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GEOLOGY AND ORE DEPOSITS OF THE CHICHAGOF MINING DISTRICT ALASKA

BY

JOHN C. REED AND ROBERT R. COATS

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GEOLOGY AND ORE DEPOSITS OF THE CHICHAGOF MINING DISTRICT, ALASKA

By John C. Reed and Robert R. Coats

ABSTRACT

The Chichagof mining district lies on the west side of Chichagof Island, one of the larger islands of the Alexander Archipelago of southeastern Alaska, about 50 miles northwest of Sitka. From its discovery in 1905 through 1938 the district produced about $16,250,000 worth of gold and about $170,000 worth of silver, practically all of which came from two mines, the Chichagoff and the Hirst-Chichagof.

Much of Chichagof Island, including parts of the Chichagof mining district, is made up of granitic rocks in masses that are believed to be parts of the very extensive Coast Range batholith, which, in some places at least, was intruded probably late in Jurassic or early in Cretaceous time. Other bedrocks of the district include slightly to intensely metamorphosed sedimentary, intrusive, and extrusive rocks, some of which are probably of Triassic age and others probably of Lower Cretaceous age. The oldest rocks of the district may be Paleozoic.

Except the surficial deposits, which include glacial moraine, volcanic ash, and alluvium, the bedded rocks are grouped into five units or formations—greenstone-schist; greenstone, limestone, and schist of probable Triassic age; and Lower Cretaceous (?) graywacke. Each of the formations contains rocks other than the diagnostic rock that characterizes it.

The intrusive rocks embrace three distinct groups—diorite, albite granite and granodiorite, and dike rocks. Each of the groups is made up of several rock types. The rocks of the diorite group were intruded first and the dikes probably last, although the age relations between the albite granite and granodiorite and the dikes are not clear. All the intrusive rocks may be related to the Coast Range batholith.

The Chichagof district lies on the western limb of the Chichagof-Glacier Bay anticlinorium, one of the major anticlinoria of southeastern Alaska. The general trend of the rocks is west of north, and the general dip is steep to the southwest. Locally the rocks dip steeply northeast. The average trend in the district is N. 50° W. With local exceptions the bedding and the foliation of the rock are parallel.

Many faults cut the rocks of the district. Practically all the ore so far mined has come from quartz bodies that occupied one or the other of two of the most prominent fault zones of the district, the Hirst fault and the Chichagof fault. In general the faults trend about parallel to the rocks, but locally the faults and the bedding diverge considerably. In the vicinity of Doolth Mountain, for example, the bedding in general strikes about N. 62° W. and dips 67° SW., whereas the

strike of the Hirst and Chichagof faults there approaches N. 34° W., and the dip 75° SW. Such deviations from parallelism may have been an important factor in the formation of the ore bodies.

Characteristic features of the fault zones are the splits or branches that diverge from main faults to enter either the hanging wall or the footwall. The splits range from tiny cracks that penetrate the wall rocks for only a few inches to strong faults that rival the main fault zones. Two types of splits are recognized—a more common type whose members diverge from the main faults parallel to the bedding and foliation surfaces, and a less common type whose members diverge from the main faults across or against the bedding and foliation surfaces. Many split faults connect main faults.

The most recent movements on the faults appear to have been southwestward and downward at an angle of about 30° for the northeast or footwall sides, relative to the southwest sides. For the most part the movements on the faults followed the intrusion of the dikes, but at some places dikes have been intruded into preexisting fault zones.

Within the district all the ore so far mined has come from fault zones in the Lower Cretaceous (?) graywacke. Other faults in the graywacke and in the older formations may be worthy of further prospecting.

The ore deposits are quartz bodies in the fault zones. Many of them have been formed at places along the faults where large splits diverge from main faults and in or adjacent to distinct warps in the faults. The quartz bodies are steeply inclined and tabular in form. Commonly the thickness is only a few feet, the horizontal length a few hundred feet, and the pitch length from many hundred to a few thousand feet. Many shoots pitch steeply southeastward in the southwestward-dipping fault zones.

Most of the vein quartz is "ribbon quartz," but some is massive. Much of the quartz has been crushed by fault movements that followed the quartz deposition, but these later movements are believed to have been of minor magnitude. The metallic minerals, which include pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, and gold, commonly form less than 3 percent of the ore. Of the metallic minerals, pyrite is by far the most abundant and arsenopyrite is next. The record of production for the district indicates that the ore so far mined has contained on the average a little more than an ounce of gold to the ton.

The Hirst and Chichagof faults may contain other ore bodies not yet found, and similar faults in the district may be ore-bearing. Because of the sporadic distribution of the ore bodies in the fault zones much of the future prospecting will probably be done by relatively expensive underground methods.

In this report the Chicagoff and Hirst-Chichagof mines are described in detail. About 35 prospects and one small mine within the district are described more briefly. In addition the report includes short descriptions of three mines—the Apex, the El Nido, and that of Cox, Bolyan & Loberg; and four other prospects on Chicagof Island, one west and the others either north or south of the district as mapped.

INTRODUCTION

For nearly three decades the Chichagof mining district has been an important contributor to the gold produced in southeastern Alaska. Until 1938 no detailed investigations of the gold ore deposits were made by the Geological Survey. In the spring of 1938 it was decided that the funds available to the Survey for use in southeastern Alaska should be employed in the study of the ore deposits of this productive district. A factor in this decision was the hope that a better understanding of the deposits in the vicinity of Chichagof would be of help in prospecting and geologic investigations in other parts of the little-known and long belt of country, presumably similar geologically, that stretches along the west coasts of Baranof and Chichagof Islands at least as far north as Lisianski Strait.

In 1938 most of the work was focused directly on the ore deposits, and a large part of the season was spent underground. In the field season of 1939 the study of the district was continued. That season was spent largely on the surface and the work included the study and mapping of the rocks of the district and a relatively detailed study of its structural features, except those features that are exposed underground and had been observed the previous season.

In addition to the areal and structural geologic studies that were the principal objectives in the season of 1939, the mines and some of the prospects in the district were again visited in order to keep the Survey's information on mining developments as nearly current as possible and to observe and record geologic features exposed by mining and prospecting since the visits in 1938. Opportunity was afforded also to visit several mines and prospects close to the district, but outside its limits. The information on mining and ore deposits gained by the examination of the mines and prospects in 1939 both within and without the district is included in this report.

PREVIOUS INVESTIGATIONS

Several members of the Geological Survey have made examinations in the district in the last 30 years. Prior to the investigations whose results are recorded in this report, the observations of these men, together with those of the operators in the district, constituted the main geologic information on the district.

In 1905 C. W. Wright made observations in the district during a reconnaissance investigation of Chichagof Island; in 1910 Adolph Knopf spent 3 weeks in June in the vicinity of Klag Bay; in the fall of 1917 R. M. Overbeck was engaged for about 2 months in the study and mapping of the geologic features of the west coast of Chichagof Island, including the Chichagof mining district. In August 1923 A. F. Buddington studied briefly the Hirst-Chichagof mine, an important producer of the district, but his published report does not mention the other important mine, the Chichagoff. A briefly annotated bibliography of these earlier reports is given below.

BIBLIOGRAPHY

The following list includes the principal references to the geology of the west coast of Chichagof Island and the Chichagof mining district:

Wright, C. W., Lode mining in southeastern Alaska: U. S. Geol. Survey Bull. 314, pp. 59–61, 1907. The pages cited contain a single paragraph on the general geology of the Sitka district and several paragraphs telling of the discovery of the deposits in the Chichagof mining district and a description of the claims on Doolth Mountain shortly after they were staked.

Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, 32 pp., 1912. The first 17 pages of Knopf's report contain historical and geographic data and a short discussion of the general geology of Chichagof and Baranof Islands. Pages 18–26 concern Klag Bay and vicinity (now called the Chichagof mining district) and, in addition to a brief summary of the geography, history, and general geology of the district, contain also petrographic material and a description of the ore deposits and the mines.

Overbeck, R. M., Geology and mineral resources of the west coast of Chichagof Island: U. S. Geol. Survey Bull. 692, pp. 91–136, 1919. Overbeck states that the chief object of his work was the investigation of deposits of the war minerals, copper and nickel. Nevertheless, his paper contains about 5 pages describing the features of the Chichagoff and the Hirst-Chichagof mines as well as shorter descriptions of other prospects and claims. Pages 95–112 describe the general geology of the west coast of the island.

Baumann, H. N., Jr., Mining and milling rich gold ore on Chichagof Island: Eng. and Min. Jour.-Press, vol. 117, No. 22, pp. 876–879, May 31, 1924. Contains some historical, geographic, and geologic data but is principally about mining and milling practices at the Chichagoff mine.

Buddington, A. F., Mineral investigations in southeastern Alaska: U. S. Geol. Survey Bull. 773, pp. 124–125, 1925. The Hirst-Chichagof mine is described as developed up to August 1923.

Buddington, A. F., and Chapin, Theodore, Geology and mineral deposits of southeastern Alaska: U. S. Geol. Survey Bull. 800, 394 pp., 1929. In this bulletin is collected much of the geologic information on southeastern Alaska. Much of it, while not specifically about the Chichagof district, is of a general character and is applicable to the district. Pages 371–373 are headed the "Chichagof gold belt" and contain an abstract of the knowledge of the Chichagof district.

Reed, J. C., Preliminary report on the ore deposits of the Chichagof mining district, Alaska: Am. Inst. Min. Met. Eng. Tech. Pub. 1051, 20 pp. 1939. A preliminary report on the investigations of which the present paper is the final report.

PRESENT INVESTIGATIONS

The party was served throughout the season of 1938 by the Forest Service launch *Ranger 6*. A camp was established at the Hirst-Chichagof mine at Kimshan Cove, in order to provide living accommodations for those in excess of the capacity of the launch. Exclusive of the time required for one trip each to Sitka and Juneau the field work occupied the period from May 19 to late August.

During the season of 1938 the geologic party consisted of Walter Scott Ford, of Juneau, geologic assistant, and the senior writer. A topographic base map for the geologic work was made while the geologic party was making mine surveys underground, by J. Mark Holmes, Geological Survey topographer. Glenn A. Edwards and Edward Amelung assisted Mr. Holmes. The topographic map (pl. 1), which illustrates a land area of about 107 square miles, was published separately in 1939 as Alaska Map 52. The scale is 1:62,500 and the contour interval is 50 feet.

The rest of the party in 1938 consisted of Allen Sallee, who operated the *Ranger 6;* Ernest Kruse and Thomas Murphy, each of whom served as cook for part of the season.

Transportation to and within the district in 1939 was effected by means of the Motorship *Highway*, which was chartered for the season from the Public Roads Administration of the Federal Works Agency. During most of the season the entire party lived on the boat and the field work was done mainly by daily foot traverses from the boat. Shore-line work was accomplished by using a small boat powered with an outboard motor. Parts of the district more remote from salt water were studied from "spike" camps that were placed by backpacking from the *Highway*. One side camp was transported to a part of the district difficult to reach otherwise, by a seaplane, which landed both men and equipment on a conveniently located lake. A plane was used several times in scouting areas ahead of the mapping.

In 1939 the party assembled in Juneau early in June and left there on the *Highway* June 13. Kimshan Cove, in the mining district, was reached the next day. Field work continued in and near the district until September 22. During the later part of this period the field work was directed toward extending the surveys so as to include a start on the examination of the deposits of nickel, one of the strategic metals, which are known to be distributed in an extensive zone along the west coasts of Chichagof and Baranof Islands.

The field party in 1939 consisted of the writers and Darwin L. Rossman, camp hand. The boat crew was made up of Nels Rogne, captain; Swan Peterson, engineer; and Gordon Peterson, cook. Gerald Anderson served as a recorder for a few days in August.

The authors share the responsibility for the earlier parts of the report, but the junior author made most of the thin-section studies that formed the bases for the petrologic descriptions and inferences. The senior author is responsible for most of the section on ore deposits.

Trilens airplane photographs were available for the entire area of the district as mapped and were of great value in both the topographic and the geologic work. The average scale of the photographs is about 1:20,000. They were useful in mapping certain geologic formations, particularly alluvium in the valleys and a persistent band of marble that crosses the district. They were also useful, especially when viewed stereoscopically, in studying the country ahead of the mapping, to choose where traverses could best be made and the best locations for camp sites. The photographs proved to be of great help in the study of the geomorphologic features of the district. Most use of them, however, was made in the study of the hundreds of faults that cut the rocks of the district. Many faults that have so little surface expression that they would not have been noticed from the ground are plainly recognizable on the photographs.

ACKNOWLEDGMENTS

The writers gratefully acknowledge the whole-hearted cooperation of the operators of the district in the prosecution of the field work. Free access was given not only to the mines but also to such records as maps, notebooks, cost sheets, correspondence, and estimates. Particular acknowledgment is due to Paul M. Sorensen, manager of the Hirst-Chichagof Mining Co., for the items mentioned above and for furnishing to the Survey party every convenience of the mine camp. In 1938 James L. Freeburn and F. R. Hills, of the Chichagoff Mining Co., extended every courtesy to the Survey party, as did John D. Littlepage at the same property in 1939. The help given to the writers by several Forest Service officials is also gratefully acknowledged.

OUTSTANDING CONCLUSIONS

The belt of country along the west coasts of Chichagof and Baranof Islands has long been considered by Survey geologists who have visited it is especially favorable for the finding of ore deposits. For example, Knopf[1] says: "The indications afforded by present developments point strongly to the conclusion that the entire strip of territory contiguous to the west coast of Chichagof Island offers a more encouraging inducement to the search for new ore bodies than any other part of the region." Buddington and Chapin[2] cite this quotation and add: "This conclusion has been confirmed by later developments and still holds true." The writers subscribe in general to these statements but in the light of the information furnished by their study of the Chichagof district are of the opinion that search for ore bodies in the belt, in order to have a fair chance of success, must be guided by careful, competent, and detailed geologic work.

It has long been known that the ore bodies in the Chichagof district lie in or on fault zones. Perhaps the most noteworthy results of the investigations of 1938 and 1939 are the recognition of the hitherto un-

[1] Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, p. 32, 1912.

[2] Buddington, A. F., and Chapin, Theodore, Geology and mineral deposits of southeastern Alaska: U. S. Geol. Survey Bull. 800, p. 373, 1929.

suspected extent of certain of the faults and the extreme complexity of the fault system. The conclusion that unknown ore bodies lie in faults other than those in which the bodies so far productive have been found and in unprospected parts of the faults that have contained ore bodies is entirely consistent with the geologic evidence, and the writers believe that to be true. That such bodies, if they exist, will be difficult to find is also clearly indicated, and few if any of them may crop out at the earth's surface. The fault system extends both northwestward and southeastward beyond the limits of the mapped area. Its limits are not known, and the further study and tracing of it offers an attractive geologic problem with a distinct economic slant.

GEOGRAPHY

LOCATION AND GENERAL CONDITIONS

The Chichagof mining district lies on the outer or western coast of Chichagof Island, one of the larger islands of the Alexander Archipelago. (See fig. 1.) The district centers around Doolth Mountain, a prominent landmark 2,167 feet high, about 52 miles northwest of Sitka.

At each of the two principal mines of the district there are a post office, a store, and a small mining community. Chichagof, at the Chichagoff mine, lies near the head of Klag Bay, on the southeast side of Doolth Mountain (pl. 1). Kimshan Cove is the post office at the Hirst-Chichagof mine. The location is on a small bay off Ogden Passage, at the northern foot of Doolth Mountain.

In the summer of 1938 there were about 200 people at Chichagof and perhaps 100 at Kimshan Cove. Between the summers of 1938 and 1939 the population of Kimshan Cove increased slightly, while that at Chichagof decreased markedly. The decrease was due to the temporary cessation of underground mining in the Chichagoff mine and the start of a program, involving fewer men, to rework the old mill tailings. Those at the mining centers, together with a few scattered prospectors and transient fishermen, are the only residents of the west coast of the island.

Both Chichagof and Kimshan Cove are on landlocked water well protected from the open ocean. However, transportation by boat to either place from such other places as Juneau or Sitka involves the traverse of at least 10 to 20 miles of reef-infested open water. The district may be reached by boat by rounding either the south end of Chichagof Island, through Peril Strait, or the north end, through Icy Strait and Cross Sound. If approached from the north the open-water distance can be greatly shortened by going through Lisianski Inlet and Strait instead of outside Yakobi Island.

A mail boat that carries passengers and freight touches once a week at each post office and returns to its home port at Juneau. Many stops are made at intermediate points each way. Combined passenger and freight steamers, such as those that commonly ply Alaskan

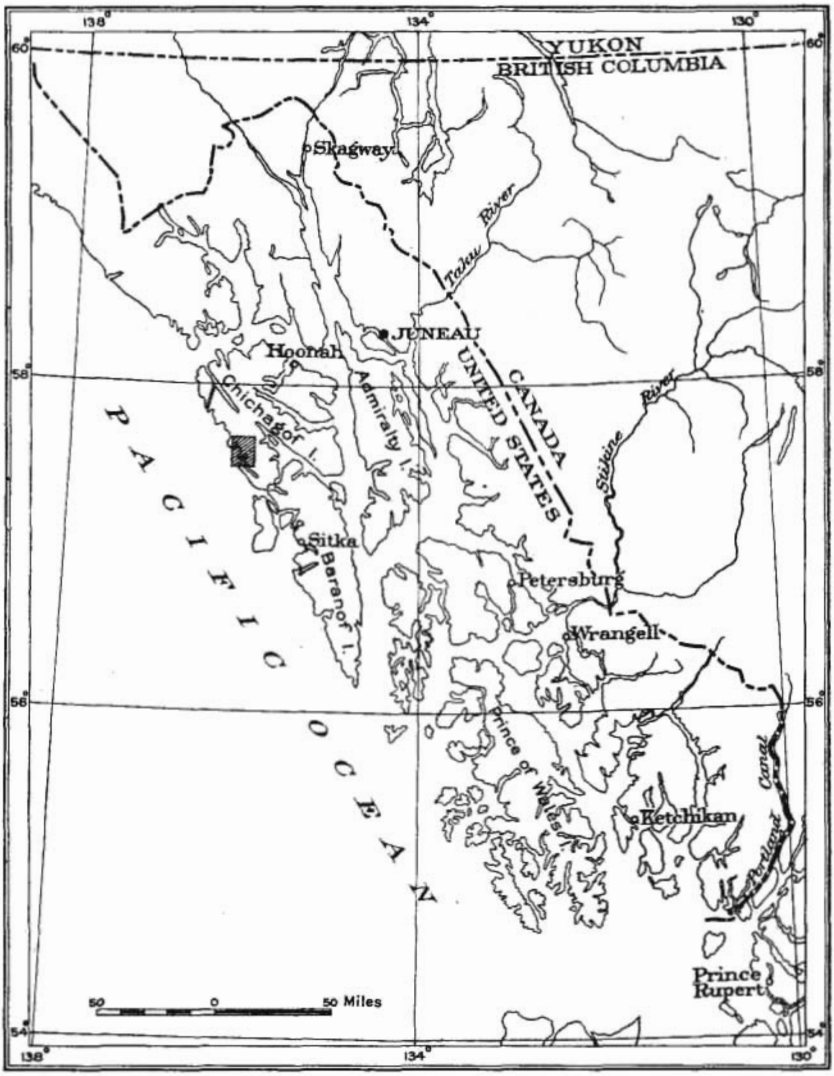


FIGURE 1.—Index map of southeastern Alaska, showing location of Chichagof mining district.

waters, do not take the narrow, tortuous channels to reach either Kimshan Cove or Chichagof. Smaller boats take freight in and concentrates out at various times throughout the year, mostly in the summer. At each settlement there is a mine-owned Diesel or gasoline boat for emergency use and for local moving of materials.

The mines are now served throughout the year by one and occasionally more planes on nearly every day that the weather permits flying. A radio station for weather reports and emergency use is maintained at Kimshan Cove by an air-transportation company. A commercial radio station is located on the lee side of one of the small islands on the west side of Ogden Passage opposite the entrance to Elbow Passage. The operator commonly makes a trip by small boat to either Kimshan Cove or Chichagof each day to deliver or receive messages. There is telephone communication between the two camps.

Travel within the district goes almost entirely by water, and short trips in such relatively protected waters as Portlock Harbor, Ogden Passage, and Klag Bay are commonly made without difficulty in any except very foggy weather. Lake Anna and Sister Lake can be entered in good-sized power boats at slack tides. These are tidal lakes, and the tide flows swiftly through the inlets except at high- and low-water slack.

The distance between Kimshan Cove and Chichagof by water is about 11 miles. A trail about $2\frac{1}{2}$ miles long connects the two settlements by crossing the saddle just east of Doolth Mountain. Another trail follows the power line from Chichagof to the power house on Sister Lake. There are several other short trails in the district, but the only other one of any considerable length branches from the Chichagof-Kimshan Cove trail near Chichagof, leads over the mountains past Black Lake and down to Black River, and thence up Black River and over the main divide of the island and down to salt water at the head of Hoonah Sound. This trail and a shelter cabin where the trail crosses Black River were built by the Forest Service.

TOPOGRAPHY

The district is one of considerable relief, and the land rises steeply in many places from the deeply indented shore of the island-studded sea to altitudes between 2,000 and 3,000 feet. (See pl. 1.)

The smaller islands and parts of the main island constitute a relatively smooth, gently sloping plain. (See pl. 2.) The plain is covered with many low, rounded hills that ordinarily rise less than 100 feet above it. In the hollows between are myriads of lakes and ponds, some of them of considerable size, such as the lake about a mile southeast of Chichagof.

In the area shown on plates 1 and 2 the plain first appears above the sea in the group of small islands in the southwestern part of the area. It rises gradually eastward toward the center of the island and terminates, in many places, at an altitude of about 250 feet, against the steeper slopes that carry the land surface to much greater altitudes.

Overbeck [3] has described this coastal plain and has pointed out that it extends from Cross Sound on the north to Khaz Head, just south of the area shown on plate 1, on the south. He also shows that the plain continues out under the sea for about 16 miles, beyond which the sea bottom descends steeply to oceanic depths.

Eastward from the eastern edge of the coastal plain most of the upland areas are discontinuous parts of a relatively subdued surface of rounded mountains and flatter areas. This upland surface, as reconstructed from its remnants, sloped upward toward the east or northeast for about 3 to 5 miles, where large parts of it now lie at altitudes between 2,000 and 2,500 feet. Eastward from the vicinities of Mount Freeburn, Hirst Mountain, Whitestripe Mountain and the mountain 2,768 feet high about 3½ miles east of the head of Pinta Bay the surface was lower for several miles. Its average altitude in that belt, as indicated by the few remnants, may have been about 1,500 feet or perhaps less. Still farther east, near the northeast corner of the mapped area, the surface again reached to about 2,000 feet. (See pl. 2.)

At some places, as for example in the southern part of the Takeena Peninsula between Slocum Arm and Ford Arm, the upland surface is separated from the coastal plain by steep, locally precipitous slopes from a few hundred to more than 1,500 feet high. At other places, such as in the area lying northeast of the heads of Klag Bay and Lake Anna, the upland surface descends relatively gradually to merge or nearly merge into the coastal plain.

The upland surface, like the coastal plain, is dotted with lakes and swamps. On it rounded surfaces prevail and sharp breaks of slope or angular features are uncommon.

Above the upland surface just described are a few steep, jagged, frost-riven peaks. (See pl. 2.) They are characterized by sharp pinnacles and comblike ridges. These constitute the higher peaks of the mapped area and include the peak locally called Devils Peak, about a mile east of the south end of Rust Lake, 3,216 feet high; the three peaks of Mount Freeburn, 3,003, 3,228, and 3,254 feet high, respectively; the peak 3,051 feet high about three-quarters of a mile northeast of Whitestripe Mountain; and Mount Lydonia, 3,252 feet high, together with two lower neighboring peaks.

[3] Overbeck, R. M., Geology and mineral resources of the west coast of Chichagof Island: U. S. Geol. Survey Bull. 692, pp. 92–93, 1919.

In the northeastern part of the district, in the area where the upland surface is relatively low and is now represented by but few remnants (see p. 10), is an extensive lowland. Through this interior lowland passes the main divide of Chichagof Island. The relief in this lowland area is relatively moderate. From it rise here and there the hills whose upper slopes are part of the upland surface. Unfortunately most of the interior lowland was not mapped topographically, but on plate 2 the 500-foot and 1,000-foot contours have been sketched and a few aneroid altitudes are shown. The lowland is in most places less than 1,000 feet above sea level and the main divide locally is below 700 feet.

Areas of muskeg and lakes are common in the interior lowland.

From the lowland radiate several large valleys in pattern much like spokes from the hub of a wheel, except that no valley runs northeastward. Granite Creek runs southeastward to reach the North Arm of Hoonah Sound. Another large stream a few miles farther south heads in the lowland and flows into the same arm of Hoonah Sound. Black River flows southwestward to Black Bay off Surveyor Passage, and Goon Dip River flows almost due west into Didrickson Bay. A large chain of lakes, locally called the Goulding Harbor Lakes, lead west and a little north from the lowland and drain through Goulding River into Goulding Harbor, an arm of Portlock Harbor. Another large valley heads in the lowland between Granite Creek and the highest of the Goulding Harbor Lakes and leads northwestward to Lisianski Inlet not far from its head. The way in which these streams radiate from the lowland is indicated on plate 2.

Only two of the radiating valleys are entirely within the mapped area—those of Goon Dip and Black Rivers. These valleys are wide, U-shaped troughs and, where they transect the higher country southwest of the interior lowland, are deep and very steep-sided.

Valleys of other streams and of tributaries of the two principal streams, Goon Dip and Black Rivers, are etched deeply into the rocks of the district and separate the remnants of the upland surface. The larger of these valleys are also U-shaped glacial troughs. Many of the valleys, such as that of Black River, are not U-shaped all the way to the sea but near their mouths flow in narrow V-shaped gorges.

The heads of many of the streams, particularly those that flow from the relatively high areas and especially from the high areas in the vicinities of the sharp peaks above the upland surface, are in glacial cirques, and many of these cirques contain lakes. Well-formed cirques, however, are not as common as might be expected for an area that has been so recently and so intensely glaciated as the Chichagof district.

CLIMATE

No systematic weather records have been kept in the district for periods of time long enough to be significant, but there is a long record of observations at Sitka that goes back, in part, to 1842. The climate in the Chichagof district is similar to that at Sitka, where the mean annual precipitation approaches 86 inches, most of which falls as rain and but little as snow. June is commonly the driest month, and October or some other month from September to December the wettest. Seldom is there less than 1 inch of precipitation in any month. The mean annual temperature is about 44°. The coldest month is commonly January, with a mean monthly temperature a little over 32°. The warmest month ordinarily is July or August, with the monthly mean not far from 55°.

Figure 2, on which are shown mean monthly temperature and precipitation, has been prepared from records published by the United States Weather Bureau.[4] They include the period from the beginning of the record through 1936.

Navigation is commonly open throughout the year, although occasionally the heads of small bays freeze up sufficiently to make them temporarily unnavigable. A great hazard to navigation in small boats is the notoriously rough water of the open ocean along the outer coasts of the Alexander Archipelago. Another hazard is the large number of foggy days caused by the condensation of the moisture from the warm, humid air blown in from the Pacific against the mountainous coasts.

Mr. Holmes, topographer of the Survey party in the district in 1938, reports that out of 101 days while he was present in the field ready for work, 20 days were either too rainy or too foggy for any kind of topographic field work, 65 days were partly cloudy and partly rainy, and 16 days were clear.

VEGETATION

The small islands and the coastal-plain part of Chichagof Island support a sparse growth of trees, mostly pines, particularly on the low ridges, but the swampy areas between the ridges are largely devoid of trees, although shrubs and other smaller plants are common. From the upper limits of the coastal plain the slopes are densely wooded to timber line, which, depending on local conditions, at most places lies between 1,500 and 2,000 feet above sea level. The trees are largely hemlock, spruce, and cedar. In the timbered belt and to a lesser extent for some distance above it is found a dense, in places almost impenetrable, growth of underbrush. Common shrubs and small trees are

[4] Climatological data: vols. 21 and 22, No. 13, U. S. Dept. Agr., Weather Bur., 1937 and 1938.

devil's club, willow, alder, and such berry bushes as cranberry, currant, salmonberry, and blueberry. This densely covered belt is a serious obstacle to foot travel and to prospecting and geologic mapping. This obstacle to geologic investigations is greatly offset by the almost perfect exposures along the indented shores and the good exposures above timber line.

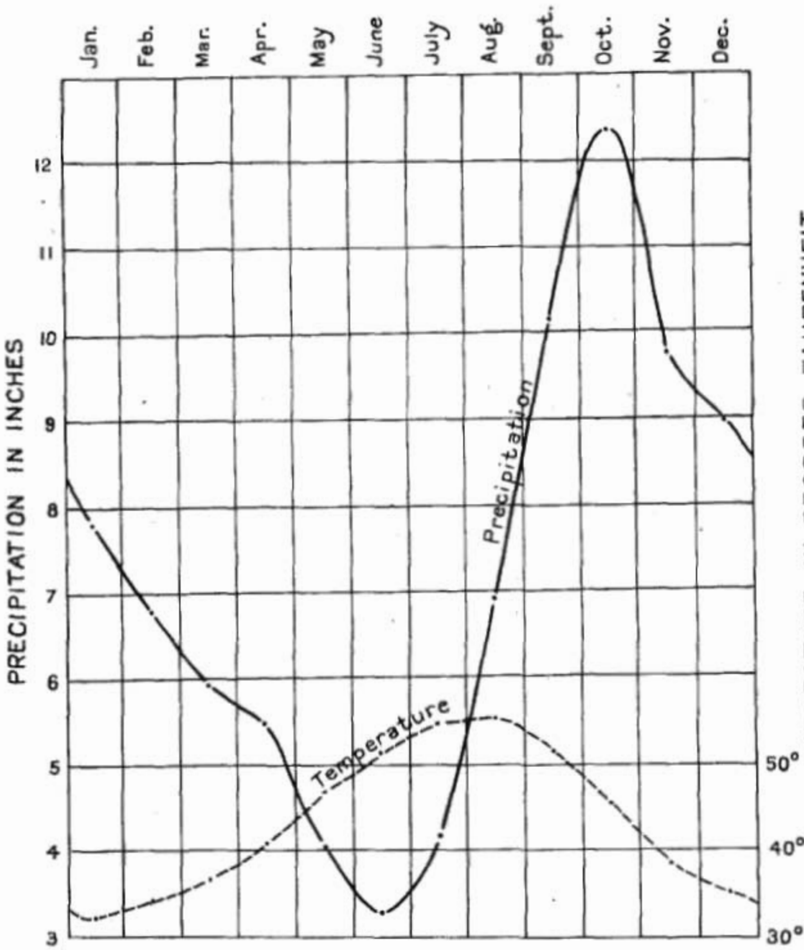


FIGURE 2.—Mean monthly temperature and precipitation at Sitka, Alaska.

Little good mine timber is available in the district. Much of that which formerly grew near enough to the coast to be felled into the water has already been used by the mines or for piling, other dock timbers, buildings, or fish traps. In recent years both the Hirst-Chichagof and the Chichagoff mines have used timber rafted in from Baranof Island or other places. Many of the rafts are towed more than 50 miles, in part through the open ocean, and serious log losses are not uncommon. The skip guides in the shaft at the Hirst-Chichagof mine are made of fir shipped from Seattle.

ANIMALS

Brown bears abound on Chichagof Island and are common in the district. The Forest Service estimated [5] in the summer of 1938 that there were 950 brown bears on Chichagof Island, or one to every 2½ square miles. These big bears, or at least certain ones, are reported to be dangerous if disturbed, and it is not considered safe by the local inhabitants to travel far over the island unless well armed. Deer are plentiful, as are certain other smaller land mammals, some of them fur-bearing.

The waters of the district, both salt and fresh, abound in fish. Salmon, halibut, and trout are those most eagerly sought by commercial and sport fishermen. Sea animals, such as whales, hair seals, and sea lions, are occasionally seen. The sea lions are said to be very common on some of the outer islands, particularly the White Sisters, where a group of a dozen or more were seen by the senior writer in 1939.

GEOLOGY

BEDDED ROCKS

GREENSTONE-SCHIST SEQUENCE

OCCURRENCE AND RELATIONS

The oldest rocks of the Chichagof mining district constitute a thick sequence of volcanic, intrusive, and sedimentary rocks that occupy much of the northeastern part of the mapped area. (See pl. 3.) The rocks of the sequence are all metamorphosed, but the degree of metamorphism is considerably different at different places. The degree of the metamorphism apparently reflects not only the susceptibility to metamorphic processes of the rocks at a given locality, but also the different intensities of the processes at different places.

The rocks as mapped include such diverse types as massive greenstone, amygdaloidal greenstone, greenstone schist, siliceous schist, schists characterized by such minerals as hornblende, actinolite, albite, biotite, and epidote, and bodies, largely sills, of diabase and gabbro. Mixed rocks gradational between greenstone or other rocks of the sequence and the much younger intrusive diorite are common near the contacts. These mixed rocks appear to be largely the result of mechanical penetration of the older rocks by the diorite. Granitic dikes that are common in the lower part of the formation are mentioned in the section of this report on intrusive rocks (p. 37).

The upper limit of the greenstone-schist is one of the major faults of the district. This fault follows a slightly meandering course from the lake, 990 feet high, about 2¼ miles east of the head of Pinta

[5] Alaska Sportsman, vol. 5, No. 1, p. 19, January 1939.

Bay, across the valleys of Goon Dip and Black Rivers to and beyond the hill 1,683 feet high about 1⅓ miles northeast of the north end of Rust Lake. The fault in general appears to be roughly parallel to the bedding of the rocks below, but it probably does not exactly parallel that bedding, and therefore slightly different horizons in the greenstone sequence are probably exposed at different places along the fault.

At its lower limit the formation abuts against intrusive diorite and associated rocks and the contact is very irregular. More and larger areas of the lower parts of the formation are exposed near and east of the head of Goon Dip River, between that locality and the long lake at the north edge of the mapped area that drains into Goulding Harbor, and between the head of Goon Dip River and the head of Black River than in any other part of the district as mapped.

Many bodies of rock belonging to the greenstone sequence lie isolated in the dioritic rocks. Some of these xenoliths are large enough to show on the geologic map, but most of them are far too small. The rocks of the greenstone formation are therefore more widely distributed in the areas of granitic rocks than a study of the map would indicate. The foliation of the rocks of the xenoliths appears to be essentially parallel to the regional structural trends, thus indicating that the intrusion may have been of the permissive type without any great moving of the xenoliths from their original positions.

The greatest exposed width of the formation, measured across the strike from the fault that limits the formation on the southwest to the northeast side of the most northeasterly xenolith seen, is nearly 5 miles. The total thickness of the exposed part of the formation may approximate the same figure. This estimate of thickness is based on several difficultly defended assumptions. It must be assumed that the space occupied by diorite crossed by the line of measurement was once occupied by part of the greenstone formation. The preceding paragraph gives the basis for this assumption. It must be assumed that the dips are vertical, which is only approximately true. It must be assumed that there is neither duplication nor cutting out of parts of the formation by close folding or faulting, and this assumption appears fairly safe. Some faults cut the formation, but they are not as numerous as elsewhere in the district. Their effect on the apparent thickness of the formation is not known.

The greatest exposed width, and by assumption the greatest thickness, of the formation as measured without including any rock mapped as diorite is a little more than 3 miles.

The sequence is divisible into two distinct parts, but the contact between them was not mapped, largely because of complications arising from the intrusion of the dioritic rocks. The upper 1 to 1½ miles of the formation is largely massive greenstone with some amygdaloidal greenstone and greenstone schist.

Apparently the upper, massive part of the formation was relatively resistant to penetration by the dioritic magma. At most places the main southwestern contact of the diorite roughly coincides with the base of the upper part of the greenstone-schist sequence. The upper part of the formation is generally dark-colored. In many places a dark-green cast to the rocks is conspicuous. At several places, notably about half a mile east of the top of Hirst Mountain and about a mile east of Whitestripe Lake, were seen zones in the greenstone in which small quartz lenses are liberally distributed. One such zone on Hirst Mountain is about 50 feet wide and trends roughly parallel to the general structural trend for an unknown distance. Individual quartz lenses reach several feet in length and are a few inches wide. It is estimated that in this zone four or five lenses commonly lie in a square 10 feet on a side. Epidote and chlorite or serpentine are associated with the quartz. Pyrite and chalcopyrite were recognized in some of the lenses.

The lower part of the formation is extensively penetrated by the diorite, and in most places only fragments of it remain. It appears to consist principally of sills of diabase and gabbro interlayered with metamorphosed sedimentary material. Some of the sills are at least 1,000 feet thick, but very little is known about their detailed distribution. The relations indicate that the bodies of basic rock may have been intruded into the sediments of the lower part of the formation at about the same time that the thick lava flows were being poured out to form the upper part of the formation or younger volcanic rocks.

Study of many thin sections in the office after the completion of the field work has shown that some bodies of gabbroic rocks were mapped as part of the greenstone formation and some as basic differentiates of the diorite. The greenstone formation, for this reason as well as because certain xenoliths were too small to map, is more widely distributed than is indicated on the map.

The sedimentary rocks of the lower part of the formation are diagnostically light-colored and contrast sharply with the dark intrusive sills and the lava flows above.

PETROLOGY

Upper part.—The lava flows of the upper part of the formation are commonly of basaltic texture. The typical rock is a mass of interlocking laths of plagioclase enclosing grains of augite. The vesicles of the amygdaloidal flows are commonly filled with quartz and chlorite. The augite in one specimen from Rust Mountain has been peripherally replaced by uralite (fibrous amphibole) and later by green chlorite. The plagioclase is now albite, which has been partly replaced by epidote crystals. A dike of similar rock from the same mountain contains masses of green serpentine about 2 millimeters across. The serpentine is probably pseudomorphous after olivine. Both of the rock specimens described above were collected within 200 feet of a contact with diorite, and the absence of igneous metamorphism is noticeable.

A schistose rock on Hirst Mountain half a mile from the nearest exposed contact with diorite has been more thoroughly recrystallized. It now consists of numerous small laths of albite with parallel orientation embedded in an almost opaque mat of tremolite, chlorite, and epidote, with a few large epidote grains. The rock is cut by veinlets of quartz and chlorite and by veinlets of cloudy prehnite. The original rock was probably a lava flow.

A rock from the ridge extending northward from the mountain 3,051 feet high, about three-quarters of a mile northeast of the top of Whitestripe Mountain and about 4,500 feet from the 3,051-foot peak, is similar to the one just described but is coarser-grained and shows traces of an original porphyritic texture. The amphibole is bluish-green actinolite. The nearest exposed diorite contact is about one-eighth of a mile away.

Specimens taken from outcrops of nonschistose greenstone at different places near contacts with the diorite show evidence of originally having been amygdaloidal and porphyritic. The rocks are now hornfels. The principal minerals, which make up the rocks in different relative amounts, include bluish-green hornblende, albite, epidote, and clinozoisite. Titanite is a common accessory. Biotite was observed in one specimen. Secondary minerals such as chlorite and prehnite are ordinarily present. Prehnite has replaced the rock minerals and also fills veinlets.

Lower part.—In the area unmapped topographically, in the northeastern part of the district, principally north of latitude 57°45′N. and east of longitude 136°W., the volcanic and sedimentary rocks of the lower part of the formation, which are interbedded with metagabbro sills, are banded and have textures that range from schistose to granulose. The rocks progressively farther northeast are more coarsely crystalline and more schistose and contain feldspars of more calcic composition. One well-defined type is hornblende schist with considerable plagioclase.

At one locality near the divide between the Black Bay and Goulding Harbor drainage basins hornblende-albite-chlorite schist crops out. Epidote and magnetite are accessories. The rock is cut by prehnite veinlets. A light-gray, fine-grained schistose rock was observed about a mile southeast of the head of the long lake near the northern boundary of the district. Quartz, orthoclase, hornblende, andesine, and chlorite are the principal constituents. The relatively large proportions of quartz and orthoclase suggest that the rock was originally a sediment. Farther northeast the schistose rocks are richer in hornblende, in most places accompanied by andesine, orthoclase, and some biotite. Secondary prehnite is common.

A specimen of hornblende-plagioclase schist was obtained from the isolated area of rock mapped as greenstone near the northeast corner of the district. Hornblende, in stubby green prisms, makes up about 70 percent of the rock, labradorite about 20 percent, quartz and ilmenite about 5 percent, and augite, titanite, and apatite the rest. That this rock has been metamorphosed relatively intensely is suggested by the presence of augite and the calcic character of the plagioclase. The rock is probably a metabasalt.

