iron stained, and slippery; it ranges from 6 inches to several feet in thickness. The thickest deposits apparently become thicker through deposition of ash that was derived from surrounding areas by erosion.

INTRUSIVE IGNEOUS ROCKS

During the course of the geologic mapping the question arose as to whether the rocks shown as gabbro, diorite, and quartz diorite are true intrusive igneous rocks or metamorphosed older rocks. Transitions from recognizably metamorphosed older rocks to rocks closely resembling igneous rocks are common. It is clear that tens of square miles are underlain by rocks which are so highly metamorphosed that they are nearly, or in places completely, indistinguishable from true igneous rock. On the other hand, it is evident that igneous rock in a few places has intruded and cut older strata.

The writer concluded that the mapped area probably contains an unusually broad zone in which the rocks have undergone sufficient

metamorphism to destroy most of the original structures, but that part of at least one body of intrusive rock crops out between the heads of Lisianski and Tenakee Inlets. Probably most of the rocks mapped as diorite are derived in part from true plutonic magma.

GABBRO

DISTRIBUTION AND GEOLOGIC RELATIONS

The oldest intrusive rock mapped on the northwestern part of Chichagof Island is gabbro. At some places the gabbroic rock is cut by diorite and is, therefore, older; but in other places the contact between the two is gradational and possibly part of the gabbroic rock may be the same age as the diorite. Probably two similar rocks are present, one an intruded plutonic gabbro and the other a metamorphosed older rock. The gabbro shown on the map includes only that believed to be older than the diorite.

The gabbro north of Lisianski Inlet crops out in several large stocks. The southernmost stock is 4 miles north of the head of the inlet. A tongue of gabbro extends southeastward from the main body to a point beyond the mapped area. The rock mass has a mean diameter of about 3 miles and is nearly everywhere in contact with diorite. A gabbroic mass lies on the ridge west of the north branch of Phonograph Creek, and another extends along the west valley wall of the south fork of Trail River. Near the lake at the head of Phonograph Creek the northern body of gabbro is narrow and highly mixed with older rock.

PETROLOGY

Typical gabbro in outcrop is dark gray. Usually the rock can be recognized from a considerable distance by its massive form and dark color; much of it contains inclusions of older rock. The inclusions grade into gabbro, and those which are as coarsely crystalline as the gabbro are difficult to distinguish from it. The sedimentary rocks where in contact with the gabbro are folded and faulted, in marked contrast to the diorite contact with the bedded rocks which generally show little or no evidence of local folding at the contact.

Normal gabbro in outcrop is an equigranular rock with granitic texture. On slightly weathered surfaces the rock is rough owing to the weathering of all the minerals except magnetite, which stands out in relief. Masses of magnetite range from barely visible grains to pieces three-fourths of an inch in diameter. Small white veinlets cut the gabbro and are so ubiquitous that the gabbro commonly can be recognized from a considerable distance simply by their presence. The veinlets are composed of feldspar and small amounts of quartz, prehnite, laumontite, epidote, and calcite.

Under the microscope the gabbro shows a xenomorphic-granular texture. All the minerals except olivine and orthorhombic pyroxene are nearly unaltered. The hornblende is a dark-green variety; some thin sections show it forming from pyroxene, and probably an appreciable percentage of hornblende in the gabbro was formed in that manner. Feldspar ranges in composition from labradorite to anorthite, and is generally complexly twinned. Olivine and orthorhombic pyroxene probably made up 5 to 15 percent of the original rock, but subsequently they have been largely altered to chlorite and amphibole. Gabbro that is contaminated by the partial assimilation of older rock differs from the more normal gabbro in several characteristics: It is more variable in composition and in grain size; it is generally finer grained, but in a few places it is coarser grained than the normal gabbro and contains crystals of hornblende several inches long; most of the hornblende in the contaminated rock forms from pyroxene. The feldspar has a composition ranging from andesine to bytownite; it is generally altered and simply twinned. Locally the contaminated gabbro contains quartz.

DIORITE

DISTRIBUTION AND GEOLOGIC RELATIONS

Rocks included under the term "diorite" crop out in about half the mapped area. The diorite is in several masses which are separated at the surface by other rocks or by water but which are probably connected at depth. The cores of the large bodies contain rock that is typical of normal igneous intrusions, but the smaller bodies and the borders of the larger bodies are made up mostly of recrystallized older rock. Some of the rock included under the general heading of diorite should, perhaps, be differentiated as highly recrystallized metamorphic rock. This was not done because it was thought impossible to distinguish everywhere true diorite from some of the more highly recrystallized metamorphic rock. The geologic map (fig. 3) accompanying this report shows by symbols, as far as possible, the distribution of metamorphosed rock in the diorite.

The distribution of the diorite is complex in detail; but, in general, one mass crops out south of Lisianski Inlet, a large body crops out in the area between the head of Lisianski Inlet and Gull Cove, one small body lies on Althorp Peninsula, and another extends diagonally across the base of Inian Peninsula.

The diorite south of Lisianski Inlet extends from Mite Cove on Yakobi Island southeastward to the southeastern corner of the mapped area. It continues across the Chichagof mining district, and probably continues on farther south to Baranof Island. In the area

mapped, this mass of diorite is about 25 miles long and 4 miles wide. The southwest side is in contact with older sedimentary and volcanic rocks. On the northeastern side the contact is concealed beneath Lisianski Inlet. The diorite is in fault contact with the quartz diorite in the area south of Lisianski River.

The large body of diorite that crops out between the heads of Lisianski and Tenakee Inlets is made up largely of typical intrusive diorite. The part exposed is circular in outline on its west side, but this represents only the northwestern tip of a much larger rock mass. The southeastern extent is not known; but, from the older geologic reports and from the writer's investigations the body is believed to extend to the east edge of Chichagof Island. Within the mapped area this diorite is in contact with gabbroic rock and with parts of the marble-gneiss sequence. The body of diorite is probably continuous with that which crops out east of Idaho Inlet. This body extends from Icy Strait southeastward to the east edge of the mapped area. Although not mapped in detail, it almost certainly extends southeast as far as Tenakee Inlet, and probably is part of the large mass of diorite cropping out south of Tenakee Inlet. The diorite between Idaho Inlet and Mud Bay probably extends northeastward to make up part of Lemesurier Island, the eastern part of the Inian Islands, and the land west of Dundas Bay. Subsequent mapping has shown that this diorite extends northward to the head of Glacier Bay; undoubtedly it is connected with the Coast Range batholith. Within the mapped area, the east side of the diorite between Idaho Inlet and Mud Bay is in contact with a younger quartz diorite, and the west side is in contact with rocks of the marble-gneiss sequence. Much of the diorite along the western contact contains large amounts of older bedded rock.

A smaller diorite body intrudes the schist unit on the Althorp Peninsula. It extends northwestward from a point 4 miles north of Basalt Knob on Lisianski Inlet to the west shore of Port Althorp. The diorite exposed on the George Islands and on the west edge of the Inian Peninsula and the Inian Islands is probably a northwesterly continuation of this body. Assuming that the isolated outcrops on the George Islands and on the Inian Islands are connected to the diorite on Althorp Peninsula, the length of this body is more than 15 miles. The average width is about 1½ miles.

A fourth body of diorite trends diagonally across the base of Inian Peninsula, extending from a point 2 miles north of Pelican to a point nearly opposite the entrance to Idaho Inlet. It appears to be intruded mainly between rocks of the greenstone unit and of the marble-gneiss sequence.

PETROLOGY

In order to simplify the description of the diorite, which includes several types, the rock has been divided into two groups. One group, called intrusive diorite in this report, includes rock which has the characteristics normally associated with plutonic diorite; the other group, called metadiorite in this report, is composed of recrystallized older rock that now has the texture and composition of diorite. The chief megascopic differences between the intrusive diorite and the metadiorite are the better developed granitic textures of the intrusive diorite and the more apparent alteration and more pronounced foliation of the metadiorite.

Most of the intrusive diorite crops out between Idaho Inlet and Mud Bay and between the heads of Lisianski and Tenakee Inlets. Smaller amounts are found on the north end of the westernmost Inian Island, and in the center of the diorite mass south of Lisianski Inlet. Generally a border zone of metadiorite lies around the periphery of the intrusive diorite.

In outcrop the intrusive diorite is gray or tan and has a medium-grained granitic texture. Foliation is generally visible but is less marked than in the metadiorite. Except for slight weathering the rock appears to be unaltered.

In thin section the rock commonly shows a hypautomorphic- to xenomorphic-granular texture. The longer axes of the hornblende crystals tend to be parallel, giving the rock a recognizable lineation.

Plagioclase feldspar is the most abundant mineral in the instrusive diorite. In thin section it appears nearly unaltered. The crystals of plagioclase are complexly twinned and a few are zoned. In places the zoning appears to be partly destroyed by alteration, and all that remains to indicate that the mineral was zoned are regular, thin lines of alteration along the position of one or more of the original zones. Probably many more of the plagioclase crystals were zoned than can now be recognized. The normal composition of the plagioclase in the intrusive diorite is about An_{50}, but it ranges from An_{25} to An_{80}.

The hornblende is a common green variety and makes up 10 to 30 percent of the rock by volume. The crystals are generally elongate but anhedral. The borders are irregular but much less so than the borders in the hornblende found in the metadiorite. Sieve structure is common, but the feldspar, which is the enclosed mineral, is generally present as euhedral crystals. Alteration of the hornblende is slight and restricted to thin incrustations of chlorite bordering the crystals. Tiny euhedral crystals of hornblende, recognizable only under high magnification, are also enclosed within feldspar crystals. A few specimens contain pyroxene, near augite in composition, which is

altered and replaced by chlorite, biotite, and green hornblende. In the cores of some pyroxene crystals are myrmekitelike intergrowths of pyroxene and quartz. The pyroxene near the myrmekitic structures has a lower birefringence than that away from these structures.

Because the metadiorite has a wider range in composition and texture, it has a more varied appearance than the intrusive diorite. Outcrops range in color from light gray to nearly black, depending upon the rock type and the amount and type of weathering. The rock is sufficiently altered that newly fractured surfaces do not appear to be particularly fresh.

The recognizable minerals in the hand specimens of metadiorite are hornblende, feldspar, quartz, and locally, chlorite and epidote. Less commonly, sphene, magnetite, and pyrite, are visible.

Most of the rock shows a preferred orientation of the constituent minerals. Planar foliation is common, but in places only a faint lineation of the hornblende crystals can be recognized. Usually the plunge of the lineation is indistinct and not easily measured in the outcrop. Generally the dark minerals do not have sharply defined borders against lighter minerals. Under high magnification this is seen to be caused by a zone of alteration and replacement between the mineral grains. Feldspar makes up 40 to 60 percent of the metadiorite by volume. Commonly in the hand specimen the feldspar is some shade of gray or green, or, as in one locality near the top of Mount Althorp, a pale but distinct pink. On freshly fractured surfaces the feldspar has neither the clean-cut cleavage nor the striations due to twinning that are typical of the feldspar of the intrusive diorite. In thin section the plagioclase appears cloudy, and the twinning is commonly masked by alteration.

The metadiorite contains several varieties of hornblende, the most abundant being the ordinary green variety. Less abundant, but not uncommon, is a variety, believed to be relatively rich in sodium, which shows a distinct blue pleochroic color in polarized light. A nearly nonpleochroic, pale-brown variety and a darker brown pleochroic variety occur on the George Islands and on the western part of the Inian Islands. The hornblende in the metadiorite characteristically has a highly irregular outline. As a rule the hornblende crystals include small crystals or grains of plagioclase or quartz. Hornblende is one of the minerals least altered in the metadiorite, but it also generally shows some alteration.

Hornblende forms from pyroxene, the process apparently taking place preferentially in the more mafic phases of diorite. Formation of hornblende from pyroxene takes place by at least two separate and distinct processes. In one, pyroxene interacts with adjacent minerals

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to form hornblende. This process involves chemical readjustment and probably results in a chemically more stable rock. Hornblende formed by this process forms around the outside of the parent pyroxene crystal and as a rule does not occupy exactly the same space as did the original pyroxene. There appears to be no systematic crystallographic relation between the pyroxene and the hornblende formed by this process. In the other type of transformation the hornblende occupies exactly the same space as did the original pyroxene. The transformation takes place more gradually, apparently by slight shifts in the molecular structure, and the new hornblende appears at widely separated points throughout the pyroxene crystal without regard to proximity to the borders of the crystal. The material in the pyroxene makes up the new hornblende, and there appears to be no chemical interaction between the two minerals.