The composition of certain of the rocks of the lower part of the sequence clearly indicates their sedimentary origin.

Xenoliths of calcareous sandstone lie in diorite in the valley of the large fork of Black River about a mile north of the top of Rust Mountain. The rock is light brown and fine-grained. Quartz, albite, epidote, actinolite, and brown, pleochroic biotite are the principal constituents. Veinlets of orthoclase and of calcite and orthoclase cut the sandstone. There is little evidence of metamorphism.

Banded light-colored rocks are unusually well exposed in a small creek valley about half a mile east of the hilltop 1,785 feet high at latitude 57°45′ N. and longitude 136° W. Before they were metamorphosed they probably were sandy limestones and limy sandstones. One band is composed of small grains of diopside and albite. A little of the diopside has been altered to tremolite. Another thin band is made up of quartz, garnet, calcite, and clinozoisite; a third of quartz and albite with prisms of tremolite and scattered grains of titanite; and a fourth of albite, quartz, chlorite, tremolite, and epidote. All the bands contain small grains of pyrite and are cut by veinlets of prehnite.

A specimen of metagabbro obtained a short distance east of the group of small lakes at the head of the northernmost headwater of Goon Dip River consists largely of large plates of green hornblende enclosing prisms of cloudy albite. Small hornblende needles also lie in large numbers in the albite. Concentrations and stringers of brown biotite are present, and magnetite and leucoxene occur in large skeletal pseudomorphs after ilmenite. Apatite appears in stout prisms, some of which are broken.

A little more than a mile east of the locality just mentioned a similar rock crops out. Here cloudy andesine is rimmed with clear albite. Swarms of small prisms of hornblende display a subparallel orientation. The outer prisms of individual swarms are pleochroic in darker, bluer tones than the crystals of the interior. Magnetite is present in large grains and myriads of smaller ones. The magnetite crystals are distributed through groups of brown biotite flakes. Apatite is an accessory mineral.

AGE AND CORRELATION

The age of the greenstone-schist is not definitely known. The sequence is lower in the stratigraphic column than the rocks that yielded the fossils of doubtful Upper Triassic age. (See pp. 29–30.) As has been pointed out, the recognized upper limit of the formation all the way across the district is marked by a fault. Because the fault appears to be generally parallel to the bedding it is believed that the fault does not cut out any great stratigraphic thickness and that, so far as is known, no very great span of geologic time elapsed between the pouring out of the flows of the upper part of the greenstone-schist and those of the greenstone above. The upper part of the sequence may be Triassic, or it may be older.

The age of the sediments of the lower part of the formation is even more in doubt. The main mass of dioritic magma penetrated upward about to the division between the upper and lower parts of the formation. No unconformity between the two parts was seen, and none is believed to be present, but if one were present there, it might well be concealed by the effects of the intrusion on the preexisting rocks or by the intrusion itself.

It is possible, from the field evidence, that the lava flows of the upper part of the formation were being extruded at or about the same time as the bodies of basic rock were being intruded into the lower part of the formation. On the other hand, the intrusion of the basic masses may have been unaccompanied by any surface volcanism, or they may correspond in time to any of the Triassic volcanic rocks or, less probably, to the greenstone in the graywacke of probable Lower Cretaceous age. If the last-named possibility should be true the basic intrusive masses of the lower part of the formation may have been the immediate forerunners of the main diorite intrusion, herein correlated with the Coast Range batholith.

GREENSTONE

OCCURRENCE AND RELATIONS

The formation herein designated greenstone is a persistent unit that trends across the district stratigraphically above the greenstone-schist. The lower limit of the greenstone is marked by the fault that separates it from the underlying sequence. At most places it is overlain by a persistent band of limestone.

Locally thin lenses of limestone occupy a zone several hundred feet thick near the top of the greenstone formation. This feature was noticed particularly near the eastern border of the mapped area. The rock of these lenses is made up of limestone masses a few inches in diameter set in a matrix of scoriaceous greenstone. In the vicinity of Black River at two or more places parts of the limestone formation extend down into the greenstone sequence for a considerable distance. In the valley of Goon Dip River, north of the river, the limestone band is locally cut out by faulting and the greenstone is in contact with the schist.

The width of the outcrop of the greenstone as mapped ranges from about 5,500 feet at Goon Dip River to about 800 feet at Mount Freeburn. The thinning at Mount Freeburn appears to be due to the cutting out of the lower part of the formation by a local divergence from parallelism with the bedding of the fault that marks the lower side of the greenstone. A short distance farther south, east of the north end of Rust Lake, the width of outcrop is more than 3,500 feet.

The formation is cut by a considerable number of faults, but in general they appear to be neither large nor continuous, and their effect on the apparent thickness of the formation is probably not great. As the dips are steep, the maximum width of the outcrop probably approximates the maximum exposed thickness of the formation.

So far as is known the formation is made up almost entirely of massive lava flows. At many places the stratification, because of the massive character of the rock, is very difficult to determine.

The rock is in general dark-colored. At many places a reddish cast on the weathered surface is conspicuous. At others the rocks are dark gray or green. In a few localities the fresh rock is a distinct purplish red.

Parts, presumably the tops, of many of the flows are amygdaloidal, and the amygdules, some of which are an inch in diameter, are commonly made up of readily recognizable quartz and epidote. The amygdaloidal zones on Hirst Mountain, where they are well exposed and appear to be typical, are as much as 6 feet thick and are separated by 20 to 100 feet of greenstone that is not amygdaloidal.

At many places the nonamygdaloidal greenstone is cut in varying directions by tiny veinlets of quartz, epidote, and prehnite (pl. 4, *A*).

PETROLOGY

The greenstone is commonly porphyritic, and the spaces between the feldspar laths are ordinarily filled with alteration minerals or with augite. Locally the feldspar crystals are concentrated in conspicuous groups that simulate amygdules.

A thin section cut from a specimen collected near the summit of Hirst Mountain contains feldspar crystals as much as 0.5 millimeter long forming a network of tiny laths with interstitial augite and magnetite. Usually the feldspar is albite, but the larger crystals contain a few ragged remnants of labradorite, which perhaps indicate the composition of the original feldspar. The groundmass contains much secondary epidote, chlorite, and leucoxene. The many large, rounded amygdules are made up of quartz grains and epidote. Small irregular cavities are partly filled with green chlorite, some of which is radially arranged, and epidote. Some of the cavities have thin linings of quartz.

A thin section from a neighboring locality is similar to the one just described except that no remnants of calcic plagioclase remain and the augite has been completely altered. Much secondary calcite is present.

The color of a purplish-red amygdaloidal flow in the greenstone formation near the eastern edge of the district is due to the presence of finely disseminated hematite in the groundmass. The feldspar is albite. The rock is similar to the rocks of the Hirst Mountain vicinity.

A dark, relatively coarse-grained rock that lies just below the Triassic(?) limestone on the ridge between Mount Freeburn and Black River appears to be a diabase sill. The maximum grain size is about 2 millimeters. The principal minerals are a calcic feldspar (bytownite) and actinolite. The actinolite is present as large plates that contain numerous inclusions of ilmenite and as needles, commonly radiating, that have replaced other minerals, principally bytownite and chlorite. Bytownite in laths as much as 0.5 millimeter long makes up about 40 percent of the rock. Many of the bytownite crystals are enclosed in the actinolite plates. The feldspar has been partly altered to actinolite, sericite, chlorite, epidote, and prehnite. The chlorite has been in part replaced by epidote. Prehnite and epidote are also present as veinlets. Part of the ilmenite has been replaced by leucoxene.

The brecciated volcanic rock near the top of the Triassic(?) greenstone not far from the eastern border of the mapped area that contains rounded masses of limestone as much as several inches in diameter appears to have resulted from basaltic lava having been intruded into or extruded over limy mud. Such an origin has been suggested for similar rocks elsewhere.[6]

The brecciated rock is made up principally of fragments of scoriaceous lava in a matrix of calcite grains that lack good crystal boundaries. The numerous vesicles contain such minerals as chlorite, zeolites, and sericite. The rock is cut by calcite veinlets. The feldspars have been replaced by sericite. Much pyrite is present in the volcanic fragments and in the calcite adjacent to the fragments.

[6] Macdonald, G. A., An intrusive peperite at San Pedro Hill, Calif.: California Univ., Dept. Geol. Sci. Bull., vol. 24, pp. 329–338, Nov. 12, 1939.

The walls of the vesicles, which presumably were originally glassy, consist of dull, opaque white material resembling leucoxene that is scattered through a matrix of sericite and pale-green chlorite.

AGE AND CORRELATION

No fossils have been found in the greenstone, and its age is known only from its relations to other formations in the stratigraphic column. The limestone lenses and the breccia containing small limestone masses that occupy a position near the top of the greenstone appear to indicate a gradation into the limestone formation above. The fossils of somewhat doubtful Upper Triassic age that were collected from limestone float (see p. 29) may have come from the limestone formation, but it is thought more likely that they came from a limestone lens higher in the stratigraphic section. All that can be definitely said as to the age of the greenstone formation is that it is older than rocks of doubtful Upper Triassic age but that there is no known unconformity or disconformity between.

Most of the greenstone is similar to the upper part of the underlying greenstone-schist and therefore at least the upper part of the greenstone-schist formation may also be Triassic. The two formations are separated by a fault.

The diabase sill at the top of the greenstone between Mount Freeburn and Black River affords a basis for speculation as to the age of some of the older intrusive rocks of the district. If this basic sill is the age equivalent of the old basic intrusive bodies in the lower part of the greenstone-schist, then those bodies must be younger than the upper part of the greenstone-schist. The basic sill at the top of the greenstone, mapped as part of that formation, may be the age equivalent of volcanic rocks higher in the section.

LIMESTONE

OCCURRENCE AND RELATIONS

A group of persistent limestone beds forms one of the most easily traced and conspicuous formations of the district. (See pl. 5.) It extends, with a few very short breaks, all the way across the district from the head of Goulding Harbor southeastward to the edge of the mapped area east of Rust Lake.

The width of outcrop of the band of limestone beds, which presumably is in most places approximately the same as the stratigraphic thickness, ranges from about 100 feet to about 1,500 feet. Such thin calcareous formations are characteristically incompetent and are believed to yield more or less plastically to deformative forces. The suggestion is offered that the differences in thickness of the limestone at different places may be due, at least partly, to the plastic transfer of material from one place to another.

The formation is cut by many small local faults. At the southern extremity of the outcrop of the limestone within the district the formation is cut off by a fault that is considered in more detail in the section on structural geology (p. 73 and pl. 13). South of this fault the limestone has not been found on the ground, although only a little time could be spent in searching for it. Study of airplane photographs also has failed to reveal the continuation of the limestone.

Where the limestone crosses Rust Creek a large fault cuts at a flat angle across the formation. North of Goon Dip River another large fault crosses the limestone and cuts it out in two short intervals, each about half a mile long. The only other known break in the outcrop is east of the head of Pinta Bay, where the formation is displaced about 800 feet.

The formation is predominantly from light to dark gray, but in some places the rock is cream-colored and in others almost white. In general aspect the formation is much lighter than either the underlying or the overlying formations, and the rocks stand out in sharp contrast. (See pls. 4, *B*, and 5.) It is the band of light-colored limestone that gives the name to Whitestripe Mountain.

The limestone has been deeply etched by solution, both above and below timber line. The surfaces are rounded and pitted, and deep gashes, resembling mine stopes, have at many places been dissolved along bedding surfaces and joints. Commonly the sides of these gashes are fluted vertically, like a giant washboard, where the abundant rain has coursed into them. The formation is cavernous, and underground drainage is very common. Rust Creek flows for a considerable distance underground where it crosses the limestone belt. (See pl. 6, *A*.)

No unconformity appears to exist between the base of the limestone and the underlying greenstone. The same appears to be true of the upper contact, although only one lens of limestone was found stratigraphically close to the main limestone belt in the overlying formation. In the vicinity of Whitestripe Lake there is an interfingering between the limestone and the overlying schist, and this condition may also exist elsewhere.

Lenses of greenstone, mostly much darker in color than the limestone, are common in the formation. (See pl. 4, *B*.) Some of these lenses are of considerable size, but not all are shown on the geologic map. In many places it is difficult to tell whether a particular body of greenstone is more closely related to the overlying or the underlying formation.

Many lenses of a light-colored, cherty-appearing rock were noticed in the limestone on and near the mountain top about half a mile northwest of Whitestripe Lake. Thin sections of this rock show that the lenses may originally have been intrusive bodies similar to the dikes of the district. The rock is now made up of more than 80 percent of very fine-grained quartz, with the rest mostly sericite.

Parts of the limestone have been recrystallized to marble. The recrystallization appears to have been irregular, and no apparent relation either to structural features or to younger intrusive rocks was found. At the prospect of the New Chichagof Mining Syndicate near Pinta Bay (see p. 139 and pl. 32), very coarsely crystalline calcite has been formed in irregular bodies where the limestone is cut by a fault. At this prospect shaly limestone, interbedded with more massive limestone, is common. The shaly rocks contain a large proportion of sericite.

The calcite limestone commonly contains quartz, magnetite, and graphite as accessories. Albite and pyrite were noted in the calcareous rocks at the prospects near the head of Pinta Bay.

In places the formation is dolomitic, but the distribution and relative abundance of the dolomitic parts are not known. All the dolomitic specimens studied are cream-colored, but not all the cream-colored rock is dolomitic. Where the rock is dolomitic the small dolomite crystals commonly stand out in relief from the rest of the rock and give outcrops a rough, pitted appearance. Two specimens of dolomitic limestone from Mount Freeburn, one from the southeast flank of the mountain and the other from a locality east of Black Lake, are made up of poorly formed crystals of calcite about 0.02 millimeter in diameter in which are set rhombohedrons of dolomite as much as 0.1 millimeter in diameter. Later veinlets of coarse calcite cut both specimens. The percentage of dolomite ranges widely within very short distances. Different parts of a thin section, for example, display a range of dolomite content from 30 to 80 percent.

AGE AND CORRELATION

No fossils have been found in the limestone formation. It is possible that the fossils found in float and doubtfully assigned to the Upper Triassic (pp. 29–30) came from the limestone formation, but it is thought much more likely that they came from a limestone lens higher in the section, in the schist. The limestone formation is doubtfully assigned to the Triassic, as no unconformity is known to exist between it and the overlying schist.

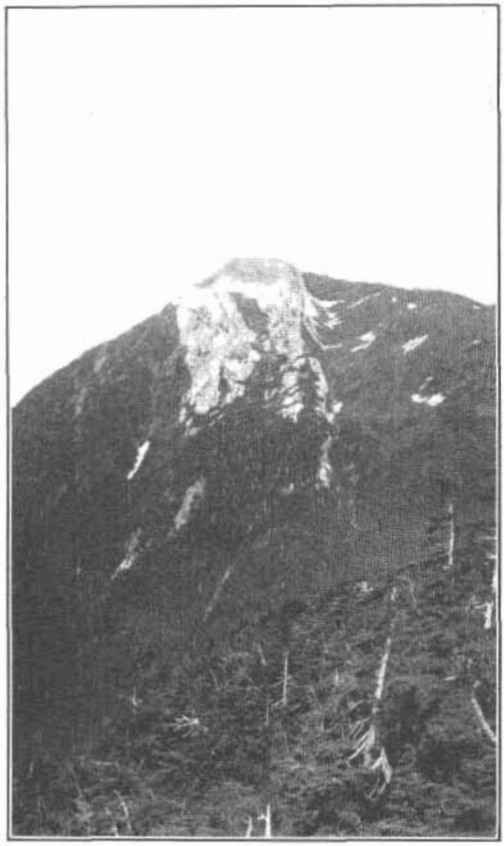
SCHIST

OCCURRENCE AND RELATIONS

The complex group of rocks collectively designated schist is one of the most widespread units in the Chichagof mining district. Its wide belt of outcrop extends from the northwest corner to the southeast corner of the mapped area. The belt is wider both to the northwest

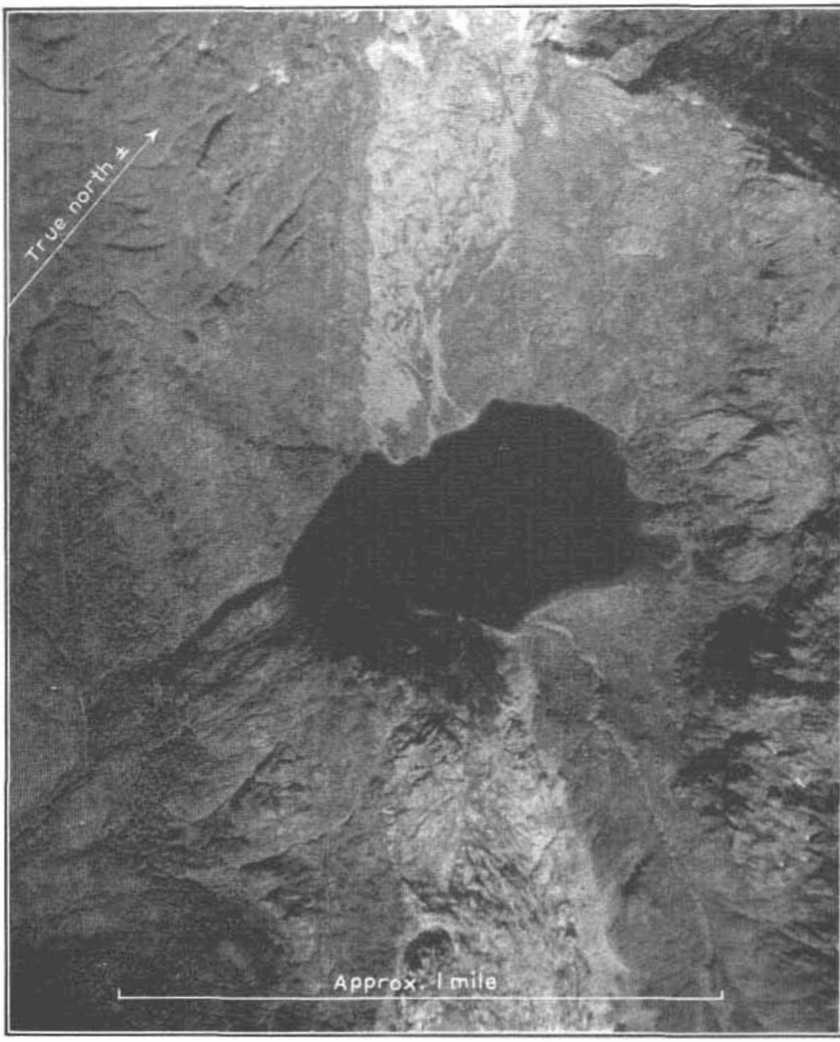
A. OUTCROP OF GREENSTONE ON HIRST MOUNTAIN.

The greenstone is cut by many small veinlets of quartz, epidote, and prehnite.



B. VIEW NORTHWARD ACROSS BLACK RIVER FROM SLOPE OF HIRST MOUNTAIN SHOWING LIMESTONE ON WHITESTRIPE MOUNTAIN.

Note darker lens of greenstone near the center of the limestone band.



VERTICAL AIRPLANE PHOTOGRAPH SHOWING APPEARANCE OF LIMESTONE AT WHITESTRIPE LAKE.

and to the southeast than it is in the central part of the district. The width, measured across the approximate average strike, in the vicinity of Sister Lake is about 4½ miles, whereas a little farther north, near Black Lake, the belt is only 2 miles wide. At Portlock Harbor the belt is nearly 4½ miles across. The formation is cut by myriad faults, including some of the largest and most persistent faults of the district. (See pl. 9.)

A diagnostic feature of the schist is the intricate and small-scale crumpling that it displays. (See pl. 6, *B*.) In some places the rock is massive and not crumpled, but as a rule the layers are twisted, contorted, and pulled apart in a complex manner.

The formation appears to have yielded in a more or less plastic manner to structural disturbance. The thinning of the outcrop in the central part of the district may be due entirely to the plastic transfer of material from a region of high pressure both northwest and southeast to regions of lower pressure. Vein quartz in irregular masses and as veinlets parallel to and crossing the foliation is very common in the formation. (See pl. 6, *B*.)

Because the schist sequence is relatively incompetent and appears to have yielded plastically, because crumpling and contortion are common, and because it is cut by numerous large and small faults the width of outcrop of the formation is entirely unreliable as a measure of stratigraphic thickness. It is probably safe to assume that the formation is many thousands of feet thick.

No unconformity has been recognized either above or below the formation as mapped, nor at any place within the formation. The structural complications, however, are such that one or more unconformities may exist, and the evidence for their recognition may have been entirely destroyed.

The schist is made up of many different kinds of rocks. Among these massive greenstone, greenstone schist, graphitic schist, graywacke, chert, and limestone are perhaps the most abundantly represented and readily recognized. More detailed mapping would probably permit the division of the formation into smaller units, and such mapping might definitely answer the question as to the presence or absence of an unconformity or unconformities below, in, or above the greenstone schist. Of the principal rock types mentioned only the larger masses of limestone have been differentiated on the geologic map. Most of these lie north of Black Bay and between that locality and Goon Dip River.

The distribution of other rock types is not known in detail, but a few generalities may be mentioned. The rocks in the vicinity of the peak, 3,216 feet high, southeast of Rust Lake, are largely graphitic schists. Thick zones of graphitic schist were also noted near Ford

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Arm. The graywacke of the formation was noticed particularly in the upper part where the outcrop is narrow—that is, east of Kimshan Cove and the head of Klag Bay.

At Black Bay graphitic schist and greenstone schist alternate in zones from a few tens to a few hundreds of feet wide. Greenstone schist is particularly abundant on Mount Lydonia. Alternating bands of greenstone schist and graphitic schist appear to predominate in the northwestern part of the district.

The massive greenstone represents for the most part flows of basic lava such as basalt. Some intrusive sills may be present. Some of the massive rocks are fragmental and may be the result of intrusions into unconsolidated sediments on a sea floor or of under-water extrusions. The finely banded green schists are probably largely volcanic tuffs. Interbedded graphitic schists show that carbonaceous sediments were being deposited between repeated outbursts of volcanic material.

PETROLOGY

Massive greenstone.—Basic lava near the head of Ford Arm, about 1 mile west of the eastern border of the district, is closely associated with chert and contains small lenses of limestone a few inches long. Long laths of labradorite in this rock are embedded in brown augite. The labradorite has been partly altered to oligoclase. The augite is mostly in bundles of needles separated by chlorite. Green spinel and magnetite are present in rounded aggregates. Secondary chlorite and calcite are common.

Thoroughly crushed igneous rock, probably basalt or diabase, was found on the hill about half a mile west of the small lake about 3 miles north of the southeast corner of the mapped area. The rock now consists of fragments of albite, as much as 0.5 millimeter long, with a few remnants of purplish, pleochroic augite. The groundmass is yellowish-green serpentine with much finely divided leucoxene.

Massive igneous rock, probably intrusive, was collected from the schist about half a mile north of the peak 2,551 feet high a little more than a mile east of the top of Mount Lydonia. Before it was altered it probably consisted of about 60 percent plagioclase, 20 percent augite, and 20 percent micropegmatite and quartz. The micropegmatite is interstitial to the larger crystals of feldspar and augite. The plagioclase is now albite. Most of the augite has been altered to chlorite and to a mineral that may be talc. The albite has been partly replaced by epidote and chlorite. The rock contains a small amount of prehnite.

Greenstone schist.—The greenstone schist is made up of metamorphosed volcanic rocks, probably in large part tuffs, of generally basic composition. Locally it contains different amounts of sandy or limy sedimentary material. The rocks are schistose, but locally traces of older structural features remain, including those generally associated with tuffs and lava flows. The schist is finely banded, and in most places, though not everywhere, the banding and the schistosity coincide. Because the rocks are fine-grained, their mineral composition and texture are commonly determined with difficulty.

Common minerals of the green schist include epidote, clinozoisite, tremolite, actinolite, chlorite, albite, and quartz. Muscovite and calcite are locally present but ordinarily are not associated.

Epidote-chlorite-tremolite schist crops out on the hilltop 1,789 feet high northwest of Black Lake. The rock is made up of about 40 percent epidote-clinozoisite, 30 percent tremolite, 20 percent albite, and 10 percent chlorite. A small amount of magnetite is present. The rock consists of a feltlike mass of subparallel tremolite needles and chlorite flakes enclosing granules of epidote-clinozoisite and lenticular masses of clear albite. The average grain size approaches 0.02 millimeter. The rock is finely banded. The bands are contorted and parallel the schistosity.

Sodic amphiboles are rare but noteworthy constituents of the greenstone schist. From the south shore of the arm of Sister Lake north of Flat Top Mountain was collected a specimen of schist composed of about 38 percent epidote, 30 percent chlorite, 10 percent calcite, 10 percent albite, 5 percent augite, 5 percent sodic amphibole, and 2 percent titanite. Small amounts of pyrite and quartz are present. The sodic amphibole has optical properties resembling those of the amphibole crossite. Augite grains have been marginally replaced by chlorite, sodic amphibole, and epidote. The outer portions of the sodic amphibole have been altered to another greenish-blue amphibole that is probably sodic also. Part of the calcite is present as large plates enclosing other minerals.

Sodic amphibole was found also in a rock from the east shore of Pinta Bay a little more than a mile inside the entrance. The rock contains about 38 percent epidote-clinozoisite, 30 percent amphibole, 20 percent albite, 10 percent quartz, and 2 percent biotite. The amphibole is zoned. The outermost zone is pale and apparently is tremolite. Inside the tremolite zone the bulk of the crystals consist of an amphibole pleochroic from colorless to blue green to yellowish green. A few prisms have cores that, from the optical properties, resemble glaucophane. Biotite is an unusual mineral in the greenstone schists. In this specimen the biotite is of an olive-green color.

Graphitic schist.—The graphitic schist is largely metamorphosed carbonaceous shale that locally contains notable amounts of volcanic material. Some of the graphitic schist contains albite; some does not. That without albite contains more quartz, locally as much as 95 percent. The albitic rocks generally contain a mineral of the epidote group in amounts up to about 10 percent. Graphite gives the rocks their dark color. The amount of graphite in a rock is commonly less than it appears. It is conspicuous because of its opacity and because it is commonly found smeared over shear surfaces in the rock. Chlorite and muscovite are everywhere present in the graphitic schist. Garnet in small, well-formed crystals is common. Titanite, calcite, and pyrite are common accessories.

Typical graphitic schist crops out at an altitude of about 2,000 feet on the southern spur of Mount Lydonia. The rock contains about 90 percent quartz and 10 percent muscovite, with traces of garnet, titanite, and graphite. Most of the muscovite forms films and layers separated by quartz-rich layers in which there are only scattered flakes of muscovite. The isolated garnet crystals are faintly pink.

An albitic phase of graphitic schist crops out at the outlet of Black Lake. Albite and quartz in roughly equal amounts make up about 80 percent of the rock. About 10 percent of chlorite, 5 percent of muscovite, 5 percent of graphite, and traces of garnet, zoisite, and pyrite are present. Quartz and albite are generally in elongated grains as much as 0.1 millimeter long. The albite crystals are crowded with graphite inclusions. Certain layers are rich in graphite and long flakes of muscovite. The quartz-albite layers contain lenses of chlorite. Garnet grains are scattered, but pyrite is concentrated in the more graphitic layers.

Graywacke.—For the most part the graywacke of the younger greenstone schist has not suffered much dynamic metamorphism. Locally in the vicinity of faults it is intensely crushed. The graywacke is made up principally of angular sandy grains less than 0.2 millimeter across. The grains are embedded in a chloritic matrix, sparse in unsheared rock but abundant where the rock is intensely sheared.

The rock and mineral fragments of the graywacke include, in approximate order of abundance, quartz, graphitic shale or slate, albite, basic volcanic rock, epidote, chlorite, tremolite, garnet, bleached biotite, and magnetite. All specimens show veining and replacement by prehnite in different amounts in specimens from different places.

A complex sequence of late veinlets was observed in a specimen found about 1½ miles west of the outlet of Black Lake. The earliest veinlets consist of cloudy prehnite. These were followed in turn by veinlets of clear prehnite and quartz with hematite apparently pseudomorphous after pyrite, veinlets of quartz with a little prehnite, veinlets of clear quartz with a little albite, and veinlets of quartz in grains elongate normal to the walls.

Chert.—The chert is very fine-grained and is brownish to greenish gray or light green. The chert is cut by many shear surfaces smeared with graphite. Some closely spaced joints are filled with narrow quartz veinlets. The chert is in lenticular layers that reach 6 inches in thickness. Individual layers are from 1 foot to 6 feet long. These are separated by slaty material. The lenses are generally much contorted. The small lenses make up the greater part of larger lenticular masses, some of which are 30 feet long.

The chert is principally cryptocrystalline quartz that contains numerous ovoid masses, 0.03 to 0.08 millimeter across, composed of clearer, slightly more coarsely crystalline quartz. The groundmass is rendered cloudy by flakes of chlorite and locally by sericite, with granules of leucoxene, irregular masses of pyrite, or with zoisite.

Some quartz ovoids have a radial structure, and the radiating fibers are elongated at right angles to the *c* axis. Some ovoids have thin outer rims of quartz. Whether or not the ovoids are of organic origin is not known.

Some of the quartz veinlets that cut the chert contain sericite, albite, or chlorite. A few chlorite veinlets are present, and some of these contain pyrite or magnetite.

Limestone.—Lithologically the limestone of the schist is very similar to the underlying limestone formation. Its colors include dark gray, light gray, buff, and white. Most of the rock is fine-grained, but locally it is coarsely crystalline marble. Disseminated carbonaceous matter, quartz, and volcanic material are common in greatly different proportions.

A limestone lens near the east side of the entrance to Didrickson Bay contains masses of green schistose rock that weather out in relief. The rock is largely coarse calcite with scattered quartz grains. Some thin layers are quartz-sericite schist.

Weathered surfaces of fine-grained impure buff limestone from Goon Dip Mountain are gray and rough. Apparently considerable volcanic material was mixed with the limy sediment. The rock now contains about 50 percent calcite, 20 percent garnet, 10 percent chlorite, 10 percent albite, 5 percent epidote, and 5 percent quartz.

AGE AND CORRELATION

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 (see p. 49) 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 *Thecosmilia* 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.

GRAYWACKE

OCCURRENCE AND RELATIONS

The term graywacke is here used to designate a thick sequence of predominantly sedimentary rocks that occupies almost all of the Chichagof mining district southwest of the upper contact of the schist. A few of the small islands in the southwestern part of the district are made up of intrusive rock younger than the graywacke formation. Most of the coastal-plain part of the district is underlain by the graywacke, but the formation composes, in addition, such prominences as Doolth Mountain and the lower mountains between Ford Arm, Slocum Arm, and Sister Lake.

The greatest width of outcrop of the graywacke is about 7½ miles. The general dip is steep to the southwest, but that the thickness of the formation is approximately the same as the outcrop width is not considered a safe assumption for reasons given in the following paragraphs.

The graywacke is cut by many faults. Parts of the formation may be cut out or may be repeated by the faulting, although in many places the faults do not appear to diverge very greatly from the bedding. Faults may be more numerous than shown on plate 9 because of the difficulty with which such features can be recognized on the low coastal plain.

Local drag folds are present in the formation, and in places the dip is to the northeast rather than in the more common southwest direction. Here and there overturned beds were doubtfully recognized. At a considerable number of localities the foliation planes are not parallel to the bedding. No horizon markers have yet been recognized in the formation.

The graywacke is much less contorted than the schist stratigraphically below it, but whether this is due to the difference in age or to differences in the competency of the rocks involved is not definitely known.

A conspicuous feature of the contact between the schist and the graywacke formations is the large bulge to the eastward that it describes between the southeast end of Surveyor Passage and the narrow channel between Lake Anna and Sister Lake. In that interval of about 5 miles the contact is about 1½ miles farther east than would be predicted from the trend of the contact either to the northwest or to the southeast.

There has been considerable speculation as to whether or not there is a large unconformity between the younger bedded rocks (the graywacke) and the older bedded rocks. Attempts to decide the matter during the investigations resulting in this report were relatively unsuccessful, and the answer is still somewhat in doubt. Careful search for evidence bearing on the problem was made along the contact and in the rocks above and below it. The older rocks are much more metamorphosed and structurally disturbed than the rocks above the contact. These differences may be due to the greater competency of the graywacke formation and to the closer proximity of the schist to the dioritic intrusions of the northeastern part of the district.

It has been suggested that the embayment of the contact between the two formations in the central part of the district is due to a deep trough eroded in the schist before the deposition of the graywacke. The trough would have been about 5 miles across and more than a mile deep. It would be expected, under the hypothesis suggested, that the sediments in so deep a trough would be recognizably different in type from those on either side of it, but no differences were recognized. The evidence, as described in the section on the origin of structural features (p. 74), appears to indicate that the bulge in the contact is the result of structural movements.

On Lock Island in Portlock Harbor 230 feet of coarse graywacke and conglomerate of the graywacke formation overlie graphitic schist and greenstone of the schist formation. The contact surface is slightly irregular, but there is no indication of weathering of the upper part of the greenstone formation before the deposition of the graywacke and conglomerate. The fragments of the clastic rocks above the contact consist of materials such as is known to exist in the older rocks. This is the only locality along the contact within the district near which conglomerate was found.

Overbeck,[7] like the present authors, was unable to decide definitely whether or not an unconformity separated the two formations. The authors are inclined to the belief that an unconformity is present.

Massive graywacke, shaly graywacke and slate, conglomerate, greenstone schist, and chert have all been recognized in the graywacke formation. The rocks in a zone about a mile wide next to the granitic intrusions of the islands in the southwestern part of the district contain biotite readily recognized in the field. This belt is apparently a contact-metamorphic zone. The microscope shows that biotite has developed farther from the contact than was recognized in the field. Carbonates and silica have been extensively formed by hydrothermal alteration in close proximity to the mines and are discussed in the chapter on metamorphism (p. 55).

The rocks of the formation are commonly dark gray. Some, particularly the massive varieties, weather to light gray. Below the level of storm waves the weathered graywacke commonly has a greenish cast. The greenstone schist is light green or brown, and the chert is light gray, green, or nearly white.

The formation is made up predominantly of clastic sedimentary material derived from older rocks, with a minor amount of volcanic material, probably largely tuff, and chert of obscure origin.

PETROLOGY

Massive graywacke.—Bedding in the massive graywacke is commonly obscure. Individual beds may be at least 30 feet thick. Locally massive graywacke, in relatively thin beds, alternates with shaly graywacke in beds of comparable thickness to form a composite rock sometimes called "ribbon graywacke." The massive graywacke is well indurated and ordinarily well jointed, so that many outcrops are bounded by joint surfaces.

The rock is made up of grains that ordinarily range from 0.1 to 1 millimeter in diameter. Exceptional grains are as much as 4 millimeters in diameter. Some beds contain angular fragments of fine-grained, shaly graywacke as much as 2 inches long in a coarse, sandy matrix.

Grain counts were made of a total of 185 grains in two slides of apparently typical massive graywacke, in order to obtain an idea of the relative abundance of grains of different minerals and fragments of different rocks. The results are not widely applicable except to furnish an approximation of the relative abundance of the constituents of the typical rock. One slide was cut from a specimen

[7] Overbeck, R. M., U. S. Geol. Survey Bull. 692, p. 108, 1919.

obtained about 1¾ miles north of Trap Point, on a mountain between Slocum Arm, Ford Arm, and Sister Lake, and the other from a specimen obtained about three-quarters of a mile south of Point Hope, on the east side of Ogden Passage. The results of the grain counts are tabulated below.

Percentages of grains of rocks and minerals in typical massive graywacke

Quartz	29	Chert	6
Quartzite	14	Chlorite	4
Albite	12	Graywacke	4
Graphitic slate	10	Muscovite schist	1
Albitized greenstone	10		
Quartz-sericite schist	7		97

Grains forming less than 1 percent of the total number of grains counted include fragments made up of magnetite, pyrite, and quartz; epidote; epidote and feldspar; tremolite and feldspar; allanite; muscovite; orthoclase; and microperthite.

In thin sections from other places other minerals and rock fragments recognized, in addition to those listed in the preceding paragraph and in the table, include oligoclase, quartz-chlorite schist, aplite, fine-grained granitic rock, magnetite, zircon, metarhyolite (?), titanite, brown tourmaline, apatite, biotite, garnet, and clinozoisite.

The ground mass of the massive graywacke consists chiefly of very fine grained sericite, chlorite, and graphitic material. It forms a relatively small proportion of the coarser-grained rocks, as the angular, clastic fragments are closely fitted together, leaving little room for interstitial material.

Shaly graywacke.—The shaly graywacke commonly weathers to a darker color, more like the fresh rock, than the massive graywacke. Many closely spaced joints cut the shaly rocks, so that outcrops readily disintegrate into small lenticular chips. In many but by no means all places close to large faults the shaly graywacke splits easily along irregularly curved shear surfaces coated with polished graphite.

The largest measured clastic fragments in shaly graywacke are about 0.05 millimeter across. The grains are angular except where shearing movements have buffed them to a lenticular shape. The proportion of groundmass material, relative to that in the massive graywacke, is very large. In places in the shaly graywacke true slaty cleavage has been developed. In the slate minute flakes of sericite lie in or define the cleavage.

Conglomerate.—Conglomerate was seen at a few places in the graywacke. A bed about 6 inches thick containing pebbles and fragments as much as an inch in diameter was found on the northern slope of Doolth Mountain. It was traced for a short distance only, and whether it was originally of small extent or has been cut out by some of the numerous faults is not known.

On Lock Island, where conglomerate occurs near the contact with the schist, the contact is immediately overlain by coarse sandstone composed of fragments of greenstone and graphitic schist. Above this is breccia made up of larger fragments, 3 inches in maximum diameter, of the same rocks interbedded with coarse graywacke. These rocks are overlain by beds of conglomerate in which the pebbles and fragments are chiefly graphitic schist and graywacke, with small amounts of greenstone schist and limestone.

DISTRIBUTION AND PETROLOGY OF THE GREENSTONE SCHIST IN THE GRAYWACKE

Lenses of greenstone schist large enough to be shown on plate 3 were found between Kimshan Cove and the head of Klag Bay, about half a mile southeast of the head of Klag Bay, along the southwest side of Herbert Graves Island at the northwest entrance to Kukkan Passage, on the same island near the entrance to South Passage and at the head of Elkugu Bay, and on Hogan Island at the entrance to South Passage. The greenstone on Hogan Island may be part of the same lens as that across South Passage on Herbert Graves Island. Smaller lenses and beds of greenstone schist were seen at other places in the graywacke but are not large enough to show on the map.

The greenstone schist on both sides of South Passage has suffered the same contact metamorphism from the granitic intrusions to the southwest as the enclosing graywacke. The rock of the lens ranges in texture from massive to schistose. The schistose phase consists principally of a fine-grained aggregate of oligoclase, biotite, and chlorite, but clinozoisite is abundant in some layers and the rock contains calcite crystals as much as 2 millimeters long. The massive rock is made up of a felt of tremolite needles, with random orientations, enclosing biotite flakes, grains of clinozoisite, and relict phenocrysts of albite and is cut by veinlets of coarse albite, clinozoisite, and biotite. At other localities the greenstone schist consists of a matrix of sericite, chlorite, and commonly also of carbonate in which are embedded albite laths or quartz fragments. Carbonaceous material is conspicuously lacking in the greenstone schists.

DISTRIBUTION AND PETROLOGY OF THE CHERT IN THE GRAYWACKE

Much, but not all, of the chert of the graywacke formation is found in the lower part of the formation. Chert is conspicuous near the small lake at the west foot of Doolth Mountain. There appears also to be a general association between bodies of chert and lenses of greenstone schist, but many greenstone-schist lenses have no known associated bodies of chert. The chert is very fine-grained. Individual beds are ordinarily less than 6 inches thick. The thin beds are separated by argillaceous partings. Lenticular masses of chert, made up of groups of the thin beds, are as much as 30 feet thick and 200 feet long.

The chert is composed largely of cryptocrystalline quartz. The siliceous matrix contains locally many minute flakes of chlorite, which impart the greenish color to some of the chert. Veinlets of chlorite commonly cut the chert. In one specimen calcite is present in small tabular masses and in veinlets in part intergrown with zoisite and prehnite. The average grain diameter of the chert may approach 0.01 millimeter. Irregularly distributed through the chert are ovoid masses of clearer quartz that are relatively free of chlorite. The quartz grains in these masses reach about 0.02 millimeter in diameter, and the masses themselves range from about 0.03 to about 0.10 millimeter. Much of the chert is cut by veinlets of microcrystalline quartz, generally coarser than that of the main mass of the rock.