During the course of the geologic mapping on the northwestern part of Chichagof Island, three small bodies of intrusive diorite were found which appear, from field relations, to be younger than the diorite described above. One of these crops out on top of the mountain southeast of the Cobol mine, another about 1,000 feet southwest of the Apex mine, and a third in the Chichagof mining district 1 mile due east of Pinta Bay. All three crop out near gold-bearing veins and all appear to be related to the mineralization in their respective areas. The map (pl. 13), which includes the Apex and El Nido mines, distinguishes a small body of diorite from the more abundant type. The diorite east of Pinta Bay strongly resembles, both structurally and in hand specimen, the two types shown on plate 12; however, it was not examined closely nor studied microscopically by the writer.

The diorite that makes up the top of the mountain southeast of the Cobol mine is everywhere completely exposed; because of this, its relation to the adjacent rock is clear: It is circular and about a half a mile in diameter; its shape and contact relations suggest that it was forcibly intruded; it consists of a fine-grained border zone, 20 to 50 feet thick, and a central core of medium-grained rock. The core is gray and is extremely friable. The outer phase, which is probably a chilled border, is hard and dense and stands out as a rim around the core. Many gold-bearing quartz veins occur near all three of these bodies. The close spatial relation between the known gold-bearing veins and this relatively scarce type of diorite suggests that they may be genetically related.

AGE

The diorite very probably formed during Cretaceous time. Buddington and Chapin (1929, p. 183–186) thought that the main diorite intrusions on Chichagof Island took place in Jurassic or Early Cre-

taceous time. Reed and Coats (1941, p. 40) concurred with this opinion. They pointed out that if the many fine-grained dikes which cut the graywacke have their source in the main diorite intrusion, then the diorite must be younger than the graywacke, which is believed to have been deposited in Early Cretaceous time. The writer believes that the diorite was intruded near the time of the main period of folding of the graywacke, and thus must be younger than the graywacke. The diorite cuts the gabbro described above and is therefore younger, but it is in turn cut by quartz diorite and the intrusive rocks associated with the nickel-bearing deposits at Bohemia Basin on Yakobi Island.

From the foregoing, it appears that the diorite represents one of a series of intrusions which took place over a long period of time. The diorite intrusion was the largest, and probably all later intrusions were related to it.

QUARTZ DIORITE

DISTRIBUTION AND GEOLOGIC RELATIONS

Small stocks of quartz diorite crop out throughout the northwestern part of Chichagof Island. They have intruded the graywacke, schist, and greenstone units as well as the marble-gneiss sequence and the diorite. Several quartz diorite stocks crop out south of Lisianski Inlet. The largest is around Lake Elfendahl. This stock is intruded into rocks of the graywacke, greenstone, and schist units. Two other stocks of the same type, probably genetically related to the stock at Lake Elfendahl, crop out a few miles farther northwest. Both have less than 1 square mile of outcrop area, and intrude rocks of the schist unit. The larger stock crops out near the entrance to Stag Bay on the west flank of Mount Hill, and the smaller stock crops out about midway between the larger stock and the stock at Lake Elfendahl. Another body of quartz diorite, with an outcrop area of about 1 square mile, crops out 4 miles due east of the stock at Lake Elfendahl, on the south flank of the mountain southeast of the Cobol mine and on the south shoulder of Big Chief Mountain. It is intruded into rocks of the greenstone unit and the marble-gneiss sequence. Other bodies of quartz diorite are exposed along Lisianski Inlet and southeast of its head; the westernmost body of this group crops out over about three-fourths of a square mile, and is north of Lisianski Inlet at the outlet of Meadow Creek. It lies entirely within rocks of the schist unit. An elongate exposure of quartz diorite is in contact with older diorite along the south shore of Lisianski Inlet at the mouth of Cann Creek. Two other bodies of quartz diorite lie southeast of the head of Lisianski Inlet: The southernmost is intruded between a mafic phase of the diorite on the south and rocks of the schist unit on the north; the

northernmost lies between the schist and marble units on the south and highly metamorphosed rock on the north which may be part of the marble-gneiss sequence or part of the schist unit. These quartz diorite bodies extend at least 6 miles southeast of the head of Lisianski Inlet.

Another large quartz diorite stock lies next to the diorite batholith between Idaho Inlet and Mud Bay on the west and the sedimentary rocks of Paleozoic age on the east. This stock may not be genetically related to those mentioned above, but it has been grouped with them because its rock type and known age relationships are similar. Its areal extent is unknown.

PETROLOGY

The quartz diorite in outcrop is a light-colored even-grained rock. The minerals generally show a preferred but poorly developed orientation. Feldspar, most of which is near oligoclase in composition, quartz, and one or more dark minerals make up most of the rock. The large body of quartz diorite southwest of Mud Bay contains as much as 10 percent orthoclase. The others contain only small quantities of orthoclase. The smaller stocks, such as those between Stag Bay and Lake Elfendahl, contain pyroxene in several stages of alteration.

In the smaller stocks, hornblende is the most abundant dark mineral, most of it partly altered to chlorite. The feldspar is also commonly partly altered. Quartz crystallized after the feldspar and the dark minerals and in part replaces them. The rock in the smaller stocks is shattered and contains numerous seams filled with adularia and calcite. In thin section, the majority of the quartz crystals show undulatory extinction, and both the quartz and the feldspar are shattered.

The stock at Lake Elfendahl consists of a coarse-grained slightly altered rock whose principal dark mineral is biotite. Zoned plagioclase was seen in all the thin sections examined. Cataclastic textures are almost entirely absent. From etching and staining methods and from petrographic studies of thin sections and of grains, it is estimated that the rock contains from 2 to 5 percent orthoclase.

AGE

The quartz diorite intrudes the lower part of the graywacke formation, which is probably of Early Cretaceous age. Light-colored dikes have not been found in the quartz diorite, and probably none exist. One dark-colored dike was found in the quartz diorite stock that crops out along the south shore of Lisianski Inlet near its head. The dike rock resembles the basalt plug that crops out on the north side of Lisianski Inlet north of Miner Island. The plug is probably

the youngest igneous rock in the area and may have formed in late Pleistocene or Recent time. The quartz diorite is partly altered, but most of the alteration apparently was caused either by retrogressive metamorphism which took place during the last stages of cooling or by failure of the rock to attain chemical equilibrium after it had engulfed and partly assimilated large amounts of older material. Because it seems to be associated with and is intruded along the marginal zones of the diorite, the quartz diorite is believed to be a late segregation of the diorite.

INTRUSIVE ROCKS ASSOCIATED WITH NICKEL DEPOSITS

DISTRIBUTION, GEOLOGIC RELATIONS, AND PETROLOGY

A group of related intrusive rocks that are associated with nickel deposits crop out on Chichagof and Yakobi Islands. These rocks consist of two genetically related rock types which are called the younger gabbro and the younger quartz diorite in this report. The gabbroic rocks are composed of gabbro, norite, and small amounts of pyroxenite. The quartz diorite has the composition of normal quartz diorite and in outcrop has a uniform and fresh appearance.

The rocks in this igneous complex were described by Reed and Dorr (1942, p. 105–138), and by Pecora (1942, p. 221–243). None of the rocks are unusual types.

The largest known body of igneous rock associated with these deposits occupies most of the southwestern half of Yakobi Island. The exposed part covers about 30 square miles. A small stock, roughly circular in shape, crops out on the peninsula between Lisianski Strait and Ilin Bay. A small stock, roughly circular in shape, crops out at Lost Cove on the peninsula between Lisianski Strait and Ilin Bay. A third stock crops out along the coast at Mirror Harbor. It has an outcrop area of about 1½ square miles, but it probably extends for a greater distance beneath the sea.

A group of intrusive rocks, believed to be related to those containing the nickel deposits, crops out in the Fairweather Range north of Cross Sound, outside the area of this study. The writer has mapped several of these mafic rock masses since doing the work on Chichagof Island. One mass crops out over an area of about 3 square miles on Astrolabe Peninsula and Mount De Langle; another, about 16 miles long, crops out from a point several miles southeast of Mount La Perouse to the north side of Mount Crillon. A third body, which has never been examined, lies somewhere on the south flank of Mount Fairweather. Its existence is known from the fact that a large part of the moraine in front of the Fairweather Glacier is composed of this type of rock. The stock at Mirror Harbor and the three bodies of

mafic rock in the Fairweather Range have the unique feature of being layered. The stock that crops out between Mount Crillon and Mount La Perouse has an exposed thickness of over 30,000 feet.

AGE

Most of the data regarding the age of the intrusive rocks associated with the nickel deposits are indirect and inconclusive. The diorite and quartz diorite have been metamorphosed throughout the area. On the other hand, the rocks associated with the nickel deposits have a clean-cut crystallinity, are unfoliated, show little or no alteration, and consequently have a fresh appearance. Because the intrusive rocks associated with the nickel deposits are within a few miles of the diorite and the quartz diorite, it does not seem likely that the diorite and quartz diorite could have been metamorphosed over such a wide area without the metamorphic process or processes also affecting the intrusive rocks associated with the nickel deposits. Furthermore, the rocks associated with the nickel deposits apparently intruded the rocks of Mesozoic age after they had reached the position in which they are found today. These facts seem to indicate that the intrusive rocks associated with the nickel deposits were not present when the diorite and quartz diorite were metamorphosed, and that the rocks associated with the nickel deposits were intruded after Early Cretaceous time.

FELSIC DIKES

APLITE

The most abundant dikes on the northwestern part of Chichagof Island are the aplites; they have not been differentiated on the geologic map from the enclosing rocks. They intrude all the major rock units except the younger intrusive rocks associated with the nickel deposits and the quartz diorite, which is probably the source of the aplite. The dikes are most abundant between Lisianski Inlet and the stock at Lake Elfendahl. In this area all dikes radiate from the stock at Lake Elfendahl, and, although no dikes were observed that actually were in contact with the stock, at least 50 crop out within a few hundred feet of its north side. The body of quartz diorite that cropped out on the south side of Lisianski Inlet at the mouth of Cann Creek apparently had similar dikes extruded from it. The aplite dikes that crop out near the Apex and El Nido mines may have their source in the quartz diorite stock that crops out at the mouth of Cann Creek; one aplite dike was traced from the El Nido mine to the fault along the west side of the stock.

In outcrop the dikes range from a few inches to more than 20 feet in thickness; most are 4 to 15 feet thick. Chilled borders are un-

common. Locally the intruded rock is altered for a few feet on each side of the dike. In certain parts of the mapped area, at the Apex and El Nido mines, for example, the aplite dikes are intimately associated with gold mineralization. The experienced prospectors in the area are aware of the relation of the aplite dikes to gold mineralization, and have spoken of it many times to the writer. From their accounts it is evident that the same relation holds true throughout much of the western part of Chichagof and Baranof Islands.

Fresh surfaces of dike rock are light green, owing to the presence of small amounts of chlorite, amphibole, and minerals of the zoisite group. Ordinarily the aplite is slightly porphyritic, and contains visible grains of mica. Euhedral or subhedral phenocrysts of quartz are rare, but subhedral phenocrysts of feldspar are common. Although the rocks grouped as aplite are similar in general appearance, few appear identical even in the hand specimen. They differ from one another in grain size, texture, color, and, to some extent, in mineral composition. The aplite is altered, and most is fine grained. The lighter colored dikes contain a more sodic plagioclase and a smaller percentage of mafic minerals. Textures range from granular to one characterized by small lath-shaped feldspar crystals that have only a slight tendency toward parallel orientation. Plagioclase is generally oligoclase but ranges in different dikes from albite through andesine. Some of the feldspar crystals are zoned, but for the most part zoning is obscured by alteration and replacement products. Most of the plagioclase is altered to sericite and muscovite, but some is altered to clinozoisite. Chlorite also replaces feldspar, but not extensively. The darker aplite dikes owe their color to chlorite and small crystals of amphibole. Dark-colored minerals, of which hornblende is the most common, may make up as much as 45 percent of these rocks.

Not all the aplite dikes are the same age, as shown by the fact that they cut one another. Low-grade metamorphism apparently took place in the aplite dikes during initial cooling. Most of the dikes have not been metamorphosed as severely as the rocks in which they lie; they probably were intruded after the enclosing rock had undergone its most extensive metamorphism.

HORNBLENDE-FELDSPAR PEGMATITE DIKES

Coarse-grained dikes have intruded the amphibolite and diorite on Chichagof Island. In mapping, these dikes have not been differentiated from the enclosing rocks. Several crop out along the east shore of Lisianski Strait in a contact zone between diorite and amphibolite, and a few are in the diorite batholith south of Lisianski Inlet between Lisianski Strait and Steelhead River. Other horn-

blende-feldspar pegmatite dikes have been found on the Inian Islands, on the east side of the Inian Peninsula, and on Mineral Mountain. From a distance the hornblende-feldspar pegmatite dikes appear to be predominantly white, but close observation shows the dikes to have a strong color contrast between areas composed of quartz and feldspar and areas composed of hornblende.

Although a few contain fragments of older rocks, most of these dikes show no positive evidence of intrusion. They do not have chilled borders, although contacts with adjacent rocks are generally sharp; typically they are irregular in shape. They are found, without exception, in rocks which have undergone extensive recrystallization. Based largely on field relations such as those given above, it is the writer's opinion that this group of rocks formed mainly by replacement, with the constituents being derived largely from the host rock.

The feldspar in most of these coarse-grained pegmatites is albite, or more rarely, oligoclase. Most of it is cataclastically deformed, and all is more or less altered. Because of the deformation and alteration, twinning is not easily seen. Hornblende crystals, because of their large size, are the most conspicuous mineral. Crystals 6 to 8 inches long are common. One dike three-fourths of a mile northeast of Elfin Cove contains skeleton crystals of hornblende more than 3 feet long and 6 to 10 inches in diameter.

QUARTZ-FELDSPAR DIKES

Many light-colored, migmatitelike dikes occur on northwestern Chichagof Island. The dikes which were mapped with the enclosing rocks, are coarse-grained and consist of quartz, feldspar and a small amount of muscovite. In this report these dikes, which are called quartz-feldspar dikes, are variable in thickness, short, and consist of fairly coarsely crystalline rock. The largest proportion are in one poorly defined zone which is nearly 40 miles long. The north edge of the zone joins a granodiorite stock in the area east of the west arm of Dundas Bay north of the mapped area. The zone extends south to a point about 2 miles north of the outlet of Meadow Creek on Lisianski Inlet. South of this point the zone is less well defined, and extensive areas in the valleys of Pelican and Meadow Creeks are covered. The southernmost known occurrence of the zone is on the west flank of the mountain east of Phonograph Creek. In addition to this zone, quartz-feldspar dikes have been found at widely separated points, but invariably all are in highly metamorphosed rocks. A few dikes crop out along the contact zone between the diorite and the greenstone unit on Mount Hill south of Stag Bay. Light-colored bands observed in the upper drainage basin of Steelhead River are probably quartz-

feldspar dikes, but exposures are poor. The exact nature of the bands could not be determined with certainty; they may well represent recrystallized silicic beds. Other quartz-feldspar dikes were found 1 mile above the outlet of the large creek that enters Idaho Inlet 2 miles south of the unnamed village on the east side of the inlet.

The quartz-feldspar dikes are most abundant in the northern half of the main dike-bearing zone where they make up from 10 to 80 percent of the total rock volume. The dikes are generally parallel to the foliation of the host rock and dip steeply. In one small area on the south shore of the largest of the Inian Islands, quartz-feldspar dike rock forms the matrix of a brecciated zone. Another such brecciated zone occurs along the contact of the diorite and the greenstone unit in the southeastern corner of the mapped area.

At several widely separated localities the dikes show an internal structure which almost certainly represents incompletely replaced relicts of the host rock. These structures generally take the form of foliation or bands parallel to and on strike with the foliation planes in the host rock. Although the relict bedding of the wall rock is observable in a few dikes, it is not common and can be found only by diligent search. At no place has the relict structure been observed to pass completely through a dike.

In some of the quartz-feldspar dikes, particularly those which clearly were injected, there is a systematic arrangement by grain size, texture, and mineral composition from the edge to the center much like that found in some pegmatite dikes and quartz veins. The outer margin of the dike is composed mainly of quartz and feldspar which show no apparent alinement of the crystals. In the dike adjacent to the outer marginal zone, the crystals are slightly larger and are composed of feldspar and hornblende. The hornblende crystals are elongate and show some tendency to have their long axes normal to the walls of the dikes.

In places, quartz-feldspar dike masses are large enough to be classed as small stocks; the rock appears to be similar to the quartz diorite and is possibly the same age. Aplite dikes have not been observed in contact with the quartz-feldspar dikes, and, consequently, their relative ages are not known. The quartz-feldspar dikes on the northwest side of Mineral Mountain are cut by mafic dikes. These younger mafic dikes have not been observed to be cut by any other rock.

MAFIC DIKES

Mafic or dark-colored dikes which were not differentiated on the geologic map from the enclosing rocks are scattered throughout the northwestern part of Chichagof Island. Although they are not as

highly concentrated in any one area as are the aplite or the quartz-feldspar dikes, the dark-colored mafic dikes are more evenly and widely distributed. Within the mapped area the total number of mafic dikes may nearly equal the number of aplite dikes.

Mafic dikes in general vary only slightly in appearance, but most fall within five distinct types. Probably the most common is a gray to green fine-grained dike containing scattered phenocrysts of feldspar. The second type, nearly as abundant as the first, is a fine-grained gray dike without phenocrysts; this type is mineralogically similar to the groundmass of the first and will not be discussed further. Another type, but one which is found in only a few places, is dark green with large blocky phenocrysts of hornblende or feldspar. A few fine-grained composite dikes occur at widely scattered points; they are dark-brown and contain needle-shaped crystals of hornblende or pyroxene. The last type is a fine-grained composite dike.

The ages of the different types of dikes vary widely. Some of the dikes have been strongly metamorphosed with the diorite and obviously were present when the metamorphism took place. Others are similar in rock type to the basalt plug which crops out on Lisianski Inlet. If the dikes were derived from the same source as was the plug, they probably were intruded in Pleistocene time or later. It is believed, however, that most of the mafic dikes were formed after the metamorphism of the diorite and before the intrusion of the basalt plug.

GRAY TO GREEN PORPHYRITIC DIKES

Gray to green porphyritic dikes are common along Lisianski Inlet. They have not been differentiated on the geologic map from the enclosing rock. In outcrop they are usually inconspicuous and easily overlooked, particularly in areas where they intrude partly recrystallized dark-colored rock. The phenocrysts are abundant and consist mostly of pyroxene and feldspar, both presumably primary. Both pyroxene and feldspar form euhedral crystals. The rock contains hornblende, prehnite, calcite, magnetite, zoisite, and sericite. Because the feldspar is highly altered, its composition has not been determined accurately. The average index of refraction is about 1.545, which indicates that the feldspar is oligoclase. The main alteration product of the feldspar is clinozoisite. The pyroxene crystals in general have resisted alteration remarkably well, considering the condition of the feldspar. A few have been altered to hornblende, and some are slightly replaced by chlorite.

The range in age of the green porphyritic dikes is unknown, but some cut the quartz diorite; they probably have been intruded since Cretaceous time.

DIKES CONTAINING BLOCKY HORNBLENDE AND FELDSPAR PHENOCRYSTS

Many dark-colored dikes crop out on the northwestern flank of Mineral Mountain. The dikes mapped with the enclosing rock, are from 2 to 6 feet thick and occupy steeply dipping joints which trend northeast. Although all the dikes are probably similar in composition, they differ in texture; few appear to be identical even in the hand specimen. In thin section the dike rock shows a relatively coarse-grained groundmass of zoned plagioclase and hornblende crystals. The hornblende phenocrysts are euhedral and reach a maximum of about 1 inch. The larger crystals usually are unaltered internally, but the margins are replaced and altered. Smaller anhedral hornblende crystals in the matrix are generally unaltered except where they are in contact with magnetite.

The plagioclase is zoned and euhedral. Usually the core, presumably the most calcic part, is highly altered. Because of extensive alteration of the plagioclase, its composition is difficult to determine. In most dikes the feldspar is highly calcic, averaging about An_{75}. Other minerals common in the dikes are chlorite, prehnite, and sericite.

BROWN DIKES

A few dikes containing needle-shaped phenocrysts of hornblende or pyroxene crop out on the northwestern part of Chichagof Island. These dikes were not mapped separately from the enclosing rock. Apparently those containing pyroxene phenocrysts are distinct from those containing hornblende phenocrysts. The pyroxene-bearing type contain subordinate plagioclase feldspar and an opaque mineral. The pyroxene is monoclinic but its other optical properties have not been determined. The feldspar is andesine. In thin section the pyroxene and feldspar appear highly elongate and tend to lie with their long axes parallel.

FINE-GRAINED GRAY DIKES

A few fine-grained gray dikes that crop out on the northwestern part of Chichagof Island resemble fine-grained metamorphosed sedimentary rocks. The dikes are unmapped. Most are either within the diorite that is probably a recrystallized older rock, or in the diorite contact zone. In outcrop the dike rock is gray and evenly textured. Individual grains of hornblende and feldspar are about 0.4 millimeter in diameter. One specimen was collected about half a mile south of Lisianski Inlet, 6 miles from its head; the plagioclase in this specimen, as determined with the universal stage, is about An_{85} and occurs in rounded grains intermixed with hornblende. Some hornblende crystals show sieve structure.

EXTRUSIVE IGNEOUS ROCKS

BASALT

A small body of basalt crops out on the northeast shore of Lisianski Inlet 1½ miles north of Miner Island; it forms a low rounded hill, Basalt Knob, which projects into the inlet beyond the general line of the shore. The basalt lies along a major fault zone, and two other similar, but smaller bodies have been found cropping out along the same zone in the area between Basalt Knob and Cross Sound.

The basalt in outcrop is compact, fine grained, and dark colored. Crystals are too small to be identified with a hand lens. Columnar jointing is imperfectly formed. About 50 percent of the rock is composed of feldspar in simple twinned, lath-shaped crystals. The remainder of the rock is composed of two ages of brown hornblende, a clinopyroxene, a carbonate mineral, and an opaque mineral, probably magnetite. An unidentified dark-colored isotropic substance makes up 2 to 5 percent of the rock. The older hornblende consists of larger grains than the younger; it shows evidence of having formed in part from clinopyroxene. Both types of hornblende show crystal outlines, but the younger crystals are the most perfectly formed. The younger hornblende crystals commonly occur within older feldspar grains as tiny rod-shaped crystals.

Alteration of the basalt is pronounced, and both feldspar and the older hornblende are replaced by chlorite. Probably the alteration took place during the final stage of cooling.

Two facts indicate that Basalt Knob is an extrusive body of relatively youthful age: (1) Its rock shows crude columnar jointing; this type of jointing takes place by rapid cooling of the rock usually under near-surface conditions. (2) The rock forms a rounded hill which stands out from the general shoreline of Lisianski Inlet. It is likely that the basalt was not present when glacial erosion formed Lisianski Inlet. The basalt is probably no more resistant to erosion than is the adjacent schist formation and would have been planed off level with the neighboring rocks if it had been present at the time the inlet was carved.

METAMORPHISM

Nearly all the rocks on the northwestern part of Chichagof Island are metamorphosed to some extent, and in much of the area the metamorphism has been so intense that the original nature of the rocks is obliterated. In general the most highly metamorphosed rocks are in the northern and eastern parts of the mapped area. For the most part the metamorphism is characterized by recrystallization at high temperature with low attendant stress. The processes discussed below involve rocks that have been described in the preceding pages.

AMPHIBOLITIZATION

In this report the amphibolite is subdivided into two groups: Massive amphibolite, a rock made up almost entirely of coarse-grained hornblende and augite; and amphibole-plagioclase, composed of elongate hornblende crystals set in a matrix of plagioclase feldspar.

Massive amphibolite occurs in large, widely scattered bodies in or adjacent to diorite throughout the southern and western part of the mapped area. The largest crop out on the peninsula between Lisianski Inlet and Stag Bay. Others crop out on Yakobi Island, 1 mile south of Elfin Cove, along the east shore of Port Althorp, and on the George Islands. Some of the best exposures of amphibolite known to the writer are in the range of hills between the west arm of Dundas Bay and Brady Glacier. This is outside the mapped area, but the rocks are part of the same geologic province that includes the amphibolite at Elfin Cove, the George Islands, and Port Althorp.