AGE AND CORRELATION

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 believed the graywacke possibly to the Permian, and Knopf thought it might be late Jurassic or early Cretaceous. (See p. 49.)

The fossils collected by Overbeck from Slocum Arm (see pp. 49–50) 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 (see pp. 49, 50) 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.

INTRUSIVE ROCKS

In the descriptions of the bedded rocks of the district several bodies of intrusive rocks, largely diabase and gabbro, are mentioned. These are mostly sills and have been considered parts of the bedded sequence into which they were intruded. They are believed to be older than any of the intrusive rocks that are described in this section of the report, but, as pointed out on page 19, it cannot be demonstrated definitely that at least some may not be as young as the graywacke. In that event some of the sills of basic rocks are probably not much older than the diorite next described. The basic sills are not considered further in this section.

DIORITE

OCCURRENCE AND RELATIONS

"Diorite" is here used as a general term to include several rock types mostly more or less gneissic, in the Chichagof district that are closely associated geographically and genetically. The diorite is the most abundant rock in the northeastern part of the mapped area. What might be termed its principal upper contact is stratigraphically about at the horizon separating the upper from the lower part of the greenstone-schist. (See p. 16.) In the vicinity of the low divide between the Goulding Harbor, Goon Dip River, and Black River drainage basins large masses of the lower part of the greenstone-schist sequence lie deep within the diorite.

At several places—for example, near the eastern edge of the district east of Hirst Mountain the diorite is crowded with inclusions of rocks of the greenstone-schist sequence, and over considerable areas it is an arbitrary matter whether to map the rocks as diorite or as greenstone-schist. At other places, such as about 2 miles east of the lake 1,325 feet above sea level in the northern part of the district, some rocks were mapped as diorite that later turned out to be gabbro. These probably should have been included with the greenstone schist and so mapped. The map (pl. 3) therefore emphasizes the areal distribution of the diorite largely at the expense of the lower part of the greenstone-schist. (See pp. 15–16.)

A conspicuous tonguelike mass of diorite branches from the edge of the main body near Rust Mountain and extends for 1½ miles to reach a position at its tip about 2,000 feet stratigraphically above the lower part of the greenstone sequence.

Other bodies of diorite that intrude rocks higher in the stratigraphic section and are not connected at the surface with the main mass are common in the district. Some of these, such as those in the vicinity of the prospects near the head of Pinta Bay, are either too small or barely large enough to show on the geologic map. Larger ones include a sill-like mass about 1⅓ miles long that crosses the lake 1,325 feet above sea level in the northern part of the district; a smaller body on the north side of Goon Dip River about three-quarters of a mile south of the east end of the above-mentioned sill;

a sill just below the limestone a short distance south of Black River; and a mass of unknown size and shape along the eastern edge of the district east of the south end of Rust Lake.

These bodies are probably all connected in depth with the main body of diorite. All but the last-mentioned one are in the upper part of the greenstone-schist or in the greenstone or limestone. The last-mentioned body is in the schist and therefore reaches higher in the section within the district than any other known part of the diorite.

PETROLOGY

The dominant rocks of the diorite group are diorite and quartz diorite. Common also are sodic types including albite-quartz diorite, albite diorite, and albite granodiorite. Apparently the more sodic rocks are largely confined to zones relatively close to contacts with the intruded rocks. Thus, in general, the rocks to the northeast are more calcic than those farther southwest. Because of the irregularity of the contacts, the large number of inclusions of masses of the older rocks, the lack of detailed mapping, and the lack of enough specimens, the more sodic zones could not be differentiated on the map on the basis of thin-section study. Albite-bearing rocks are also common as granitic dikes that cut extensively the lower part of the greenstone-schist.

Buddington and Chapin[8] have noted for southeastern Alaska in general a concentration of soda-rich rocks near the borders of diorite masses, such as was found within the Chichagof district. They say:

> Albite and oligoclase-quartz diorite, so far as known, form a very minor portion of the Upper Jurassic or Lower Cretaceous intrusive rocks and are restricted to very small stocks, to dikes, or to local marginal variants of larger dioritic stocks.

The few thin sections of diorite and quartz diorite that were studied indicate that the plagioclase is andesine but that its anorthite content may range from about 30 to about 50 percent. The plagioclase of the soda-rich rocks is albite that, so far as is known, appears to contain not more than 5 percent of anorthite.

The amount of plagioclase in each of the two divisions of the diorite (diorite and quartz diorite as distinct from albite-quartz diorite, albite diorite, and albite granodiorite) appears to average about 60 percent. Quartz in both divisions ranges widely, commonly from a trace to about 30 percent. Some of the soda-rich rocks, however, contain nearly 50 percent of quartz. The average quartz content for each division is about 20 percent. The albite-bearing rocks

[8] Buddington, A. F., and Chapin, Theodore, Geology and mineral resources of southeastern Alaska: U. S. Geol. Survey Bull. 800, p. 213, 1929.

probably average a little more and the andesine-bearing rocks a little less than that.

Hornblende and biotite are about twice as abundant in the diorite and quartz diorite as in the albitic rocks. The sodic rocks are richer in potash feldspar but are leaner in magnetite and apatite.

The alteration products differ somewhat in the two divisions. The sodic rocks contain epidote and locally prehnite. The more calcic rocks all contain prehnite but only locally carry epidote and clinozoisite.

The reasons for the discontinuities in the composition ranges between the more calcic and the more sodic diorites are not known. The average mineral composition of the andesine-bearing rocks is similar to the average composition of four samples from Chichagof Island reported by Buddington and Chapin.[9] The same authors[10] tabulate a group of several sodic rocks from southeastern Alaska that are mineralogically similar to the sodic rocks of the Chichagof mining district.

The larger amounts of quartz and potash feldspar and the smaller amounts of hornblende, biotite, apatite, and magnetite in the albite-bearing rocks suggest that they were developed by normal magmatic differentiation. Furthermore, there appears to be no relation between amount of crushing and content of albite, as might be expected if the soda-rich rocks were due to alteration by late magmatic emanations. Albite-bearing veinlets are scarce in the albitic rocks. No evidence of replacement of quartz by albite was noted, and no soda-rich amphiboles were recognized.

On the other hand, in certain features the albitic rocks are reminiscent of the albite granite near Sparta, Oreg. This granite is generally considered to be of replacement origin, as described by Gilluly.[11] The features include the replacement of andesine by networks of albite veinlets, seen in one thin section only; the presence in albite crystals of clear outer zones and cloudy, altered cores; and the general presence of the alteration mineral epidote or a closely related member of that group.

The possibility that the albite of the intrusive rocks is due to the assimilation of albitic rocks of the older greenstone schist, is attractive in that it would explain the distribution of the soda-rich zones near the contacts. The rocks of the greenstone schist, however, are rich in ferromagnesian minerals, in which the albitic rocks are relatively poor.

Hornblende diorite, apparently typical of much of the rock of the diorite group, crops out on the ridge northeast of the long lake at

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[9] Buddington, A. F., and Chapin, Theodore, op. cit. (Bull. 800), p. 212.

[10] Idem, p. 213.

[11] Gilluly, James, Replacement origin of the albite granite near Sparta, Oreg.: U. S. Geol. Survey Prof. Paper 175–C, 1933.

the northern border of the district. About 60 percent of the rock is made up of irregular prisms of andesine as much as about 2 millimeters long, which contain about 50 percent of the anorthite molecule. These prisms are slightly zoned. The rest of the rock is principally hornblende in ragged green crystals, but there may be a total of about 3 percent of biotite and magnetite. The biotite is partly chloritized. Orthoclase and apatite are sparingly present, the apatite in stout prisms. The rock is cut by narrow prehnite veinlets.

About 2 miles east of the southeast end of the lake mentioned above the rock is gneissic biotite diorite. Trains of parallel biotite flakes lie in an aggregate of poorly formed crystals of quartz and of cloudy sericitic andesine. Epidote, many grains of which have cores of allanite, is intergrown with the biotite. A little interstitial orthoclase is present. Prehnite is present as lenses in biotite and as veinlets.

Quartz diorite forms the peak 2,076 feet high a little more than 1½ miles east and a little north of the top of Hirst Mountain. The mineral composition of the rock is about 57 percent andesine, 25 percent quartz, 9 percent biotite, 5 percent orthoclase, 3 percent magnetite, and 1 percent hornblende. The andesine prisms are about 2 millimeters long, are zoned, and are partly sericitized. The outer zones are clear. The rock contains a little apatite. The quartz grains are cracked, and the biotite flakes are partly altered to chlorite and prehnite.

From the western tip of the granitic tongue on the ridge about 1 mile northeast of Whitestripe Lake was obtained a specimen of albite granodiorite. Euhedral prisms of albite as much as 3 millimeters long make up about 60 percent of the rock. Poorly formed quartz crystals constitute about 25 percent, microcline 10 percent, and hornblende and biotite 5 percent. Allanite and apatite are accessory minerals.

The albite prisms have cloudy saussuritic cores, apparently of albite composition. The cores are surrounded by clear rims that grade from oligoclase to albite. The microcline is clear and entirely interstitial. The quartz is cracked and contains numerous minute vacuoles that give it a milky appearance in the hand specimen. Most of the hornblende has been altered to chlorite and epidote, only a few shreds remaining. Allanite cores are surrounded by epidote.

On the hilltop about three-quarters of a mile south of the east end of the long lake at the northern border of the district gneissic albite granodiorite crops out. About 65 percent of this rock is albite in rounded prisms as much as 2 millimeters long. Quartz makes up about 15 percent, biotite about 10 percent, hornblende about 5 percent, and potash feldspar about 5 percent. Apatite is the principal accessory. The quartz and some of the potash feldspar are present as an interstitial mosaic of small clear grains. The biotite is in contorted stringers and has been partly altered to chlorite, epidote, and titanite. Some of the potash feldspar forms veinlets and rims around albite prisms. Pyrite is present.

AGE

The main diorite masses on Chichagof Island have long been correlated with the Coast Range batholith, which is believed to have been intruded late in Jurassic or early in Cretaceous time. (See p. 50.) However, the intrusion of many cubic miles of magma to form the large and small masses now called the Coast Range batholith and its satellites may well have occupied a considerable span of geologic time. It is possible, therefore, that detailed evidence at any place may indicate a somewhat different age for a granitic rock there than for one at another place and that the two may still be genetically correlated.

Bodies of the diorite in the Chichagof mining district reach, so far as is known, up into the lower part of the schist. Thousands of relatively fine grained dikes believed to be genetically related to the diorite cut the graywacke. Thus, if the somewhat doubtful age assignments are correct, some of the diorite must have been intruded after the time in the Triassic during which the rock that now forms the schist was laid down. If the dikes are essentially of the same age as the coarser-grained rocks lower in the stratigraphic column, then the main intrusion in the district can be safely dated as postgraywacke. The dikes, however, may be considerably younger than the larger intrusive bodies. The writers have no reason to disagree with the conclusion of earlier authors that the main diorite intrusion took place late in Jurassic or early in Cretaceous time.

ALBITE GRANITE AND GRANODIORITE

OCCURRENCE AND RELATIONS

The Granite Islands and several other islands, including the White Sisters, in the southwestern part of the district are made up of granitic rocks. Unfortunately the contact between the intrusive rock and the graywacke that is adjacent to it on the northeast was found at only two places. At all other places the sea intervenes. The contact was found on the northeast sides of the two northernmost of the three larger Granite Islands. The biotite-rich contact metamorphic zone in the adjacent graywacke is described on pages 32 and 54.

The intrusive rocks of these outer islands include several different types. Diagnostically they are light-colored, locally almost white, massive, unsheared, and unaltered. The types include biotite granodiorite, albite-biotite granite, and albite-muscovite granite. Because not more than one type was found on any one island the relations between the several types are entirely unknown. The rocks differ from the diorite and associated rocks in being of fresher appearance, in containing muscovite in most places, in not containing hornblende, and in not having gneissic structure.

A tiny island between the Granite Islands and Outer Rocks is composed of biotite granodiorite. Its texture is granular, and the average grain diameter is about 3 millimeters. One thin section indicates a mineral composition of about 49 percent zoned andesine, 26 percent quartz, 13 percent orthoclase, and 12 percent biotite. Muscovite, zircon, apatite, and magnetite are accessories. The biotite is slightly chloritized. The andesine is irregularly zoned and is partly replaced and veined by oligoclase. The rock contains a little myrmekite. The feldspar is slightly altered to saussurite.

The rock of the most southerly of the White Sisters is a medium-grained biotite-albite granite of granular texture. It is made up of about 35 percent potash feldspar, 34 percent albite, 24 percent quartz, 3 percent biotite, and 1 percent each of muscovite, allanite, zircon, and titanite. The potash feldspar includes microperthite (albite in orthoclase) and microcline-microperthite (albite in microcline). The microcline-microperthite in places forms an outer zone on a core of microperthite. Muscovite occurs in ragged flakes and in close association with biotite where that mineral is in contact with microcline. Euhedral prisms of albite are clearer than the crystals of potash feldspar. Myrmekite is present on the borders of albite crystals.

Specimens from the island about half a mile northeast of the northernmost of the Granite Islands and from the tiny island about halfway between Black Island and the White Sisters are nearly identical. They are medium-grained albite-muscovite granites. They contain about 42 percent of albite in clear, well-formed crystals, 30 percent of quartz, 20 percent of cloudy microcline, in part perthitic, and 8 percent of muscovite. Accessory minerals include garnet and titanite. Microcline has replaced albite in irregular stringers and is in part intergrown with muscovite.

AGE

The freshness of the granitic rocks of the islands and their lack of gneissic structure suggest that they are distinctly younger than the diorite in the northeastern part of the district.

These fresh intrusions are younger than the graywacke, as is shown by the presence of the contact-metamorphic zone. As pointed out in the paragraph on age of the diorite, that rock is younger than the schist, but it is not definitely known to be younger than the graywacke. This adds perhaps a little strength to the contention that the intrusive rocks of the southwestern part of the district are probably younger than the diorite of the northeastern part.

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Some further evidence is furnished by the work of Overbeck, although it depends on the lithologic correlation of separate intrusive masses a considerable distance apart. Overbeck [12] mapped a nearby round, stocklike mass of granite around Lake Elfendahl, about 14 miles north of the White Sisters. He says: [13]

> The rocks of this body are very light in color and are of very coarse grain. They are somewhat weathered but otherwise are not greatly altered. They differ from the other granites of the region in their coarseness of grain, their light color, their uniformity in character, and in the fact that the alkali feldspar is orthoclase instead of albite.

Examination of one of Overbeck's thin sections cut from the rock of this body and on file in the Geological Survey showed the presence of biotite and muscovite but no hornblende.

The shape of the body mapped by Overbeck implies a relatively late age for its intrusion, as it is not elongated roughly parallel to the general structural trend, like most other bodies of the diorite.

DIKE ROCKS

The rocks of the Chichagof mining district are cut by many dikes that have a wide distribution throughout the district. They are present in all divisions of the bedded rocks from the oldest to the youngest. They have a considerable range in size but are generally small in areal extent and hence are not shown on the geologic map.

The dikes also have a wide range in chemical and mineralogical composition and in texture. They are divided somewhat unsatisfactorily into two general groups—fine-grained light-colored dikes and lamprophyre dikes.

FINE-GRAINED LIGHT-COLORED DIKES

Occurrence and relations.—The fine-grained light-colored dikes are by far the more abundant. These dikes are usually called "aplite" locally, but many of them differ somewhat from true aplite. They are common throughout the stratigraphic sequence but appear to be particularly numerous in the schist and in the lower part of the graywacke. They are present at practically all the mines and prospects in the district. There seem to be fewer of them in the upper part of the graywacke formation than at any other horizon in the stratigraphic section. None of the light-colored dikes were noted in the granitic rocks of the district, but the writers are reluctant, without further search, to assert that they are not present there.

The dikes are fine-grained, and common colors include pale yellow, gray, or green. A few dikes included in this group are relatively

[12] Overbeck, R. M., Geology and mineral resources of the west coast of Chichagof Island: U. S. Geol. Survey Bull. 692, pl. 2, 1917.

[13] Idem, p. 110.

dark gray or dark greenish gray. Flow banding was seen in the dikes in a few places.

The dikes range in thickness from a few inches to several hundred feet. Many of them could be traced for only short distances, because of cover or because of interruptions due to faulting. A few were traced on the surface for several thousand feet, and some of considerable extent are visible on the airplane photographs. (See pl. 10, *B*.) One of the largest recognized is the "footwall dike" in the Hirst-Chichagof mine. (See pl. 19.)

At most places the contacts of the dikes against older rocks are sharp and clean-cut. At a few places, principally seen underground, the contacts are blurred by alteration of the intruded rocks or of the dike and the intruded rocks. Inclusions of wall rocks in the dikes are common locally. Most of these inclusions have been greatly altered but are easily distinguishable by their much darker color.

The dikes are all altered rocks. Such processes as chloritization, sericitization, albitization, silicification, and carbonatization have all been very active. Different processes have been relatively more effective at different places. The alteration of the dikes is further considered in the section on metamorphism (p. 55). Silicified dike rock is commonly readily recognized by its cherty appearance and very light color and has been distinguished from unsilicified dike rock on many of the mine and prospect maps. The bodies of silicified dike rock appear to be irregularly bounded masses many feet in greatest width within less altered dike rock.

The green color of many of the dikes appears to be due to chlorite. In general the more chloritic rocks are poorer in quartz and the lighter-colored, less chloritic rocks richer in quartz. The dikes locally are extensively sheared, and the darker green of the sheared rock is possibly due to the smearing out of chlorite on the shear surfaces. At many places the rock contains well-formed cubes of pyrite, and locally these are abundant. At a few localities, notably at the Bauer prospect, on the south side of Herbert Graves Island, and at the southernmost of the Woll prospects, on the west side of Lake Anna, crystals of arsenopyrite, associated with pyrite, are abundant in the dike rock and in quartz veinlets that run through the rock.

Because of the wide differences in mineral composition that probably existed originally among the dikes and because of the several alteration processes that have acted on them in a complex manner it is difficult to subdivide the dikes into groups based on such features as mineralogy, stage of alteration, or texture. In order to systematize the discussion, however, the commonly found fine-grained light-colored dikes described below are divided into a pyroxene-albite group and an albite-quartz group.

Dikes characterized by pyroxene and albite.—A few dikes contain remnants of pyroxene crystals. In these are embedded stout prisms or long laths of plagioclase that is now albite. Most of the pyroxene has been altered to chlorite. Considerable leucoxene has been developed. Calcite, chlorite, and albite fill fractures in the rock.

Some dikes are relatively rich in albite and poor in the interstitial chlorite, which presumably was derived from pyroxene. Some show considerable crushed rock, commonly accompanied by calcite. The calcite was apparently formed by the replacement of other constituents of the rock.

Dikes characterized by albite and quartz.—The diagnostic features of the dikes characterized by albite and quartz are a large amount of albite, a considerable amount of quartz, and a relatively light color. The texture of the dikes varies widely. These are the most abundant dikes of the district, and the most abundant of these are dikes containing about 60 to about 80 percent of roughly tabular but poorly formed albite crystals. Quartz, also poorly formed, is interstitial to the albite. The grain size of the rock is commonly about 0.5 millimeter. Locally are present albite phenocrysts as much as 4 millimeters long and chlorite and leucoxene pseudomorphs after some dark mineral. Quartz, chlorite, calcite, and sericite are common replacement minerals.

A dike that cuts a large xenolith near the eastern border of the district northeast of Rust Mountain contains phenocrysts of albite and quartz as much as 4 millimeters long. These crystals are strained and deformed. The groundmass, which has a sugary texture, is composed of quartz and albite. Sparse secondary minerals are chlorite and sericite.

A small fine-grained dike in the Hirst-Chichagof mine contains albite plates about 0.2 millimeter across in a microcrystalline groundmass of albite, sericite, and calcite. Quartz, rutile, and pyrite are secondary minerals. The amount of primary quartz appears to be small.

At the Cobol prospect, on Island Cove, Slocum Arm, southeast of the district as mapped (see pp. 139 and 140), is a dike containing a large amount of quartz that forms an aggregate of rounded grains in which are embedded albite laths. Secondary minerals include quartz, chlorite, sericite, and leucoxene. The rock of the cherty-appearing lenses in the limestone north of Whitestripe Lake (see p. 23) is similar to the dike on Island Cove.

LAMPROPHYRE DIKES

The lamprophyre dikes of the district are much less abundant than the fine-grained light-colored dikes. However, as they are much darker and do not contrast as conspicuously with the wall rocks as the light-colored dikes, they may be more abundant than was recognized.

One lamprophyre dike cutting diorite in the northeastern part of the district was observed. Flow banding is well displayed in a dike several feet wide along the shore of the Takeena Peninsula between The Gate and Double Cove.

The lamprophyre dikes are characterized by an abundance of small prisms of hornblende. These commonly constitute about 40 percent of the rock and attain lengths of about 2 millimeters. About 45 percent of the rock is albite in prisms cloudy with alteration products. The interstices between the albite and hornblende crystals are filled with chlorite or epidote. Magnetite, pyrite, and titanite are common accessory minerals. Alteration minerals include calcite and prehnite.

AGE OF THE DIKE ROCKS

So far as is known the relations to older rocks of both the fine-grained light-colored dikes and the lamprophyre dikes are the same, but because of the greater abundance of the fine-grained light-colored dikes the evidence as to the geologic age comes principally from that group.

Many of the dikes cut rocks of the graywacke formation and hence in general the dikes are younger than that formation. The possibility that some dikes in the older rocks may have been intruded prior to the deposition of the graywacke cannot be completely ruled out, although it is thought unlikely.

Because only a few dikes were seen in the southwestern part of the district near the albite granite and granodiorite and because they are much more abundant farther northeast, they are believed to be genetically related to the diorite of the northeastern part of the district and are thought to have been intruded during or after the intrusion of the diorite. (See p. 40.) That the dikes were intruded over a considerable time interval, during which the rocks were being structurally deformed, is clearly evident. Many dikes are older than many faults and are cut by the faults, as is shown on many of the maps and diagrams of mines and prospects. Other dikes are younger than some faults and have been intruded along the faults. Such dikes were seen at the Cobol prospect, on Slocum Arm (see pl. 33), and near Elf Cove on Ford Arm. At the Cobol prospect renewed faulting has sheared the dike. The small dike at the Kay ore shoot in the Hirst-Chichagof mine (see p. 107 and pl. 23) was intruded after the deposition of vein quartz along a fault. At the Woll prospect, on Lake Anna, and at a few other places sulfide minerals in dikes have been smeared out by later fault movements. Thus dike intrusion, faulting, and quartz deposition apparently all went on concomitantly during a relatively long time interval after and possibly in part during the main period of diorite intrusion.

UNCONSOLIDATED ROCKS

GLACIAL MORAINE

Over most of the Chichagof mining district, ice action has resulted in the removal rather than the deposition of material. Scattered morainal deposits are present at many places in the coastal-plain part of the district. These appear to be small and thin. Most of the ice-deposited material on the coastal plain is probably related to the older, ice-cap glaciation. The material is, at least locally, partly weathered. It is unsorted, is mostly poorly rounded, and contains many boulders of granitic rocks. A great deal of rock detritus must have been carried over and scraped from the coastal plain and other parts of the district. The lack of any considerable quantity of such material within the district shows that most of it has been dumped into the sea or deposited on parts of the coastal plain now below sea level.

The largest accumulations of glacial moraine within the district are in the northeastern part, around the heads of Black River, Goon Dip River, and the streams that drain to Goulding Harbor, Lisianski Inlet, and Hoonah Sound. This area covers part of the main divide of Chichagof Island and represents a local ice field that lay for a long time after the disappearance of the main ice cap. (See section on Geomorphology, pp. 74–77.)

This material, which was not everywhere differentiated from alluvium, is typically morainal. It is bouldery, unsorted or poorly sorted, and mostly unstratified. It was observed to reach at least 50 feet in thickness and in some places may be much thicker. The material is such as could have been contributed from local bedrocks, but some of it may have been brought in from the northeast by the extensive ice cap.

Smaller deposits of morainal material, mainly bouldery, are present at other places in the district, but most of them either are not shown on the map because of their small size or are not differentiated from associated deposits of alluvium. Such deposits are common in the higher mountain passes of the district and are presumed to have been left when the ice cap receded from this part of Chichagof Island.

Small morainal accumulations are present also in certain places along the present valleys. Typical among these are deposits around Rust Lake, along the lower part of the stream that empties into the head of Klag Bay, along the creek that drains Whitestripe Lake between points about half a mile and about 1 mile below the lake, in the valley of Goon Dip River and the valley of the small stream that enters it from the southeast east of Goon Dip Mountain, and in the valley about half a mile upstream from the head of Pinta Bay. The moraine was differentiated from alluvium at several of these localities.

Deposits such as those mentioned in the preceding paragraph were left by valley glaciers that were active in the district after the retreat of the main ice cap. Similar deposits are conspicuously absent from the main valleys in the district, although these are believed to have contained valley glaciers that headed in the local ice field in the northeastern part of the district. The suggestion is offered that the large quantities of water liberated during the later melting of the local field coursed down the main valleys in streams so vigorous that they were able to rework or remove the moraines of the preexisting valley glaciers.

As the local ice field shriveled and disappeared the material contained in it, which was largely or entirely contributed from the surrounding mountains, was not removed but was deposited as a moraine after being transported for only short distances.

The main ice cap of southeastern Alaska is commonly believed to have existed in Wisconsin time, the last great stage of the Pleistocene epoch. The sparse deposits left by the main ice cap, principally on the coastal plain, are therefore probably of Wisconsin age. The deposits left by the dwindling and disappearance of the local ice field in the northeastern part of the district are younger and may be as young as Recent. The local valley moraines are approximately correlative with the moraine of the local ice field. Small ice fields and valley glaciers still exist in the higher parts of Chichagof and Baranof Islands and are depositing morainal material today.

VOLCANIC ASH

Volcanic ash, presumably from the crater of Mount Edgecumbe, on Kruzof Island, near Sitka and about 45 miles southeast of Chichagof, is widespread in the Chichagof mining district. At many places the ash has been removed by recent erosion, and at other places it has been carried from the slopes and divides to form thicker accumulations in the valleys. It is present over much of the coastal-plain part of the district as a blanket that on the average is perhaps 6 inches thick. Nearer the volcano, on Krestof Island, the ash was observed to be much more abundant, and local reports are to the effect that it becomes increasingly abundant as Mount Edgecumbe is approached.

The ash is light, soft, and fluffy and is buff or reddish yellow. The color apparently is due to hydrated oxides of iron. When wet it forms a slippery, soft mud. The material does not appear to furnish much nourishment to plants. At many places along cut banks, where trees have fallen over, and at other exposures the trees and shrubs are seen to have little if any root system in the ash but have developed their roots either above or below the ash. The ash is made up largely of angular glass fragments in which flow lines and small gas bubbles are common. The index of refraction of the glass is about 1.52. Angular fragments of quartz are common, and some other minerals such as feldspar and hornblende were noted as minor constituents.

The ash is plainly younger than the most recent morainal deposits that were seen, as it everywhere lies on top of the moraines.

ALLUVIUM

Deposits of sand, silt, and gravel are widely distributed in the district but are mostly of small extent. Many of them are too small to be shown on the geologic map. The largest deposits are those along Black River and its large tributary that enters from the east south of Hirst Mountain and along Goon Dip River. At some places material shown as alluvium on the map includes also some glacial moraine. Small deposits of alluvium are widely distributed along the beaches, but none are large enough to map. The larger streams have carried considerable quantities of relatively fine sediments into the salt water and have built deltas. (See pl. 7, *B*.)

Cut banks in alluvium along the larger streams almost invariably expose a section that is made up of finer material above, underlain by gravel. During the waning of the local ice field and the valley glaciers the streams probably carried much more water than they do now and hence were then depositing coarser material.

When visited in 1939, Rust Lake had been lowered considerably by the drawing off of water for the power plant on Sister Lake, and sections of unconsolidated material were well exposed around the shores. Locally two kinds of clay (both apparently varved) were exposed. The lower clay is greenish, is somewhat distorted, and is tilted toward the lake. The upper clay is gray, undisturbed, and apparently horizontal.

Cut banks are numerous along Rust Creek in the alluvial area just above the lake. At one place the lowest material seen consists of poorly sorted, poorly rounded fine gravel and very coarse sand. This is overlain by 2 feet of dark-gray sand, silt, and mud in which are developed the root systems of the present plants. The lower material contains thin carbonaceous streaks, local peat layers, and lenses a few inches thick that are stained rusty brown by limonite.

In the valley of Rust Creek above the point where it crosses the limestone are several well-developed terraces that lie as much as about 30 feet above the present valley floor. These terraces may be related not to any widespread sequence of erosional and depositional events, but to the establishment of the present course of Rust Creek across the limestone through a limestone cavern. (See p. 23 and pl. 6, *A*.)

SUMMARY OF AGE OF THE ROCKS

It has long been known that the bedded rocks of the western part of Chichagof Island, including the Chichagof mining district, are readily divisible into two belts of different age. The eastern belt, next to the main mass of granitic rocks, is composed of greenstones, schists, and other rocks, and the western belt is largely graywacke.[14]

So far as the writers know, no determinable fossils had been found in the rocks of the older, eastern belt prior to 1938. In that year some fossils were collected from Kruzof Island, south of Chichagof Island, by an employee of the Hirst-Chichagof Mining Co. These fossils indicated, on determination by J. B. Reeside, Jr., of the Geological Survey (see p. 30), that some of the rocks in that vicinity are limestone of Upper Triassic age. The rocks from which the fossils came have not been definitely correlated with any of the rocks of the older belt in the Chichagof mining district, but it is thought that they represent part of that belt.

In 1939 a few poorly preserved fossils were collected from limestone float in the belt of older rocks in the Chichagof mining district. These were somewhat doubtfully assigned by Mr. Reeside to the Upper Triassic. (See p. 30.)

The Wrights[15] believed the rocks of the older belt to be "upper Carboniferous" and in a table listed them as Permian to Pennsylvanian. Overbeck,[16] on the other hand, tentatively correlated these rocks with some rocks of Gravina Island, near Ketchikan, which Chapin believed to be Upper Triassic or Jurassic. Buddington and Chapin[17] on a compiled map of southeastern Alaska show a band of Paleozoic rocks between the batholith and the Sitka belt of Mesozoic rocks.

The writers believe, from the evidence given above, that at least part and perhaps all of the rocks of the older belt are Upper Triassic. Some may be older.

The Wrights[18] believed the belt predominantly made up of graywacke possibly to be Permian. Knopf,[19] on lithologic similarity and degree of metamorphism, thought that the belt might be late Jurassic or early Cretaceous. On the basis of fossils collected on Slocum Arm a probable Upper Jurassic age is assigned to the graywacke by Overbeck.[20] It is the writers' understanding that the Geo-

[14] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 38, 1908. Knopf, Adolph, The Sitka mining disitrict, Alaska: U. S. Geol. Survey Bull. 504, p. 15, 1909. Overbeck, R. M., Geology and mineral resources of the west coast of Chichagof Island: U. S. Geol. Survey Bull. 692, pp. 95–109, 1917.

[15] Wright, F. E. and C. W., op. cit. (Bull. 347), pp. 35, 37.

[16] Overbeck, R. M., op. cit. (Bull. 692), p. 100.

[17] Buddington, A. F., and Chapin, Theodore, op. cit. (Bull. 800), pl. 2.

[18] Wright, F. E. and C. W., op. cit. (Bull. 347), p. 35.

[19] Knopf, Adolph, op. cit. (Bull. 504), p. 14.

[20] Overbeck, R. M., op. cit. (Bull. 692), p. 108.

logical Survey paleontologists now believe that the particular fossil on which the determination was made (a form related to *Aucella fischeriana*) is found in both Upper Jurassic and Lower Cretaceous rocks. T. W. Stanton, who made the determinations for Overbeck, recognized the doubtful nature of the age assignment and said in his report, "The distinction between Jurassic and Lower Cretaceous on the basis of *Aucella* alone is not always safe."

Some of the material collected in 1938 on Kruzof Island that was given to the writers (see p. 35) contains fossils (*Terebellina palachei* and *Aucella crassicollis*) that indicate definitely a Lower Cretaceous age for the graywacke there. The graywacke of the Chichagof mining district is therefore definitely Mesozoic and is believed by the writers to be Lower Cretaceous.

Several geologists have correlated the dioritic rocks of Chichagof Island with the Coast Range batholith and expressed the belief that they were intruded late in Jurassic or early in Cretaceous time.[21] As the graywacke is definitely intruded by the batholithic rocks along the west coast of Chichagof Island they must have been intruded later in Cretaceous time than the Lower Cretaceous (?) rocks. The granite and granodiorite of the southwestern part of the district are believed to be younger than the diorite and associated rocks but how much younger is not known.

METAMORPHISM

In a broad way all the rocks of the district have been somewhat metamorphosed. Several types of metamorphism have occurred. Dynamic metamorphism, due to lateral compression and shearing of the rocks, was widespread. Near the larger bodies of intrusive rocks there has been considerable igneous metamorphism. Farther from the intrusive rocks, commonly near faults or other channelways, the rocks have been affected by hydrothermal alteration due to heated solutions that were presumably derived from the intrusive rocks. The study of the metamorphic history is difficult because of the overlapping in large areas of several types of metamorphism. The type of metamorphic rock depends not only on the kind and intensity of the metamorphism but also on the competency, chemical composition, and geologic environment of the original rock. In the Chichagof district the zones of equal metamorphic intensity apparently are parallel to the trend of the formations. This fact renders it difficult to discriminate between changes due to different degrees of metamorphism and those due to original

[21] Knopf, Adolph, op. cit. (Bull. 504), p. 15. Overbeck, R. M., op. cit. (Bull. 692), pp. 109, 110, and 197. Buddington, A. F., and Chapin, Theodore, op. cit. (Bull. 800), pp. 185–186, 252–253.

lithologic differences. However, certain broad features are apparent and are the basis for the following discussion, which is divided according to the most readily recognized features into (*a*) dynamic metamorphism and (*b*) igneous metamorphism including hydrothermal alteration. Each of these is subdivided so far as the information permits. This area is an attractive field for the further study of metamorphic processes.

DYNAMIC METAMORPHISM

STRUCTURAL CHANGES

The lower part of the greenstone-schist sequence contains much sedimentary material, which is not as competent as the overlying massive lava flows and would therefore be expected to be more affected by dynamic metamorphism. The igneous metamorphism due to the nearby large masses of diorite appears to have obscured any structural changes previously produced in these rocks. The relatively competent lava flows of the upper part of this sequence and of the overlying greenstone have been little affected structurally by the dynamic metamorphism.

The limestone is much thinner near Black Lake than it is either to the northwest, near Whitestripe Lake, or to the southeast, near Rust Lake. The thinning is believed to be due, at least in part, to plastic flow in response to differential pressure (p. 22). The limestone is notably thinner directly opposite the marked bulge in the contact between the graywacke and the schist. (See pl. 3.) The underlying thick sequence of massive lava flows apparently acted as a rigid foundation for the relatively thin limestone and prevented its deflection from the general trend.

The thinning of the schist in the central part of the area and the deflection of its upper contact were apparently due to the same differential pressure that is believed to have squeezed out the underlying limestone. Exceptionally intricate crumpling and contortion were observed in the incompetent rocks of Mount Lydonia and Mount Freeburn. The rocks of these areas are believed to have been forced plastically from the region of higher pressure, where the formation is now thin. In the incompetent strata of the schist formation the small brittle beds of quartzite and quartz veinlets have been locally broken into small fragments, between which has flowed the more plastic, schistose matrix. Possibly some of the thin lenses of limestone northeast of the top of Mount Lydonia (see pl. 3) are stretched and distorted fragments of beds originally much thicker.

The schist sequence, especially southeast of Black River, is more intricately faulted than any other formation (pl. 9). This may be due to the considerable differences in the competence of the various rocks of the sequence. Such differences are favorable for the splitting and branching of faults.

The massive beds of the graywacke were little affected by dynamic metamorphism. The shaly graywacke has in places a slaty cleavage. Locally this cleavage diverges from the bedding by an angle of as much as 20°. Such divergences were noted particularly along the west side of Ogden Passage, south of Duck Island; near the Baney prospect, on Elbow Passage; and near the southeast end of Sister Lake (p. 60).

MINERALOGICAL CHANGES

The mineralogical changes produced by dynamic metamorphism on the rock units of the district are taken up below in the order of the stratigraphic succession of the rocks. This order is not that of either increasing or decreasing intensity of metamorphism, because the intensity of the metamorphic change at any place is a function not only of the stress applied to the rock but also of the competency of the rock to withstand the stress, and of its texture and mineral composition. The less competent rocks, such as the thin-bedded schists of the schist formation, are those which have been most markedly modified by dynamic metamorphism.

The sediments and igneous rocks of the lower part of the greenstone-schist have been so greatly altered by igneous metamorphism that little can be said about any mineralogical changes due to dynamic metamorphism which they may have undergone before the intrusion of the diorite. The massive, competent lava flows of the upper part of the formation have resisted dynamic metamorphism. The new minerals developed are chiefly chlorite, calcite, epidote, and leucoxene. Albite, which is the common feldspar of these rocks, may be due largely to the dynamic metamorphism, as albite is a normal product of low-intensity metamorphism of such basic igneous rocks. The albite is commonly accompanied by lime-bearing minerals, such as calcite, or minerals of the epidote group. However, in the local presence of albite-bearing rocks without lime-bearing metamorphic minerals there is a suggestion of either the introduction of soda or the removal of lime.

The dynamic metamorphism of the greenstone formation is similar to that of the greenstone of the greenstone-schist just discussed. Introduction of soda seems less likely as an explanation for the albite in this younger formation, because lime-bearing minerals, presumably derived from calcic plagioclase, are widespread and abundant.

The limestone contains quartz (p. 24), which shows no reaction with the calcite. Had the limestone been subjected to igneous metamorphism the quartz probably would have reacted with the calcite to form wollastonite. The irregularly distributed and scanty marbleization of the limestone (p. 14) is not understood. It may or may not be due to dynamic metamorphism.

The grade of metamorphism in the schistose rocks of the schist sequence has only a small range. Differences in the rocks are due chiefly to differences in chemical composition. The characteristic metamorphism of the graphitic mica schist is that of the so-called chlorite zone. Chlorite and muscovite are closely associated. Although these rocks lack biotite, small garnets are present locally. Harker [22] has pointed out that in some areas garnet is present in muscovite-chlorite schists. In the greenstone schist of this sequence the metamorphism is characterized by albite, epidote, and chlorite. Some of the rocks contain tremolite and sodic amphibole. The degree of metamorphism is the same as that in the associated graphitic mica schist. The purer limestone of the schist sequence has been locally recrystallized without mineralogical change. In some limestone that contains volcanic material reaction between the calcareous and the volcanic material has resulted in the production of garnet, in addition to the common minerals of the greenstone schist.

The chief mineralogical change due to dynamic metamorphism in the graywacke has been the development of minute flakes of sericite and chlorite, which generally lie in the plane of the foliation. These minerals have been developed by dynamic metamorphism in the dikes that cut the graywacke close to major faults where the rocks have been intensively sheared.

IGNEOUS METAMORPHISM, INCLUDING HYDROTHERMAL ALTERATION

The discrimination between dynamic and igneous metamorphism is more difficult in those rocks which have been intensely metamorphosed. Discrimination is also difficult where igneous metamorphism has been superposed on dynamic and where the igneous rocks have been intruded under lateral stress, so that the igneous rocks themselves contain metamorphic minerals and have metamorphic textures. In many places the distinction between igneous metamorphism and hydrothermal alteration is difficult, because the heat that effected the igneous metamorphism was transferred by means of heated solutions.

In the northeastern part of the district the intimate penetration of the country rock by magma suggests that at the time of the intrusion the rocks of that area must have been nearly as hot as the magma. The metamorphic nature of these rocks is therefore due partly to dynamic effects and partly to recrystallization produced by the intrusion. The rocks locally retain traces of foliation and schistosity.

[22] Harker, Alfred, Metamorphism, pp. 217–218, London, 1932.

Thermal effects are shown especially in some of the gabbros and diabases, which have been recrystallized to hornblende-plagioclase rocks. (See p. 18.) The texture and mineral composition of the metamorphosed sandy limestones and calcareous sandstones (p. 18) indicate that their metamorphism was due predominantly to heat that presumably emanated from the diorite. The progressively more calcic composition of the plagioclase in the rocks deeper within the diorite (p. 17) indicates that the intensity of the metamorphism increased toward the northeast. The presence of augite in some of the metamorphic rocks, along with labradorite (p. 18), is also indicative of a higher grade of metamorphism.