The amphibolite commonly occurs in highly metamorphosed older rock, chiefly diorite. Its contacts are irregular and show no evidence of forceful injection. Another common characteristic is its tendency to form small, widely scattered masses. Apparently many of these amphibolite masses are completely surrounded by older rock and have no connection to other bodies or to any outside source.

In outcrop the massive amphibolite is dark green to nearly black. The rock typically is coarse grained with the crystals forming a mat or felt. The crystals lie in all directions and form a decussate texture. Internal structures have not been found and, at best, must be considered a rarity.

The principal minerals in the massive amphibolite are hornblende and a pyroxene, usually augite. Other minerals include chlorite, zoisite, clinozoisite, epidote, quartz, feldspar, and pyrite. Of the latter group, chlorite and zoisite are the most abundant. Hornblende, as seen in thin section, ranges from brown to nearly colorless; some is nearly nonpleochroic. Chlorite forms from hornblende and augite. The minerals of the epidote group are formed by the alteration of feldspar or of pyroxene.

Field relations do not clearly show whether the amphibolite was formed by injection or through recrystallization and replacement. The contact between the amphibolite and adjacent rock is sharp, but shows no evidence of chilling or metamorphic phenomena commonly found at the contacts of injected masses. The contact is nearly everywhere very irregular, and small anastomosing stringers of amphibolite commonly lead out into the host rock. The amphibolite is invariably found in rocks which have undergone high mesothermal or low katathermal metamorphism; the writer believes that most of these

massive amphibolites have formed in place from the rock at hand. At one place on the south side of the George Islands where the process of amphibolitization is particularly well shown in outcrop, the writer found evidence that massive amphibolite formed from an older garnet-bearing dioritic rock. At this place all the structures are present which are commonly associated with massive amphibolite. In addition the diorite at one place has been altered to amphibolite for one-half inch on each side of a small fracture. The fracture itself is still preserved, precluding the possibility that the amphibolite is an injected dikelet, and in thin section the outlines of the garnet crystals of the older diorite are still visible in the massive amphibolite. Thus it is fairly certain that part of the massive amphibolite is a recrystallized or replaced diorite.

The formation of amphibole-plagioclase rock is better understood than is the formation of the massive amphibolite. The amphibole-plagioclase rock is mainly in areas where the diorite or gabbro came in contact with lime-rich sedimentary rocks. There appears to be a distinct relationship between the size of the hornblende crystals and the amount of lime present: the more lime, the larger the hornblende crystals. This does not hold true for pure limestone beds, however, which simply recrystallize to marble without the formation of new hornblende.

The amphibolite composed of feldspar and hornblende is mineralogically simple. In addition to plagioclase and hornblende, the rock contains small amounts of epidote, calcite, and quartz. The feldspar is anorthite, reaching a maximum of An_{98}. It is unusually clear and free from alteration products or inclusions. Twinning is well developed. Zoning was not observed.

The amphibole-plagioclase rock is coarse grained and ordinarily contains hornblende crystals ½ to 2½ inches long. Locally, however, under particularly favorable conditions of crystallization, the crystals may be 8 to 10 inches long. The minerals of the amphibole-plagioclase rock show little or no tendency to form parallel orientations.

RECRYSTALLIZATION OF GREENSTONE TO METAMORPHIC DIORITE

At several places on the northern part of Chichagof Island, greenstone that has been recrystallized to a rock outwardly resembling diorite is exceptionally well exposed. The recrystallized rock is similar to normal diorite in texture, grain size, and mineral composition.

One such exposure is on the central part of the largest island in the George Island group. Here the transformed rock contains garnet, and thus is not completely typical diorite. The greenstone at the contact consists of monoclinic and orthorhombic varieties of pyroxene

and a pale-brown, faintly pleochroic amphibole. Both the hornblende and the orthorhombic pyroxene are chloritized. The monoclinic variety in any one specimen is generally less altered than the orthorhombic variety. Near the place in the zone of alteration where the first change in texture can be discerned in the hand specimen, the pyroxene, in thin section, is partly recrystallized to zoisite. The zoisite increases in abundance away from the greenstone and toward the diorite. At a certain point in the outcrop, where the rock shows an igneouslike texture, the zoisite appears as patches which resemble milky-colored feldspar. Upon further crystallization, the zoisite is transformed into plagioclase, and at about the same point new hornblende appears.

ALBITIZATION

Albitized rock apparently is abundant in a broad belt around the south and west sides of the diorite bodies south of Lisianski Inlet and in bands along the east side and central part of the Inian Peninsula. Most of the albitized rock was originally either mafic volcanic rock or sedimentary rock. The initial stage of albitization is difficult or impossible to recognize in the hand specimen. Near the diorite the albitized rock is coarser grained than the original rock; generally it has a pronounced planar foliation parallel to the strata of the original rock. The most notable change, however, is in color, for the rock grades from a dark gray or green in slightly albitized rock to the color of normal quartz diorite in the highly albitized rock.

The wide extent of the albitization was not recognized until completion of the field work when the material was examined under the microscope. The specimens collected as representative of the initial stages of albitization are seen in thin section to be already well albitized. Specimens showing the complete sequence of events in the process were not collected, and the only specimens available that show the process in its earliest stages were collected from widely separated places and for a different purpose. Thin sections of rocks collected by Reed and Coats from the Chichagof mining district that show the process of albitization were also examined by the writer, but the exact location and geologic environment of these latter specimens were unknown, and the value of the data thus obtained was correspondingly lessened.

One area characterized by albite believed to be formed by metamorphism extends from Stag Bay southeast as far as Big Chief Mountain. Smaller bodies of similar rock crop out on the south side of the two mountains directly south of the Goulding Lakes. In outcrop the quartz-albite rock closely resembles quartz diorite.

The rock is light colored, medium grained, and foliated. Quartz, sodic plagioclase, and muscovite are everywhere present. Most albitized rocks contain chlorite, zoisite, clinozoisite, and rarely pyroxene. Hornblende is present in places. A potash feldspar, probably adularia, was identified as a fracture filling in one of the specimens. Two ages of plagioclase were recognized, the younger being the more sodic. Original and secondary quartz is abundant, and probably some is introduced.

Evidence that additional sodium was introduced to form albite was not recognized. In places albite does replace older feldspar, but this does not necessarily indicate that sodium has been introduced; rather, the presence of chlorite, zoisite, clinozoisite, and epidote suggests that the albite was formed by dissociation of the calcic feldspar, the calcium and some of the alumina going into the formation of these minerals and the remaining material forming albite.

CONTACT METAMORPHISM

The introduction of the magmas composing the stock at Lost Cove, the stock at Lake Elfendahl, and the stock at Mirror Harbor produced normal contact aureoles. These are the only stocks at which this occurred within the mapped area, and the extent and degree of metamorphism is small.

At Mirror Harbor and at Lost Cove the graywacke is recrystallized for a few tens of feet from the gabbro and quartz diorite contact. The recrystallized rock is fine grained, and few minerals are identifiable in the hand specimen. Under the microscope, the rock shows plentiful new biotite with a strong preferred orientation. A few small garnet crystals also have formed. The original quartz and feldspar are largely recrystallized but have not increased greatly in size. Andalusite is also present, but its origin may be unrelated to the metamorphism produced by the intrusion. Andalusite is actually more abundant several miles away from the stocks than at the contact.

The stock at Lake Elfendahl intruded only rocks of the schist and greenstone units. The degree of metamorphism produced by the quartz diorite is slight. Within a foot or so of the contact, the stratified rock is recrystallized to hornfels. Beyond this, the rock appears in the hand specimen to be unaffected. The quartz diorite becomes slightly finer grained within a few feet of the contact, and maintains this finer grain to within 2 inches of the contact. Closer than 2 inches the rock becomes perceptibly finer grained. Thin sections taken across the contact show nothing unusual. The quartz diorite at the contact is composed of quartz and feldspar, and the greenstone contains pale-green hornblende and small amounts of feldspar, quartz, and magnetite.

STRUCTURE

Inasmuch as most of the bedded rocks in the mapped area are conformable, one of the best ways of portraying structure is to map those beds possessing some lateral extent. For this reason most of the limestone beds were mapped. Their trace faithfully reflects the over-all structural pattern (pl. 12).

On the map, three large areas of bedded rocks are evident. One lies along the southwest side of the mapped area, one is a bifurcated mass extending from Lisianski Inlet northward to include parts of the George and the Inian Islands, and the third is between the head of Lisianski Inlet and the outlet of Idaho Inlet.

The bedded rocks in the southern part of the mapped area are structurally a continuation of the greenstone schist, greenstone, limestone, schist, and graywacke units as mapped by Reed and Coats in the Chichagof mining district. The rocks between Goulding Harbor and the stock at Lake Elfendahl strike northwest and dip about 60° SW. Farther north they show a tendency to steepen almost to vertical; near Stag Bay and on Yakobi Island they are overturned. The graywacke unit separates the stocks at Lost Cove and Lake Elfendahl. It is in this area, near the longitude of Porcupine Bay, that the graywacke unit is offset to the north. The offset may be due to the intrusions of the stocks at Lake Elfendahl and Lost Cove or to a deep-seated regional flexure.

Bedded rocks believed to be correlative with rocks in the greenstone, marble, and schist units crop out between Idaho Inlet and Lisianski Inlet. Their general strike is northwest and they dip steeply in both directions or are vertical. If the correlation shown on the geologic map is correct, the youngest part of the sequence lies on the southwest side of the mass; thus, the sequence is overturned where the rocks dip southeastward. The bedded rock nearest Lisianski Inlet and north of a point 2 miles northwest of Basalt Knob strike N. 30° W. and dip to the southwest. The beds on the northeast side of the western part are either vertical or dip to the northeast. The bedded rocks on Inian Peninsula strike N. 10° E.–N. 10° W. The dip is vertical or steep in either direction.

Between the southern part of rocks of the marble-gneiss sequence north of the head of Lisianski Inlet and a line due east from the town of Pelican, the strata strike N. 25°–30° W. and dip 50°–70° E. The trend changes in a few places; for example, the strata in the vicinity of the south fork of Phonograph Creek change in trend from N. 30° W. to N. 60° W. At the point of the greatest change in strike the beds flatten and dip 40°–50° NE.

A fault, possibly having great displacement, trends N. 80° E. under the largest lake a mile east of Marble Mountain. North of the fault and east of the band of dioritic rock the strata strike N. 10°–20° W. and dip 40°–50° E. The rocks south of the fault strike almost due north in the area about 2 miles south of the fault until, at the fault, they strike N. 80° E. The dip remains fairly constant at about 45° E.

The marble beds and sedimentary rocks included in the diorite between Idaho Inlet and Mud Bay strike N. 10°–50° W. and dip steeply northeast. The bedded rocks along the west shore of Mud Bay and Goose Island show that they have been subjected to considerable movement under high confining pressure. At one place on the east side of Goose Island, marble has been squeezed into a dike-shaped body along a vertical joint. The regional trend of the bedded rocks on the east shore of Mud Bay is N. 15°–30° W.; they dip steeply to the northeast.

PREFERRED MINERAL ORIENTATION IN THE INTRUSIVE ROCKS

The minerals of most of the intrusive rocks on the northwestern part of Chichagof Island develop a preferred orientation. Usually this structure consists of an aggregation of minerals formed into lenticular or disk-shaped parallel bodies. Ordinarily these bodies are evenly distributed throughout the rock; banding is rare. In some of the intrusive rocks, minerals such as hornblende are oriented with their long direction parallel to a line rather than to a plane, a feature referred to in this report as lineation. Probably many of the rocks that show foliation also have lineation, but lineation is commonly difficult to recognize and has not been systematically mapped. In many areas preferred orientation of crystals is only vaguely discernible.

DIORITE

The diorite shows foliation over most of its surface, but commonly the degree of foliation diminishes toward the center of the dioritic bodies and ordinarily becomes vague or is indiscernible at distances greater than 2 miles from the contact. Southeast of Stag Bay, most of the diorite masses separated by elongate strips of bedded rock are foliated parallel to the bedding. The large body of diorite immediately south of Lisianski Inlet shows a strong foliation over most of its surface. The average trend is northwest, parallel to the long direction of the body, except along the south side of Lisianski Inlet. In this area the trend is generally due north, but the significance of the change in direction is not known. The foliation in the dioritic rock body in the vicinity of Port Althorp is also variable. At the south end of the body the foliation strikes N. 20°–60° E. and dips

from vertical to 60° S. Most of the northern part of the body is submerged beneath Port Althorp. In the few outcrops, near the contacts with the enclosed bedded rocks, the average trend of the foliation is northwest, parallel to the contact.

The large body of diorite between Idaho Inlet and Pelican shows definite foliation. The foliation is unusual in that it is generally not parallel either to the contacts or to the bedding in adjacent bedded rocks. In the area 2½ miles north of Pelican the foliation strikes N. 30°–45° E. and dips 60° SE. The contact is parallel to the bedding and strikes 20° W. Farther north, in the area drained by the largest creek emptying into the upper end of Port Althorp, the foliation strikes N. 40°–70° E. and dips 40°–80° SE. This strike is, in places, nearly at right angles to the long axis of the exposed diorite body. The diorite batholith that lies due north of the southeast end of Lisianski Inlet is somewhat foliated. The foliation curves around the margin of the batholith in an arcuate form; it generally dips steeply toward the center. This rock mass is poorly foliated for more than 2 miles from the contact; nearer the center of the batholith the rock is almost structureless.

QUARTZ DIORITE

Except for the younger rocks associated with the nickel deposits, all the quartz diorite is foliated. In general the foliation is northwest parallel to the regional structural trend of the enclosing rocks. This is true even in the stock at Lake Elfendahl where the stock is elliptical in outline and has its long axis almost at right angles to the strike of the enclosing rock (pl. 3).

INTRUSIVE ROCKS ASSOCIATED WITH NICKEL DEPOSITS

Because little detailed mapping has been done of the intrusive rocks associated with the nickel deposits, few valid generalizations concerning their foliation can be made. The quartz diorite associated with the nickel deposits is only slightly foliated. Minerals in the gabbro and norite bodies, which generally are encircled by quartz diorite, show in outcrop no tendency toward parallel alinement. Primary banding in the norite crops out at two localities in the stock at Mirror Harbor. One outcrop is on the east shore of Davison Bay, and the other is on Cormorant Islands. In both localities the banding is nearly horizontal.

FAULTS

The rocks of northwestern Chichagof Island, including those in the Chichagof mining district, are cut by many faults. Reed and Coats (1941, p. 63–73) discuss at length the subject of faults and faulting. They describe most of the larger faults, some of which can be traced into the area mapped by the present writer.

Most of the major faults trend northwestward and dip at steep angles. Many cut the stratified rocks at low angles; some trend parallel to the stratification for a few thousand feet and then break away at angles as great as 30°. These faults gradually swing back parallel to the stratification planes, only to repeat the process farther on.

Splitting is characteristic of the faults; generally they split where a change in trend occurs. The last movement on many of the northwestward-trending faults was either horizontal or at angles of less than 30° in either direction. The displacement is generally small on any one fault, but the total displacement of all the faults genetically related to the northwestward-trending network is probably great. Most faults found are normal faults. Low-angle thrust faults are rare.

Because the fault zones contain highly sheared rock which is easily eroded, most of the fault traces are marked by elongate depressions formed by erosion of the softer rock. For this reason, unless the fault zone cuts a surface on slopes too steep for detritus to accumulate, or is kept clear of detritus by running water, the zone is covered. The partly filled depressions that represent the fault traces are visible, however, both on the ground and on aerial photographs, and many faults shown on the geologic map were traced by photogeologic methods. The presence of many of these faults has been verified in the field.

Few fault traces are greater than 10 miles long at the surface, but most faults are connected by splits and the effective length of the fault zones is greater than the length of any one fault. The widths of fault zones vary greatly. Some zones are only a few inches wide, but others consist of subparallel faults and are as much as several thousand feet across. Rock within most of the fault zones is highly comminuted. The color and consistency of the sheared rock, or gouge, depend largely upon the original rock. Gouge from greenstone or diorite is usually gray or grayish green. Graywacke or carbonaceous shaly rocks are dark-gray or black. Carbon is present on slickensided surfaces and in the gouge; pyrite is also pulverized to a black powder resembling carbon. This is apparent along the main fault at the El Nido mine. A few completely healed fault zones have been noted in the diorite. They can be detected in the outcrop by the discordance of the foliation and by broken recrystallized rock fragments. These faults probably formed at great depth and under high confining pressure.

There is an apparently continuous gradation between typical joints and faults, which could not always be distinguished in mapping. This difficulty was even more pronounced in photographic interpretation mapping. Some geologists might label a few of the fault traces shown on the geologic map as well-developed joints.

FAULT ON HIRST MOUNTAIN

Reed and Coats (1941, p. 72–73) describe a large fault that crops out on Hirst Mountain and trends across the Chichagof mining district. They believed the fault separated the greenstone and the greenstone-schist formations. They traced it to the edge of the lake 3½ miles due east of the head of Pinta Bay. Apparently the fault splits under the lake. One part continues northwest as far as the south side of the lowest lake of the chain draining into Goulding Harbor. The other split trends northward to Otter Lake, but has not been recognized with certainty any farther north. Neither of these faults forms a contact between different rock types in the area mapped by the writer.

FAULT BETWEEN MIRROR SLOUGH AND ISLAS BAY

A fault zone about 50 feet wide extends from the eastern shore of Islas Bay to a point one-half mile southeast of Sea Level Slough. The south side of the fault, over nearly all its exposed length, is topographically higher than the north. The scarp seems to have been formed in Recent time, for the area in which the fault trace lies is a well-developed wave-cut bench. If the scarp had been present when the coast was submerged and cut by wave action, it almost certainly would have been eroded so that opposite sides were level.

NORTHWESTWARD-TRENDING FAULTS SOUTH OF LISIANSKI INLET

An interrelated group of northwestward-trending faults cuts the rocks in the area south of Lisianski Inlet. The same group extends across the Chichagof mining district. The faults in this group are better developed than others in the areas in which they occur. Most of the faults split at several places, and probably all are interconnected. The most persistent of these faults occurs at the contacts of the bedded rock and the diorite in the area southeast of Stag Bay.

The contacts are inherently zones of structural weakness; hence, the position of the faults is largely controlled by the position of the contacts. The displacement along the faults is small and the faults, although long, are of no great structural significance, their main importance being that they are potential locations for ore deposition. Both the Hirst-Chichagof and the Chichagof veins occur in this northwestward-trending network.

FAULTS WITHIN THE LISIANSKI INLET TROUGH

Evidence of faulting is present in the rocks along the shores of the inlet, and major faults that are probably parts of the same zone exist southeast of its head. The zone may extend farther southeast be-

neath Hoonah Sound and under parts of Peril Strait. Quartz diorite has been intruded along the fault zone both in the area of Lisianski Inlet and southeast of its head. Undoubtedly the faulting antedates the quartz diorite intrusion, but renewed faulting has taken place both at the contacts and within the quartz diorite.

FAULT PARALLEL TO THE IDAHO AND TENAKEE INLETS

A fault of great length parallels Idaho Inlet. The northernmost exposure is on a stream that flows into Idaho Inlet 1¾ miles southeast of the small village on the east side of the inlet. The fault zone, over most of its exposed length, is exceptionally wide. The average width is more than 1,000 feet. Due east of the head of Idaho Inlet, the land surface is higher on the southwest side of the fault than on the northeast side. Ground observation and examination of aerial photographs suggests that this topographic feature is a fault scarp. If this interpretation is correct, movement has taken place along the fault since the area was glaciated, for such a feature would be erased by even moderate glacial erosion.

AGE OF THE FAULTS

Little is known of the age of the faults. A few faults are present in the diorite that were completely healed when the rocks were recrystallized; these faults are older than others in the diorite that are not healed. Most of the faults are in the northwestward-trending network which cuts the rocks of Mesozoic age. This same network cuts the diorite; thus it was formed after Early Cretaceous time.

Large faults cut the mafic and silicic rocks associated with the nickel deposits on Yakobi Island. Most of these trend northeastward and are believed to be younger than the northwestward-trending network, which probably was formed before the intrusion of the mafic rock. The northeastward-trending group was formed later, possibly in Tertiary time.

As mentioned above, certain fault scarps apparently formed in post-glacial time, and other faults have disturbed talus and alluvial deposits of Recent age. From this it is inferred that movement along these faults probably is still taking place.

GEOLOGIC HISTORY

An outline of the geologic history of the north end of southeastern Alaska is given here in order to relate the mapped area to its geologic environment.

The oldest rocks known in the northern part of southeastern Alaska consist of a thick succession of marine sedimentary rocks of Paleozoic

age. In the mapped area these are probably represented by the marble-gneiss sequence. The sea in which these rocks were deposited was fairly deep but possibly rather narrow. That the bottom was partly irregular is suggested by the marked changes in thickness which take place in some of the formations over relatively short distances. Penecontemporaneous slumping, brecciation, and marine landslides suggest that during part of the Paleozoic era the sediments were deposited in a geosynclinal basin or along a continental slope that trended northwestward and occupied an area that today is the central part of southeastern Alaska. Volcanism was intermittent throughout the Paleozoic era, but it never was as intense as volmanism of the Mesozoic era.

During the Triassic period the area was uplifted until part of it stood above sea level. Volcanism was common and lava and ash were deposited in seas which lay both to the east and to the west of the central upland area. The volcanic rocks were partly interbedded with marine sediments, in this report called the greenstone unit. The volcanoes occasionally rose above sea level, and ash and lava in places filled the geosynclinal basins until deposition was in part subaerial. The close of the Triassic period was marked by the greatest volcanic activity of the Mesozoic era. At the end of the era the major volcanic activity ceased and the land subsided below sea level.

Although the age of the bedded rock in the mapped area is not well established, the first Jurassic rock deposited possibly was limestone (the marble unit) including a few lenses of volcanic ash which indicate that volcanic activity had not ceased. At the close of the limestone deposition, carbonaceous clastic sediments were deposited. These form the lower part of the schist unit. Locally under favorable conditions limestone beds were formed in small but persistent lows in the ocean floor. Submarine sedimentation continued until near the end of the period, when volcanic activity had gradually increased almost to the exclusion of sedimentation; however, even at its maximum, volcanic deposition of Jurassic time did not equal in magnitude that which had occurred at the close of the Triassic period. Volcanic activity stopped suddenly near the close of Jurassic time and the land was again submerged. At many places the contact between rocks believed to be Jurassic and those believed to be Cretaceous is marked by thin discontinuous beds of limestone analogous to those between the rocks of Triassic and Jurassic age. During the first part of the Cretaceous, graywacke was deposited, probably on the bottom of a shallow sea adjacent to a fairly high landmass. In the mapped area, these rocks are represented by the graywacke unit. Most of the sediments deposited were fairly well sorted and fine grained. Locally

over a few tens of square miles conglomerates with rounded boulders were deposited. Graded bedding and other structures found in the graywacke suggest that much of this material was deposited by turbidity currents. Generally the graywacke is interbedded with carbonaceous siltstone and argillite, indicating that the intervals of rapid deposition were followed by long periods of quiet. After about 10,000 feet of interstratified graywacke and siltstone had been deposited, volcanic activity again started. The last part of this record is missing in the rocks of the mapped area.

The sedimentation and volcanism of the rocks of Mesozoic age seem to have been governed by a systematic law. The same cycle of geologic activity is found in each period of the Mesozoic: sedimentation followed by volcanic activity which began gradually and increased in intensity until the end of the period when it ceased abruptly. Furthermore, the ratio between sedimentation and volcanic activity seems to show a systematic variation for each period of the Mesozoic, and each period had more sedimentation and less volcanism than the preceding.