The aureole of metamorphism in the graywacke adjacent to the granite and granodiorite of the southwestern part of the district is characterized by biotite, which gives the rock a brownish cast (p. 32). The sericitic muscovite found elsewhere in the graywacke is, in this contact zone, progressively more coarse-grained toward the contact. Some traces of the earlier slaty cleavage remain in the partial orientation of the biotite flakes parallel to the regional foliation. The mica flakes therefore preserve in part the orientation of the chlorite and sericite from which they were formed.

The secondary biotite in the rocks of the contact zone is progressively darker toward the contact. In the rocks near the outer part of the aureole it is pale brown, in those nearer the contact it is brown with a slight greenish cast, and in those close to the granite and granodiorite it is deep reddish brown.

The more highly metamorphosed graywacke of the contact zone contains minute crystals of garnet and of chlorite that is possibly pseudomorphous after chloritoid. One specimen obtained near Mirror Harbor, a few miles northwest of the mapped area, contains andalusite and sillimanite. A specimen found near the granitic contact on the northernmost of the Granite Islands contains an elongate aggregate of muscovite flakes with random orientation. The shape of this aggregate suggests that the mica may be pseudomorphous after andalusite.

As mentioned above, no definite distinction was made between igneous metamorphism and hydrothermal alteration. Hydrous minerals and minerals closely associated with hydrous minerals in such a way as to suggest a common origin, particularly those forming late veinlets, are probably due to hydrous emanations from the cooling igneous rocks.

In some places, particularly in the greenstones, veinlets of epidote and quartz are common (pl. 4, *A*). These may be due to hydrothermal processes, though they may in part have been formed by segregation from the adjacent rock during dynamic metamorphism.

The albite of the greenstones and of the diorite may have several origins. Some of the albite in the greenstones may be a normal product of dynamic metamorphism (p. 52). Some of the albite in the intrusive rocks is probably a normal product of differentiation (pp. 37–40). Some albite, however, is believed to be due to the action of late hydrothermal solutions.

Prehnite is generally attributed [23] to heated solutions of magmatic origin. The diorite and quartz diorite, the albitic intrusive rocks, the greenstone-schist, the greenstone, and the graywacke of the schist contain considerable prehnite. Prehnite was observed in a lamprophyre dike near Elbow Passage. It is a rare constituent of the graywacke near the schist. It seems to be limited almost entirely to massive, competent rocks not more than 3 miles from exposures of the diorite. It is a vein mineral, locally with quartz and pyrite, and is present also as a fine-grained aggregate that has replaced the rock.

Portions of the diorite have been veined and replaced by one or more zeolites. The optical properties of several specimens indicate that the most common zeolite is intermediate between scolecite and laumontite.

Close to quartz veins the dikes and graywacke have been altered hydrothermally. The alteration has resulted in the widespread development of calcite and chlorite. Sericite is slightly more localized. Very close to the veins, rutile, leucoxene, apatite, pyrite, and arsenopyrite are common replacement minerals. Locally, also close to the veins, are bodies of silicified dike rock which appear to be irregularly bounded masses, the largest many feet across, within the less altered dike material. The silicified rock is commonly gray or white and cherty-appearing. The end product of the silicification of the dikes is a fine-grained aggregate of sutured, interlocking quartz grains, locally with some calcite. The rock is commonly crossed by tiny veinlets of somewhat coarser-grained sutured quartz.

All gradations are found between the relatively fresh dike and the completely silicified rock. From rocks of the intermediate stages it can be noted that as silicification proceeded the chlorite generally disappeared before the sericite and calcite. The two minerals last named are present in rocks which otherwise, except for a few plagioclase remnants, have been completely silicified.

AGE OF THE METAMORPHISM

The structural and mineralogical changes associated with dynamic metamorphism had a common origin and were produced at the same time. The significant facts concerning the age of the dynamic

[23] Harker, Alfred, Metamorphism, p. 134, London, 1932.

metamorphism are summarized below. The conglomerate in the graywacke formation contains fragments of rocks resembling some rock types in the schist sequence (p. 34). Many of the fragments in the graywacke (pp. 32–33) are of minerals and rock types common in the older rocks. Albite is particularly abundant. If this feldspar was albite before its deposition as clastic fragments in the graywacke, as appears likely, then metamorphism of the rocks from which the fragments were derived was earlier than the deposition of the graywacke. The age of the dynamic metamorphism may not be very different from the age of the diorite, which is in part gneissic. The contact metamorphism must be of the same geologic age as the intrusive rocks that produced it. The age of the hydrothermal alteration must be nearly the same as that of the quartz veins with which it is associated, which in turn are of nearly the same age as the light-colored dikes. (See p. 45.)

The evidence set forth above and the age of the diorite, albite granite, and granodiorite (pp. 40–42) suggest that at least some dynamic metamorphism of the schist and older rocks took place prior to the deposition of the graywacke. If this is true the granitic rocks of the district must be of two distinct ages and their difference in age must be at least the time required for the deposition of the graywacke and its folding to its present position.

STRUCTURAL GEOLOGY

The Chichagof mining district lies principally in a belt of rocks, that is believed to be in large part Mesozoic and that has been called the Sitka Mesozoic belt, which extends for many miles along the west coasts of Chichagof and Baranof Islands. Within the district these bedded rocks extend northeastward (down the stratigraphic column) to a large mass of diorite that is part of the main granitic core of Chichagof Island. It is possible that the lower part of the stratigraphic section may be made up of rocks of Paleozoic age. The bedded rocks extend southwestward (up the stratigraphic column) to a body of albite granite and granodiorite of unknown size that forms a few small islands in the southwestern part of the district.

The stratified rocks lie on the west side of the major Chichagof-Glacier Bay anticlinorium, which extends northeastward into the Glacier Bay country from the northwest end of the Prince of Wales and Kuiu anticlinorium.[24] In the vicinity of the Chichagof district the axial portion of the anticlinorium is occupied largely by granitic rocks.

[24] Buddington, A. F., and Chapin, Theodore, Geology and mineral deposits of southeastern Alaska: U. S. Geol. Survey Bull. 800, pp. 289, 290, 315, 1929.

The stratified rocks, partly on the basis of structural differences, have commonly been divided into two groups. Those of the older group include the schist and older rocks; those of the younger group include the graywacke. So far no unconformity has been definitely recognized between the two groups. The time interval between the deposition of the highest beds of the older group and the lowest beds of the upper group has been thought by some to represent the interval between the Paleozoic and the Mesozoic eras. The present authors believe the interval to be that between the upper Triassic and Lower Cretaceous epochs. (See pp. 49, 50.)

At most places on the western limb of the Chicagof-Glacier Bay anticlinorium, including the Chichagof mining district, the general trend of the rocks is west of north at different angles. (See pl. 3.) This is in accordance with the general structural trend of southeastern Alaska. At most places the rocks dip steeply to the southwest, but there are some exceptions to this generalization.

STRUCTURAL TRENDS

CONTACTS

The average strike for the bedded rocks of the district as mapped may approach N. 50° W., but there are many local and some general deviations from the average. The dip of the rocks also varies widely.

Generalized structural attitudes of the rocks are as a rule more reliably determined by study of the contacts between the formations recognized than by the study of individual dip and strike observations. The contact between the greenstone-schist and the greenstone is, within this district, a fault contact. The fault, however, is essentially parallel to the bedding of the rocks both above and below it wherever the bedding was observed. Apparently the fault closely follows a normal depositional contact. The greenstone is very thin on the ridge extending northeastward from Mount Freeburn. It is several times as thick on Hirst Mountain and near the eastern border of the district. Whether the thinning is the result of faulting or is original is not known.

The best indicator of the main structural trend within the district is the limestone. This is a relatively thin formation and is persistent across the district, except for local interruptions due to faulting. In many places the dip is indicated on the map by the effect of the irregular topography on the trend of the formation. Near the eastern border of the district the limestone dips about 50° SW. From Mount Freeburn to Whitestripe Mountain the dip is nearly vertical. (See pl. 4, *B*.) The dip is only about 30° SW. where the limestone descends toward Goon Dip River from the mountain northwest of Whitestripe Lake

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to be cut off by a fault near the river. About half a mile north of the east end of the lake northwest of Goon Dip Mountain the limestone strikes N. 83° W. and dips about 70° S. At the head of Goulding Harbor the dip is 80° NE.

The contact between the schist and the graywacke runs in a general way about N. 45° W. across the district. It exhibits many more local deviations from the general trend than the contacts between the older formations. It also makes several rather broad changes in direction. The most conspicuous departure of this contact from the average strike is between Surveyor Passage and Sister Lake, where a long and deep embayment is made into the schist. This departure from the normal strike is not reflected in the trend of the limestone below the schist. The contact is offset very slightly, or not at all, where it is crossed by the Chichagof fault at the narrow strait between Lake Anna and Sister Lake. Two faults, one about 4,000 feet and the other about 7,000 feet farther north along the contact, offset the contact on the northeast side of the fault about 1,100 feet and 800 feet, respectively, to the southeast. The contact is displaced about 300 feet in the same direction by the fault that extends between Black Bay and the small lake at an altitude of 254 feet northeast of Kimshan Cove.

BEDDING AND FOLIATION

The strikes and dips plotted on plate 3 were chiefly measured on foliation surfaces, which are commonly much more conspicuous than bedding surfaces. Where the bedding was definitely recognized it is almost invariably parallel to the foliation. At a few places the foliation forms angles as great as 20° and perhaps more with the bedding. Bedding is particularly difficult to recognize underground. Most of the observations of bedding and foliation were made on rocks of the graywacke. (See pl. 3.) The shore line in the district is developed principally on the graywacke, and exposures are generally better along the shores than anywhere else. Compared to the massive limestone and greenstone of the district, the graywacke is well bedded. Foliation and bedding are easily recognized in parts of the schist but are obscure in other parts, where over large areas they are so twisted and contorted that useful observations could not be made.

On the basis of a very few observations, some of which were taken on xenoliths, the average strike of the lower part of the greenstone schist in the vicinity of the head of Black River is about N. 50° W. A short distance farther northwest, near the northern border of the district, in the area that drains mostly to Goulding Harbor, the strike may average about N. 70° W. The dip at most places in both these areas is toward the northeast. (See pl. 8.)

The few observations of attitude made on rocks of the upper part of the greenstone-schist, the greenstone, and the limestone indicate that the bedding corresponds essentially with the strike and dip as indicated by the formation contacts.

In many places within the schist bedding and foliation are well displayed. This is particularly true in areas of graphitic schist and where the graphitic schist alternates with layers of greenstone-schist. However, the rocks of this formation apparently reacted so plastically to structural deformation that abrupt changes in strike and dip are very common, and in many places the formation appears as a crumpled, contorted mass where it is hopeless to make any generalized observations of attitude. (See pl. 6, *B*.) The complexity of the structure is incompletely indicated by the observations plotted on plate 3.

The two areas in which the crumpling and contortion were observed to be most pronounced are in the vicinities of Mount Lydonia and Mount Freeburn (p. 51).

North of Ford Arm to the vicinity of Rust Lake and in the schist formation the dip and strike vary considerably but not nearly as much as a little farther north, around Mount Freeburn. The rocks of this area are largely graphitic schist. The average strike is about N. 50° W and the average dip 65° SW.

The average strike in the schist between Black Lake and Black River is about N. 55° W., and the dip is generally steep to the southwest. This area embraces the thinnest part of the formation, from which much material has been squeezed toward Mount Lydonia and Mount Freeburn. It now contains a relatively large proportion of graywacke, which elsewhere makes up a very small part of the formation.

Southwest of the contorted mass of Mount Lydonia, on Williams Hill, around Black Bay, and on Lydonia Island the general strike of the formation is about N. 70° W. and the general dip about 60° SW. North and northwest of Mount Lydonia toward Goon Dip River and Pinta Bay the attitude of the rocks is relatively uniform. The strike averages about N. 65° W. and the dip 70° SW. The rocks of this area are largely alternating bands of greenstone schist and graphitic schist. There also are the largest lenses of limestone seen in the formation.

Near Goulding Harbor the formation strikes in general a little more northerly, about N. 55° W., and dips a little less steeply, about 65° SW.

From Ford Arm to the east side of Ogden Passage and south of Doolth Mountain the attitude of the graywacke is relatively uniform. The strike appears to average between N. 55° W. and N. 60° W., and the dip nearly 70° SW.

On and around Doolth Mountain and in the principal mines in that vicinity the average of 262 observations of strike is N. 62.42° W. and the average of 257 observations of dip is 66.74° W. On the north side of the mountain the general trend is slightly more westerly and the dips a little flatter than on the south side. This is illustrated by the averages of strike and dip observations in the Hirst-Chichagof mine, on Kimshan Cove, compared to those in the Chichagoff mine at the head of Klag Bay. The average attitude of the rocks in the Hirst-Chichagof mine from 77 readings is strike N. 65.42° W., dip 64.42° SW. In the Chichagoff mine the average of 125 observations is strike N. 58.22° W., dip 67.81° SW.

Around the shore of Kimshan Cove the attitude of the rocks is somewhat different at different places, but in general the strike appears to be about N. 75° W. and the dip 80° SW. Over the northeastern third of Herbert Graves Island the average strike is about N. 62° W. and the average dip about 74° SW.

Along the west shore of Ogden Passage southward to the southern tip of Herbert Graves Island from a point about opposite Point Hope the general strike approaches N. 57° W. and the dip 82° SW. At one place in this vicinity the rocks were observed to dip steeply northeast. Over the rest of Herbert Graves Island, some of the more northerly of the Myriad Islands, and the parts of Hogan and Hill Islands that lie within the mapped area the average trend of the rocks is N. 45° W. and the average dip a little more than 80° NE. The rocks that constitute the more southerly of the Myriad Islands and the islands lying farther southeast toward Klag Bay strike in general about N. 43° W. and dip about 77° SW.

In a few places the bedding and the foliation surfaces are not parallel. Divergences between them were noted particularly near the southeast end of Sister Lake, in the vicinity of the Baney prospect west of Klag Island, and along the western shore of Ogden Passage. The divergence between the strike of the bedding and the strike of the fracture cleavage was observed to reach 20°, and locally it may exceed that amount. At no place was the divergence in dip observed to be more than 5°. At all but one place where the bedding and foliation were observed to diverge from each other the foliation has a more westerly trend than the bedding. On Herbert Graves Island on the southeast shore of South Passage the bedding at one place strikes N. 50° W. and the foliation N. 45° W. Both dip 80° SW.

STRETCHING

A linear element, or stretching, that is a common feature of many metamorphic and intrusive rocks is present in a few places in the schist and in the graywacke. The stretching lies in the foliation surfaces. In the schist stretching was observed in the banded quartz-rich schist and phyllite. It appears in detail to consist of tiny folds in the foliation surfaces that give a larger surface a diagnostic "grain". No noteworthy elongation of individual minerals was observed.

So far as is known stretching in the graywacke is confined to contact-metamorphic zones near the albite granite and granodiorite of the southwestern part of the district. In this zone the stretching generally takes the form of trains of biotite flakes and quartz grains on the foliation surfaces.

The stretching pitches 38°–67° SE. It is as a rule nearly normal to the principal associated joints. In general the stretching is about parallel to, perhaps on the average, a little steeper than the many striations seen on fault surfaces. The average pitch of the striations may lie between 25° and 30°, but the observed range was 5° to 50°.

JOINTS

Occurrence.—The bedded rocks of the district are traversed by numerous joints. These are best developed in the more massive beds of the graywacke formation, where many smooth, even joint surfaces can be traced for several tens of feet. They are less conspicuous and less uniform in the rocks older than the graywacke formation. In the older rocks many individual joints curve and split in a complicated manner. Most of the principal joints of the district belong to a well-defined set, the individuals of which trend northeast. Most of these joints dip northwest at angles greater than 45° . A considerable number dip northwest at less than 45°, and a few dip southeast.

In the schist between Ford Arm and Rust Lake the average strike of the principal joints is about N. 17° E. and the average dip about 77° NW. Between Mount Freeburn and Williams Hill the joints strike about N. 30° E. and dip about 70° NW. From Black River to Pinta Bay the strike of the joints is also about N. 30° E., but the dip is slightly flatter, about 65° NW.

In the graywacke between Ford Arm and Lake Anna the joints in general trend about N. 40° E. and dip 70° NW. Between Klag Bay and Ogden Passage, south of Doolth Mountain, the average strike of the joints is about N. 45° E. and the average dip about 66° NW. In the vicinity of Doolth Mountain most joints strike about N. 18° E. and dip about 72° NW. On the west shore of Ogden Passage, southwest of the Bauer prospect, there are, in addition to the joints of the principal set, many joints that strike a few degrees East of North and dip about 50° E. On the northernmost part of Herbert Graves Island the average strike of the joints is N. 20° E. and the dip 55° NW.

Along the west shore of Ogden Passage southward from a point opposite Point Hope and on the more southerly of the Myriad Islands the principal joints trend about N. 32° E. and dip about 70° NW. On the more northerly of the Myriad Islands and over the western half of Herbert Graves Island joints of two sets were recognized. Joints of both sets strike about N. 25° E., but those of one set dip about 74°

NW. and those of the other about 33° NW. The strikes of the joints that have the flatter dips vary much more widely than those of the steeper joints.

Relations to other structural features.—Measurements were made of the dihedral angles between bedding surfaces and joint surfaces at about 80 localities. At about two-thirds of the localities the joints diverge less than 15° from a position at right angles to the beds. Where the foliation and the bedding are not parallel the joints are more nearly normal to the foliation than to the bedding.

The dihedral angle between the average attitude of the bedding and the average attitude of the joints was calculated for several areas. The divergence of this angle from a right angle differs considerably in different areas, and the reason is not known. In the schist in the area between Ford Arm and Sister Lake the angle between average bedding and average jointing is about 60°. Between Goon Dip River and Pinta Bay the angle is 94°. In the Lower Cretaceous(?) graywacke between Ford Arm and the east side of Ogden Passage south of Doolth Mountain the angle between average bedding and average jointing is almost exactly 90°. On Doolth Mountain and on the northern part of Herbert Graves Island the divergence from a right angle is about 16°; on the southern part of Herbert Graves Island, about 4°; and for the part of Herbert Graves Island along South Passage and the more northerly of the Myriad Islands, about 11°.

Only a few observations permit a comparison between joints and stretching. On Herbert Graves Island opposite Drip Point the angle between the stretching and the normal to the joints is 4°. On the shore of Kukkan Bay the corresponding angle is 16°; and on Didrickson Bay, in the schist, 25°.

The joints appear to be no more common nor better developed in the vicinity of faults than elsewhere. There is a general parallelism between faults and foliation, but there are many divergences. (See p. 64.) The joints in general are more nearly at right angles to the bedding than to the faults. Some local joints, however, apparently are related to faulting. An illustration of this is furnished by an exposure on a small island in Ogden Passage half a mile south of Snipe Rock (fig. 3). The angle between the bedding and jointing in the unsheared rock is about 91°. The angle between the fault and the jointing in the fault zone is about 97°. The angle between the stretching of the sheared rock of the fault zone (probably the direction of the fault movement) and the normal to the jointing in the fault zone is 9°. The angle between the jointing in the fault zone and the bedding is 81°.

Few joints were observed in the diorite of the northeastern part of the district. The albite granite and granodiorite of the islands in the southwestern part of the district are jointed, but the observations on them are very scanty. The joints appear to belong to three sets. Those of two sets dip steeply, but those of the third are at least locally, nearly horizontal.

FAULTS

Occurrence.—The rocks of the Chichagof district are cut by many faults (pl. 9.). Some of these have been traced for many miles by field observation and by the study of airplane photographs. Faults of similar trend have been recognized on the photographs and on the ground at places at least 20 miles northwest and southeast of the mapped area. The total extent of the fault system is not known, but it is probably much greater than the extent of any individual fault.

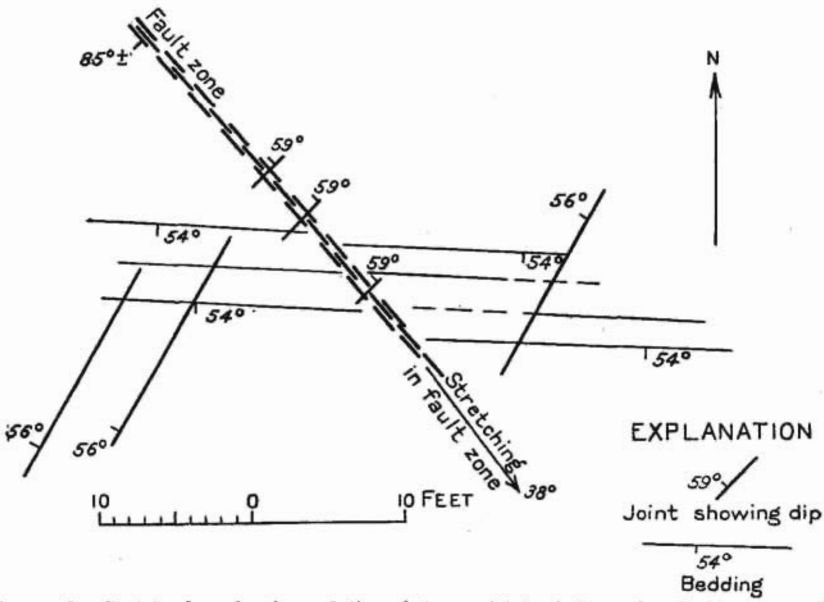


FIGURE 3.—Sketch plan showing relations between joints, beds, and a fault on a small island in Ogden Passage half a mile south of Snipe Rock.

Because the sheared rocks in the fault zones are commonly less resistant to erosion than the wall rocks, the faults ordinarily occupy linear depressions. Many of these depressions are too small to show on the map, but they generally show plainly on the photographs (pl. 10). The faults shown by solid lines on plate 9 were definitely identified by field observations on the ground and most of them were recognized on the photographs. Those shown by dotted lines were plotted solely from the stereoscopic study of the photographs.

The width of the lines on the map indicates roughly the prominence of the depressions occupied by the faults that the lines represent. The width and depth of the depression are dependent not only on the strength of the fault, the thickness of the fault zone, and the amount of crushing but also on the exposure to erosion of the outcrop of the fault zone.

Most of the faults of the district, including nearly all the principal ones, trend northwest and dip steeply southwest, in rough parallelism with the general attitude of the bedding and foliation. Neither the foliation nor the faults are plane surfaces, so that at most places there is some divergence between the two and at many places they diverge widely. Individual faults have considerably different attitudes at different places.

Most of the faults cut the bedded rocks, and relatively few were recognized in the diorite of the northeastern part of the district. More of the faults, particularly the smaller faults, in the rocks older than the graywacke diverge widely from the general trend than the faults in the graywacke. The small faults in the older rocks southeast of Black River appear more numerous than elsewhere. Many of them have a much more northerly trend than the general trend of the principal faults.

Two of the principal faults of the district, the Hirst fault and the Chichagof fault, have been opened extensively in the Hirst-Chichagof and Chichagoff mines respectively. Opportunity was afforded by the mine openings to study these two faults much more thoroughly than any others, and a large part of the following discussion of the faults of the district is based on observations on these faults.

A characteristic feature of the faults of the district is the splits [25] or branches that have formed at many places along them. Many of these splits are large and are recognizable on the photographs (pl. 11, *B*).

Many splits are associated with bends or warps in the larger fault from which they diverge. Movement on the splits appears to have relieved part of the stress on the stronger faults. Some splits of this type show plainly on plate 11, *A*, at a bend in the large fault south of the large fork of Black River between that stream and Mount Freeburn.

Splits of the type shown on plate 11, *B*, but smaller, are seen underground to be very numerous. Apparently many of these splits extend for short distances only into either the hanging wall or the footwall of the main fault, but others, as opened by mine workings, are of great length. The main level of the Hirst-Chichagof mine, for example, has followed one of these splits for about 2,250 feet.

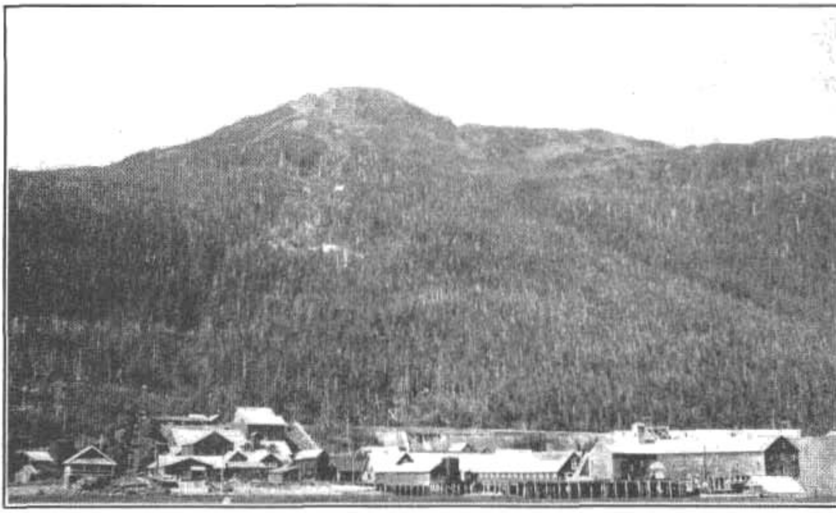
[25] In this report the term "split" or "split fault" is used to designate a fault that diverges, commonly at acute angles, from other, usually stronger or more continuous faults. These splits are of two general types—those that diverge from other faults into a position more nearly parallel to the foliation of the rocks, and those that diverge from other faults into a position that makes a greater angle with the bedding than the main fault. Figure 4 illustrates in a simplified way the two types of splits.

A. UPSTREAM ENTRANCE OF LIMESTONE CAVERN OCCUPIED BY RUST CREEK WHERE THE CREEK CROSSES THE LIMESTONE.

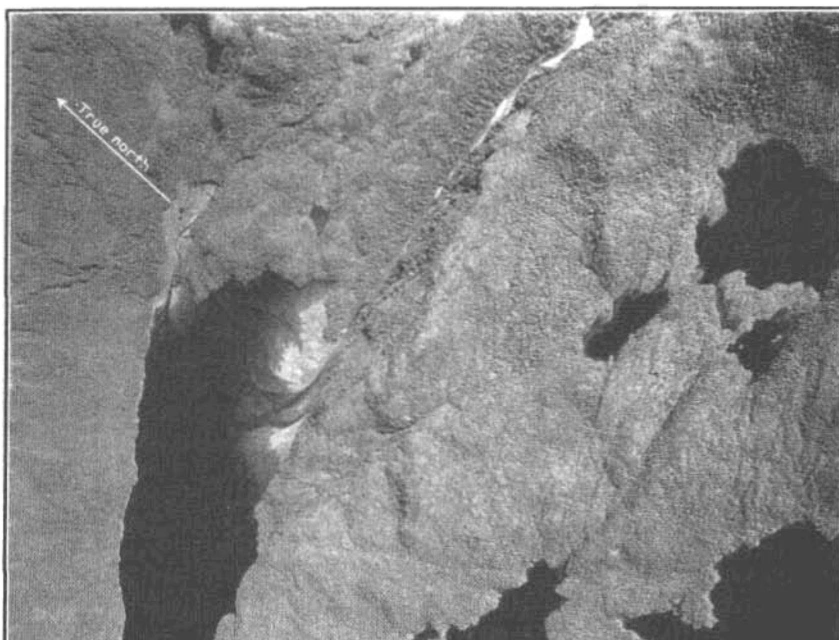
The opening is about 40 feet across and 30 feet high.

B. CONTORTED SCHIST ABOUT HALF A MILE EAST OF THE TOP OF MOUNT LYDONIA.

Note vein quartz (white) between foliation surfaces and in irregular masses.



A. VIEW OF DOOLTH MOUNTAIN FROM SMALL ISLAND NEAR HEAD OF KLAG BAY SHOWING CHICHAGOF AND TRACE OF THE CHICHAGOF FAULT.



B. VERTICAL AIRPLANE PHOTOGRAPH SHOWING DELTA BUILT INTO THE HEAD OF BLACK BAY BY BLACK RIVER.

In the Hirst-Chichagof mine and to a lesser extent in the Chichagoff mine many of the splits leave the main fault by curving to a position parallel or nearly parallel to the bedding. Thus, in a northwesterly direction, a split of this kind leaves the main fault by passing to the left into the hanging wall. In a southeasterly direction the splits depart from the main fault by passing to the left into the footwall. This type of split is well illustrated on the main level

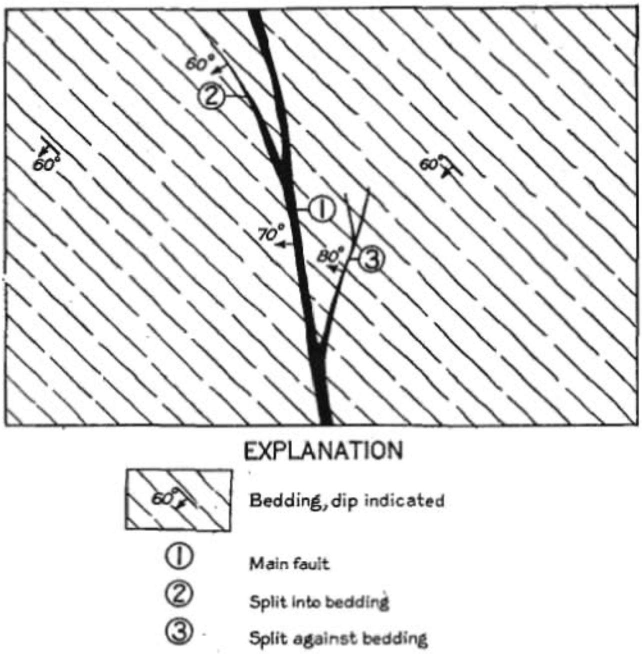


FIGURE 4.—Diagrammatic sketch plan illustrating splits, or split faults.

of the Hirst-Chichagof mine, about 2,100 feet from the portal. (See fig. 5.)

At some places in the mines the tendency of the rocks to yield along the bedding instead of in the direction of the average trend of a fault is so marked that locally all the movement has taken place parallel to the bedding. After continuing for a distance parallel to the bedding the fault resumes its more northerly general trend and steeper dip. A warp or bend of this type in the Hirst fault has formed one of the most conspicuous structural features of the mine and can be traced from the 180 level through the 700 level. (See pl. 19.) This feature was formerly regarded as a cross fault that offset the Hirst fault and vein, but no continuation of the cross fault could be found either northwest or southeast of the places where the so-called cross fault joins the main fault. Hence the interpretation of the feature as a cross fault is thought to be incorrect.

Splits that leave the main faults against the bedding are also common in the district and appear to be particularly numerous in the Chichagof mine, where one of the largest splits that diverges from the Chichagof fault against the bedding is at the Chichagof

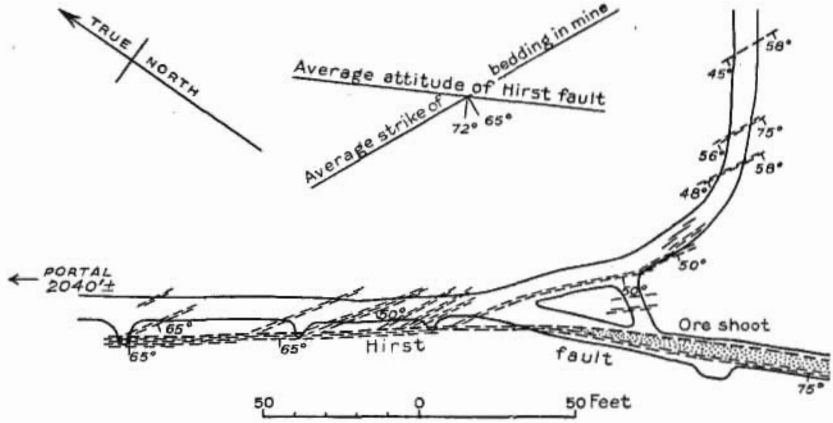


FIGURE 5.—Sketch plan of splits from Hirst fault on main level of Hirst-Chichagof mine.

ore shoot about 780 feet from the portal of the main level. (See fig. 6.) This split carried a considerable quantity of ore, known as the footwall ore shoot, and can be recognized from the main level through the 400 level of the mine.

The faults, as seen in the two productive mines and in the prospects of the district, range in thickness from a few inches to many

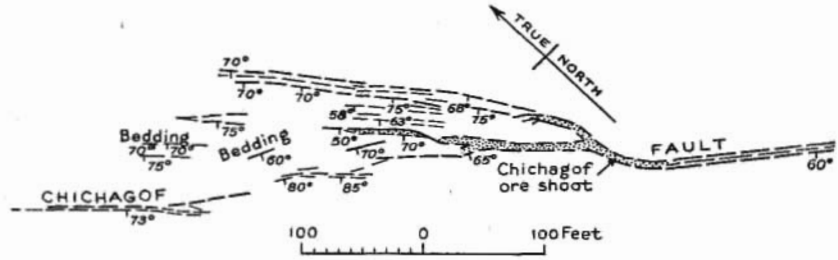


FIGURE 6.—Sketch plan illustrating splits from Chichagof fault at Chichagof ore shoot.

feet. Where the movement on the faults was confined to a relatively narrow zone, perhaps as much as 8 or 10 feet thick, the faults are commonly gouge-filled fissures with rather well-defined walls. At other places where the fault zone is wide it is ordinarily made up of hundreds of smaller shear surfaces with but little gouge on any individual surface. The bounding walls of such zones are in many places very difficult to identify, but many of them are at least 50 feet wide.

The faults appear to widen into thicker shear zones where the wall rocks or at least those on one of the walls are particularly shaly. Conversely the faults appear to be thinner and more localized in the more massive graywacke and where dike rock forms one or both walls.

The material in the faults is commonly black with graphite. Many shear surfaces are brightly polished and striated. Where true gouge fills the fault it is in most places a black clayey mass, full of graphite. Where the fault matter has been formed from dike rock it is greenish gray and contrasts strikingly with the more common black material. Locally the fault zone contains bands and discontinuous streaks of alternating gray and black gouge.

Throughout the district the movements on the faults have been for the most part northwestward and upward at about 30° for the southwest or hanging-wall sides, or southeastward and downward at about 30° for the northeast or footwall sides. Striae on the shear surfaces and plucking pits are very common. Drag of the wall rocks along the faults is well shown in the Hirst-Chichagof mine by the dike that forms the footwall of the mine at many places. (See pl. 19.)

The evidence indicates that there have been repeated movements along the faults. In fact, without any confirmatory evidence, it would seem almost inconceivable that the movements on all the faults of the system described or on any one fault could have taken place at one time. The vein quartz, as pointed out in the section on ore deposits, came in along preexisting faults and migrated at many places from the faults into joints that intersect the faults. At many places the vein quartz is sheared, roughly parallel to the fault along which it came in, and crushed. (See pl. 26, *A*.) Also at many places quartz veinlets in joints in the wall rocks have been offset by post-quartz movements on the faults. In order to crush widely bodies of quartz lying in the faults and to offset veinlets in wall-rock joints there must have been fault movements long after the movements that formed the faults.

At many places in the district the dikes were intruded before the formation of the faults. In the Hirst-Chichagof mine, for example, the large footwall dike is cut off by the Hirst fault and does not appear in the hanging wall. The dike is dragged along the fault (see pl. 19), and pieces of the dike have been dragged for long distances in the fault, away from the locality where the dike is in place. Farther in the main level of the Hirst-Chichagof mine, beyond the productive part, along a large split from the main fault there is a thin dike, lithologically similar to the main footwall dike. Unquestionably this dike came in along a fault that already existed. (See pls. 19 and 23.) At other places in the district, particularly in the vicinity of Ford Arm, thin dikes occupy preexisting faults. It appears to follow, therefore, that the faults came into existence after many of the dikes had been emplaced, but not very long after, because the thin dikes that occupy some of the faults were intruded after the formation of those faults.

It is thought that the diorite of the northeastern part of the district may not have been solidified while the principal fault movements were taking place. This would explain the sparse faults recognized in the diorite (p. 64). Over large areas, however, the diorite is soft and crumbly, and faults in such rock may easily have been overlooked.

It is apparent that the faults existed before the formation of the quartz bodies that now lie in them.

Both the dikes and the quartz bodies are believed to be genetically related to the batholithic rocks of the district, and the batholithic rocks are supposed to have been intruded late in Jurassic or early in Cretaceous time. (See p. 50.) The dikes possibly represent a very late event in the batholithic intrusion cycle, and the deposition of vein quartz a still later but partly overlapping event. The formation of the faults appears to fit best into the sequence of events principally between the intrusion of the dikes and the deposition of the quartz. Movements on the faults, probably minor movements, evidently continued after the quartz deposition.

The amount of the movement at most places on most of the faults of the district is not known, largely because there are few recognizable horizons within the rocks, displacements of which can be measured. Most of the places where the displacements could be measured are noted below. Some of the measurements probably show the horizontal displacement with reasonable accuracy, but others are approximations only.

In the Hirst-Chichagof mine the distance that the material of the large footwall dike has been dragged along the Hirst fault and the fact that the dike does not appear in the hanging wall show that the minimum amount of the horizontal component of the movement there must exceed 1,100 feet.

At several places the contact between the schist and the graywacke has been displaced along faults. About midway along the large split that apparently joins the Hirst and Chichagof faults between a point under Sister Lake and a point about a mile north of the north end of Lake Anna the contact has been offset about 1,100 feet. A little more than half a mile farther north the same contact has been displaced along another branch of the Hirst fault about 800 feet. About a mile north of the Hirst-Chichagof mine dock at Kimshan Cove the contact has been offset along another fault, in the same direction, about 300 feet.

The contact appears to be displaced, or warped, beneath Surveyor Passage. The displacement, which is probably along the Hirst fault, is apparently about 2,000 feet, but this figure may not be correct within wide limits.

The limestone is offset about half a mile along a prominent split about a mile northeast of Goon Dip Mountain. (See pp. 23, 72.) The horizontal component of the movement on a split fault that cuts the limestone northeast of Rust Lake may be about 2,500 feet.

Half a mile east of the head of Pinta Bay along a minor fault that trends about N. 17° E. the limestone has been displaced about 800 feet horizontally. The northwest side has moved northeastward relative to the southeast side. A short distance farther north the lower tunnel on the property of the New Chichagof Mining Syndicate follows for about 600 feet another fault that cuts the limestone. This fault strikes N. 36° E. and dips at different angles between 55° and 85° NW. The northwest side has moved northeastward relative to the southeast side a horizontal distance of about 22 feet.

In addition to the movements along the large faults and the splits therefrom, a great deal of shearing was accomplished on countless foliation surfaces, which so far as is now known, are parallel at most places to the bedding surfaces. There is scarcely an outcrop in the bedded rocks that does not exhibit many shear surfaces. The total amount of movement that took place along these individually insignificant surfaces must have been tremendous and may easily have exceeded that along the well-defined faults. So far, however, nothing is known of either the absolute or the relative amount of such movement. All the shear surfaces that were examined show movement similar to that on the large faults—that is, northwestward and up at about 30° for the hanging-wall side. This feature is illustrated by figure 7, which is drawn from a photograph of an exposure on a small island in Elbow Passage, a few hundred feet east of Klag Island.

Chichagof fault.—The Chichagof fault, on which the Chichagoff mine is principally developed, has been followed continuously by underground workings for a horizontal distance of 4,750 feet and a vertical distance of about 3,950 feet. The fault can be traced on the surface from the beach past the outcrop of the Golden Gate ore shoot to the top of Doolth Mountain, where it makes a distinct notch in the ridge top. (See pl. 7, *A*.) The fault probably continues down the other side of the mountain under a large slide of loose rock.

The fault exposed in the tunnel of the Bauer prospect, on Herbert Graves Island, is almost directly in line with the Chichagof fault on Doolth Mountain and probably is that or a closely associated fault. From the Bauer prospect northward the trace of the fault skirts the northeast end of Herbert Graves Island and enters Portlock Harbor.

Southeast of Chichagof, between the head of Klag Bay and the head of Lake Anna, the Chichagof fault appears to be one of a large number of relatively strong splits that converge toward Lake Anna. (See pls. 9 and 11, *B*.) The fault probably continues under the strait between Lake Anna and Sister Lake. It appears distinctly as a wide and complicated zone between Sister Lake and Ford Arm. (See pls. 9 and 10, *A*.) It has not been recognized southeast of the vicinity of Elf Cove, on Ford Arm.