Geologic investigations of other parts of southeastern Alaska show that mountain building, injection, and intense folding and faulting took place not long after Early Cretaceous time. The mountains formed are collectively known today as the Coast Range. In the northern part of southeastern Alaska diastrophism took place in two parallel northwestward-trending zones, each along the east side of its respective geosynclinal basin. Probably as the rocks of Mesozoic age were deposited in the geosynclinal basin, the earth's crust was depressed by their weight. If this is true, then it is possible that either no rocks of Mesozoic age or a much thinner succession was deposited in the central part of southeastern Alaska. The lithologic sequence on the eastern geosynclinal basin is not known in detail to the writer, but the rock types are much the same as those in the western basin. The volcanoes which supplied the ash and lava for the rocks of Mesozoic age probably were in the area now occupied by the diorite batholiths, and it was in the lower parts of these volcanoes that intrusion first started. It was during or just preceding this period of intrusion that the rocks of Mesozoic age were intensely folded to the northeast to angles of more than 45°. The strike was northwest, parallel to the axes of the geosynclinal basins. In the mapped area only the east flank of the western geosynclinal basin remains, but most of the eastern syncline is preserved, as the intrusives came in along its east side (Buddington, 1923, pl. 2). On Baranof Island the dioritic intrusions appear from Buddington's map to have been injected directly into the rocks of Mesozoic age which make up the western basin, and the structure is therefore more complex. Through-

out southeastern Alaska the rocks of Paleozoic age between the two basins were uplifted differentially, so the oldest rocks were exposed along the west side of their outcrop.

By the time intrusion of the diorite started, the lowest of the rocks of Mesozoic age were buried to a depth of 25,000 feet or more. At this depth the rocks in the vicinity of the magmas became either thoroughly recrystallized or completely melted and incorporated in the magma. This widespread metamorphism and fusion is an outstanding characteristic of the rocks related to the Coast Range intrusive masses. By the time the diorite had solidified, probably through cooling brought about principally through uplift and subsequent erosion, the rocks had reached the approximate structural position in which they are found today.

Intense faulting followed the solidification of the dioritic rocks. These faults produced great displacement. The trace of one such fault lies along Lisianski Inlet and Hoonah Sound. Through movement along this fault, at least 5,000 feet of the rocks of Mesozoic age has been repeated to the northeast of the fault (pl. 12).

Intruded along these faults as well as into the now steeply dipping strata of Mesozoic age were small masses of quartz diorite. Their last residual fluids on cooling probably deposited the gold-bearing quartz veins. There was possibly a similar sequence of events along the western part of the eastern geosyncline, for the gold-bearing veins at the Treadwell mine near Juneau are associated with silicic dike rock. Largely because of the topography of that area, the writer believes that this dike was also intruded into or near a major northwestward-trending fault.

Still later the rocks of Mesozoic age on the west coast of Chichagof and Yakobi Islands and on the mainland in the central part of the Fairweather Range were intruded by a layered mafic rock. This rock is associated with nickel-bearing deposits and thus is of some economic importance. It crops out along a remarkably straight zone that lies at a low angle to the regional structural trend and to the general trend of the major faults. The reason for this is not known. The intrusions of mafic rocks were followed by further intrusions of quartz diorite.

During Tertiary time marine and continental sediments were deposited along the west coast and in the low-lying basin within the interior of southeastern Alaska. Intermittent volcanic activity continued through most of Tertiary time but did not materially affect the structure of the older rocks. The youngest rocks of the succession are either Pliocene or Pleistocene and contains glacially derived sediments. West of the layered mafic intrusive mass between Icy Point and Lituya Bay, these sediments contain the unusual minerals of the

layered rocks. For this reason the writer believes that some of the layered mafic rock was exposed to erosion by Pliocene or Pleistocene time. The coastal rocks were further folded, as is attested by the structures in the rocks of Tertiary age of the area today. This resulted in raising the mainland by as much as 5,000 feet; however, the coast was more submerged than it is today, and wave erosion and intermittent uplift have been active ever since. The terraces along the west coast are evidence of this fact. The highest is still clearly visible, at an altitude of 1,600 to 1,700 feet. Lower terraces form several levels between 1,700 and 200 feet and minor ones have formed at even lower altitudes.

ORE DEPOSITS

APEX AND EL NIDO MINES

LOCATION AND HISTORY

The Apex and El Nido gold mines are the largest in the area. In 1947 the mines were the property of the Apex-El Nido Mining Co. and were controlled by Mrs. J. H. Cann of Seattle, Wash.

The mines are about 3 miles west-southwest of Pelican, on the south side of Lisianski Inlet in the headwaters of a small stream locally called Cann Creek. A road about 1¼ miles long, now impassable except by foot, connects Lisianski Inlet and the mine mill. It is built on a moderate grade, and the upper end is at an altitude of about 500 feet. Above the mill, the valley gradient increases so sharply that no road has ever been built, and the only means of reaching the mines is by trail. The ore was delivered to the mill by aerial tram. Living quarters for the miners are at an altitude of 800 feet. Both mines are driven in the backwall of a huge cirque. The lower portal of the Apex is 870 feet in altitude and that of the El Nido 1,055 feet, nearly at timberline (pl. 13). During the winter months the area is covered with so much snow that it is necessary to curtail mining operations. Power for the mill and for mining was supplied from the waters of Cann Creek. Bedrock and the network of veins making up the ore are well exposed except below the mines where deposits of talus and alluvium have accumulated.

The history of the mines before 1923 is given by Buddington (1923, p. 116–121). Reed and Coats (1941, p. 143–145) give a short account of activities between 1923 and 1939. No mining has been done since 1939, and the buildings and equipment have been nearly destroyed by vandalism and the effects of the weather. In 1951 the timbers and underground workings in the El Nido mine were in good condition, but timbering in the Apex was rotting.

GEOLOGY

The Apex and El Nido mines are near the center of a large diorite body. Scattered through the diorite are a few masses of amphibolite. The Apex mine is in one of these amphibolite masses, but the gold-bearing quartz veins on which the mine was founded extend into the adjacent diorite. The El Nido mine lies within the diorite.

The Apex and El Nido veins lie in the well-defined Apex and El Nido faults (pl. 13). The El Nido fault strikes about N. 68° E. and dips 30°–80° SE.; the Apex fault strikes N. 42°–60° E. and dips 30°–80° NW. A large almost vertical fault that strikes N. 65° E. lies between the Apex and El Nido faults; it intersects the El Nido fault near the projected junction of the El Nido and the Apex fault, and bisects the angle the two ore-bearing faults form at the surface. The main ore veins and their respective offshoot veins constitute a composite structural pattern of remarkable symmetry. The plane of the large vertical fault is the symmetry plane.

The offshoot veins southeast of the strong vertical fault strike N. 50° E. and dip 50°–80° SE., and those northwest of the fault strike N. 45° E. and dip 50°–80° NW. It is not known what control this structural vein pattern had on ore deposition.

APEX MINE

The Apex mine is developed along a fissure-type quartz vein that crops out in the cliff backwall of the cirque. The Apex vein is in a fault which strikes N. 42°–60° E. and dips 30°–80° NW. The average dip is about 50°. The vein is not as persistent along the strike as it was reported to be by Buddington (1923, p. 118), but pinches out at the surface about 550 feet south of the highest tunnel portal. The plane of the Apex vein has a wavy, stairlike structure. The steep parts dip as much as 80° and the flat parts as little as 30°. The thickness of the vein is not entirely dependent upon the degree of dip, but in general the steep parts are the thickest. Because records on richness of the ore were not available and because the mine was not accessible underground, below or above the main working level, little is known to the writer concerning the size and extent of the main ore shoot. It plunges to the northeast at about 55°. Several offshoot veins have been mined near their intersections with the Apex vein. An offshoot vein, containing gold and traces of scheelite, branches from the Apex vein just above the highest tunnel. It extends about 700 feet due south of the tunnel; beyond this point it is covered. A vein, which may be an extension of this offshoot, is exposed in an isolated outcrop within the covered area and also farther southwest. Here the offshoot vein, or another vein on strike

with it, has a structure that strongly resembles that of the Apex vein. Its dip is about the same as that of the Apex vein, and steeply dipping veins also branch from it.

The most common metallic minerals other than gold in the Apex vein are, in order of decreasing abundance, pyrite, arsenopyrite, chalcopyrite, galena, sphalerite, and tetrahedrite. Arsenopyrite, pyrite, and chalcopyrite are more abundant in the offshoots than in the main vein. The offshoots contain traces of scheelite, but none was found in the Apex vein itself. Free gold occurs along fractures and shear zones in the quartz veins.

The amphibolite, which is the wall rock, is hydrothermally altered from 6 inches to 10 feet on both sides of the vein. The altered rock is purplish gray to gray on freshly fractured surfaces; on weathered surfaces it is gray or rust brown. Pyrite and magnetite can be recognized in the altered rock, and some gold is present. One sample of altered amphibolite, taken 10 feet from an adjacent vein, contained 0.02 ounce of gold and 0.10 ounce of silver to the ton. Rock closer to the vein probably contains greater amounts of gold and silver. In thin section the altered rock shows a mass of isotropic material intimately mixed with a carbonate, probably calcite. Outlines of relict hornblende crystals generally are not visible.

The writer was unable to examine much of the underground workings because the condition of the timbers rendered extensive underground mapping unsafe. The main working level and the small tunnel 25 feet below the main level were examined. The inclined raise was examined for a short distance below the small tunnel, and a crosscut from the raise toward the Apex vein was examined. The entire lower adit tunnel was mapped.

This cursory examination showed that the main ore shoot plunges northeast at about 50°–60°; plans for future exploration should take this into account. The steeply dipping offshoot veins justify some exploration, particularly in the area near their intersection with the Apex vein.

EL NIDO MINE

The El Nido mine, like the Apex, is on typical fissure-type quartz veins along the El Nido fault. The El Nido veins and fault strike N. 68° E. and dip 30°–80° SE. (pl. 14). One or more aplite dikes occur within the fault zone, and the quartz veins are on either or both sides of the dike. The El Nido fault can be traced for about 2,000 feet on the surface by means of intermittent outcrops. Quartz containing free gold has been collected by the writer from isolated outcrops for a linear distance of 1,700 feet along the fault. The part of the vein that has been developed is the thickest part thus far dis-

covered, but the vein may maintain this thickness beyond the end of the underground workings for some distance to the southwest.

Many veins branch from the El Nido vein. The ore shoots on both the Apex and El Nido veins lie along the intersection of the main vein and the zone of greatest concentration of offshoot veins. At the El Nido mine this zone of concentration, when projected to the lowest level, probably lies slightly beyond the southwestern limit of the lower tunnel; this fact merits serious consideration in planning future exploration. Many of the offshoot veins contain sulfides and probably some gold, but most are too narrow or too lean to be mined profitably.

A light-colored dike adjacent to the main quartz vein extends farther northeastward than the quartz vein. Near the mine the dike has an average thickness of about 10 feet, but the southwestern part splits into two smaller parallel dikes; locally it has been highly altered by hot solutions. Small veins of banded quartz occur along one or both margins of the dike, and similar quartz veins are exposed in isolated outcrops along the sides of the dike for more than 1,000 feet northeastward from the mine. The writer found free gold where the dikes and accompanying veins cut across the large vertical fault southwest of the El Nido mine.

The main vein is characterized by alternating light- and dark-colored bands. The lighter bands are quartz, and the narrower dark bands are gouge, formed from pulverized sulfides, talc, and chlorite. Free gold in this vein is signaled at many places by a distinctive green stain on the surrounding quartz.

Scheelite, a valuable tungsten-bearing mineral, has been found in the El Nido mine. W. S. Twenhofel, J. C. Reed, and G. O. Gates (1949, p. 20–23) examined the mine with an ultraviolet lamp. Below is an excerpt from their report.

> Both adit levels of El Nido mine were examined for scheelite with an ultraviolet lamp. On the lower level, between the place where the vein is first encountered by a crosscut from the surface and a raise to the upper level, the vein contains scheelite in disseminated grains and in small streaks against the hanging wall. Near the raise the scheelite is somewhat more abundant than farther northeast, but farther back in the adit, where the vein is thin and discontinuous, scheelite is very sparsely distributed. Scheelite is abundant in the last 6 feet of the adit and in the face, where the vein is 4 to 6 inches wide.

An area along the vein in the upper adit level, 133 feet northwest of the raise, contains some scheelite (pl. 14). The report further states that:

> At this place material, presumably largely scheelite, has been gouged out of both the floor and the back of the adit, and the walls indicate that the veinlet, before the material was removed, was 6 inches or more in width.

Based on the examination with the ultraviolet lamp, the authors (op. cit.) believed that:

. . . the vein on the lower adit level between the crosscut and the raise may carry about 0.2 percent of WO_3 and that the relatively high grade part of the vein near the face may contain about 3 percent WO_3. The scheelite content of the vein in the upper level, except locally, is probably less than 0.2 percent of WO_3. These estimates may be widely in error.