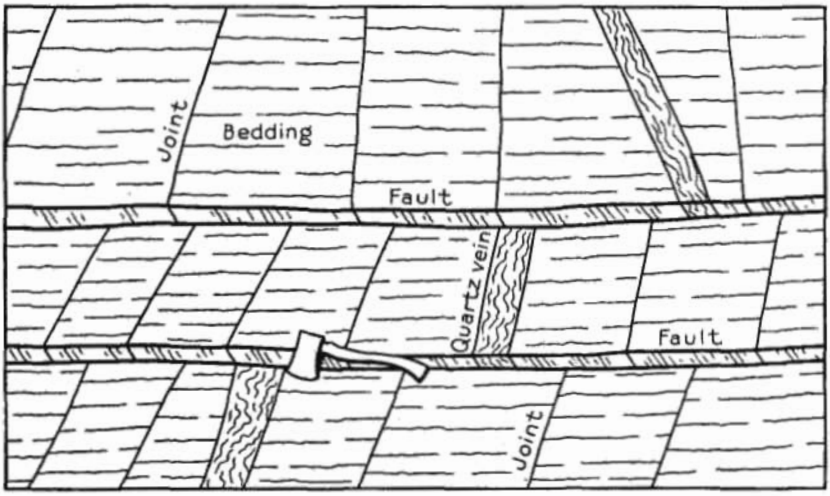


FIGURE 7.—Sketch illustrating shearing along bedding surfaces that has offset a quartz veinlet in jointed shaly graywacke. View southwestward across strike.

The general trend of the Chichagof fault across the district is about N. 45° W. Its attitude is known in much more detail in the part opened by the Chichagoff mine. On the main level of the mine the average strike of the Chichagof fault is N. 39½° W. and the average dip about 70° SW. Within the mine and no doubt elsewhere the fault differs appreciably in both strike and dip at different places. The mine as a whole exposes the fault on a large warp or twist. (See pls. 16 and 17.) The dip is much steeper in the northern part of the workings and in the deeper parts of the mine. In fact, between the 2000 and the 2100 levels of the mine the fault actually dips about 80° NE. and strikes about N. 20° W.

Hirst fault.—The Hirst fault lies about 4,000 feet northeast of the Chichagof fault. At many places it is not readily recognized on the surface, but it has been followed underground definitely for about 1,850 feet horizontally and through a vertical range of about 1,780 feet in the Hirst-Chichagof mine. A split from the Hirst fault into the hanging wall of the main fault has been followed in the mine for 2,250 feet farther southeast.

Northwest of the mine at Kimshan Cove the trace of the Hirst fault is largely concealed by arms of the sea. The fault may continue under Kimshan Cove and Surveyor Passage. Other faults, some of which may represent the main Hirst fault, but are thought more likely to be splits from it, were recognized at several places along the northeast shore of Herbert Graves Island, on Lydonia Island, and on the westward extension of Williams Hill.

Southeastward from the Hirst-Chichagof mine the Hirst fault was recognized to a point about 4,000 feet north of the northeast end of Lake Anna. There the fault appears to branch into numerous splits, some of which were identified southeastward as far as Sister Lake. The most southerly and one of the most prominent of these splits is the one exposed in the Anderson prospect, on Sister Lake. This split probably joins the Chichagof fault under Sister Lake and thus is a connecting link between the Hirst and Chichagof faults.

The general trend of the Hirst fault is about N. 42° W. In the Hirst-Chichagof mine the average strike of the fault is about N. 28° W. and the average dip 72° SW. Locally the fault, as seen in the mine, diverges considerably from the average attitude (see pl. 19), and strikes as northerly as N. 10° W. and as westerly as N. 70° W. have been observed. Similarly the fault dips from as steep as 90° to as flat as 40° SW.

Fault along Elbow Passage.—A prominent fault extends along the south side of Elbow Passage. Several exposures show it to consist of a strongly sheared zone about 4 feet wide in a less strongly sheared zone in places at least 20 feet wide. The sheared rock is commonly stained with hydrated oxides of iron. No appreciable quartz was seen in this part of the fault, but quartz occupying joints is common in the vicinity. The fault trends considerably more westward than most of the other large faults of the district. Numerous splits, like the foliation and bedding of the vicinity, have a more northerly trend.

Southeastward from Elbow Passage the trace of the fault almost coincides with the south end of Lake Anna. It has a more northerly trend farther southeast, follows for a short distance the southwest shore of Sister Lake, and apparently disappears in numerous splits on the Takeena Peninsula, between the south end of Sister Lake and Ford Arm.

Along Sister Lake the fault dips steeply northeast. In this vicinity several small quartz veins were noted on minor shear surfaces that are apparently associated with the stronger fault, but the fault itself is not well exposed, probably owing to the considerable erosion of the sheared rock.

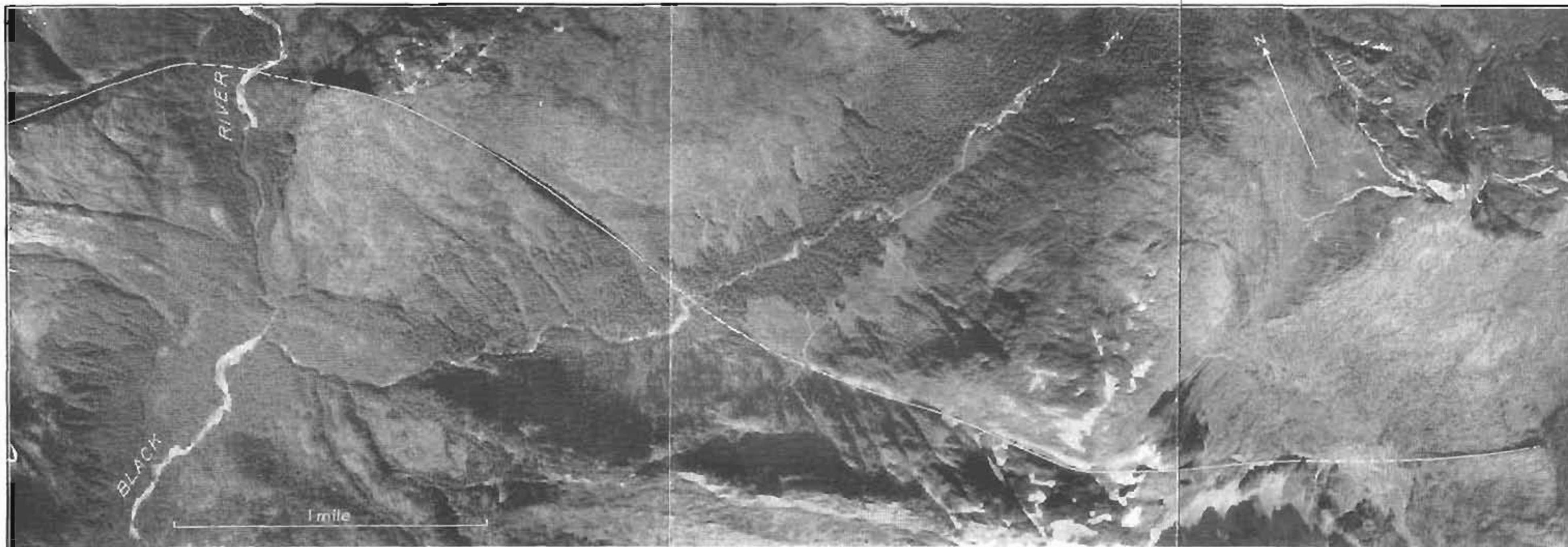
Fault between Ogden Passage and Klag Bay.—A fault is well expressed topographically from the east shore of Ogden Passage about half a mile south of Point Hope across the peninsula extending southward from Doolth Mountain to a point on the west shore of Klag Bay west of Klag Island. The trend of this fault has a considerable range.

Faults southeast of Rust Lake.—Several prominent faults cut the schist in the relatively rugged area south and southeast of Rust Lake. Much of this area has not been mapped topographically. (See pl. 9.) Probably the traces of the faults in this vicinity are prominently etched out partly because of the relatively steep slopes. (See pl. 10, *B*.) Nevertheless strong faults appear to be uncommonly abundant. The faults at most places appear to be vertical or nearly vertical.

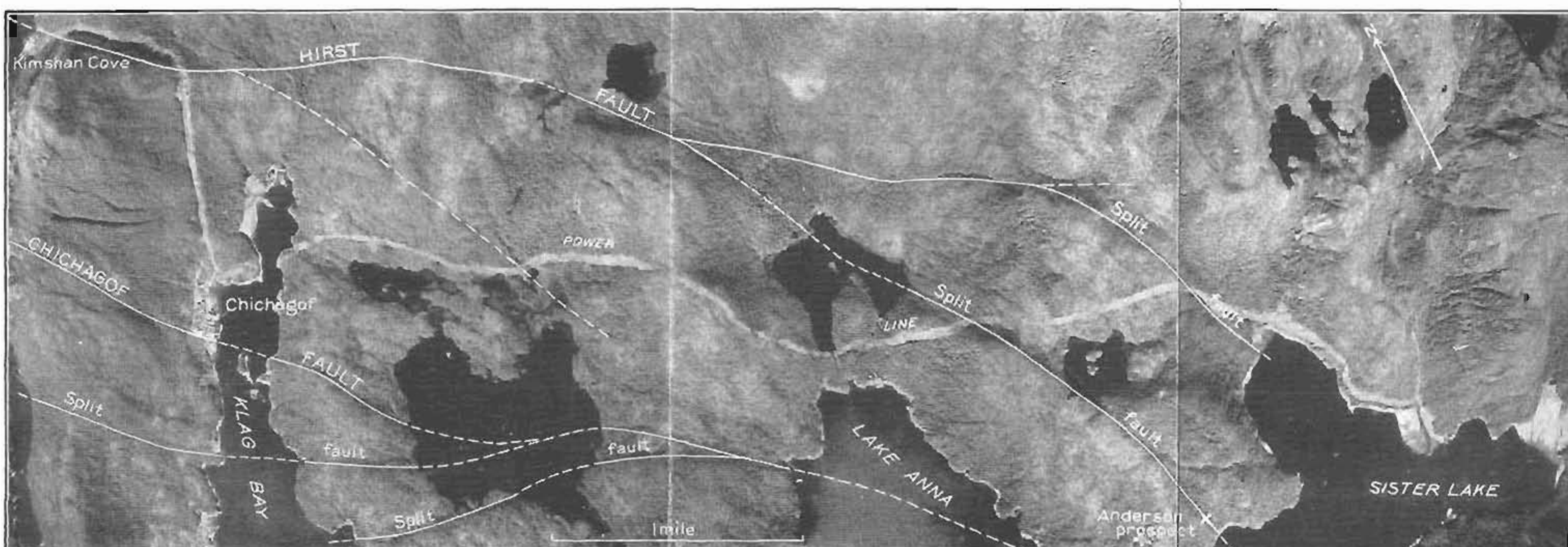
Fault between Black Bay and Black Lake.—A fault, apparently of considerable strength, which, like the fault along the south side of Elbow Passage, trends in general more westward than most of the other strong faults of the district, follows for about half a mile the south shore of Black Bay. Thence it extends up the lower course of Black River and about 1¼ miles upstream from the mouth leaves the valley floor and extends southeastward to the southwest end of Black Lake. At this point the fault appears to split. One prominent split passes north of and close to the peak 3,228 feet high that stands a little less than a mile south and a little east of Black Lake. Other splits, largely concealed by loose rock near Black Lake, cross Mount Freeburn farther north. At least one of these appears to join, north of Rust Lake, a long fault that is described in the next paragraph.

Fault between Goulding Harbor and a point east of Rust Lake.—A fault that is traceable for a longer distance within the district than any other was recognized, with a few minor breaks, principally where its trace is covered with alluvium, from a point near the head of Goulding Harbor southeastward to the border of the mapped area east of Rust Lake. A major split apparently branches from this fault south of Goon Dip River, where the trace of the split is concealed by glacial moraine. The split has a more northerly trend than the main fault. On the mountain 1,835 feet high north of Goon Dip River the limestone is displaced about half a mile along this split. This split is well exposed on the north side of the valley of Goon Dip River. (See pl. 12, *A*.)

Fault on Hirst Mountain.—At a distance ranging from about three-quarters of a mile to 1½ miles northeast of the fault just described is another fault that has been recognized almost all the way across the district. This fault crosses Hirst Mountain near its top. It is easily

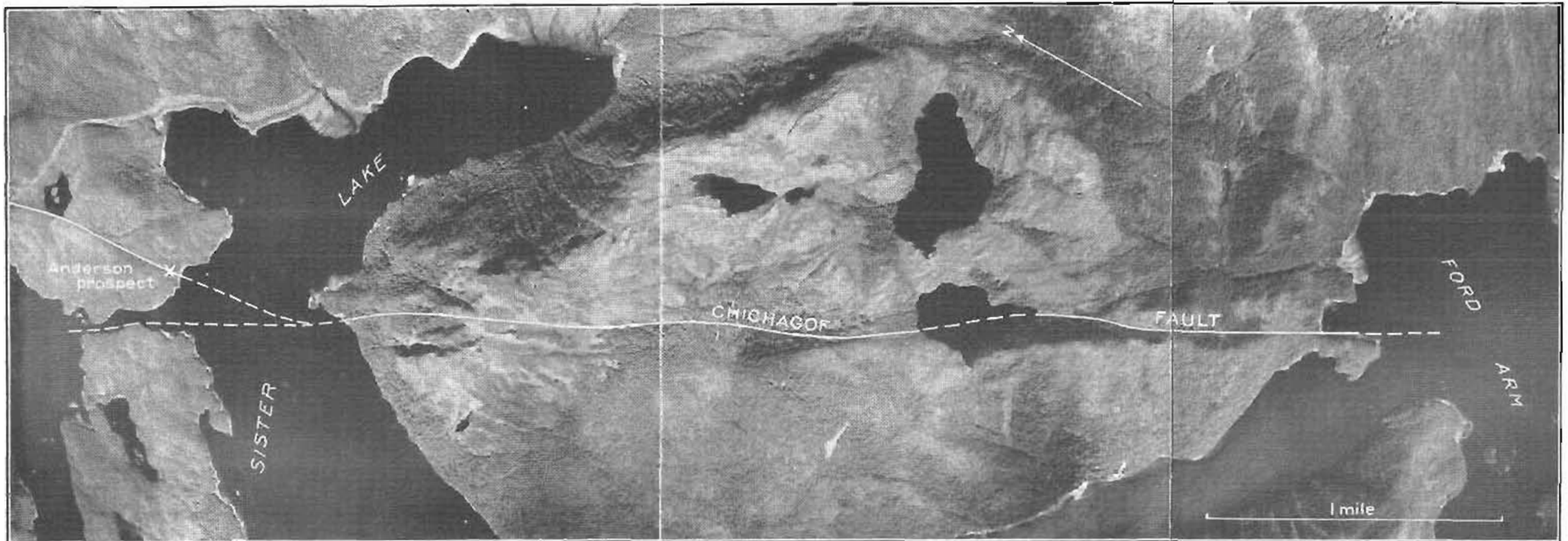


A. LARGE FAULT EXTENDING FROM A POINT NORTH OF BLACK RIVER ACROSS HIRST MOUNTAIN TO VICINITY OF MOUNT FREEBURN.

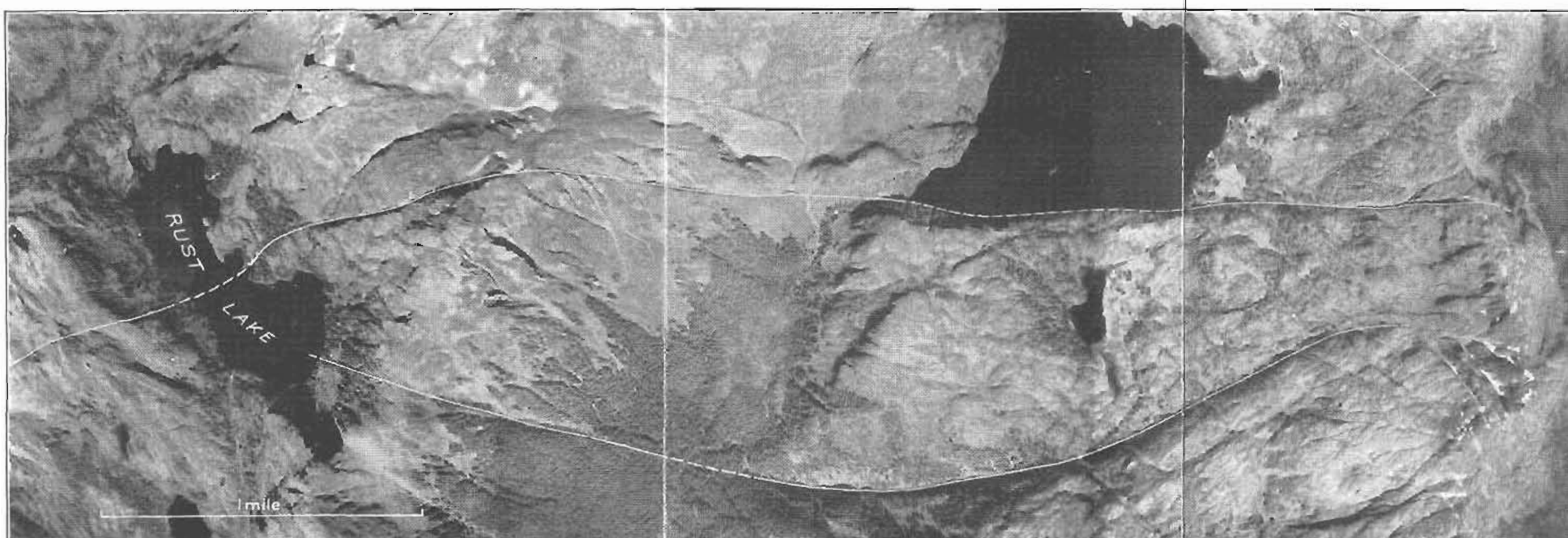


B. HIRST AND CHICHAGOF FAULTS AND SOME ASSOCIATED SPLITS FROM DOOLTH MOUNTAIN TO SISTER LAKE.

TRACES OF FAULTS IN THE CHICHAGOF MINING DISTRICT AS SEEN ON AIRPLANE PHOTOGRAPHS.



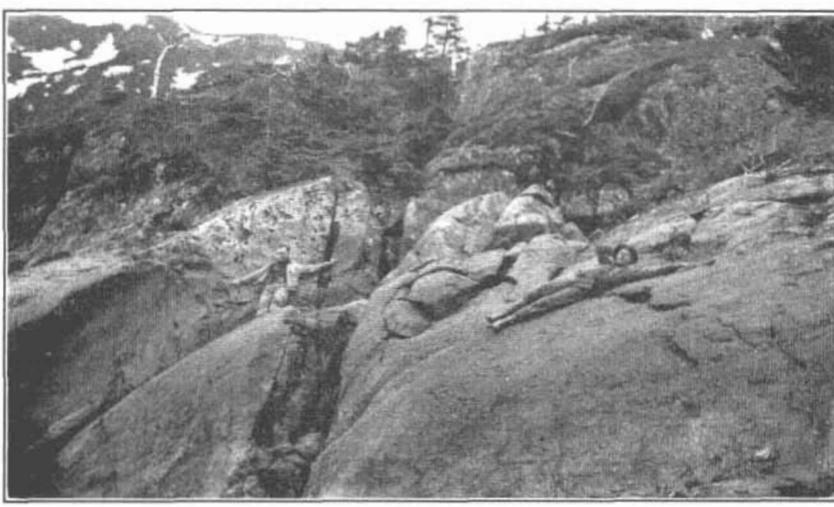
A. CHICHAGOF FAULT FROM NORTH END OF LAKE ANNA TO FORD ARM.



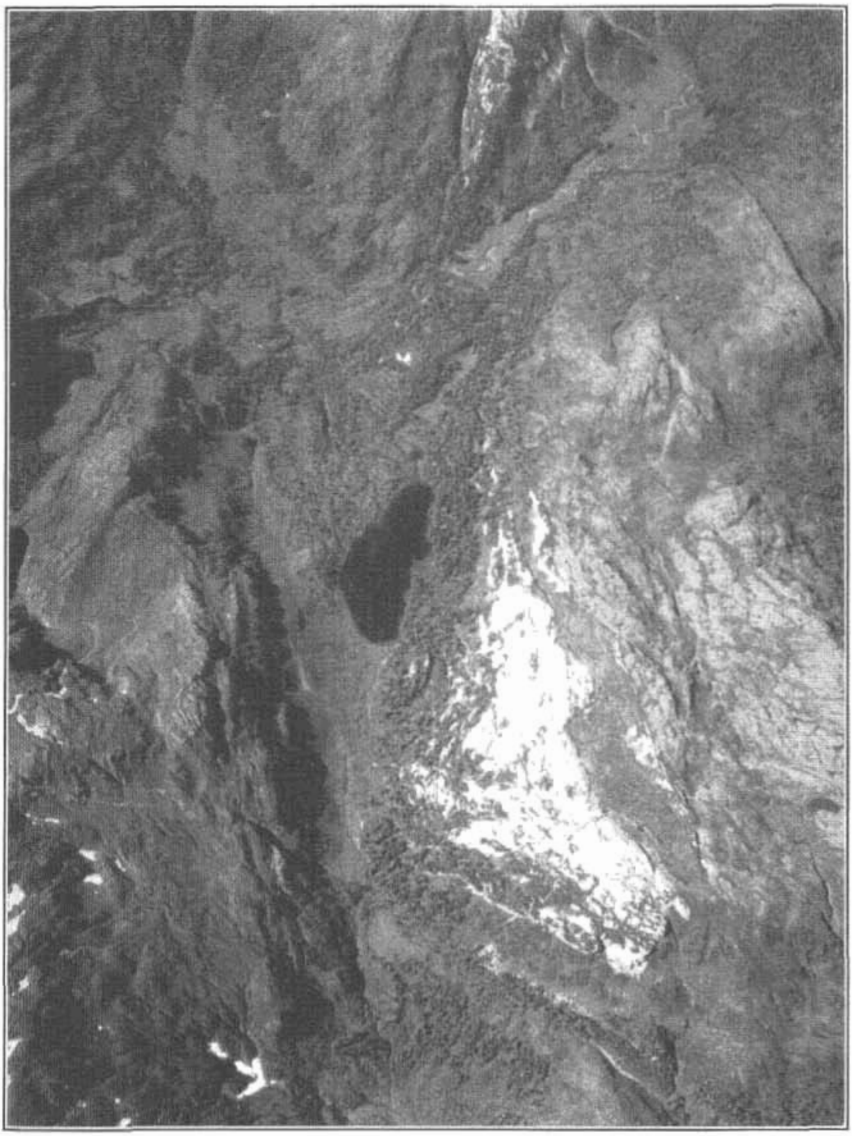
B. FAULTS FROM VICINITY OF RUST LAKE SOUTHEASTWARD.

TRACES OF FAULTS IN THE CHICHAGOF MINING DISTRICT AS SEEN ON AIRPLANE PHOTOGRAPHS.

A. VIEW NORTHWARD FROM VALLEY OF GOON DIP RIVER SHOWING LIMESTONE CUT OFF BY LARGE SPLIT FAULT.



B. VIEW SHOWING DEEP GOUGES CUT BY SMALL VALLEY GLACIER AT OUTLET OF RUST LAKE.



AIRPLANE PHOTOGRAPH SHOWING MANNER IN WHICH LIMESTONE IS CUT OFF BY FAULT EAST OF RUST LAKE.

recognizable southeastward from that point to the east edge of the mapped area and northwestward as far as Goon Dip River. Apparently it extends for a considerable distance under the alluvium of the river. The fault that extends from the north side of the alluvium to the lake 990 feet high about half a mile north of the river is thought to be the same fault.

This fault is unusually well expressed topographically (see pl. 11, *A*), and the movement along it must have been extensive and perhaps across a relatively wide zone. The fault forms the boundary between the greenstone schist and the greenstone formations. East of Mount Freeburn and a short distance west of the upper part of Rust Creek a large split diverges southward from the fault and cuts the limestone. The limestone has been dragged on this split, thus making the measurement of displacement difficult. It appears that the horizontal component of the displacement approaches 2,500 feet. The west side of the split has moved northward relative to the east side.

Fault east of Rust Lake.—Extending eastward from a point a short distance east of Rust Lake is a fault that cuts off the limestone near the eastern edge of the mapped area. The truncation of the limestone shows well on the airplane photographs (pl. 13). The continuation of the limestone south of the fault has not been found. The fault has been traced eastward on the photographs to a point about 2 miles east of the eastern edge of the mapped area, where it disappears, apparently at the contact with the diorite. The horizontal displacement along this fault must be at least 2 miles. The north side has been displaced to the west relative to the south side.

SUMMARY OF THE ORIGIN OF STRUCTURAL FEATURES

Most of the points taken up in this section are mentioned at different places in other parts of this report. The material is merely summarized here to give the reader a less scattered outline of the structural events that have taken place in the district.

The bedded rocks of the district were originally laid down in a horizontal or nearly horizontal position. Widespread compression by mountain-building forces acting in a northeasterly or southwesterly direction folded and tilted the rocks to their present general steeply dipping attitudes and imposed on southeastern Alaska its general northwest structural trend. The greatest compression probably took place early in Cretaceous time, but after the deposition of the graywacke. The diorite of the northeastern part of the district probably was intruded at the same time under the influence of the same orogeny. Mountain-building movements, about which very little is known, probably preceded the deposition of the graywacke formation.

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The Chichagof district lies principally in a belt of Mesozoic rocks on the southwest side of one of the several major anticlinoria of southeastern Alaska.

The schist formation is less competent to withstand crustal movement than most of the other rocks. Either because of locally greater pressure, or locally greater incompetency of this formation, probably the latter, large volumes of it flowed plastically from the central part of the district northwestward to the vicinity of Mount Lydonia and southeastward to the vicinity of Mount Freeburn. This plastic transfer of material has resulted in a deep northeastward bulge of the contact between the schist and the graywacke. The thin, incompetent limestone was protected from similar distortion by the competent massive greenstone formation that underlies it. As might be expected, exceptionally strong shearing has taken place in both formations near the contact between the graywacke and the schist within the eastward bulge of the contact.

The general structure of the district is homoclinal, the rocks at most places dipping southwest. Locally the rocks dip steeply northeast, but there is no evidence of tightly compressed folds. The rocks in only a very few places lie nearly flat, as they would near the crests of folds. These places appear to be on very small crumples or drag folds on the larger homoclinal structure.

After the rocks had been tilted and then tightly compressed, with the attendant plastic flowage that resulted in the large eastward bulge in one of the contacts, they began to yield by shearing, both along foliation surfaces and along faults.

The faults trend generally northwest and dip steeply southwest, and many of them cross, without interruption, the bent contact in the eastward bulge. The stretching that has been developed on foliation surfaces apparently reflects the direction of movement on larger faults.

Joints of the major joint system in the district trend for the most part northeast and dip northwest. They are tensional features that have developed in general about at right angles to the foliation, to the stretching, and to the direction of movement on the faults.

GEOMORPHOLOGY

Before the geomorphology of the Chichagof district can be adequately treated much larger areas on Chichagof Island and at other places in southeastern Alaska will have to be carefully studied. It is proposed here to point out only a few of the major processes that have been active and events that have taken place in the development of the large, striking topographic features that characterize the district. (See pp. 9–11 and pl. 2.)

The broad coastal plain, although it has been modified by glaciation, was apparently developed before Pleistocene time by other than glacial processes. The extent of the plain is much greater than is now apparent, because much of it is below sea level. Its average width may approach 20 miles, and traces of it above sea level extend from Cross Sound on the north to Khaz Head on the south (see p. 10), a distance of about 40 miles. It is at most places bounded on the east by steep slopes that reach upward for hundreds or thousands of feet. On the west the plain terminates abruptly at the top of a steep slope that plunges downward to depths of several hundred to more than a thousand fathoms. The surface of the plain ranges from a depth of about 100 fathoms below sea level at its western edge to an altitude of about 250 feet above sea level at its eastern limit. Thus the plain has a southwesterly slope of about 850 feet in approximately 20 miles.

The eastern limit is not straight but is modified by indentations, such as the one that reaches northeastward beyond the head of Klag Bay, and by high promontories, such as Doolth Mountain. The crookedness of the eastern limit of the plain appears to rule out the possibility that the plain is a structural feature. Although within the district mapped the plain is largely developed on the graywacke, there are many exceptions to this generality. Parts of the plain are underlain by schist. Large areas of graywacke, such as Doolth Mountain, do not form part of the plain. Therefore it appears unlikely that the underlying rock was a controlling factor in the development of the plain.

The manner of formation of the plain is not definitely known, but the suggestion is offered that it was formed largely by the action of waves and shore currents, including tidal currents, along a gradually subsiding coast. The highest position of the sea, relative to the land, was apparently about at the present 250-foot contour.

The highland northeast of the coastal plain, even before Pleistocene time, apparently was deeply dissected by steep, narrow valleys. The major valleys, although narrow and deep, were of relatively gentle gradient. That these valleys existed before the late valley glaciation is indicated by the fact that such valleys as those of Goon Dip and Black Rivers are not glaciated near their mouths but farther upstream were molded to U shapes by valley glaciers that existed during the waning stages of glaciation.

In Pleistocene time climatic conditions were such that an extensive ice cap was formed over Chichagof Island and most of the rest of southeastern Alaska. First were formed small local ice fields. These expanded and coalesced, and the ice began to extend down the valleys as valley glaciers heading back in the higher parts of the island. These gradually grew until the snow and ice fields at their heads merged into local ice caps. The small caps in turn became larger until the whole area was deeply buried in ice. On Chichagof Island a few peaks rose above the icy expanse and were never covered. These nunataks are distinguishable now by their greater altitudes, steep slopes, jagged ridges, and sharp, frost-riven peaks. The peak southeast of Rust Lake, Mount Freeburn, and Mount Lydonia are examples in the mapped area of the peaks that rose above the Pleistocene ice cap.

For at least a part of the time during which Chichagof Island and most of the rest of southeastern Alaska were buried by the great ice cap, much of the ice that passed over the island probably came from sources to the northeast. The greater part of the outward flow of ice from more extensive source areas on the mainland was probably concentrated along the lines of the present large waterways of southeastern Alaska and the so-called "through valleys" that transect the large islands of the Alexander Archipelago.

The moving ice eroded the surface of the Chichagof mining district as high as its upper level and produced the rounded, smoothed surfaces so common in the area. Some parts of the district were modified much more than others by the passage of the ice, and these parts appear to indicate the places where the ice flow was concentrated. A relatively large amount of ice apparently flowed southwestward past the vicinity of Black Lake. A large part of this ice continued southwestward toward Klag Bay and Lake Anna, where it beveled down the escarpment between the coastal plain and the highland so that the two now merge in that vicinity, without any pronounced break in the slope. Part of the ice was diverted to a westerly direction by the obstruction formed by Doolth Mountain and planed down the escarpment in the vicinity of Kimshan Cove and Williams Hill. Many high areas, such as Doolth Mountain, were at the height of the ice flood thinly covered by the ice cap. At some places the ice of the cap flowed over the escarpment without greatly modifying it and passed out to sea over the coastal plain. The plain has been extensively glaciated, but very little morainal material lies on the part of it now above sea level.

The massive greenstone formations were resistant to erosion by the ice and now form a distinct highland belt lying athwart the direction of the ice flow. Northeast of the highland belt, in the northeastern part of the district, is an interior lowland developed largely on soft, altered granitic rocks. Through this lowland runs the main divide of the island. The lowland may have been excavated, at least partly, through the agency of normal stream erosion before the advent of Pleistocene glaciation. During the time of ice flood the lowland was filled with an accumulation of ice probably relatively static compared to the more rapidly moving higher parts of the ice cap above the basinlike lowland.

After reaching a maximum stage sometime in the Pleistocene epoch the ice cap gradually diminished and separated into smaller ice fields, with valley glaciers reaching from them down valleys toward the sea. Other valley glaciers again, as in the advancing stages, moved down valleys from cirques in the uplands. At the present time all glacial ice has disappeared from the Chichagof district as mapped, but local ice fields and valley glaciers are still present at a few places on Chichagof and Baranof Islands.

Some of the ice that had accumulated at the height of the ice flood in the interior lowland in the northeastern part of the district remained for a long time as a local ice field after the general recession of the ice cap. From it, valley glaciers pushed down Goon Dip and Black Rivers within the district, and down other valleys toward Portlock Harbor, Lisianski Inlet, and Hoonah Sound, largely outside the district. At the same general time other valley glaciers headed in cirques on the higher peaks, such as Mount Freeburn and Mount Lydonia, and on some of the lower mountains. These valley glaciers further shaped the valleys, but most of them did not reach the sea, as is shown by the ending downstream of the U shape of valleys, such as that of Black River, some distance from the coast. The effectiveness of these valley glaciers as agents of erosion is illustrated by deep gouges in bedrock at many places in the district. (See pl. 12, *B*.)

ORE DEPOSITS

For all practical purposes the history of mining in the Chichagof district consists of the histories of its two productive mines, the Chichagoff and the Hirst-Chichagof. As the histories of these mines are recorded in some detail in the mine and prospect descriptions the material is not repeated here, and the reader is referred to pages 87–88 and 102–104.

CHARACTER

Mining in the Chichagof district is confined to gold lodes. The productive deposits are quartz bodies that lie in the steeply dipping fault zones that trend northwestward. The deposits appear more commonly to have been formed at places where large splits diverge from the main faults, or in or adjacent to distinct warps in the faults. Most of the quartz bodies have a very much longer pitch length than either thickness or horizontal length along the fault. Many of the ore shoots pitch steeply southeastward in the southwestward-dipping fault zones.

The quartz bodies are ordinarily associated with fault gouge, crushed wall rock, and slabs and irregular blocks of wall rock. Most of the quartz is of the banded or "ribbon" type. Much crushed quartz and other evidence indicate that postquartz movements have taken place along the faults.

Each of the characteristics of the deposits mentioned in the above two paragraphs is elaborated below.

LOCALIZATION, SIZE, AND POSITION OF THE DEPOSITS

The ore deposits of the district lie in or adjacent to the fault zones. The desirability of as complete information as possible with regard to the location, extent, thickness, splits or branches, and other features of the fault zones is therefore immediately apparent. As pointed out on pages 63–64 there are many large faults in the district and, in spite of many local divergences in their attitude, they may be grouped into a well-defined system, most of the members of which trend in general about N. 50° W. and dip steeply southwest.

The two productive mines have been developed on the Hirst and Chichagof faults, respectively, and to a lesser extent on smaller splits or branches from these large faults. The Chichagof ore shoot, in the Chichagoff mine, for example, lies on the main fault at a major split, and a considerable ore body, known as the "footwall shoot" extended out for some distance on the split. (See pl. 16 and p. 97.) Similarly, in the Hirst-Chichagof mine a split, which locally carried ore, diverges from the Hirst fault at the principal ore shoot. This split was recognized from a point a little below the 1,000 level to a point below the 1,250 level. (See pl. 19, fig. 11, and p. 110.) The No. 2 ore shoot in the Hirst-Chichagof mine lay in the Hirst fault zone at the southeast end of a distinct warp in the fault. The upper part of the principal shoot, which is now being mined at greater depths, lay at the northwest end of the same warp. (See pl. 19.) The ore shoots in the Chichagoff mine appear to occupy a very large warp in the Chichagof fault. This is shown by the steeper dip of the fault in the northwestern part of the mine and in the lower levels. (See pls. 16 and 17.)

The quartz bodies that occupy parts of the fault zones and constitute the ore deposits of the district commonly have a short dimension to be measured in terms of a few feet, an intermediate dimension commonly a few hundred feet in extent, and a long dimension of several hundred to several thousand feet. The short dimension, or thickness, lies across the strike of the fault zone, the intermediate dimension is parallel to the fault and commonly inclined at less than 30° from the horizontal, and the long dimension, or pitch length, is also parallel to the fault and commonly makes an angle of more than 60° with the strike line of the fault measured in the plane of the fault.

Some of the quartz bodies are blunt on their edges and give way abruptly to fault-zone material without quartz. Others taper gradually over several hundred feet.

Most of the deposits pitch southeastward. The position of the longest axis of many of the shoots is very close to the position of the lines of intersection of the bedding planes and the fault that is occupied by the shoot. In the vicinity of the two productive mines of the district the Hirst and Chichagof faults lie at considerable angles to the bedding and foliation.

Some of the known ore shoots reach the surface; others do not. The No. 1 ore shoot of the Hirst-Chichagof mine is the only one so far found in this mine that crops out at the surface, and there it is too low grade to mine. The Golden Gate and the Chichagof shoots of the Chichagoff mine both reached the surface, but the Temby and Rust shoots apparently do not extend that high.

MATERIAL

The deposits are commonly separated from the walls by fault gouge, locally more than a foot thick but elsewhere a paper-thin seam.

Quartz may occupy all or any part of a fault zone at a particular place. Large slabs of graywacke are sometimes mistaken for a bounding wall, commonly the hanging wall, until drilling, crosscutting, or sloughing off of the wall shows more quartz beyond. The fault zone and the quartz contain many irregular blocks and fragments of the wall rocks.

Two principal types of quartz are recognized—massive white quartz and ribbon quartz. The ribbon quartz is more abundant in the ore shoots and is banded in layers from less than an inch to more than a foot thick, separated by silicified, graphitic, shaly graywacke or gouge. In many places the quartz, particularly the ribbon quartz, is crushed, twisted, and cut by small local faults in a most complex manner. (See pl. 25.)

At many localities quartz veinlets extend for considerable distances away from the faults into joints in the wall rocks. These veinlets appear to be particularly abundant in the rock between a split and a main fault. Some of the prospects in the district—for example, the Lillian and Princela—are on veinlets in joints with no visible connection to a large fault. For the most part the veinlets are reported to be of low grade.

In places along the main faults the wall rocks are broken to form a breccia, and the breccia fragments are cemented by quartz. The quartz also commonly appears to have actively replaced much of the original material of the brecciated rock. Such cemented breccia commonly carries only a little gold. An unusual type of quartz-cemented breccia is that present along the fault in the prospect of the New Chichagof Mining Syndicate near Pinta Bay. (See p. 139.) There much of the breccia is made up of limestone and marble fragments. Small flecks of free gold were seen in some of the quartz.

THE ORE AND ITS MINERALOGY

The most complete study of ore from this district so far has been that made on Hirst-Chichagof ore by the American Cyanamid & Chemical Corporation, and the results of that study are freely used in the description of the Hirst-Chichagof mine. (See pp. 114–116.)

At many places in both productive mines the limits of the quartz bodies are the limits of the ore. At other places, particularly in the Chichagoff mine, prospecting has opened up large quartz bodies that contain too little gold to form ore. Most of the ore is of the ribbon type, but some massive quartz has been mined.

The ore was massive and of relatively low grade in the stope on the 800 level of the Hirst-Chichagof mine. A few very high grade pockets were found there, but they were small. From one very small stope in the Chichagoff mine was taken some good but unusual ore, composed of fault gouge, fragments of graywacke, gold, and sulfides, which contained little if any visible quartz.

In addition to quartz the veins contain as gangue calcite, fault gouge, fragments of the wall rocks, and sparse albite, sericite, and apatite. The quartz apparently was originally very coarse-grained, and some massive quartz is still very coarse. At most places the quartz is broken, strained, and locally pulverized, the original texture being thus largely destroyed. Calcite is not abundant but is present in small quantities in most of the quartz. Some of the calcite occurs as irregularly distributed masses or crystals, but much of it is in tiny seams and veinlets that cut the quartz and included fragments of wall rocks.

The metallic minerals include pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, and gold. None of the metallic minerals are abundant. The concentrates over a long period of production from one mine have constituted about 2.21 percent of the ore.

Pyrite is by far the most abundant of the metallic minerals. Even the relative order of abundance of the other minerals is imperfectly known at most places, although sphalerite and chalcopyrite are very rare. Gold is present as free specks in quartz and in the other metallic minerals. The average amount of gold in ore from the Chichagoff mine has been about 1.16 ounces to the ton. The Hirst-Chichagof ore in 1938 was carrying about 1.3 ounces to the ton.