The wall rock on both sides of the vein has been altered, and the rock-forming minerals are extensively replaced by a carbonate mineral. The visible effect of alteration is not as prominent in the diorite along the El Nido vein as it is in the amphibolite at the Apex vein. The altered diorite, however, can usually be distinguished from the unaltered rock by differences in texture and color. The altered rock is iron stained on weathered surfaces, and has a greasy appearance on unweathered surfaces. The altered diorite and the dike contain gold and also well-formed cubes of pyrite.

The known ore reserves at the Apex mine are not large. At the El Nido mine there remains much unmined quartz, but its tenor is not known. The writer has found free gold in some of this quartz, and in places it appears to be present in economically significant concentrations. Exploratory work at the El Nido mine, to the southwest along the El Nido fault and below the lower level, seems justified.

FAULT ZONE BETWEEN THE APEX AND EL NIDO MINES

The fault zone that lies in the bottom of a boulder-filled gully between the Apex and El Nido veins may contain a gold-bearing quartz vein. The rock on both sides of the gully is highly altered, like the rock along the Apex and El Nido veins. Several large pieces of quartz vein material, as much as 3 feet long and 2 feet thick, were found in the boulder bed of the stream below the gully; they very likely came from a concealed vein in the fault zone. These pieces of quartz contain abundant sulfides, but no free gold was observed. The most favorable area for exploration for this possible vein appears to be in the area along the fault at, or just below, the mouth of the gully.

GOLDWIN PROPERTY

The Goldwin property consists of 13 claims on the south side of Lisianski Inlet 1½ miles south of Miner Island. The claims extend southeastward from sea level on Lisianski Inlet to the top of the ridge at an altitude of about 2,000 feet (fig. 41). The claims were first staked in 1920 by Schotter, Dodge, and Borland as the Paramount group. From 1920 to 1947 a number of persons held partnerships in the claims, but the exact history of ownership is not known to the writer. In 1947 the claims were held by an association formed originally in 1938 by August Chopp, Joe Repik, J. A. Ronning, A. S.

Thompson, and Frank Schotter. In 1938 the property was named the Goldwin property by that association. A. F. Buddington (1923, p. 123–124) visited the prospect in 1923 and wrote a short description of it; in 1939, J. C. Reed (1941, p. 145) visited the property, and included a description in his report.

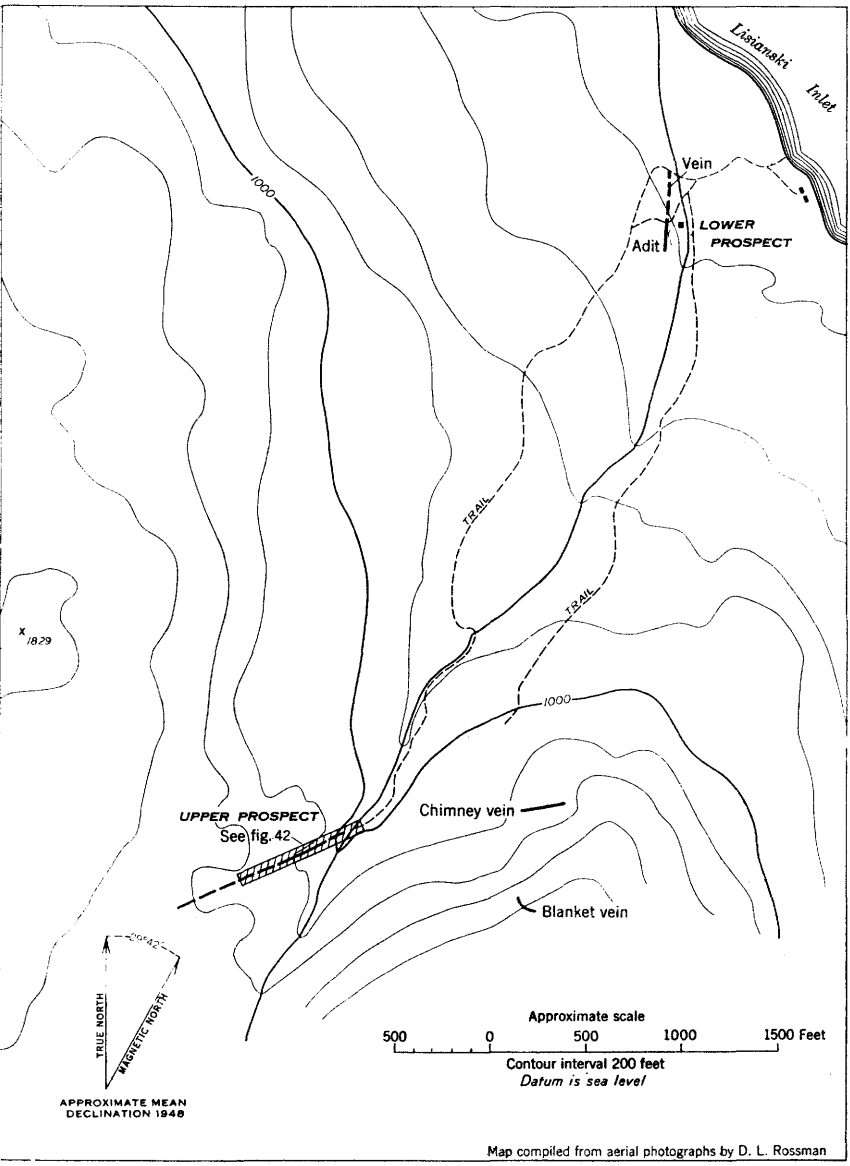

FIGURE 41.—Map showing prospects and veins at the Goldwin property, Chichagof Island.

The Goldwin group of claims contains several gold-bearing veins which lie along minor faults in the same diorite batholith that contains the Apex and El Nido veins. The lowest vein on the Goldwin property is at an altitude of 200 feet and lies about 750 feet from tidewater. The vein strikes N. 5°–25° E. and dips 50° NW.; it has a maximum thickness of about 2 feet but pinches out entirely at a few places; it is about 400 feet long, and its average width is about 14 inches. An adit has been driven southward along the vein for about 300 feet; north of the adit portal, it has been exposed in a series of pits and trenches for about 200 feet. The quartz is milky white but includes altered green diorite fragments which consist principally of chlorite. Pyrite and chalcopyrite are sparsely distributed through the quartz and are most concentrated near the included masses of altered diorite.

A second vein, which lies in a small fault that strikes N. 60° E. and dips 85° SE., crops out along the west side of a deep gulch about 4,000 feet southwest of the adit (fig. 42). A trail connects the prospect with the beach. The vein tends to be lenticular; in places it is more than 2 feet thick but at other places along the fault it is missing. The quartz resembles that in the vein at the lower prospect described above; it also is milky white and contains green fragments of altered diorite. In 1938 and 1939 most of the rich gold-bearing quartz was mined from the surface, so the parts of the vein now visible are either narrow or of low grade. In general, the vein contains pyrite which is usually associated with high concentrations of gold. For example, a lenticular-shaped mass of pyrite-bearing quartz (loc. 1, fig. 42) was uncovered by the writer about 100 feet southwest of the last outcrop of the higher vein. A representative sample taken across the pyrite-bearing part assayed 69 ounces of gold and 5.3 ounces of silver to the ton. The exposed part is only 6 inches wide and 30 inches long. A channel sample taken across the vein, beyond the pyrite pocket, assayed 0.11 ounce of gold and 0.89 ounce of silver to the ton (fig. 42).

The gold in this higher vein was introduced toward the end of the period of pyrite mineralization. Alteration of the wall rock along this fault zone is not easily detected but probably extends 4 to 8 feet on each side. The altered zone contains some gold, but the gold is not easily detected nor is its concentration predictable. A 4-foot chip sample taken at a distance of 4 feet from the fault, of material showing little alteration, contained 0.24 ounce of gold and 0.06 ounce of silver to the ton (fig. 42). On the other hand, two chip samples of altered rock, taken adjacent to the vein across widths of 10 and 13 inches on the northeast and southwest sides, respectively, assayed only a trace of silver and 0.05 ounce of gold per ton.

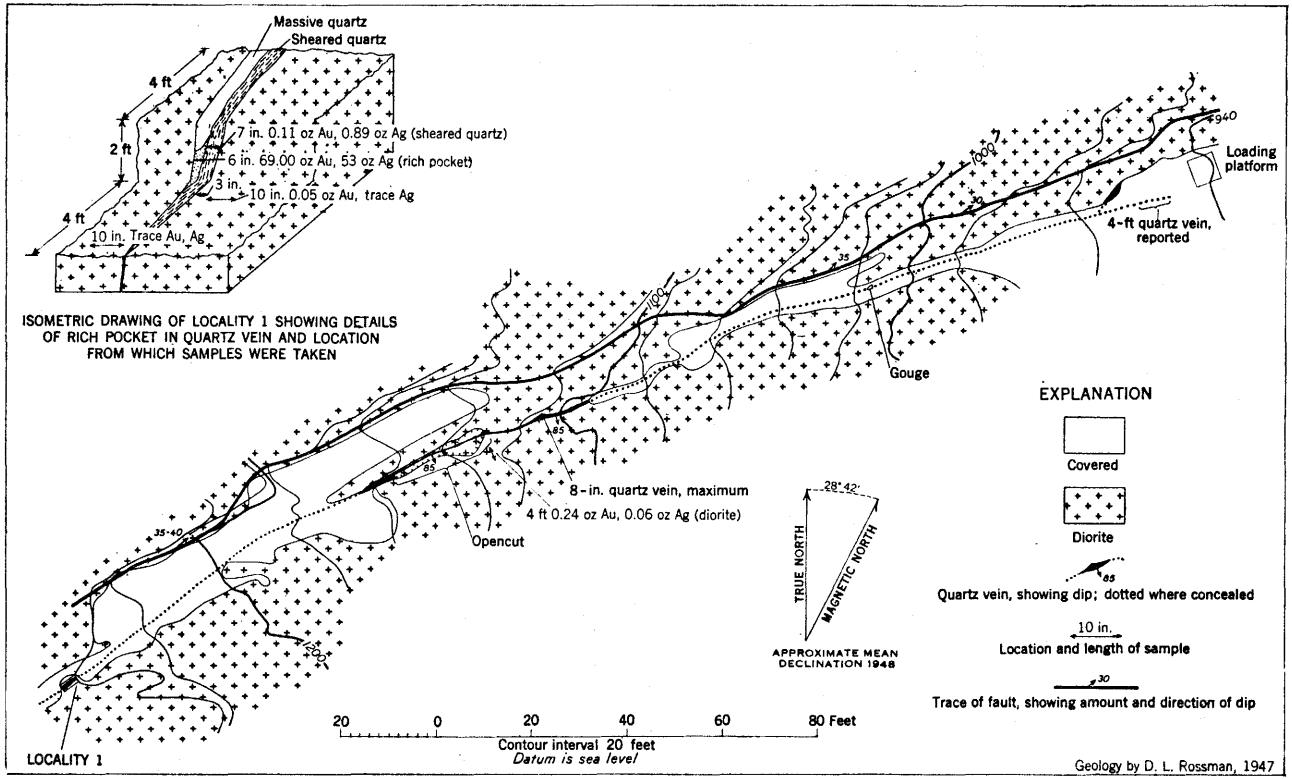

FIGURE 42.—Geologic map of the main upper prospect, Goldwin property.

The fault that contains this vein is covered for most of its length, but it can be traced several thousand feet southwestward by its topographic expression. Stripping or drifting on the fault will probably disclose additional bodies of quartz. On the northeast projection of this fault another vein crops out on the opposite side of the gully mentioned above (fig. 41). This vein, which is reported to contain free gold, is known locally as the chimney vein because it crops out along the side of a steep gorge known locally as the chimney. No gold was found by the writer either on the outcrop or in the float below the vein, although a careful search was made. The vein is on such a steep slope, however, that it could be examined in only a few places.

Another vein, known locally as the blanket vein, crops out on the east wall of the gully at an altitude of about 1,400 feet and is almost inaccessible. The writer discovered that the vein could be reached by climbing down from the top of the mountain to the level of the vein at a point about 1,000 feet southwest of the exposure. From this point the vein can be reached by traversing along the mountainside. The upper part of the vein strikes north and dips 30° W. A few feet westward, at the edge of the cliff, the dip steepens to 70°. The quartz is white and does not contain much altered diorite. The margins of the vein show slickensides, but there is little gouge, and the quartz is only slightly sheared. The vein has an average thickness of 5 inches and a maximum thickness of 8 inches. In the hand specimen the wall rock appears unaltered. The quartz contains free gold and many rich specimens have been taken from the talus at the foot of the cliff below the vein.