The Hirst-Chichagof ore apparently contains much more arsenopyrite than the Chichagoff ore, in which arsenopyrite is very rare or absent. The suggestion is made that there may be some relation between the large dike at the Hirst-Chichagof mine (see p. 107) and the arsenopyrite in the ore. At several places in the district large quantities of arsenopyrite are associated with dikes. In both the upper and lower tunnels on the Bauer prospect, on Herbert Graves Island,

and at the southernmost of the Woll prospects, on the west side of Lake Anna, dikes and quartz veinlets in them are heavily mineralized with arsenopyrite and pyrite. (See pp. 121–122, 135–136.)

In the Chichagoff mine the presence of galena has long been taken as an indication of high gold content. Galena and sphalerite appear to be unusually abundant at one of the Woll prospects (see p. 123), but the gold content of the material so far found is reported to be low.

GENESIS

After the bedded rocks of the district had been steeply folded, so that they had a general northwesterly trend and a steep southwesterly dip, a shearing force became effective in a direction that was in general about parallel to the strike of the rocks but in the heart of the Chichagof mining district was at an angle of about 30° to the strike. The rocks yielded to this force along countless shear surfaces, but a large part of the movement was accomplished along comparatively thin fault zones, such as the Hirst and Chichagof faults. The shearing force was locally diverted by planes of weakness formed by bedding planes, and much of the force was dissipated by movements along these surfaces. Thus were formed many of the splits from the main faults. Locally split faults were diverted from the main faults across the bedding.

The structural disturbances were probably accompanied by the intrusion of the diorite. The fact that the diorite in the prospect of the New Chichagof Mining Syndicate near Pinta Bay is cut off by a fault zone (see pl. 32) indicates that much of the movement on that fault took place after the intrusion of that particular body of diorite.

The dikes of the district and the quartz bodies are both believed to be related to the granitic rocks. Commonly the dikes appear to have been formed late in the magmatic sequence. Ordinarily also the dikes were earlier in the sequence than the quartz veins, as in the Chichagof mining district, but there was some overlapping. In most places the dikes are cut by the faults and the veins occupy the faults; but at one place in the Hirst-Chichagof mine (see pl. 23) a quartz vein has been split by a dike that was intruded into it. At several other places dikes occupy faults.

The silica-bearing solutions from which the quartz of the veins was deposited apparently traveled upward from depth through the most readily accessible channels. Most of these channels lay along the faults. Locally the solutions spread from the faults into joints in the rocks. Some large and long joints, such as that occupied by the vein at the Lillian and Princela prospect (see p. 132), may have been important solution channels. The length of time during which the rocks were being traversed by hydrothermal silica-bearing solutions was probably considerable. There is at many places abundant evidence of more than one introduction of such solutions. Movement along the faults no doubt took place intermittently during all this time. One of the earliest effects of the solutions apparently was the widespread silicification and carbonatization of large volumes of rock both near and at considerable distances from faults. The dikes appear to have been particularly susceptible to such replacement. Later the solutions were probably more localized in the faults and other channels. Much of the quartz was crushed by repetitive movements on the faults.

Late in the interval of time during which the silica-bearing solutions invaded the rocks the components of the metallic minerals were introduced and were accompanied by some late quartz. These final solutions found channels of access through fractured and crushed earlier quartz. Ordinarily this later material, possibly because of widespread sealing of openings during the preceding silicification, was not able to migrate very far from the main channels. The deposition of the late quartz and metallic minerals in the crushed earlier quartz formed most of the ore bodies. Where the earlier quartz was uncrushed and massive, as in the stope above the 800 level of the Hirst-Chichagof mine, it offered little chance for the introduction of ore-bearing solutions and the deposition of metallic minerals except along widely spaced fractures and hence became low-grade ore.

Where the dike splits the vein on the main level of the Hirst-Chichagof mine very late quartz has filled fractures in both the dike and the earlier quartz. (See pl. 23.) Locally, as in one small stope in the Chicagoff mine in which quartz is rare or absent (see p. 100), the later ore-bearing solutions, because of the complexity of the structural movements, had access to ground not accessible to earlier silica-bearing solutions.

Many of the splits from the main faults leave by curving to a position parallel or nearly parallel to the bedding. Such splitting was generally accompanied by considerable fracturing at and near the line of intersection of the main fault and the split. These fractured zones therefore lie roughly parallel to the intersections of the bedding and the faults and were favored channels for the passage of metal-bearing solutions. Deposition of ore minerals in them resulted in the formation of southeastward-pitching ore bodies. Ore bodies that cannot be definitely tied to a particular split may be related to fractured zones that were formed without appreciable splitting of the main fault.

Some of the splits, such as that at the Chichagof ore shoot in the Chichagoff mine, leave the main fault to cross and not to parallel the bedding. Even the split cited, and hence the fractured zone that became the ore body, joined the main fault along a line in general parallel to the intersection of the fault and the bedding.

Some fractured zones do not parallel the intersections of the bedding planes and the faults. Where structural movements were as widespread, intense, and complex as they were in the Chichagof district it would hardly be expected that a feature as simple as the intersections mentioned above would control without exception the formation of fractured zones. Fractured zones may have developed more readily where the faults and the bedding were at considerable angles. (See p. 64.) In general, however, the intersections exerted a dominant influence on the formation of fractured zones and hence on the channels followed by the ore-forming solutions.

Continued movements on the faults have broken and crushed much of the ore. These post-ore movements are believed to have been of relatively small magnitude. If they had been great it would be expected that the ore on a split and the ore on the main fault would not merge at the split as one continuous body but that one part of the ore would have been separated by the movement from the other part. Furthermore, at such places, particularly in the Chichagoff mine, the joints in the wedge of wall rock between the split and the main fault are commonly filled with numerous quartz veinlets, showing that these places were, as might be expected because of the considerable breaking of the thin wedge by fault movements, particularly favorable for the deposition of vein quartz.

HINTS TO PROSPECTORS

Practically all the ore so far mined in the Chichagof district has come from the Hirst fault or the Chichagof fault. The study of the district shows that similar faults are widespread and that locally the faults split into two or more branches. In general, it appears that the large faults over a considerable area of the district are worthy of much more prospecting than they have received in the past. Of particular interest should be the places where large splits diverge from the main faults. Plate 9, on which are plotted the fault traces recognized on the airplane photographs as well as those seen in the field, should serve as a general guide to the location of the faults. Many faults not shown on this plate no doubt exist and must be found by more careful examination on the ground than was possible during the investigation resulting in the present report.

So far no considerable body of ore has been found to extend continuously on a split from either the Hirst or the Chichagof fault for more than about 180 feet. That ore has been deposited on splits much farther from a main fault is shown by such ore bodies as the one found on the drift from the main-level crosscut in the Chichagoff mine, about 550 feet in the footwall of the Chichagof fault (see p. 95), and the Kay shoot in the Hirst-Chichagof mine (see p. 112). It would appear that much of the prospecting should be concentrated on the main faults and on major splits near main faults. That ore bodies may be present on major splits at considerable distances from a main fault seems possible but is not yet proved.[26]

The ore deposits that have so far been productive lie on faults in the graywacke not far stratigraphically above the underlying schist. Whether or not certain physical or chemical characteristics of the graywacke cause the ore to be localized in this formation is not known. The graywacke is less metamorphosed than the underlying rocks and probably is more brittle than most of them. Therefore the movements along the faults may have developed more open fractures in the graywacke than in the generally less brittle older rocks. That some fractured zones along faults in the older rocks have been mineralized is proved by the free gold contained in limestone breccia of the limestone formation at the New Chichagof Mining Syndicate's prospect and the Golden Hand prospects (see pp. 136–139). So far as structure is concerned the area of rocks older than the graywacke should probably be considered almost as favorable for prospecting as the graywacke, unless further work shows that the faults through the older rocks were not open enough to give access to ore-bearing solutions.

Northeastward from the Hirst and Chichagof faults lies the granite heart of the island. When the ore deposits were being formed solutions traversing fractures at a given level in the earth's crust in the zone between the Hirst and Chichagof faults and the batholith itself were probably hotter than those traversing the faults at the same level. Similarly the solutions traversing fractures farther southwest were probably colder unless they were affected by the albite granite and granodiorite of the southwestern part of the district. Whether or not distance from the batholithic rocks was a factor in localizing the deposits is not definitely known. Theoretically the distance from the batholith, within limits, should not be very important, because it would merely mean that deposits farther away would be formed earlier than those nearer the batholith. Furthermore, the fact that ore shoots in

[26] The possibility of finding ore bodies on major splits at long distances from a main fault appears to be greatly increased by development work done on the Kay ore shoot of the Hirst-Chichagof mine in the summer of 1939. (See pl. 19.) A winze was sunk 150 feet down the dip near the northwest end of the shoot. A level driven southeast from the winze has disclosed that the Kay shoot at that depth is longer, wider, and richer than on the main level. On the 150 level the shoot is narrow but of minable width, is more than 150 feet long, and carries ore of unusually high value. In the fall of 1939 the winze was being sunk farther, and it was planned to open the Kay shoot on the 300 level.

the two productive mines extend over a vertical range of several thousand feet without any change in mineralogy or texture indicates that distance from the batholith probably was not influential as a factor in ore deposition. Therefore, the areas northeast and southwest of the Hirst and Chichagof faults should not be ruled out as unlikely areas for prospecting, on the basis of distance from the batholithic rocks.

In general the strike of the bedding and foliation and the strike of the faults are about parallel, but there are many local divergences. Whether or not this is true of the dips is not known, because the dips of the faults are not generally known except in the mines. In the vicinity of the productive mines, however, there is a considerable divergence between the attitude of the faults and the bedding and foliation. Moreover the intersections of the faults and the bedding and foliation planes apparently have had a marked influence on the emplacement of the ore bodies. Prospectors should therefore keep in mind both the attitude of the faults being prospected and the attitude of the bedding in the vicinity. A question yet to be answered is whether or not ore shoots have formed in places where the faults and the beds are essentially parallel.

The absence of quartz on a fault that is being prospected is no indication that a valuable ore body may not lie within a short distance. Of the shoots so far developed in the district only three—the Chichagof and Golden Gate shoots of the Chichagoff mine and the No. 1 shoot of the Hirst-Chichagof mine—cropped out at the surface. Where the last-mentioned shoot comes to the surface it is of too low grade to mine.

The facts that the ore shoots of the district are sporadically distributed in the fault zones and that a shoot may or may not reach the surface mean that much of the prospecting of the faults must be of the relatively expensive underground type. This practically excludes the small-scale prospector from the finding and subsequent development of any ore bodies except those that crop out.

Well-financed individuals or groups that are willing to incur relatively great risks for the sake of large prospective returns might justifiably go to considerable expense to open fault zones at likely places, such as splits or warps in the fault, in the hope of picking up ore bodies that do not reach the surface.

At many places the diamond drill might be effectively employed for preliminary prospecting, to be followed, if the drilling results appeared to justify it, by more costly underground work. The diamond drill was used in the summer of 1938 by the Hirst-Chichagof Mining Co. for preliminary prospecting of the Hodson claims. (See p. 117.)

In the underground prospecting of a fault zone occasional crosscuts are desirable into both the hanging wall and the footwall. The quartz bodies may occupy all or any part of the fault zone, and the zones are in many places much thicker than the width of a drift. The crosscuts also will help to identify splits from the main fault. It is very easy in underground work to get off on a split in the thought that it is the main fault. Under some circumstances the same information as would be furnished by a crosscut is obtained much more easily and cheaply by a relatively short diamond-drill hole.

MINES AND PROSPECTS

In the following pages are described the mines and prospects of the district that were examined during the course of the survey resulting in this report. All properties within the district as mapped are considered prospects except the three from which appreciable quantities of gold have been produced—the Chichagoff mine, the Hirst-Chichagof mine, and the Alaska Chichagof Mining Co.'s mine. Because of the shortness of time available for the work some prospects were not examined and hence are not included in the descriptions; others, for the same reason, were visited only briefly, and the descriptions are necessarily short. The omission of a description or a short description is not intended to discredit the value of a prospect and should not be so interpreted except where the wording of the description is unmistakable.

First the two principal mines of the district are described, and next the prospects owned or controlled by the companies that own those mines. The general order of treatment of the remaining properties within the district is geographic from south to north. All the properties in the district that are described are shown on plate 1.

Plate 14 is a claim map of the district that has been compiled from various sources, but principally from plats made by Frank A. Metcalf, Juneau engineer. No responsibility is assumed for the validity of the claims shown nor for their correct locations. Many claims are not shown on plate 14, because their locations are not definitely known.

A few mines and prospects outside the limits of the district as mapped are described in a final section.

MINES AND PROSPECTS IN THE DISTRICT

CHICHAGOFF MINE

The Chichagoff mine lies near the head of Klag Bay on the southeast side of Doolth Mountain. It is owned by the Chichagoff Mining Co. The locations of the claims owned or held by this company and their relation to other mining claims of the vicinity are shown on plate 14.

HISTORY

The following account of the history of the Chichagoff mine is supplied principally by James L. Freeburn.

The first ore discovered at Chichagof was float found in 1905 by two natives, John Newell and Ralph Young, along a small creek that enters the bay at the site of the camp. The Indians took samples of the quartz to Judge Edward DeGroff, of Sitka. Judge DeGroff financed staking and prospecting and later obtained the interests of Young and Newell as well as of three white men, Bach, Gamble, and Kelly, who had returned from Sitka with the discoverers to prospect. With these five men Judge DeGroff had formed the Chichagoff Gold Mining Co.

Early prospecting yielded between \$500 and \$600 worth of gold from float, and in 1906 the vein was found in place. This was the discovery of the Chichagof ore shoot. (See pl. 15.) The upper tunnel on the ore shoot was started, and about \$2,000 worth of gold was produced. With the proceeds were purchased two mortars, plates, and Wilfley concentrators.

Meanwhile, in 1906, the Golden Gate property had been discovered and located by Alexander Pihl, Joe Simmons, and W. P. Mills. Pihl's interest was bought by W. H. Topscott. These men bonded the property to James Casey and partner, who drove the Golden Gate No. 1 tunnel. (See pls. 16 and 17.) On Casey's death the property reverted to Mills and Simmons, who installed the 10-stamp Golden Gate mill.

In 1909 the DeGroff and Golden Gate interests together put up the first power plant on Sister Lake. The same year the Golden Gate mine was stoped above the Golden Gate No. 1 tunnel, and in 1910 the Golden Gate No. 2 tunnel was started. Also by 1909 the DeGroff interests had added a Lane slow-speed mill.

In 1909 the Chichagoff property was examined by James L. Freeburn. On the strength of his favorable report W. R. Rust, Hugh C. Wallace, Henry Bratnober, and Captain Jarvis bought a three-quarter interest in the property for about \$140,000 and formed the Chichagoff Mining Co. Mrs. Lena DeGroff, widow of Judge DeGroff, retained the other quarter interest. Mr. Freeburn was put in charge of operations.

In 1910 the Chichagoff Mining Co. optioned the Golden Gate property and in 1911 took it over. Meanwhile the Bratnober and Jarvis interests had been purchased by Rust and Wallace.

By April 1913 the company had driven the main level to cut the Golden Gate ore shoot, had sunk the No. 1 shaft on the Chichagof ore shoot to the 1000 level, had driven the Golden Gate No. 3 and No. 4 tunnels, and had done considerable stoping on the Golden Gate ore shoot.

The Golden Gate upper tunnels were closed in 1915, and early in that year the aerial tram from those tunnels to the Golden Gate mill on the beach was abandoned.

In 1915 the mill was expanded to 15 stamps, and a tube mill was installed. In 1916 flotation machines were added to the mill. A tunnel from Rust Lake to provide water for power was finished in 1917, and the third generator was started in 1919. The flow sheet was again changed in 1920. By 1922 the mine was developed to the 900 level, and sinking toward the lower levels was begun. The 1100 level was reached in November 1922.

In the fall of 1923 the Chichagoff Development Co. took a lease and bond on the Chichagoff mine and began to operate. G. T. Jackson and W. A. Castleton were in charge. About 1927 this company was reorganized as the Chichagoff Mines, Ltd. Castleton maintained an interest in the reorganized company, and Jackson was retained as a consultant.

In February 1931 James L. Freeburn and Arthur Rust, son of W. R. Rust, took over the mine and formed the Chichagoff Mining Co. After 1931 the company developed and stoped principally below the 1200 level, but some stoping was done on higher levels.

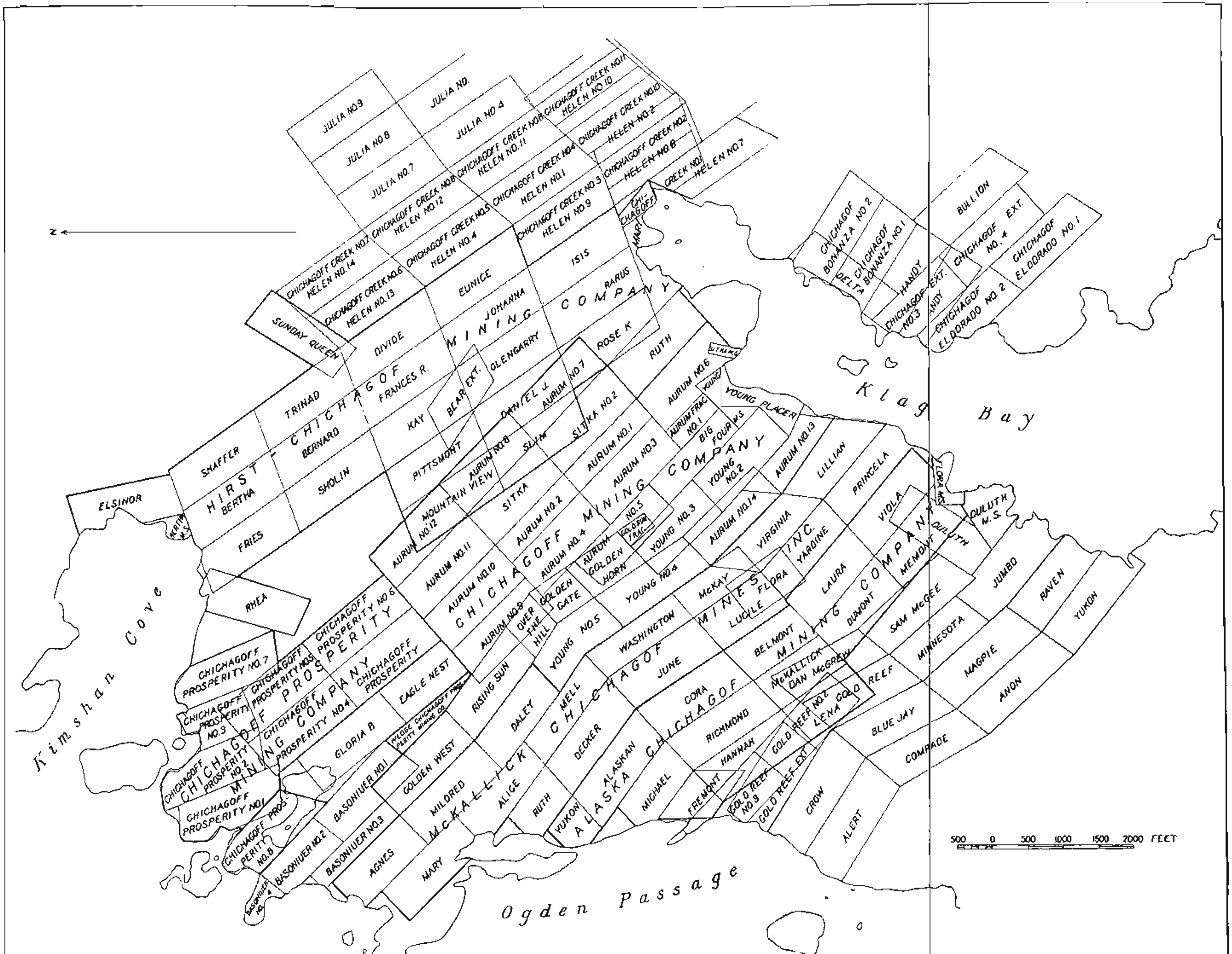
When the mine was visited in 1938 stoping was going on between the 2100 and 2000 levels.

It is understood that the company was reorganized late in 1938 or in 1939. In the summer of 1939 John D. Littlepage was in charge of operations.

PRODUCTION

The tables following have been prepared from information furnished to the Geological Survey over a long period of years by the Chichagoff Mining Co. and its forerunners. The Chichagoff Mining Co. has kindly waived the confidential condition under which the data were originally furnished to permit publication of the detailed figures.

Table 1 shows that the mine, including the Golden Gate, had produced through 1938 a total of $13,784,710 worth of gold.



SKETCH MAP SHOWING LOCATION OF CERTAIN CLAIMS IN THE CHICHAGOF MINING DISTRICT

Copied from original map by Frank Metcalf, of Juneau, with spelling of claim and company names as shown thereon.

TABLE 1.—*Gold produced at the Chichagoff mine, 1906–38*

Year	Ore milled (tons)	Concentrate sold (tons)	Value of gold		
			From mill	From concentrates	Total
1906					$7,250
1907	1,353				66,072
1908	2,071	65	$37,395	$19,827	57,722
1909					20,500
1910	4,283		126,889	34,029	160,918
1911	10,577	258	135,834	27,603	163,437
1912	22,290	625	186,765	49,868	236,633
1913	22,000	644	180,629	54,355	234,984
1914	24,584	681	252,330	60,327	312,657
1915	33,850	563	844,324	75,915	920,239
1916	36,822		740,948	74,611	815,559
1917	38,794		812,744	4,920	817,664
1918	33,978	812	1,132,242	112,196	1,244,438
1919	42,187	1,084	1,697,907	143,906	1,841,813
1920	33,243	820	1,576,092	141,326	1,717,418
1921	33,855	1,313	1,336,676	138,030	1,474,706
1922	38,307	1,093	892,225	102,943	995,168
1923	11,079	460	468,387	65,355	533,742
1924	38,267	433	291,607	25,869	317,476
1925	62,350	481	308,200	30,100	338,300
1926	25,906	428			351,913
1927					1,450
1928	347				2,503
1929	1,971				25,445
1930					9,060
1931					641
1932					269,200
1933	4,986	86	73,781	11,333	85,114
1934					163,030
1935	12,854	138	135,813	11,554	147,367
1936					222,691
1937					89,600
1938					140,000
					13,784,710

From the figures for those years for which the quantity of ore milled and the total value of the gold produced are available it is possible to calculate what is apparently a good average figure for the value of the ore from the Chichagoff mine. From 535,954 tons of ore was recovered $12,861,288 worth of gold, and the average value was therefore nearly $24 a ton. On the basis of a gold price of $20.67 an ounce through 1933 and a price of $35 an ounce after 1933 the Chichagoff ore in general appears to have carried 1.16 ounces to the ton. By the same method the average ore is found to have yielded about 2.21 percent of concentrates. The average value of the concentrates was $112.03 a ton.

From the columns of table 1 that show tons of ore milled and value of gold from the mill and based on a gold price of $20.67 an ounce through 1933 and $35 an ounce after 1933, the average plate recovery has been about $22.18 or 1.067 ounces to the ton.

Table 2 contains data in regard to silver recovered from ore from the Chichagoff mine.

TABLE 2.—*Silver produced at the Chichagoff mine, 1910–36*

Year	Quantity (ounces)		Value		
	From mill	From concentrates	From mill	From concentrates	Total
1910	(1)	(1)	$587	$353	$940
1911	1,321	736	698	382	1,080
1912	2,080	1,395	1,276	835	2,111
1913	1,916	1,135	1,167	676	1,843
1914	2,639	1,267	1,459	701	2,160
1915	9,403	2,161	4,789	1,024	5,863
1916	8,120	3,204	5,343	2,108	7,451
1917	7,597	3,943	5,850	3,036	8,886
1918	10,923	5,172	10,825	5,154	15,979
1919	16,910	7,494	19,407	8,525	27,932
1920	15,296	7,340	17,292	7,381	24,673
1921	13,395	8,219	13,395	8,219	21,614
1922	8,746	7,246	8,746	7,246	15,992
1923	4,635	4,460	3,801	3,657	7,458
1924	3,656	1,213	2,449	813	3,262
1925	3,710	1,835	2,767	1,266	4,033
1926	[2] 4,860		(1)	(1)	3,232
1927	(1)	(1)	(1)	(1)	(1)
1928	(1)	(1)	(1)	(1)	16
1929	[2] 358		(1)	(1)	190
1930	[2] 97		(1)	(1)	39
1931	(1)	(1)	(1)	(1)	(1)
1932	(1)	(1)	(1)	(1)	(1)
1933	(1)	(1)	279	802	1,081
1934	(1)	(1)	(1)	(1)	(1)
1935	891	569	657	420	1,077
1936	[2] 1,913		(1)	(1)	1,028
					157,940

[1] Record not available. Figures for silver before 1910 not available.
[2] Combined quantity of silver from mill and concentrates.

Because of the gaps in the record the total value of the silver produced from the mine is more than that shown in table 2. For the years in which the record shows tons of ore and ounces of silver the Chichagoff ore carried an average of 0.344 ounce of silver to the ton. This is probably a good average figure for the silver content of the ore.

From the columns of tables 1 and 2 that show tons of ore milled and ounces of silver from the mill, the average silver content recovered in the mill has been about 0.225 ounce per ton. From the average plate recovery of gold and of silver, and on the assumption of a dross content in the bullion of 0.01, the average fineness of the bullion is calculated as about 818 parts of gold and 172 parts of silver per 1,000.

The quantity of ore milled, the average thickness of the vein, and the assay value per ton for stopes and parts of stopes throughout a large part of the mine above the 1100 level are shown on plate 15.

DEVELOPMENT

The portal of the main level of the mine is about 60 feet above the beach, a short distance from the mine dock. The main level is a crosscut for about 440 feet and thence onward is a drift on the Chichagof fault to the face, at a distance of 4,987 feet from the portal. The extent of the underground work is shown on plates 16 and 17.

Above the main level are four other tunnels, the Golden Gate tunnels Nos. 1, 2, 3, and 4, at 1,127, 1,041, 886, and 652 feet, respectively, above sea level. Some of the ore from the upper levels of the Golden Gate part of the mine was carried by an aerial tram, which started near the portal of the Golden Gate No. 4 tunnel, to the Golden Gate mill, a short distance north of the Chichagoff mill, near the beach. Most of the ore, however, has been trammed through the main tunnel to the Chichagoff mill. Neither the aerial tram nor the Golden Gate mill has been used for many years, and both are now in total disrepair.

The No. 1 shaft is an inclined shaft from the main level, about 800 feet from the portal, to a vertical depth of 920 feet below the collar. In the summer of 1938 the shaft was inaccessible below the first level below the main level, but deeper levels in that part of the mine could be reached through raises then used as airways and through the drift from the No. 2 shaft on the 400 level.

The No. 2 shaft collar is on the main level about 2,530 feet from the portal. This shaft reaches the 700 level (887 feet below the main level) and the 100, 200, 300, 400, 500, 600, and 700 levels are turned from it. The shaft is inclined and is a short distance in the footwall of the Chichagof fault. At the 700 level the No. 2 shaft is in the fault. The No. 1 and No. 2 shafts are connected by the drift on the 400 level, but this and the main level constitute the only underground connections between the two parts of the mine.

The main level in 1938 was inaccessible northwest of a point about 250 feet northwest of the No. 2 shaft. The 100, 200, and 300 levels were not accessible at all. The 400 level was accessible from the No. 2 shaft for about 1,000 feet northwest and to and beyond the No. 1 shaft on the southeast. The 500 level was open northwestward to the face. The 600 level was accessible for about 1,300 feet northwest from the shaft. The 700 level was caved a short distance southeast of the No. 2 shaft but was still open on the northwest to a point within about 150 feet of the face.

Levels below the 700 level were reached through the No. 3 shaft to the 1200 level, the No. 4 shaft from the 1200 level to the 1900 level, and the No. 6 shaft from the 1900 level to the 2100 level, the bottom level of the mine in 1938 (2,684 feet in vertical depth below the main level).

The No. 6 shaft was sunk to the 2200 level in 1939, after the mine was examined by the Geological Survey. The 2200 level and some other new developments on the 1600 and 1800 levels are shown on plate 16 from information furnished by John D. Littlepage.

The No. 3 shaft is an inclined shaft in the footwall. Its collar is about 750 feet northwest of the bottom of the No. 2 shaft. The No. 4 shaft is about 250 feet southeast of the No. 3 shaft. It starts on the Chichagof fault, but at the 1900 level it lies about 160 feet from the fault, in the hanging wall. The No. 5 shaft was an incline on the vein between the 1800 and 2000 levels. It has now been destroyed by stoping. The No. 6 shaft is vertical and connects the 1900 and 2200 levels in the hanging wall.

All the levels below the 700 level were partly accessible in 1938, either from the various shafts or through air raises; and the lower, newer levels, were almost completely open.

All hoisting and pumping from the deeper levels is done through the No. 6, No. 4, No. 3, and No. 2 shafts successively. This complex means of hoisting with attendant handling and tramming between shafts has been an expensive item in the operation of the mine. The proper maintenance of inclined shafts, on or near the main fault of the mine, has also been difficult and expensive. All hoisting is done by air. Tramming is done by hand below the main level and by mules on the main level.

The method of ventilating the lower levels in 1938 is worthy of mention. No fans were used. The air entered the main level and passed down the No. 1 shaft and through raises near the No. 1 shaft to the 400 level. It was carried along this level northwest to and beyond the No. 2 shaft and passed through raises northwest of the No. 2 and No. 3 shafts to the 1000 level. The air then traveled southeast along the 1000 level past the No. 3 shaft to the southeast face of the level. Thence the air passed down raises, across a lower level past the No. 4 shaft, and down other raises into the lower workings. The updraft went through the No. 4, No. 3, and No. 2 shafts to the main level and thence up the long raise to the Golden Gate No. 4 tunnel and out that tunnel. The use of the shafts for exhausted air has resulted in considerable troublesome condensation in the shafts.

POWER PLANT

Power for the Chichagoff mine and mill and some of the power for the Hirst-Chichagof mine and mill are obtained from a hydroelectric plant on Sister Lake. The 6,600-volt power line from the plant to Chichagof is 4½ miles long. The water for the plant is obtained from Rust Lake through a tunnel about 1,000 feet long and an 1,800-foot pipe line. The tunnel taps the lake about 85 feet below the surface. The power units consist of two 300-kilovolt-ampere generators and one 127½-kilovolt-ampere generator. Each of the larger generators is turned by a 500-horsepower Pelton wheel and the smaller one by a 250-horsepower turbine.

SURFACE EQUIPMENT

The surface equipment includes houses for families, a store, docks, a powerboat, bunk houses, shower and dry rooms, a compressor house, an assay office, a mill, and a sawmill. (See pl. 7, *A*.)

In 1938 the Chichagoff mill was handling in three shifts between 60 and 70 tons a day. The capacity was larger when screens with larger openings than those now employed were used at the stamps. The following mill flow was reported: The ore is crushed to 2 inches by a jaw breaker and passes thence to four 5-stamp batteries. Each stamp weighs 1,000 pounds. The stamp product passes 36-mesh screens to three 5- by 4-foot amalgamating plates. A Dorr drag classifier follows the plates, and the oversize goes to a 5- by 14-foot tube mill. The mill discharge passes to another classifier, and the oversize is returned to the tube mill. The fines from the classifier are elevated to Callow cones and then go to another set of amalgamating plates. The plate tailings pass to ten No. 3 Deister slime tables, which make shipping concentrates. The table middlings are returned to the tube mill for regrinding. The table tailings are discarded.

GEOLOGY

ROCKS

Except for four very small dikes, the only wall rocks in the Chichagoff mine are massive graywacke and shaly graywacke. Of these shaly graywacke is by far the more abundant (see pl. 16), particularly close to the Chichagof fault, on which the mine is principally opened.

In this mine, as in the Hirst-Chichagof mine and at other places, the distinction between the two types of graywacke is in many places very difficult to draw. Consequently remapping of the mine probably would result in placing the contacts at slightly different places. The lack of definite horizon markers, the structural complexity in the mine, and the possibility that through shearing massive graywacke may become shaly make it impossible to trace from place to place on one level, or from level to level, horizons or zones of either massive or shaly rock. The distribution as shown on plate 16 simply indicates places where the rock in general appeared massive and where it in general appeared shaly. On the isometric drawing (pl. 17) both types have been grouped together and no distinction is made.

So far as the meager information available indicates, the rock away from the Chichagof fault is more massive than that near the fault. For example the two long footwall crosscuts, one on the main level and the other on the 400 level, are largely in massive rock. Shorter crosscuts into the hanging wall also appear to indicate rock more massive than that near the main fault. Massive graywacke is more abundant than shaly in the levels below the 1800 level. In general, even where both walls are mapped as shaly graywacke, the footwall is somewhat more massive than the hanging wall.

Dikes are common in the vicinity of the Chichagoff mine. Of the four found in the mine, one is on the main level not far beyond the No. 1 shaft, and the other three are on the 1700 level. The dike on the main level is cut off by a split from the main fault. It lies in the footwall of the main fault. The three on the 1700 level are all in the hanging wall, and all are cut off by the fault.

STRUCTURE

The dip and strike of the rocks of both the hanging wall and the footwall in the mine are remarkably uniform, even adjacent to the fault. Some divergences from the average attitude are present, but in most places these are not great. The average of 125 observations of strike in the mine is N. 58+° W., and the average of the corresponding dip observations is 68−° SW. The rocks therefore trend a little more northerly and dip a little more steeply than those at the Hirst-Chichagof mine. (See pp. 60 and 107.)

The Chichagoff mine, which has opened the fault for 4,750 feet horizontally and through a vertical range of about 3,950 feet, is developed on a small part of the fault only.

One of the most conspicuous structural features of the mine is the large warp or twist in the Chichagof fault that is partly opened by the underground workings. All the levels converge northward (see pl. 16), showing that the fault is steeper in that direction. Similarly the fault steepens downward from the 1400 level to the 2000 level. Below the 2000 level the fault, as now exposed, passes through the vertical and dips northeast.

All the levels that reach the surface—the main level and the Golden Gate levels Nos. 1, 2, 3, and 4—start in the footwall and are driven to intersect the Chichagof fault at an angle. (See pls. 16 and 17.)

The fault zone ranges in thickness from a few inches to as much as 20 feet, but at most places the thickness is between 2 and 4 feet. In general the fault appears better defined than the Hirst fault, and places are rare where the fault is dispersed through wide zones in which the individual shear surfaces are weak. The footwall, as in the Hirst-Chichagof mine, is commonly the better-defined wall.

The crosscuts into the footwall on the main and 400 levels were driven in the expectation of finding other faults, similar to the Chichagof fault, which, it was hoped, would be ore-bearing. Prospects on Doolth Mountain on the Sitka and other claims indicated that such faults probably existed. After cutting a large number of weak faults the main-level crosscut, at 550 feet from the Chichagof fault, intersected a relatively strong fault, and considerable drifting was done on it. A shaft was sunk to the 100 level and some ore was mined.

Between about 810 and about 870 feet from the Chichagof fault the crosscut passed through a zone in which there are many closely spaced faults. This zone has not been prospected by drifting or sinking.

A relatively strong fault zone was encountered at 1,380 feet from the Chichagof fault, and another, called the Munly fault, near the face of the crosscut. On the Munly fault about 50 feet of drifting has been done, but no ore was discovered. This fault may be the same as that exposed in the prospects on the Sitka claims. (See p. 101.)

The crosscut on the 400 level has cut some faults, on the strongest of which a short drift has been driven. This probably is the downward extension of the fault cut on the main level at 550 feet from the Chichagof fault.

Splits from the Chichagof fault are common, as they are from all the known faults of the district. They are of both types described on pages 64 and 165, namely, into the bedding and against the bedding. The splits that trend against the bedding appear to be more common than those that trend into or with the bedding, whereas the converse may be true in the Hirst-Chichagof mine.

Plate 9 appears to show that the faults cut by the footwall crosscut are in reality splits from the Chichagof fault and apparently join that fault on the surface in the vicinity of the lake on the peninsula between the head of Klag Bay and the north end of Lake Anna. If the fault cut at 550 feet from the Chichagof fault on the main level is the same as the one cut at 340 feet from the Chichagof fault on the 400 level, then a convergence in depth toward the Chichagof fault is indicated. By projection it should join the Chichagof fault near the 1000 level of the mine. The 1000 level has not been driven far enough southeastward from the No. 3 shaft to expose the intersection at a place directly down the dip of the main fault under the 400 level crosscut, if the intersection is there.

The most conspicuous split in the mine is the complicated one at the Chichagof ore shoot about 780 feet in from the portal of the main level. The principal split trends against the bedding and diverges from the main fault into the footwall at an angle that ranges on the horizontal projection from about 10° to about 20°. Between the main fault and the principal split are several smaller splits. The split crops out on the surface and has been traced on each level to the 400 level and stoped to the 200 level. On the main level the split has been followed for 300 feet and on the 400 level for 360 feet. The intersection between the split and the main fault pitches steeply southeast.

Another split, also against the bedding, is exposed by two short crosscuts about 90 feet apart on the 700 level, between the No. 2 and No. 3 shafts. This split leads into the hanging wall and carries about 20 feet of quartz, but the quartz is reported to be barren. Whether or not auriferous quartz bodies are present in a southeasterly direction along the split from the crosscuts is not known.

Splits carrying barren or nearly barren quartz are present in most of the levels below the 1400 level of the mine. (See pl. 16.)

In addition to the splits mentioned many smaller ones both with and against the bedding were seen. These have not been explored by mine workings.

The records kept by the operators show that at some places in the mine, particularly in the stopes on the lower levels, the vein itself is split into a hanging wall and a footwall shoot. The exact locations of these places, the amount of divergence between the two shoots, the characteristics of the material between the shoots, and other features are not known to the authors.

Striae on the fault surface throughout the mine indicate that at least the latest movement on the fault was southeastward and down at an angle of about 20° on the footwall side. Thus the latest movement was similar to that on the Hirst fault and also on the faults at most of the prospects in the district.

ORE BODIES

Five principal ore shoots are recognized in the Chichagoff mine. Like the other ore bodies of the district these are masses of quartz that lie in or near the principal fault. The subdivision into five shoots is somewhat arbitrary, because some of the shoots were separated into more than one part by barren quartz zones and because some different shoots were connected by narrow zones of ore. In addition to the main shoots several smaller ore bodies have been mined.

The location and size of the shoots in part of the mine are illustrated on plate 15. Other data, such as thickness, quantity of ore mined, and value are given for some of the stopes. Plate 17 gives a three-dimensional impression of the Chichagof fault in the Chichagoff mine and of the size and positions of the ore shoots.

The five principal ore shoots of the mine are the Chichagof, Golden-Gate, Temby, Rust, and Temby-Rust shoots. The shoots have a general southeasterly pitch of about 70° There appears to be a remarkable coincidence between the elongation of the shoots and the direction and pitch of the intersections of the main fault and the bedding planes.

The Chichagof ore shoot occupies parts of both the Chichagof fault and the principal splits from it on the main level about 800 feet from the portal. The shoot is subdivided into two parts. That on the split, known as the footwall shoot, was not mined below the 200 level, and the authors do not know whether or not it extends deeper. The drift on the split on the 400 level shows that it does not reach to that depth. At about the 300 level the pitch of the Chichagof shoot steepens and it divides into two parts, both in the main fault zone. (See pl. 15.) The southern part apparently was of much lower tenor than the ore higher on the Chichagof shoot. The southern part was mined to the 500 level, but whether or not the lower levels, which are now inaccessible, have quartz is not known to the authors. The northern part of the shoot was mined to the 400 level. It averaged 1.74 ounces to the ton as against 0.40 ounce to the ton for the southern part below the 200 level. What appears to be the downward extension of the northern part of the shoot was found on the 500 level driven from the No. 1 shaft and on the 700 level driven southeastward from the No. 2 shaft. If these are indeed parts of the northern part of the shoot, then that part of the shoot pitches northwest. Below the 400 level this part of the shoot apparently is of too low grade to mine.

The Golden Gate is a composite ore shoot that has been mined from the surface to a depth a little below the 400 level. The Hills and Riendeau shoots are considered parts of the Golden Gate shoot. The general pitch of the shoot appears to be almost directly down the dip of the Chichagof fault. Considerable quartz is present on the 500, 600, and 700 levels below the mined part of the Golden Gate shoot. Similarly, a mineralized zone is reported on the 1100 level directly down the dip below the bottom of the No. 2 shaft. This low-grade quartz probably is the downward extension of the Golden Gate shoot.

The Temby and the Rust ore shoots have been connected by stoping at several places. These two large shoots have a distinct southeasterly pitch. Neither shoot has been mined to the surface. The stoping stopped a few hundred feet above the main level, and that part of the mine is now inaccessible; therefore it is not known whether or not the shoots continue higher. The fact that stoping was not continued indicates that if the shoots continue higher they were of too low grade to mine.