KOBY PROSPECT

The Koby prospect, examined in 1939 by Reed and Coats (1941, p. 141), was formerly known as the Koby and Shepard prospect. It is 1.6 miles southeast of the head of Lisianski Inlet. A road, now impassable except by foot, connects the prospect to the Inlet; it is on the east side of a small creek, at less than 100 feet altitude The workings consist of several surface pits and trenches and an underground adit and crosscut totaling about 280 feet in length (pl. 15).

The gold-bearing material consists of lenticular bodies of quartz enclosed in a fault zone. Adjacent rock is a chlorite-quartz schist that strongly resembles the upper part of the greenstone unit and the lower part of the schist unit. A fault zone on which the veins lie strikes about N. 20°–30° W. and dips from 80° E. to vertical. Individual quartz bodies are as much as 7 feet thick. Stripping and trenching shows that the quartz extends along the fault for 300 feet or more, but that it is not everywhere present, even within this

short distance. The main adit is 40 feet below the main mineralized zone and was driven northeast for about 240 feet from a point near the stream. It failed to intersect any large bodies of quartz. A crosscut 115 feet from the portal was driven northwest along a minor fault zone. The face of the crosscut exposes several quartz lenses.

Most of the quartz is milky white and is cut by short irregular fractures containing talc and calcite. Some masses of chlorite schist altered to irregularly shaped masses of chlorite are included in the quartz. The quartz contains about 1 percent sulfides, including arsenopyrite, pyrite, sphalerite, and galena. Free gold is reported by the owners, but none was found by the writer. The material in the shear zone and in the adjacent quartz schist shows no discernible alteration in the hand specimen, and all the known gold is found in the quartz.

If further exploration is done on this prospect, the amount and grade of the quartz exposed at the rock surface should be ascertained before further underground work is undertaken. As the rocks have been glaciated recently and are only slightly weathered, the character and grade of the quartz at the surface should be almost the same as that a short distance below the surface.

COBOL MINE

A small amount of gold has been mined from a fissure-type quartz vein at the Cobol mine. In 1946 the property consisted of nine unpatented claims on the west side of Mine Mountain, about 4 miles north of the head of Goulding Harbor. The mine is at an altitude of about 750 feet. A light-rail tramway which once connected the mine to Goulding Harbor was unusable at the time of this study.

The Cobol mine vein was discovered in 1921 by Frank and Ed Cox, Ollie Loberg, and George Bolyan. In 1922 and 1923 the property was leased to the Pinta Bay Mining Co., which built the rail tramway. The claims reverted to the discoverers, who in 1933 mined and milled about 135 tons of ore. Acccording to Mr. Bolyan, $3,500 worth of gold was recovered.

The underground workings were mapped in 1939 by Reed and Coats, and a sketch map and description of the mine have been published (1941, p. 142–143). The mine lies on a contact between quartz diorite and greenstone. The mine adit intersects the vein about 75 feet from the portal and follows it for about 80 feet northeast until it pinches out. The vein apparently formed in contact with the diorite and is narrow or missing where the fault is in greenstone.

A small diorite stock crops out on top of Mine Mountain. The rock, as seen under the microscope, is quite different from that in other diorite bodies on Chichagof Island. Gold-bearing quartz veins crop out in the western half of the stock. Most veins are near diorite or quartz diorite contacts. None of the veins known to the writer that trend from the diorite or quartz diorite into greenstone extend more than a few feet into the greenstone. At most places the rock adjacent to the veins is hydrothermally altered for distances ranging from 1 to 5 feet from the contact. In general, alteration of the wall rock along veins or fractures is a favorable indicator of gold. In outcrop the altered rock is tan, gray, or light brown. Ordinarily the original texture of the rock is destroyed, the rock assuming a massive appearance.

AREAS REGARDED AS FAVORABLE FOR PROSPECTING

During the course of the geologic mapping of northwestern Chichagof Island, the writer made an effort to ascertain those factors influencing the deposition of valuable minerals and to outline areas likely to contain mineral deposits (pl. 16). A distinction is made between areas favorable and areas highly favorable for prospecting. The areas regarded as favorable are delineated on plate 16 but are not discussed other than in these introductory paragraphs. Areas classed as highly favorable for prospecting include only those that contain gold-bearing quartz veins in some degree of abundance, and which are believed to have undiscovered gold-bearing veins.

All areas, whether favorable or highly favorable for prospecting, were selected through evaluation of the number and type of quartz veins present and of geologic conditions believed to influence the deposition of the gold-bearing quartz veins. For example, some of the igneous rocks, such as the quartz diorite, and some of the diorite may have controlled ore deposition; this fact was taken into account in compiling the map. In indicating areas favorable for prospecting for minerals such as copper, nickel, and iron, greater reliance can be placed upon geologic environment that can be done in the case of gold.

The only area thought worthwhile for prospecting for copper is in the greenstone and schist units northwest of Goulding Harbor. This area contains one copper deposit and many small prospects. Magnetite occurs at many places where limestone and greenstone have been highly metamorphosed by the intrusion of quartz diorite (pl. 16).

A nickel deposit occurs at Mirror Harbor, and mafic rock that might logically be associated with nickel deposits makes up the stock at Lost Cove. But many prospectors, as well as the writer and several other geologists, have thoroughly examined these rocks and believe that

there is little chance that the stocks at either Mirror Harbor or Lost Cove contain other easily discoverable nickel-bearing deposits. Most of Yakobi Island was examined by the writer only in a cursory way, and he feels unqualified to give an analysis of its prospecting possibilities. However, parts of the eastern and southern shores do contain quartz veins, some of which are goldbearing, and the area centering around Bohemia Basin contains nickel deposits. For these reasons the writer has indicated on plate 16 that these parts of Yakobi Island are favorable for prospecting. The rest of the island remains unassessed and is so indicated on plate 16. Other areas left blank on figure 9 are believed to contain no important ore deposits.

AREA 1

The northwest end of Althorp Peninsula probably warrants careful prospecting. The most favorable parts are shown on figure 9. In this area many quartz veins have been observed, but undoubtedly the number is only a small fraction of those existing in the area. Most of the veins that were observed are less than a foot thick and are lenticular or only a few tens of feet long. Many fill joints instead of faults. Some prospecting has been done. The largest prospect is owned by M. J. Marvitz and was examined by J. C. Reed in 1936 (1938, p. 75–76). A vein, reported to contain free gold and to crop out on level ground at a low altitude about a quarter of a mile east of Column Point, was not found by the writer, although it was carefully searched for.

The beach gravel at the mouth of a stream that flows into Cross Sound about 1 mile east of Column Point contains a small amount of placer gold. The vein from which the gold is derived is probably on the northeast face of the cliff west of the stream. The vein must crop out at an altitude of about 800 to 1,000 feet. Other veins occur in the area, but only those mentioned above are known to the writer to contain gold. The veins at the Marvitz prospect are associated with dikes, which generally are favorable indicators of gold. At no place was altered wall rock observed adjacent to veins, but any vein or fault that is associated with wall-rock alteration should be carefully examined.

AREA 2

Another highly favorable area for prospecting extends along the south side of Lisianski Inlet from a point half a mile southeast of Cann Creek to Lisianski Strait. The only type of vein in the area that is known to be gold bearing is characteristically less than 2 feet wide and no more than a few hundred feet long. The veins are along weak faults which generally show little topographic expres-

sion. The strike of the faults, and hence of the veins, is generally northeast; the dips are generally steep. Faults that vary in dip are more likely to contain valuable deposits of gold-bearing quartz than faults of constant dip. The quartz commonly contains inclusions of altered diorite. Locally the veins contain calcite which readily dissolves when exposed to weathering and leaves tubular-shaped cavities in the quartz. The vein quartz is commonly milky white or translucent, and it is generally barren. Although most veins when seen in outcrop appear to be of little value, some contain large amounts of gold concentrated in small lenticular pockets or small ore shoots. Chalcopyrite and pyrite in the vein almost invariably indicate gold. However, some veins contain gold unaccompanied by sulfides, and in the field these are difficult to distinguish from barren veins unless the gold can be seen in the hand specimen.

One mineralized fault zone was found along the contact between the diorite and quartz diorite that occur along the south shore of Lisianski Inlet. A sample from this zone near Cann Creek contained traces of gold. A small vein estimated to contain as much as 1 ounce of gold to the ton was discovered at an altitude of about 700 feet about 1 mile due west of the mouth of Cann Creek. The vein is 6 to 12 inches wide and crops out intermittently for 35 feet. It strikes north and dips 80° W. Probably the vein is too small to be of commercial value, but other veins that are large enough to mine may be nearby.

Prospectors should keep the following points in mind when working in area 2: (1) The veins are sparsely distributed and are thin and lenticular. (2) They are deceptive in appearance. The veins resemble those described by most prospectors as "bull quartz", or quartz that is "watery." (9) Veins are in minor faults that have little topographic expression and are difficult or impossible to detect if covered by even a thin mantle of overburden. (4) The sulfides chalcopyrite and pyrite are almost certain indicators of gold, but high concentrations of gold have been found in quartz unaccompanied by sulfides. (5) Alteration of wall rock along the margins of veins or faults is a favorable indicator of gold, but the type of alteration of the wall rock in this area is inconspicuous in the outcrop. (6) At most places gold concentration in the altered rock near the veins is too slight for profitable extraction, but the possibility should not be overlooked that in some places the altered rock may contain economically important amounts of gold.

AREA 3

Area 3 is a northwestward-trending zone that extends from a point about 1 mile south of Apex Mountain, across the upper half of Stag

Bay, to the drainage basin of the west branch of Stag River (pl. 16). Much of the area has not been adequately prospected, but several veins containing free gold have been located by prospectors along the shore of Stag Bay. Near the end of the ridge that makes up the southeast shoulder of Cub Mountain, the writer found several quartz veins that may not have been previously discovered. Ore containing visible gold crops out on rounded glaciated surfaces and shows no evidence of having been sampled before; it is on the crest of a ridge about half a mile south of the largest of the lakes which lie about 1 mile due south of the head of Stag Bay (fig. 3). Assays of samples believed to be representative indicate that the vein may contain about 1 ounce of gold to the ton. The vein is 1 foot thick, and can be traced in isolated outcrops for about 50 feet. The area along the projected trace is covered and the vein may extend beyond its known outcrop length.

The veins in area 3 have a pronounced resemblance in size, structure, and texture to those in area 2, and the same guides for prospecting are applicable.

AREA 4

Area 4 extends eastward from Lake Elfendahl and includes all of Mine Mountain. Quartz veins are scattered throughout the area; many are known to contain gold. The vein at the Cobol mine is typical of the veins in area 4. A small vein was found along a persistent fault about 1 mile S. 20° E of the head of Lake Elfendahl. The quartz is typical fissure-type quartz and contains considerable amounts of pyrite, chalcopyrite, sphalerite, and galena. An assay has not been made, but the material in the vein probably contains some gold inasmuch as the presence of galena and sphalerite in this area is usually an excellent indicator of gold. Similar veins are known in other parts of area 4, particularly near the small diorite body that crops out in the top of Mine Mountain. Gold-bearing quartz float also was found in the headwaters of the east fork of Stag River. In the headwaters area of Saltry River, a mineralized zone was found which contains 0.01 ounce of gold to the ton. Of the 5 areas mapped, area 4 is probably the most favorable for gold prospecting.

AREA 5

For many years a mineralized zone has been recognized in the area north of Goulding Harbor (pl. 16). The zone lies within rocks of the greenstone and schist units. Copper, in the form of chalcopyrite, is the principal mineral and is disseminated in the greenstone. Many dikes cut the rock, and although the copper may be derived from this greenstone, the dikes appear to have played some part in its concen-

tration. The area has been intensively prospected but no ore has been mined. Two prospects, the New Chichagof Mining Syndicate and the Golden Hand, are located near the east side of area 5. The properties were described by Reed and Coats (1941, p. 137). The prospects are in gold-bearing mineralized areas that probably are associated with a small diorite stock. The veins and mineralized zones, however, are in contact with limestone, and this type of association of gold and limestone has not been recognized elsewhere in the mapped area. Probably no large deposits other than those already discovered are exposed in the area.

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