Below the 1100 level ore mined has been taken from smaller sporadic shoots, so that the limits of the Temby and Rust shoots could not be definitely determined. The scattered stopes below the 1100 level are therefore grouped into the Temby-Rust shoot, which is directly down the pitch from the Temby and Rust shoots. Considerable quartz shows on the deeper levels, but much of it is of too low grade to mine, partly owing to higher costs of mining at the greater depths.

In general the shoots in the Chichagoff mine have a much greater pitch length than horizontal extent. The thicknesses as indicated from stope widths range in general from about 2 feet to about 8 feet, and at many places the average thickness of stope is between 4 and 6 feet. Locally ore more than 15 feet thick has been mined, but such a thickness is very unusual.

The quartz bodies are lenticular and pinch and swell both along the strike of the fault and down the dip. In some places the quartz occupies the whole fault zone, in others only part of it. Most of the quartz constitutes ore, but particularly in the lower levels of the mine, there are considerable quantities of quartz that carry too little gold to be regarded as ore.

Evidences of postquartz faulting are widespread in the mine. They consist of banded vein matter, crushed quartz, faults in the vein but in general parallel to it, and quartz veinlets in the walls that are cut off against the fault.

Some of the ore bodies are blunt at their ends; others thin out gradually. In the latter the stope limits are largely determined by the places where the quartz becomes too thin to be profitably mined.

Figure 8 illustrates the southeast end of a quartz body on the 2100 level of the mine. Figure 9 was drawn from a photograph reproduced in an earlier publication.[27] It illustrates the appearance of a thick rich part of the Temby ore shoot and shows typical banded or ribbon quartz. The darker layers are graphitic gouge and sheared graywacke. Locally the quartz is white and massive with no graphitic layers. Apparently these parts of the vein were not disturbed by structural movements during deposition. Perhaps any

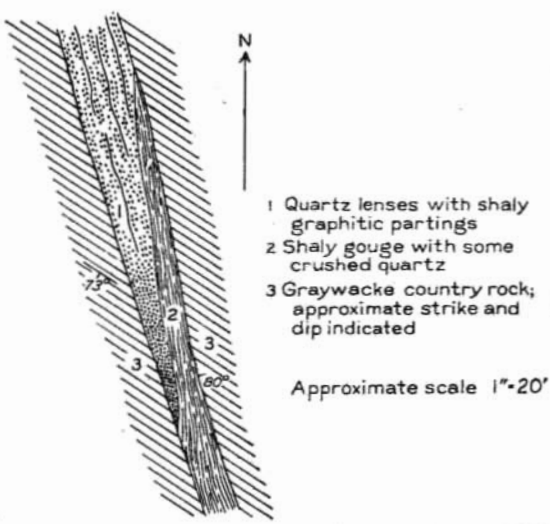


FIGURE 8.—Sketch of southeast end of ore body on 2100 level of the Chichagoff mine.

[27] Bauman, H. N., Jr., Mining and milling rich gold ore on Chicagof Island; Eng. and Min. Jour-Press, vol. 117, No. 22, p. 879, May 31, 1924.

movement during and after deposition at the places where the quartz is massive occurred on one or both walls without disturbing the vein quartz.

Quartz veinlets that fill joints in the wall rocks of the vein are very common in the Chichagoff mine, more so than in the Hirst-Chichagof mine. Many of the veinlets were cut off by postquartz movements along the Chichagof fault and show drag that indicates, like the striae and plucking pits, that the later movements trended southeastward on the footwall side.

Locally some zones contain more than 50 percent of quartz veinlets that run in all directions through the wall rock. Such a zone is exposed along the crosscut on the 1900 level and extends to a point about 35 feet from the vein. In this zone the graywacke is very pyritous. Another such zone lies between the main fault and a large split on the 1800 level about 100 feet to the northwest along the vein from the crosscut.

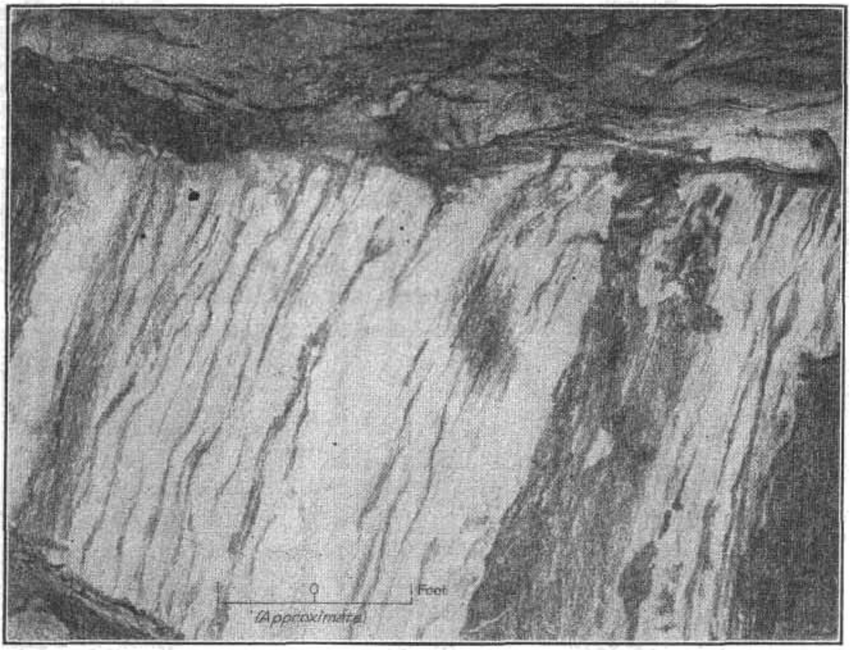


FIGURE 9.—Sketch of quartz vein at Temby ore shoot, Chichagoff mine.

ORE MINERALS

The mineralogy of the ore from the Chichagoff mine is not known in as much detail as that of the ore of the Hirst-Chichagof mine. However, the information available indicates that the ores are similar—in fact, probably almost identical.

The metallic minerals seen in the ore were pyrite, arsenopyrite, and gold. Galena also is known to be present. Pyrite is the most abundant sulfide except where it is locally subordinate in amount to arsenopyrite.

A peculiar type of ore was mined from a small stope above the 1100 level several hundred feet southeast of the No. 3 shaft. This ore, so far as is known, was unique for the district. It consisted of fault gouge, fragments of graywacke, gold, and sulfides, with little if any visible quartz.

Pyrite is the most abundant metallic mineral in the ore, but it forms only a very small percentage of the ore as a whole. It is commonly in well-formed, striated cubes as much as about a quarter of an inch in diameter. It is much more abundant in the wall rocks of the vein and in the gouge and sheared graywacke between vein layers than it is in the vein quartz itself. A few specimens show pyrite accompanying quartz and calcite in tiny seams that transect earlier quartz.

Arsenopyrite was noted in small crystals as an abundant constituent of the veinlets and graywacke in the veinlet zone exposed by the crosscut on the 1900 level crosscut near the collar of the No. 6 shaft. It is much more abundant in the graywacke than in the quartz of the veinlets. So far as is known it has not been reported in earlier publications. Arsenopyrite apparently in most places is very rare or absent. It is not as abundant in the Chichagoff ore as it is in the Hirst-Chichagof ore. (See p. 115.)

Galena is a very minor constituent of the ore, but its presence is taken as a good indicator of high gold content. Both Knopf[28] and Baumann[29] point out galena as a certain indicator of high gold content. Knopf says further that the galena is as a rule intergrown with pyrite, but no information on this point was obtained during the survey resulting in this report.

According to Knopf,[29a] "the gold is found both as isolated particles embedded in the quartz and as particles intergrown with the sulphides." The age relations between the gold and other ore minerals are not definitely known, but because of the lack of evidence to the contrary, it is believed that they are probably the same as in the neighboring Hirst-Chichagof mine. The ore from that mine has been studied in much greater detail, principally by the American Cyanamid & Chemical Corporation, and some of the results are recorded on page 114–116.

GANGUE MINERALS

The gangue minerals of the Chichagoff ore are quartz and calcite. Fragments of the wall rocks are common also, as they are in the ore from other properties in the district.

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[28] Knopf, Adolph, op. cit. (Bull. 504), p. 22.
[29] Baumann, H. N., Jr., Eng. and Min. Jour.-Press, vol. 117, p. 877, 1924.
[29a] Knopf, Adolph, op. cit. (Bull. 504), p. 22.

Quartz is by far the most abundant gangue mineral. The massive white quartz is typically coarse-grained, but its extinction is undulatory, and grain edges are locally crushed. The banded quartz is finer-grained, is commonly much crushed, and ordinarily contains fragments of wall rocks or unreplaced remnants of such fragments. These bands and inclusions are oriented for the most part more or less parallel to the vein boundaries. In some specimens fractures that cut coarse-grained quartz are filled with seams of finer-grained, younger quartz.

Calcite is widely distributed in the veins, but at no place is it abundant. It is commonly found as large crystals or in fractures that cut through early quartz. In many such fracture fillings the calcite accompanies younger quartz and pyrite.

SITKA PROSPECT

The two prospect tunnels on the Sitka claims of the Chichagoff Mining Co. were not entered during the survey of which this report is the result. It is reported that no work has been done on the claims since they were visited by Overbeck,[30] whose description of the prospects is quoted below.

> The prospects Sitka No. 1 and No. 2 are on the east slope of Doolth Mountain about a quarter of a mile north of the Chichagoff lode. Development only is reported. The upper tunnel lies at an elevation of about 950 feet. At the entrance to the tunnel in the creek bed a dozen or more quartz stringers cut across the direction of the tunnel. The tunnel is approximately 150 feet long and follows a shear zone of variable width. Almost no quartz occurs in this tunnel. A little pyrite was noted in the crushed rock of the shear zone. The strike of the tunnel is about N. 62° W., and the dip of the fault plane is 52° S. Sticky clay gouge follows the footwall at some places and the hanging wall at other places. The lower tunnel is at an elevation of about 670 feet. The shear zone that it follows strikes about N. 52° W. and dips 52° S. A little quartz occurs in the crushed zone. The footwall is graywacke, and the hanging wall is a carbonaceous argillite. At the face of the drift cross stringers of quartz occur in fractures, and a little pyrite mineralization was seen there. The quartz stringers are on the footwall of the shear zone.

Possibly one or both of the shear zones described by Overbeck are to be correlated with the so-called "Munly shear" exposed near the face of the crosscut into the footwall on the main level of the Chichagoff mine. (See p. 95.)

HIRST-CHICHAGOF MINE

The Hirst-Chichagof mine is on Kimshan Cove at the northern foot of Doolth Mountain. It is the property of the Hirst-Chichagof Mining Co., of which Lew G. Kay, of Seattle, is president. The company owns or controls a large number of claims in the district. These are all, so

[30] Overbeck, R. M., op. cit. (Bull. 692), p. 119.

far as they are known to the writers, indicated on plate 14. It is possible that the company owns or controls some claims not so shown, but the map is believed to be complete and correct in respect to most claims.

HISTORY

The first claim staked on what is now the property of the Hirst-Chichagof Mining Co. was discovered and located on December 20, 1905, by Peter Romanoff, Andrew Dixon, and Bernard Hirst, all of Sitka. This was the "Bear in All group claim" (one claim). In May of the next year the same three men and Alexander Archangelsky located two other claims, the Bernard and the Bertha. These claims covered the ground already staked as the Bear in All group claim. Hirst from time to time purchased his partners' interests in the three claims, and in January 1917 they became his sole property. No mining had yet been done.

In 1908 the Sunday Alliance claim was staked by Louis Smith and John Martinson, but after a year or so, according to reports, the assessment work had not been done and the claim became open for relocation. In July 1916 this claim was relocated as the Sunday Queen claim by Bernard Hirst, Jr.

The Hirst-Chichagof Mining Co. was formed in 1918 or 1919 by Bernard Hirst, C. W. Fries, and Goon Dip. William N. Armstrong was the first president and C. W. Fries the first general manager. The company set out to obtain options on the claims in the vicinity, to locate new ground, and to develop and mine. It obtained a lease and bond on the Bear in All group, Bertha, and Bernard claims from Bernard Hirst and a lease and bond on the Sunday Queen claim from Bernard Hirst, Jr.

In 1919 T. W. Shaffer located for the company the Sholin and Fries claims. The same year E. E. Sholin located, also for the company, the Shaffer claim.

In February 1920 D. J. Williams was retained by the company to make an examination of its property and to advise it as to a plan of procedure. At that time all three of the present tunnels had been started. The upper tunnel was 426 feet long, the intermediate tunnel 850 feet long, and the present main tunnel 400 feet long. The mill equipment then included 10 stamps, a jaw crusher, amalgamation plates, an ore feeder, and assay equipment.

Williams continued on the ground most of the time until the annual stockholders' meeting in January 1921, at which he was elected vice president. The directors elected then were Goon Dip, Lew G. Kay, C. W. Fries, A. V. Williams, and W. A. Castleton. Castleton was elected president.

In 1921 the No. 1 ore shoot (see pl. 18) was reached on the main level, and Williams proceeded with the construction of the mill. The mill started to operate on April 2, 1922, and during the rest of that year ran on ore drawn above the main level. The mine has produced every year since 1922. Williams left in January 1923 and was succeeded by George B. Smith. Later the same year Smith left and W. J. Childs took charge. In August the No. 2 ore shoot was found on the main level. Castleton dropped out of the company in the spring of 1923, and Kay was made president. In December 1923 Williams returned to Kimshan Cove and again took charge.

In May 1924 a winze was started on the No. 2 ore shoot; Williams located several additional claims for the company, and all claims were surveyed. The No. 3 ore shoot was found on the main level in October 1925. In February 1926 the No. 2 shoot was found on the 300 level by driving southeastward from the bottom of the No. 1 shaft. (See pl. 18.) By August 1926 the ore shoot that lay northwest of the bottom of No. 1 shaft on the 300 level had been found. This is the one now being mined on the deeper levels. More claims were staked for the company by Williams in 1926. Most of the mining in the latter part of 1926 was done on the No. 3 ore shoot on the main level.

In 1927 payments to Bernard Hirst were completed, and the company obtained a clear title to his interests. The same year the company began to purchase the Anna and Surprise claims (the Bahrt claims), and their purchase is now (1939) nearly completed. During 1927 ore was mined from the No. 3 shoot above the main level and from the No. 2 shoot above the 300 level. Late in December the No. 2 shaft was completed to the 500 level.

In February 1928 the ore shoot was found southeast of the No. 2 shaft on the 500 level. During this year a contract for the purchase of electric power from the Chichagoff Mining Co. was made, and in April 1929 the Hirst-Chichagof Mining Co. began to use the power.

In the fall of 1930 the post office of Kimshan Cove was established at the Hirst-Chichagof mine. Also in 1930 the No. 3 shaft was started from the 500 level, and on October 11 the ore shoot was found on the 700 level. During the rest of the year drifts were extended on the 700 level and other preparations were made for stoping.

In August 1931 the company started to raise the No. 3 shaft from the 500 level. In February 1932 the flotation circuit was put into operation in the mill, but by March no more ore was available and from May to the end of the year the mill operated on tailings.

In January 1933 Williams died, and P. M. Sorensen took charge. The next month the No. 3 shaft reached the main level. By May the shaft had been sunk to the 850 level from the 700 level, and in June the crosscut to the vein on that level encountered ore. A few days later the mill started to operate on ore from the stope above the 850 level, and it has not been shut down for lack of ore since.

The ore shoot was tapped at lower and lower levels from the No. 3 shaft until production was stopped in February 1936 in order to install electric power in the mine. At that time the 1125 level was the lowest level of the mine.

Production was resumed in May 1936 and has been continuous since then. In November 1937 the company took an option on the Brown Bear and Mother Lode claims (Hodson claims).

When the survey resulting in this report was completed, late in August 1938, the shaft had been sunk to the 1700 level, and the crosscut toward the vein on that level was under way, stoping was going on above the 1400 level; the Hodson claims were being tested by diamond drilling, and negotiations were in progress to option the nearby Bear Extension and Lena claims (Tillson claims), and the claims of the Chichagof Prosperity Mining Co.

In 1939 the main vein was cut on the 1700 level and ore was found in the Kay shoot. Considerable prospecting was done on the Chichagof Prosperity claims, as a result of which the company decided not to exercise its option.

PRODUCTION

The following table, showing value of gold produced from the Hirst-Chichagof mine, was prepared from data furnished through the courtesy of the company.

TABLE 3.—*Value of gold produced by the Hirst-Chichagof Mining Co., 1922–38*

Year	Recovered in mill	Recovered from concentrates	Year	Recovered in mill	Recovered from concentrates
1922	$4,070.73	$874.28	1932	$58,465.37	40,670.06
1923	6,214.67	None	1933	106,447.48	47,442.04
1924	46,416.05	11,475.11	1934	113,641.31	64,063.00
1925	104,811.20	17,450.02	1935	240,001.11	121,863.71
1926	57,370.24	8,633.44	1936	135,918.56	93,353.82
1927	107,134.87	31,758.83	1937	295,705.42	150,152.90
1928	60,778.06	8,025.17	1938 (to July 31)	193,760.10	131,249.93
1929	43,311.06	9,829.05			
1930	5,692.34	None		1,702,623.99	746,320.69
1931	122,885.42	9,479.33			

The gold from the concentrates was obtained from 2,717.38 dry tons. The average value of the concentrates was therefore $274.68 to the ton. The average value of the concentrates for the first 7 months of 1938 was about $312 to the ton. The figures for the silver produced are not as complete as those for the gold. The mine appears to have produced about 20,000 ounces of silver, which was sold for about $10,000. The bullion recovered in the mill, as calculated from records furnished to the Geological Survey covering the period from 1925 through 1937, except 1928 and 1933, and under the assumption that the metal contained 1 percent dross, was made up of about 810 parts of gold to 180 parts of silver. Data pertaining to the gold content of the ore, the amount of ore, and the thickness of the vein in different parts of the mine are given on plate 18.

DEVELOPMENT

The mine is now entered through a main level, whose portal is 100 feet above the beach. (See pls. 18 and 19.) Above the main level are two old tunnels. The higher tunnel is 435 feet above sea level and is 426 feet long. The lower one is 285 feet above sea level and 898 feet long. The known ore above the main level was long ago mined out.

From a point about 1,850 feet from the portal of the main level a vertical shaft has been sunk 1,670 feet to the 1700 level, in 1938 the lowest level of the mine. This shaft, called the No. 3 shaft, starts in the hanging wall of the vein but between the 300 and 500 levels passes through the Hirst fault and for the rest of the way down is in the footwall.

Formerly the 180 and 300 levels were reached through an inclined shaft, the No. 1 shaft, on the vein. The No. 2 shaft, also an inclined shaft on the vein, was sunk from the 300 to the 500 level. Both the No. 1 and No. 2 shafts are a short distance northwest of the No. 3 shaft, but neither of them is now used.

The No. 3 shaft has been connected to the 180, 300, and 500 levels, and from it have been turned all the lower levels, the 700, 850, 1000, 1125, 1250, 1400, and 1700. The workings on each level are shown on plate 19. With each succeeding level the shaft lies farther in the footwall, and the crosscut on each level to reach the vein is therefore longer than the one on the level above.

Ore was stoped from three shoots above the 300 level, and another shoot has been stoped continuously from ground between the 180 and 300 levels down to the 1400 level. In 1938, when the survey resulting in this report was made, the crosscut from the shaft station on the 1700 level had not yet reached the vein. The vein has now (1939) been cut on that level, and the map (pl. 19) has been revised according to information supplied by Paul M. Sorensen.

The mine is completely equipped, mostly with up-to-date machinery, and every precaution is taken to assure safe and efficient operation. Hoisting and the tramming on the main level are done by electricity. All underground workers are required to use safety hats equipped with electric lights. Electric power is led into the mine through a cable to a transformer station on the main level

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not far from the collar of the No. 3 shaft, where it is transformed from 6,600 to 440 volts.

The surface equipment (see pl. 20, *A*) includes a mill, a power house, a sawmill, a Diesel boat, an assay office, a blacksmith shop, bunkhouses, a cookhouse and mess hall, shower and drying rooms, a store and post office, and a few houses for some of the married employees. The employees of the company at Kimshan Cove number about 55.

The electric power for the operations of the company is obtained mainly by purchase from the Chichagoff Mining Co., which supplies 200 kilovolt-amperes. To supplement this power, and as a precautionary measure in case of interruption of the supply, a Diesel power plant at Kimshan Cove can develop 200 horsepower.

The mill of the Hirst-Chichagof mine is between the mine portal and the beach. It handles between 35 and 40 tons of ore a day, and the average tenor of the ore during the summer of 1938 was about $45 a ton. Plate 21 is a simplified flow sheet of the mill furnished by the company.

MINING AND MILLING COSTS

The Hirst-Chichagof Mining Co. has furnished the following statement of operating costs for the year 1937:

Operating costs per ton of the Hirst-Chichagof Mining Co., 1937

Mining:	
Breaking	$0.99
Transportation	1.45
Timbering	1.70
General mine expense	.62
Steel sharpening	.16
Compressed air	.39
Sampling, mapping, assaying, etc	.17
Provision for injuries	.16
Cost of ore at mill ore bin	5.64
Mine development	2.77
Milling:	
Crushing and grinding	.45
Amalgamation	.37
Flotation and concentration	.74
Power	.37
General mill expense	.33
Assaying	.22
Total cost of milling	2.48
Surface costs	1.31
Total operating costs	12.20

The cost per ounce of gold recovered is $12.98 for the same year.

GEOLOGY

ROCKS

The most abundant rocks in the Hirst-Chichagof mine are massive and shaly graywacke. (See pls. 19 and 22.) These rocks are described on pages 30–34 and need no special description here. Considerable difficulty was encountered during the mapping of the mine in finding and applying satisfactory criteria for differentiating the two types of graywacke. Consequently certain rocks intermediate between typically massive and typically shaly graywacke may be designated differently at different places in the mine. Massive graywacke is more abundant in the footwall of the Hirst fault, and shaly graywacke is more abundant in the hanging wall. At many places in the mine, however, shaly graywacke forms the footwall and massive graywacke the hanging wall.

The only other rocks so far encountered by mine openings are the various types of dike rocks. A large dike forms the footwall throughout much of the productive part of the mine and extends continuously from the highest level to and below the 1400 level. Similar dike rock in very small amounts is present in the hanging wall at several places in the productive part of the mine. Whether the dikes at these places are faulted portions of the large footwall dike or are separate smaller intrusions is not definitely known. The small dike that first appears about 3,665 feet in from the portal of the main level is in the hanging wall of the Hirst fault. This long, thin dike was intruded, probably later than the other dikes, along a split from the Hirst fault and is well exposed on the main level of the mine. (See pl. 19.) The appearance of this thin dike is illustrated on plate 23.

The boundaries between silicified and unsilicified parts of the big footwall dike appear to be very irregular, and not enough ground is open to determine the size and shape of the silicified masses. Relative to the total volume of dike material the amount of silicified material is small. The reasons for its irregular distribution are not known. The silicified masses may have been formed in fractured parts of the dikes that were more readily accessible than other parts to silica-bearing solutions capable of accomplishing the replacement.

STRUCTURE

No horizon markers were recognized in the mine, and the structure of the wall rocks is known only from numerous local observations. The attitude of the rocks appears to be about the same in the footwall and in the hanging wall. As stated on page 60, the average of 77 observations of strike is N. 65° W., and the average of the corresponding dips 64° SW.

The workings open only a small part of the Hirst fault zone, in which lie the principal known ore bodies of the mine. The main-level portal is in the hanging wall of the fault, and the tunnel reaches the fault about 900 feet from the portal. The shearing in the rocks in the vicinity of the fault becomes conspicuous about 800 feet from the portal.

Where encountered by the main level the fault is dispersed through a zone possibly as much as 50 feet thick and is not well defined. This feature is well illustrated in the short crosscut into the hanging wall at 1,160 feet from the portal. The character of the Hirst fault between 900 and 1,160 feet from the portal led to the formulation during mapping of a hypothesis to the effect that the fault was dying out northward by splitting and dispersing into the walls. This hypothesis, in the light of the evidence of the airplane photographs, is apparently incorrect. The dispersed zone is probably local only and is similar to several other such zones that have been recognized in the mine.

From a consideration of the location of the Hirst fault as shown on the airplane photographs and the location of the underground workings on the main level, beyond the known ore bodies, it seems apparent that at some place the main tunnel must leave the Hirst fault and continue southward on a large split. The exact place is difficult to identify underground but is thought to be about 2,755 feet from the portal. At this place the tunnel turns into the hanging wall of an intensely sheared, relatively wide zone (presumably the main Hirst fault) that is very similar to the fault zone first encountered.

The main tunnel follows the large split to a point about 4,915 feet from the portal. There it was turned away from the large split and was advanced about 435 feet as a crosscut in the hanging wall of the split. This crosscut reached a distinct fault, roughly parallel in strike to the Hirst fault but with a much flatter dip, which is believed by the company to be the fault exposed on the Anna claim. (See p. 116.) It has been opened by a drift each way from the crosscut for a total distance of about 220 feet, but no ore was encountered. This fault is not as strong as the main Hirst fault, and the suggestion is offered that it may be a major split from either the Hirst or the Chichagof fault, or possibly a split that connects the two larger faults. The main-level crosscut has been advanced about 225 feet farther and in that distance has encountered one other weak but distinct fault.

Splits from the Hirst fault are very common in the Hirst-Chichagof mine. These fall into two general types (see pp. 64–65), those that leave the main fault and are parallel or nearly parallel to the bedding and those that leave the main fault against the bedding. Only a few of the more prominent splits will be mentioned here. Many others are shown on plates 19 and 22.

The large split about 2,755 feet from the portal of the main level, mentioned above is remarkably persistent for about 2,260 feet. The split is much weaker than the main fault but at most places is well defined. This split trends against the bedding, its strike being more northerly than that of the main fault.

A large number of relatively small splits diverge from the Hirst fault about 2,100 feet from the portal not far from the No. 3 ore shoot. These splits, as shown on figure 5, are with the bedding. On the 500 level is a similar zone of splitting about 500 feet southeast of the main or No. 3 shaft (fig. 10). This zone is also a short distance northwest of a quartz body that is of too low grade to mine but may be the downward extension of the No. 3 ore shoot. Thus it seems possible that the zone of splitting exposed on the main and 500 levels may be one and the same. (See pl. 19.)

The distinct bend or warp in the Hirst fault that is recognizable on all levels from the 180 through the 700 is considered a special example of a split along the bedding in which practically all of the movement took place parallel to the bedding, and the main fault was thereby deflected. Some splits from the main fault near the places where it is deflected are apparently features that are related to the warp. Such a split, with several smaller associated splits, was encountered in the vicinity of the No. 2 shaft between the 180 and 300 levels. It is well shown on the 300 level. (See pls. 19 and 22.) On the 500 level it is very strong, is a considerable distance from the main fault, and carried minable ore. (See pl. 19.) This split is

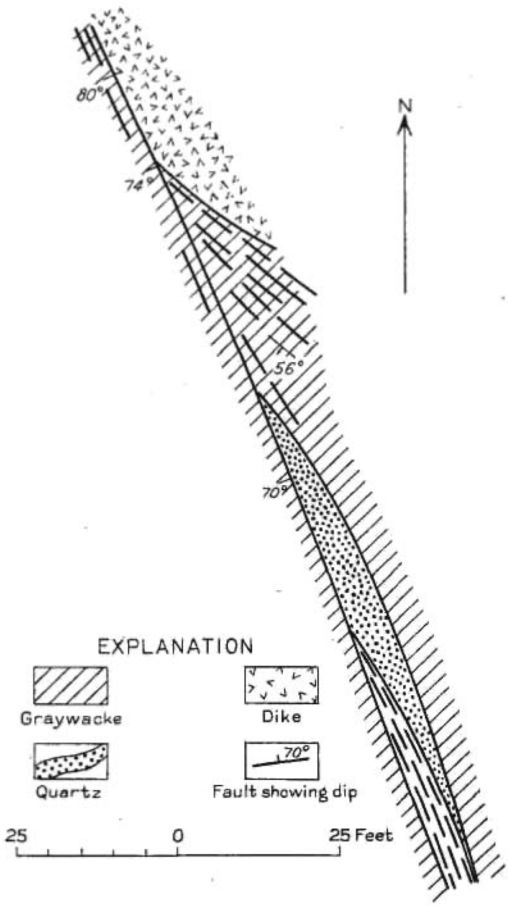


FIGURE 10.—Zone of splitting and its relation to body of quartz on 500 level, about 500 feet southeast of No. 3 shaft, Hirst-Chichagof mine.

parallel with the bedding and diverges from the main fault to the northwest, into the hanging wall.

A somewhat smaller split, important as a carrier of ore, was found in the stope between the 1000 and 1125 levels. It is distinctly shown on the 1125 and 1250 levels. (See pl. 19.) On the 1250 level it is smaller and weaker. This split, at least on the 1125 level, does not continue very far southeastward into the footwall, as a later tunnel driven in the footwall to get around unstable ground in order to prospect the fault farther southeast on that level does not expose the split, unless the few small faults that show in the later tunnel are the weak expression of the split near its southeast end. (See fig. 11.) This split is also parallel with the bedding.

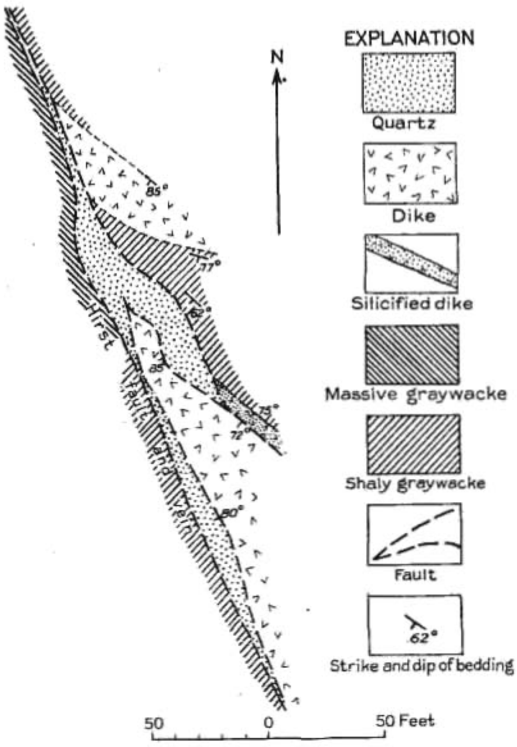


FIGURE 11.—Sketch of part of 1125 level, Hirst-Chichagof mine, showing ore-bearing split from Hirst fault.

ORE BODIES

The Hirst-Chichagof mine has developed four principal ore shoots, each a quartz body on the Hirst fault. The location and size of each shoot and the quantity of ore mined and value of the gold recovered from each are shown on plate 18. On this plate is plotted the projection on the plane of the vein of the generalized position of the intersection between the average bedding plane and the average plane of the Hirst fault. The accordance between this line and the longest dimensions of the ore shoots is notable and presumably indicates that the emplacement of the ore bodies was at least partly controlled by these intersections.

The large warp in the Hirst fault that extends from the 180 level through the 700 level is of considerable economic importance because of its relation to three of the principal ore shoots so far found in the mine. The No. 1 shoot is terminated at its lower end at or near the projection upward of the southeast end of the warp. No evidence of the warp was recognized on the main level, but that part of the level is now largely concealed by timbering. The stope above the main level was not accessible.

The No. 2 ore shoot is terminated downward by the southeast end of the warp. This termination is abrupt and is well shown on the 300 level. The small stope northwest of the No. 2 ore shoot appears to lie along a portion of the main fault that forms a minor warp on the larger one. It lies on the part of the fault that has the normal trend of the main Hirst fault and does not continue either southeast or northwest along the large warp, which trends more nearly parallel to the bedding. This small stope ends both above and below at the places where the fault warps into the bedding. See pls. 19 and 22.)

The main ore shoot of the mine, the one that has been followed from ground above the 300 level to the bottom level, appears to be cut off abruptly at its upper end against the northwest end of the large warp. At about the 500 level this shoot steepens and diverges from the warp, but it should be remembered that the warp itself is not definitely recognizable below the 700 level.

The postquartz movements on the faults are not thought to have been great enough to change appreciably the positions and shapes of the ore bodies. Under this interpretation the No. 1 and No. 2 ore shoots may have been formed from solutions traveling northwestward and up in a fractured, easily accessible zone just above the southeast end of the large warp. The material to form the small shoot above the 180 level and northwest of the No. 2 shoot may have entered the portion of the fault between the ends of the small minor warp and the large warp, near the bottom of the No. 2 shoot, where the minor warp merges into the larger one.

The solutions that deposited the quartz and gold of the main ore shoot may have traveled upward in an accessible zone on the main fault until, upon reaching the northwest or under side of the large warp, they were deflected upward in channels under the northwest end of the warp.

No quartz bodies lie in the part of fault zone that has been deflected to a position parallel to the bedding. The quartz of the main shoot, however, penetrated the strong split from the northwest end of the warp to form the split ore on the 300 and 500 levels shown on plate 19.

The No. 3 ore shoot apparently does not extend much below the main level. A raise from the 300 level showed some quartz but no minable ore. Similarly quartz that is presumably part of the quartz body that formed ore above the main level has been encountered on the 500 and 700 levels, but on neither was it rich enough to mine.

A small, thin quartz body was found on the main level about 4,590 feet from the portal on the persistent split from the Hirst fault. This body, known as the Kay ore shoot, has been developed by a short raise and level above the main level but has not been extensively mined.[31]

The quartz bodies in the Hirst-Chichagof mine are in general typical of the whole district and were used in large part in preparing the general discussion on pages 77–79. The descriptions are therefore not repeated in detail here, but the appearance of the ore bodies is illustrated by several plates and figures.

At some places, as seen in plan, the ore bodies are rather blunt; at others they thin out gradually along the strike. The quartz may occupy all or any part of a fault zone, and in many places quartz is present at more than one place in the fault zone, with other material between. (See fig. 12.)

The total thickness of quartz along an ore shoot varies widely, as illustrated by plate 24. The postquartz movements on the Hirst fault have crushed, faulted, and twisted the fault filling, including the quartz bodies, in a complicated manner, as illustrated by plates 25 and 26, *A*.

The following description of the Hirst fault and vein in the stope on the 1400 level of the mine is typical:

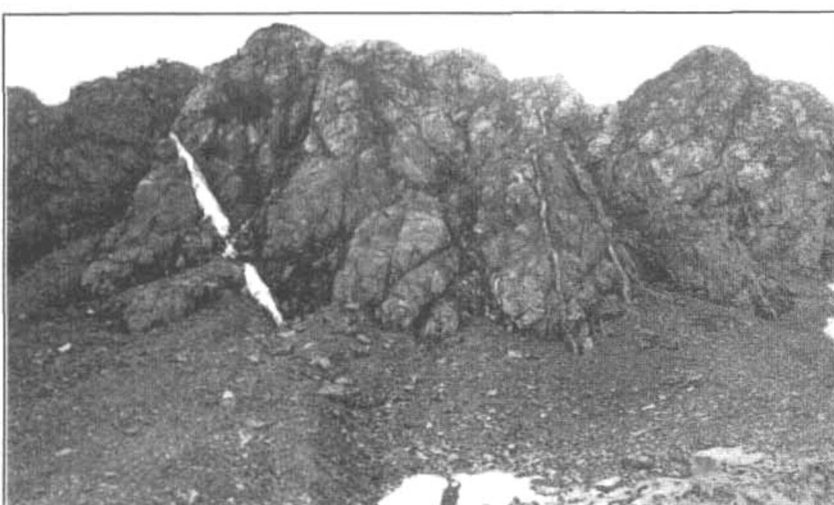
> The hanging wall for 6 feet away from the vein is intensely sheared black, graphitic shaly graywacke. This material contains a few small stringers of quartz parallel to well-developed but apparently minor shear surfaces that define the bedding and lie at a small angle to the Hirst fault. The hanging wall itself is sharp and well defined but somewhat wavy. The Hirst fault zone is 6.8 feet thick and is made up of white banded quartz in bands up to about 1 foot thick separated by bands and thin leaves of intensely sheared shaly graywacke and graphitic gouge. The shaly graywacke decreases in abundance away from the hanging wall. The quartz is in most places greatly crushed. The footwall is marked by 1 inch to 10 inches of gray gouge apparently developed from the footwall, which is slightly sheared gray, silicified dike rock.

At many places quartz has migrated from the vein into the joints in the walls, particularly the footwall, and has formed small veinlets. The postquartz movements have commonly cut off the veinlets and where they have penetrated a few inches into the walls have broken the ends of the veinlets into pieces whose distribution indicates the direction of the movements.

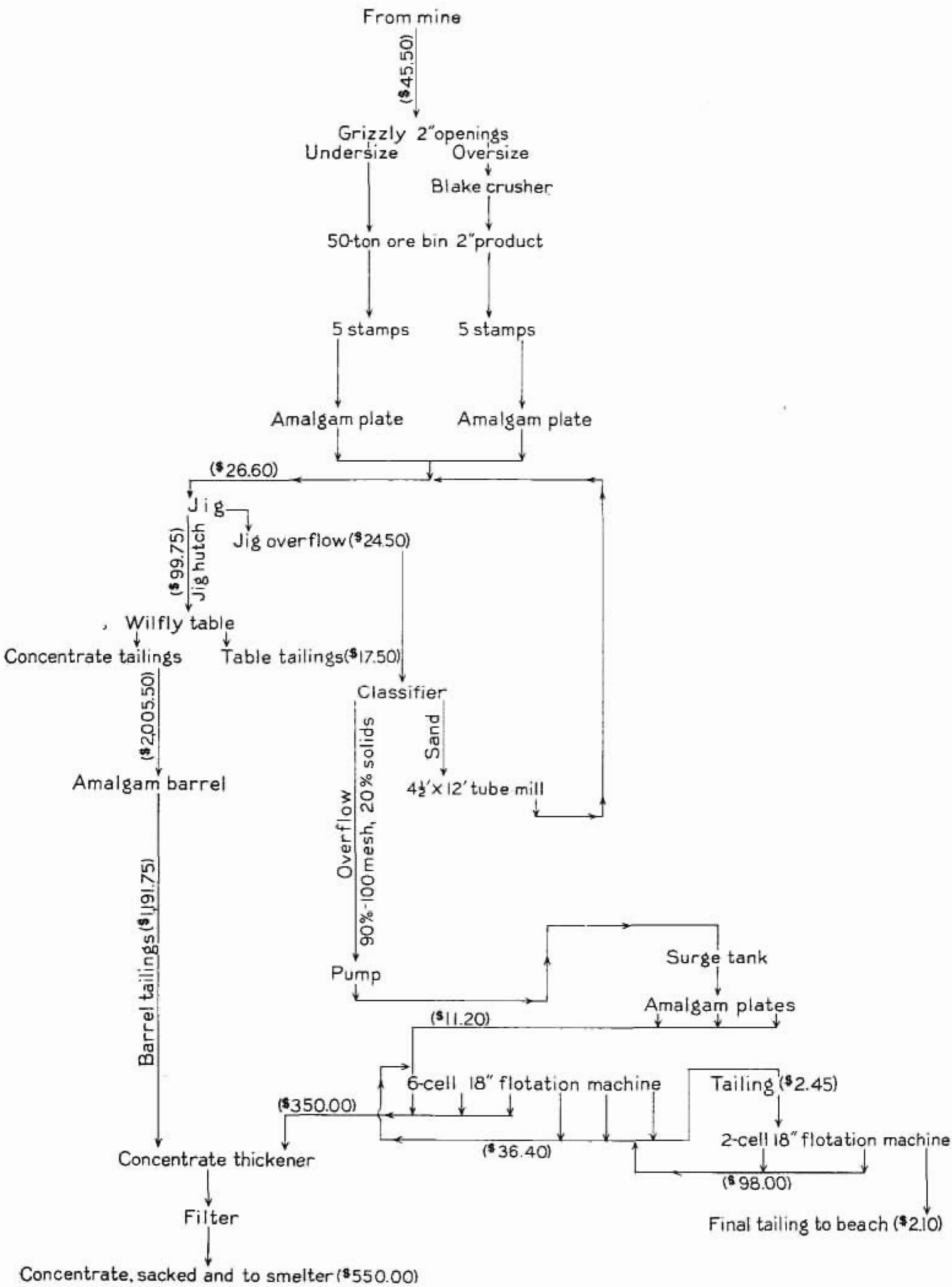
Most of the quartz has a ribbon structure, and the ribbons are defined by thin layers of graphitic shaly graywacke or graphitic gouge. (See pl. 23.) The ribbons are from a small fraction of an inch to several inches thick. Much of the postquartz movement

[31] For more information on the Kay shoot, revealed by development work subsequent to the writing of this part of this report, see footnote 26, page 84. Development work done in 1939 on the Kay shoot has been added to plate 19.

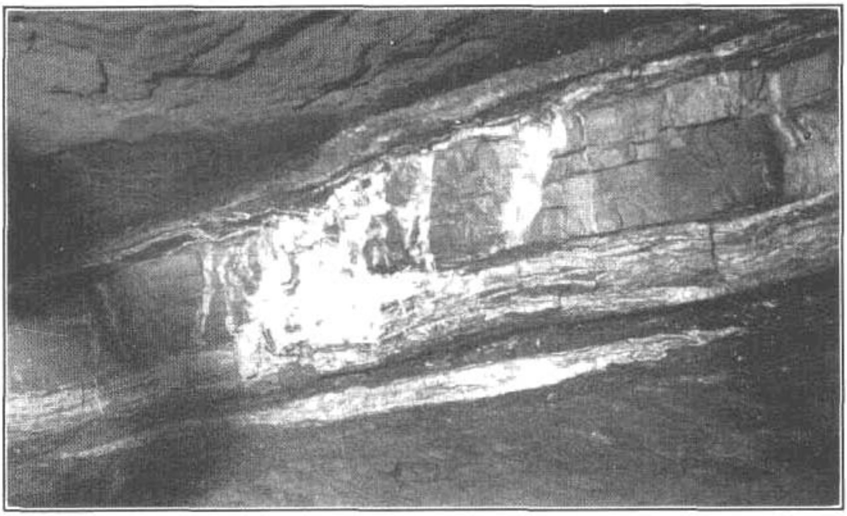
A. HIRST-CHICHAGOF MINE CAMP, FROM KIMSHAN COVE.



B. OUTCROP OF APEX VEIN ABOVE THE APEX MINE.

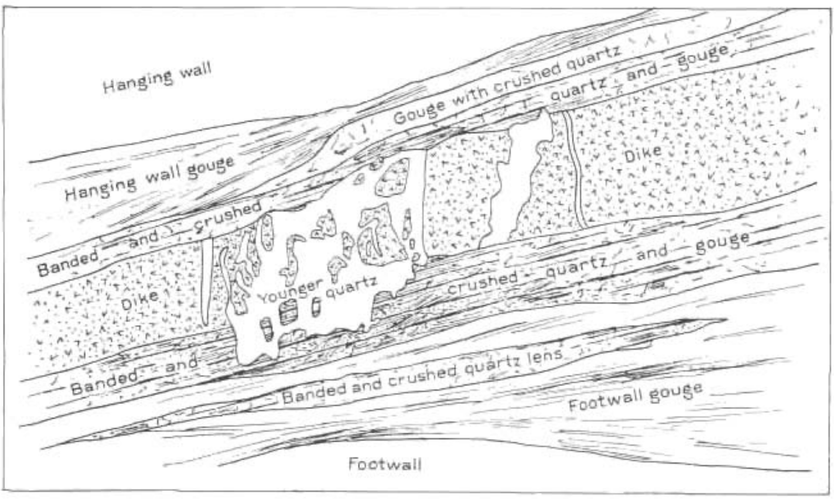


SIMPLIFIED FLOW SHEET OF HIRST-CHICHAGOF MILL.

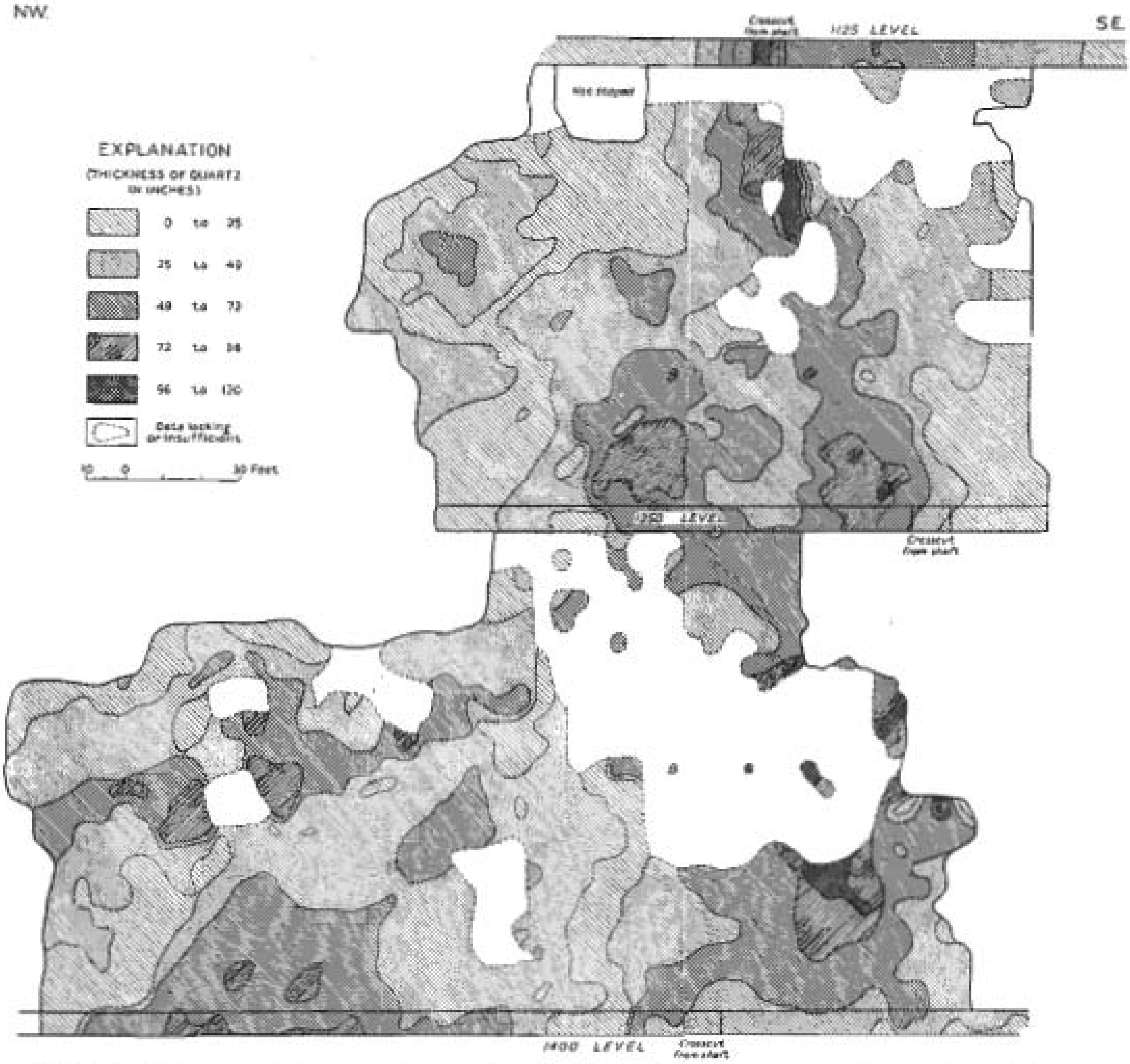


A. DIKE INTRUDED ALONG PERSISTENT SPLIT FROM HIRST FAULT AT ABOUT 4,230 FEET FROM PORTAL OF HIRST-CHICHAGOF MINE.

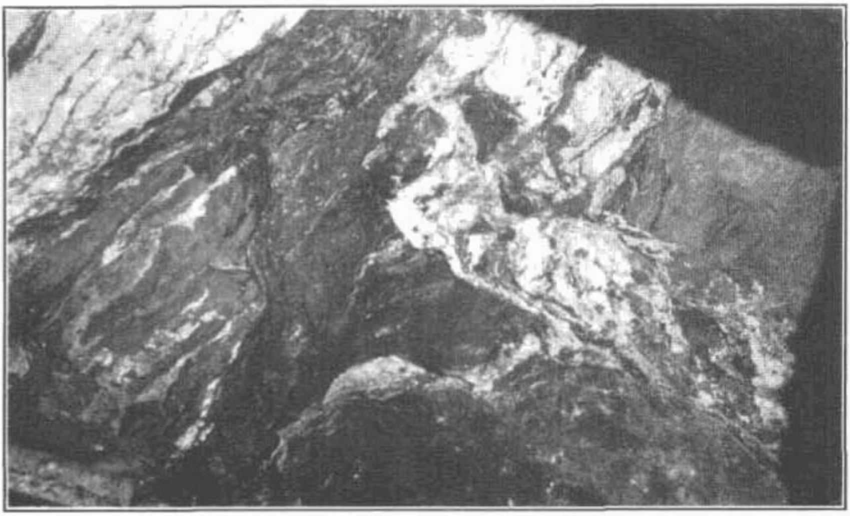
Note that unsheared dike has been intruded between layers of earlier banded quartz and is cut by later quartz veinlets largely in joints in the dike and earlier quartz.



B. PEN DRAWING OF PRINCIPAL FEATURES SHOWN IN *A*.

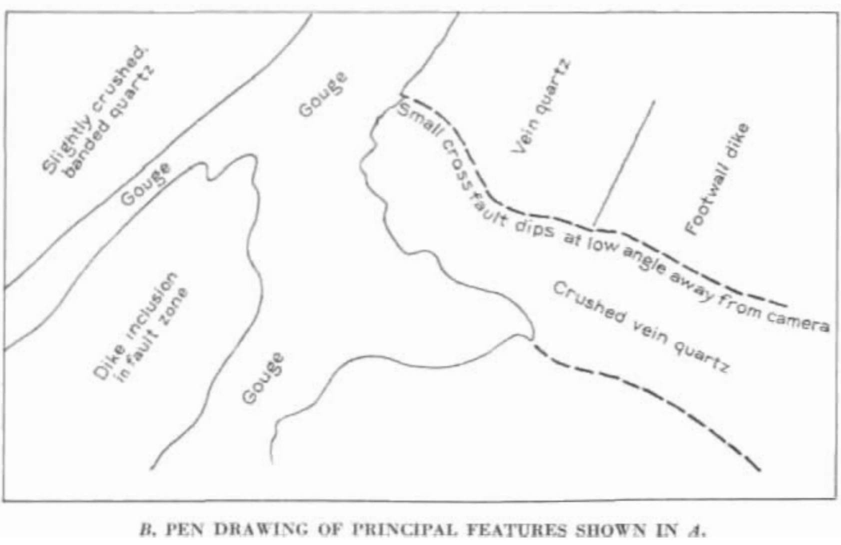


LONGITUDINAL SECTION, PROJECTED TO A VERTICAL PLANE, OF STOPES ON 1400 LEVEL AND 1250 LEVEL OF HIRST-CHICHAGOF MINE SHOWING THICKNESS OF QUARTZ.

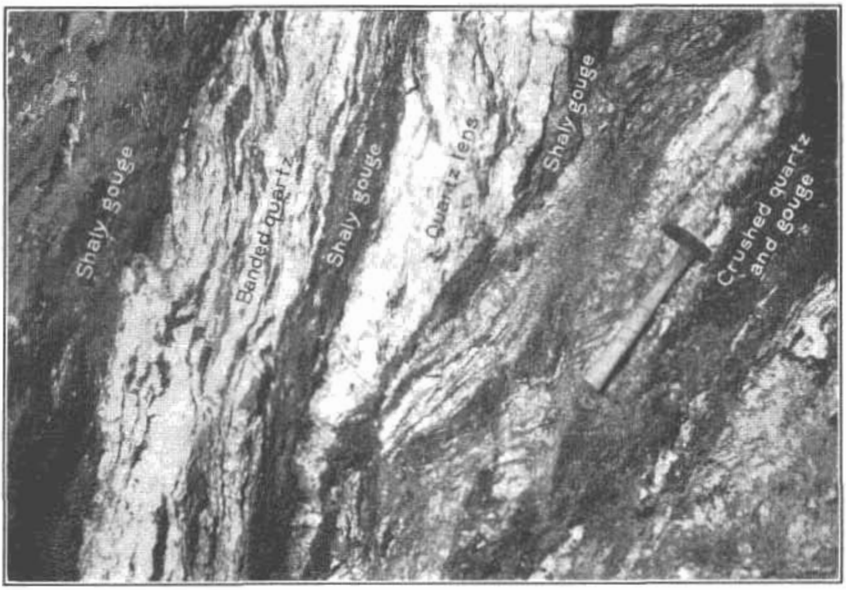


A. VIEW NORTHWEST ON 13TH FLOOR ABOVE 1400 LEVEL OF HIRST-CHICHAGOF MINE AT FACE OF 14TH SET NORTHWEST OF SECOND RAISE NORTHWEST OF CROSSCUT FROM SHAFT.

Shows inclusion of footwall dike containing quartz veinlets in Hirst fault and small postquartz cross fault that offsets footwall dike and adjacent vein quartz.

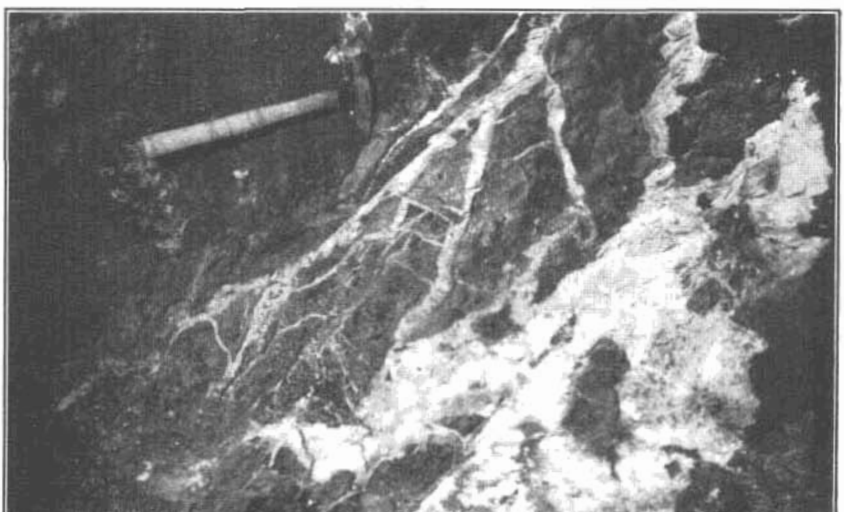


B. PEN DRAWING OF PRINCIPAL FEATURES SHOWN IN *A*.



A. VIEW NORTHWEST ON 11TH FLOOR ABOVE 1400 LEVEL OF HIRST-CHICHAGOF MINE AT FACE OF 9TH SET NORTHWEST OF 3D RAISE NORTHWEST OF CROSSCUT FROM SHAFT.

Shows crushed and banded vein quartz in Hirst fault.



B. HIRST FAULT BRECCIA, CEMENTED AND REPLACED BY QUARTZ, ON 700 LEVEL OF HIRST-CHICHAGOF MINE NEAR END OF NO. 3 ORE SHOOT.

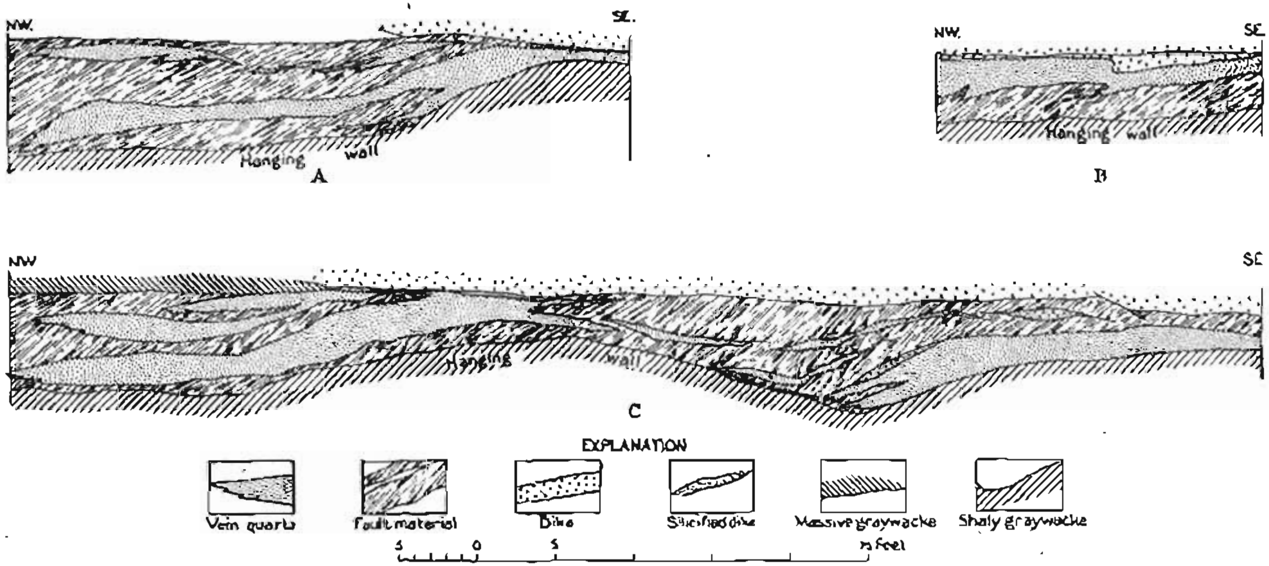


FIGURE 12.—Sketches showing Hirst vein and fault in stope on 1400 level of Hirst-Chichagof mine. (After Hollis Chatwin, Hirst-Chichagof Mining Co.) A, Nineteenth floor above 1400 level, from three sets northwestward to four sets southeast of third raise northwest of crosscut from shaft. B, Eleventh floor above 1400 level from two sets northwest to five sets northwest of second raise northwest of crosscut from shaft. C, Eighteenth floor above 1400 level from three sets northwest of third raise northwest of crosscut from shaft to two sets northwest of second raise northwest of crosscut.

appears to have taken place on the gouge or shaly graywacke between the quartz ribbons.

Locally, as for example in the stope above the 800 level, the quartz was white, massive, and solid. It was not ribbon quartz and was not crushed.

In some places, particularly where the Hirst fault cuts relatively massive graywacke, the fault material consists of jointed and fractured rock with fewer shear planes than common. The joints and other fractures in fault matter of this type are locally filled with an intricate network of quartz veinlets. Replacement by quartz of the broken rock fragments in these places appears to have been unusually widespread (see pl. 26, *B*), and although some of the fragments are sharply angular others have been rounded by replacement, and some have been completely or almost completely replaced.

ORE AND GANGUE MINERALS

Much of the material here presented on the ore and gangue minerals is the result of microscopic work done by the American Cyanamid & Chemical Corporation under the direction of Dr. P. L. Merritt. Grateful acknowledgment is made to this corporation and to the Hirst-Chichagof Mining Co. for permission to study and use the results of these investigations.

ORE MINERALS

Metallic minerals make up less than 3 percent of the ore of the Hirst-Chichagof mine. Those recognized include pyrite, arsenopyrite, sphalerite, galena, chalcopyrite, and gold. Of these, pyrite is by far the most abundant, and arsenopyrite the next.

Pyrite is a common constituent of the vein quartz, but apparently is even more abundant in the layers and leaves of the wall rock. The pyrite in the wall rocks more than a few inches away from the veins is reported to be at most places barren or nearly so. The pyrite in the veins was formed after most of the quartz—in fact, most of it appears to have been deposited after early quartz had been considerably deformed. Pyrite was the first metallic mineral deposited, with the possible exception of arsenopyrite. The age relation between the pyrite and the arsenopyrite is not known. All the other metallic minerals have replaced the pyrite and occur in fractures along which pyrite grains have broken. Plate 27, *A* shows a crystal of pyrite that has developed in a microscopic fault that has offset a tiny quartz veinlet. The pyrite is commonly found as striated cubes, many of them as much as one-eighth of an inch across and some even larger. Movements along the Hirst fault after the deposition of the pyrite have broken and deformed many pyrite crystals.

Arsenopyrite is a widely distributed constituent of the ore but is much less common than pyrite. Its relation to the other ore minerals is not known. It has been recognized in the vein quartz, in the thin layers of partly silicified wall rocks between quartz ribbons, and in the wall rocks, particularly in the dike rocks. The crystals are small but are in general megascopically recognizable. They are well formed, with bright triangular faces, and apparently are combinations of the prism and the dome crystal forms.

Sphalerite is not common in the ore from the Hirst-Chichagof mine but it has been observed under the microscope. The evidence is not conclusive, but in general the sphalerite appears to have followed pyrite in the sequence of deposition and to have preceded the galena, chalcopyrite, and gold. Plate 27, *B*, shows sphalerite embaying a pyrite grain.

Galena, like sphalerite, is rare in ore from the Hirst-Chichagof mine. It has been seen occasionally as small cubes in the quartz. Plate 28 shows minute veinlets of galena in pyrite and in sphalerite. It appears to bear the same age relation to the enclosing minerals as the gold.

Chalcopyrite is a rare constituent of the Hirst-Chichagof ore. It is reported to have been seen in larger quantities in the No. 3 ore shoot than elsewhere.

Gold is found free in the vein quartz, in the layers of wall rock between quartz ribbons, and locally in the wall rocks near the veins. It also is present in very small particles and veinlets in other metallic minerals, principally pyrite. (See pls. 27, *B*, and 28.) Most of the vein quartz does not contain gold visible to the unaided eye. Occasionally small specks are seen, and in a few places fine high-grade specimens have been obtained. The gold typically fills tiny fractures in the quartz and other minerals. It is bright yellow and contains some silver.

GANGUE MINERALS

The gangue minerals recognized in the Hirst-Chichagof ore are quartz and calcite. The gangue also contains considerable quantities of the various wall rocks.

Quartz is the predominant gangue mineral. Much of the quartz is white, but some is gray with included particles of wall rock and graphite. The uncrushed quartz is coarse-grained and bladed. At many places the blades are oriented roughly at right angles to the vein walls. The quartz typically exhibits strain shadows, and much of it is crushed. Even the more massive quartz is crossed by crushed zones roughly parallel to the vein walls. Commonly grain borders are crushed.

A little interstitial calcite is present in the vein quartz. Crushed zones provided means of access to carbonate-bearing solutions, and calcite is much more abundant in these zones. Locally veinlets of calcite cut the older quartz. Calcite also appears to be more abundant through and near layers of wall rock and gouge in the banded veins.

BAHRT PROSPECTS

In 1927 the Anna and Surprise claims, known locally as the Bahrt claims, were optioned by the Hirst-Chichagof Mining Co.

Each claim has been developed by a small tunnel. The tunnel on the Surprise claim is near the center of the east line of that claim and is a little more than a mile S. 40° E. from the Hirst-Chichagof camp on Kimshan Cove. The prospect on the Surprise claim was not visited by the writers, but developments on it are said to consist of a tunnel 40 feet long driven N. 19° W. along a small fault that dips 55°–70°SW. The fault is reported to contain locally as much as 6 inches of quartz.

The tunnel on the Anna claim is about 5,500 feet S. 32° E. from the Hirst-Chichagof camp. It extends from the portal N. 9° W. for about 25 feet and N. 37° W. for about 64 feet farther. This tunnel follows an irregular and apparently relatively weak fault. The general dip of the fault is about 54° SW., but dips as steep as 70° and as flat as 44° were observed. The fault has been traced on the surface by means of a series of pits for several hundred feet. In places the fault splits, and the main fault and the splits locally contain about 1½ feet of vein quartz. Cross joints filled with quartz veinlets are common in both walls, and a few of these also reach a thickness of about 1½ feet. Locally, the quartz contains considerable pyrite. Assay values of the quartz are reported to be spotted. The Hirst-Chichagof Mining Co. believes that the fault found about 225 feet from the face of its main-level tunnel may be the same as the Anna fault.

KAY PROSPECT

On the Kay claim of the Hirst-Chichagof Mining Co., on the southeast face of Doolth Mountain at an altitude of about 1,500 feet and about three-quarters of a mile S. 31° W. of the mine dock at Kimshan Cove, are a group of prospect pits said to have been dug by Hodson and Berkland on their Gold Bug claim. The location of the Gold Bug claim and its status in relation to the Kay claim are not known.

The country rocks are shaly, splintery, and massive graywacke that trend about N. 38° W. and dip about 50° SW. In the most northerly pit is exposed a quartz vein 1½ feet thick. About 30 feet to the south is another pit, which exposes 1½ feet of limonite-stained quartz overlain by about 4 feet of shaly or sheared graywacke that is in turn overlain by massive graywacke. The vein is exposed better in a pit a few feet farther south. This pit has uncovered the vein for about 15 feet along its strike, which there is N. 5° E. The vein dips 55° W. The maximum thickness of the quartz is 2½ feet, and the hanging wall is shaly graywacke for about 4 feet from the vein. This is followed by massive graywacke. The general trend of the vein as exposed in these three pits is N. 7° W. A fourth pit, still farther south, shows 9 inches of quartz in place, overlain by 2 feet of shaly graywacke followed by massive graywacke.

HODSON PROSPECT

In 1937 the Hirst-Chichagof Mining Co. optioned from Mr. Hodson his two claims on Doolth Mountain, the Brown Bear and the Mother Lode. In the fall of 1938 diamond drilling was started at the Hodson prospect. It is understood that the drilling had been completed by the summer of 1939, but the results have not been made public.

The principal prospect pits are on the northward-facing slope of Doolth Mountain, at an altitude of about 1,500 feet, about half a mile S. 17° E. from the mine dock at Kimshan Cove. Several pits have been dug over a horizontal extent of about 200 feet, but some of them are now sloughed in. The country rock is graywacke that strikes N. 70° W. and dips 75° SW. In several of the pits is exposed a quartz vein as much as about 2 feet thick. The vein appears to lie in a fault zone that strikes about N. 50° W. and dips 70° SW. Near the northwest end of the line of pits the vein appears to flatten and become discontinuous, but the exposures are too poor to furnish much definite information. The fault zone is reported to be traceable for a considerable distance both to the northwest and to the southeast. At the prospect pits some small veinlets occupy joints in the hanging wall of the fault zone. These joints strike N. 40° E. and dip 83° NW.

ELSINOR PROSPECT

The Elsinor prospect tunnel of the Hirst-Chichagof Mining Co. lies about a quarter of a mile northeast of the dock at Kimshan Cove and about 200 feet east of the trail that leads for a short distance north and east from the mine camp. The tunnel is about 105 feet long. (See fig. 13.)

The tunnel runs principally along a small curving fault that trends in general about N. 58° E. and dips 65°–75° NW. Between points about 64 and 75 feet from the portal the fault appears to be absent. Near the portal the fault carries about 2 feet of quartz. Along much

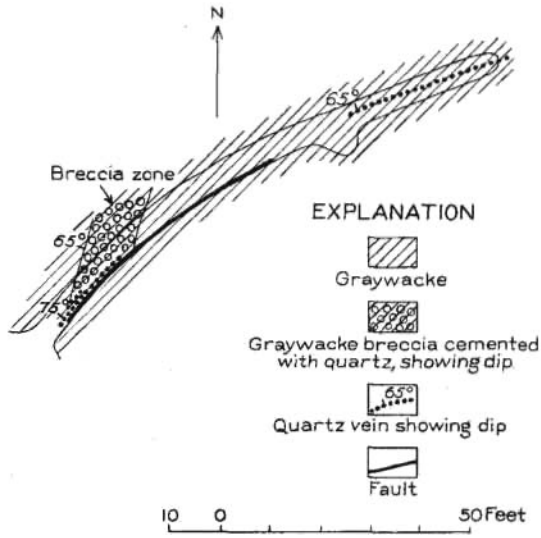


FIGURE 13.—Sketch plan of Elsinor prospect tunnel of Hirst-Chichagof Mining Co.

of the rest of the exposed part of the fault quartz is present but much thinner.

At about 6 feet from the portal the tunnel discloses a brecciated zone in the shaly graywacke. This zone is about 9 feet thick and appears to be confined to the hanging wall of the fault. It trends N. 16° E. and dips 65° NW. The fragments of graywacke in the brecciated zone are cemented with quartz. Many of the joints in the vicinity of the intersection of the small fault and the brecciated zone are filled with thin quartz veinlets.

FALCON ARM PROSPECT

The Falcon Arm prospect was formerly owned by the Falcon Mining Co. The ground was relocated in 1938 by Carl Bergstrom and Gus Gustafson. The prospect is near the head of Falcon Arm on the southeast side.

At about 185 feet above sea level a crosscut has been driven for 2,260 feet S. 59° E. About 1,200 feet from the portal a drift has been turned southward for a distance of about 750 feet. (See pl. 29.) The country rock is chiefly massive graywacke, which has an average strike of about N. 50° W. and a dip of about 70° SW. The graywacke is cut by numerous dikes of light-colored fine-grained intrusive rock, ranging in thickness from about 1 foot to about 30 feet. Some of these dikes have attitudes similar to those of the faults at the prospect, others strike roughly parallel to the bedding of the graywacke, and others were apparently intruded along joints. Joints of the principal set have an average strike of about N. 45° E. and are nearly vertical.

The crosscut intersects numerous faults, mostly rather weak, which strike from about N. 35° W. to about N. 30° E. and which generally dip steeply westward. At a distance of 300 feet from the portal the tunnel exposes a fault that strikes N. 25° E. and dips 57° NW. A 2-inch quartz vein lies on this fault. At 455 feet from the portal there is a fault that strikes N. 12° E. and dips 54° NW. It carries a 4-inch quartz vein. At 587 and 705 feet from the portal are relatively strong faults, both of which carry narrow quartz veinlets.

The drift follows a fault which strikes in general about N. 24° W. and dips very steeply to the west. At the intersection with the crosscut the fault is relatively strong, but farther southeast it is much weaker. Several splits diverge from this fault, particularly into the hanging wall. Little quartz was noted on the fault. On the fault map (pl. 9) a weak fault, of similar trend, is shown in the approximate place that this fault should crop out. This fault dies out to the south, north of the southern limit of the area mapped.

HANSEN & BOLSHAN PROSPECT

The prospect of H. O. Hansen and Nick Bolshan is on the east side of Elbow Passage about half a mile south of the entrance of Lake Anna. Hansen and Bolshan hold six claims, some of which extend southeastward as far as the south end of Lake Anna. The claims are known as the Elbow Passage group and are reported to have been staked about 1934.

The developments consist of a small shaft 29 feet deep, the collar of which is about 15 feet above sea level, and several prospect pits, most of which lie on a slightly curving line that extends from the shaft about S. 45° E. a few hundred feet toward Lake Anna. The shaft is within a few feet of the beach at Elbow Passage. A small cabin has been built not far from the shaft.

The area covered by the claims is low, the maximum altitude being less than 200 feet. It is densely timbered. Over much of the area glacial moraine is sporadically distributed, and the ash from Mount Edgecumbe is present at many places over the moraine.

The country rocks are shaly and splintery graywacke. Near the shaft the rocks strike about N. 57° W. and dip 70° SW. The rocks are distinctly jointed. The joints of the most prominent set strike about N. 40° E. and dip in general about 80° NW.

The shaft was sunk on a fault whose thickness ranges between 1 foot and 3 feet. The fault in the shaft strikes N. 48° W. and dips 84° SW., but near the bottom the dip may be slightly flatter. The hanging wall of the fault is considerably more sheared than the footwall. Veinlets of quartz about 1 inch in greatest thickness that fill joints in the hanging wall are cut off by the fault. In the bottom few feet of the shaft ribbon quartz as much as 1 foot thick was visible in the summer of 1939. The quartz contains small cubes of pyrite.

In the series of small pits that lie in a slightly curving line extending about S. 45° E. from the shaft for about 400 feet are exposed small but definite faults that may be the same as that on which the shaft is opened.

A quartz vein ranging in thickness from 6 to 12 inches has been uncovered on one of the claims a few hundred feet northeast of the shaft. The vein occupies a joint, strikes N. 40° E., and dips 70° NW. The quartz is vuggy, and the walls are clean and free. The quartz is reported to be of high grade, but no definite figure as to its gold content is available.

In the vicinity of the south end of Lake Anna and Elbow Passage are several splits from the fault that extends along Elbow Passage. (See p. 71 and pl. 9.) The shaft and pits at the Hansen and Bolshan prospect appear to be on one of these splits, but that particular split is poorly defined on the airplane photographs.

BANEY PROSPECT

The six unpatented claims of W. D. Baney lie near the southern tip of the peninsula that runs southward from Doolth Mountain between Ogden Passage and Klag Bay. The developments consist of a small shaft, now (1938) full of water but reported to be 22 feet deep, and a large number of prospect cuts, pits, and trenches. The position and size of most of the prospect openings and some of the geologic features are shown on figure 14. A cabin occupied by Mr. Baney is situated near the claims, opposite the northern part of Klag Island.

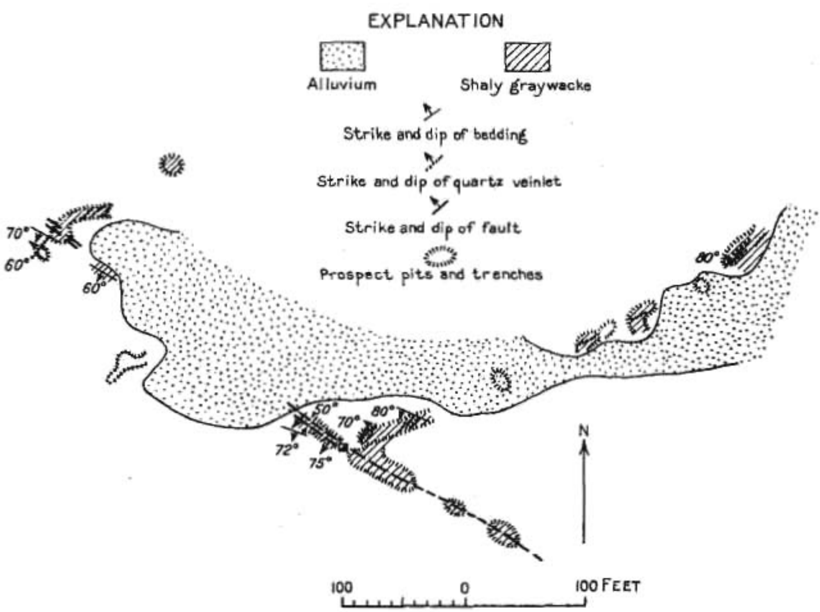


FIGURE 14.—Sketch map of Baney prospect.

The area embraced by the claims is low and for the most part covered with brush and timber. Many of the prospect openings, however, are in and near a swampy area that is practically free of trees and shrubs. Morainal deposits and the ash from Mount Edgecumbe are common on the claims.

The country rock is graywacke, largely of the shaly and splintery types. The average strike in the vicinity of most of the prospect openings is about N. 65° W. and the average dip about 70° SW.

The shaft and a series of prospect openings expose at intervals a weak fault over a distance of about 550 feet. This fault trends N. 55° W. and appears to dip 50°–75° SW. Prospecting has exposed a few quartz veinlets, mostly in the footwall of the fault. These strike northeast at different angles and dip steeply northwest. They probably occupy joints belonging to the major joint system of the district. One veinlet is about 14 inches thick and is reported to carry about half an ounce of gold to the ton. A short distance south of the prospects shown on figure 14 are several outcrops and prospect pits, over a distance of several hundred feet, that reveal large quantities of chert or silicified dike. The rock is now a mosaic of fine-grained sutured quartz cut by tiny veinlets of slightly coarser grained sutured quartz. Shaly graywacke in the vicinity strikes N. 60° W. and dips 70° SW. Locally the siliceous rock and associated shaly graywacke are crossed by small veinlets of quartz, most of which trend about N. 45° E. and dip about 80° NW.

WOLL PROSPECTS

The nine unpatented claims of Mike Woll constitute the Lucky Shot group. They lie on the west side of Lake Anna north of the entrance from Klag Bay. The principal prospecting has been done at three places, two of them 1,000 feet apart about opposite the salt-water channel between Lake Anna and Sister Lake and near the head of Lake Anna. The third is about 1 mile farther south, near Mr. Woll's cabin.

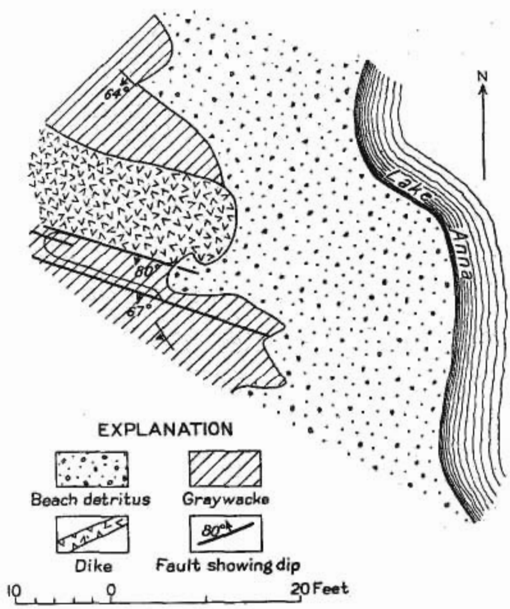
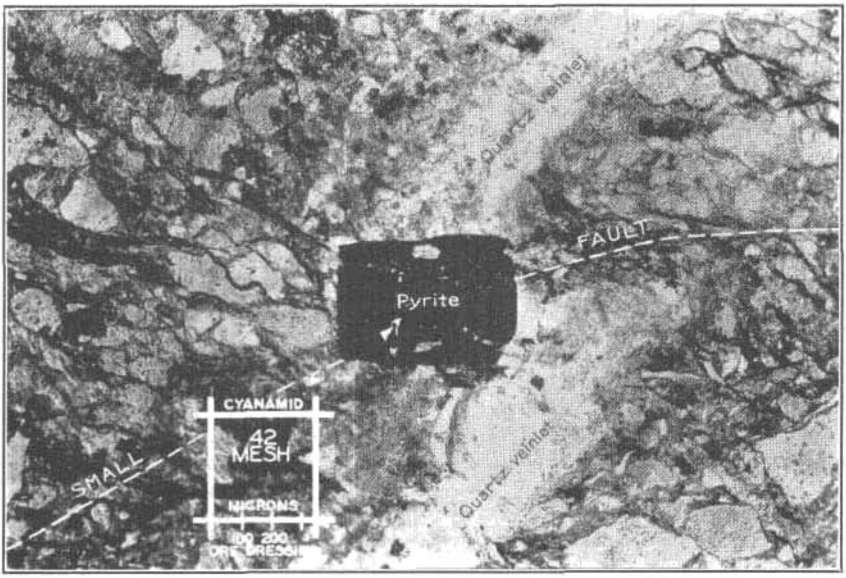
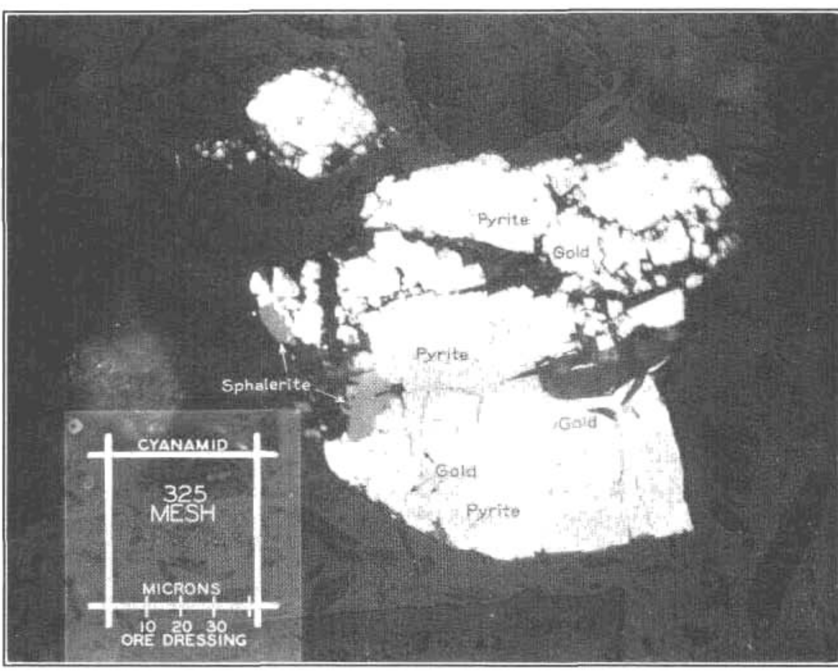


FIGURE 15.—Sketch map of Woll prospect on west side of Lake Anna.



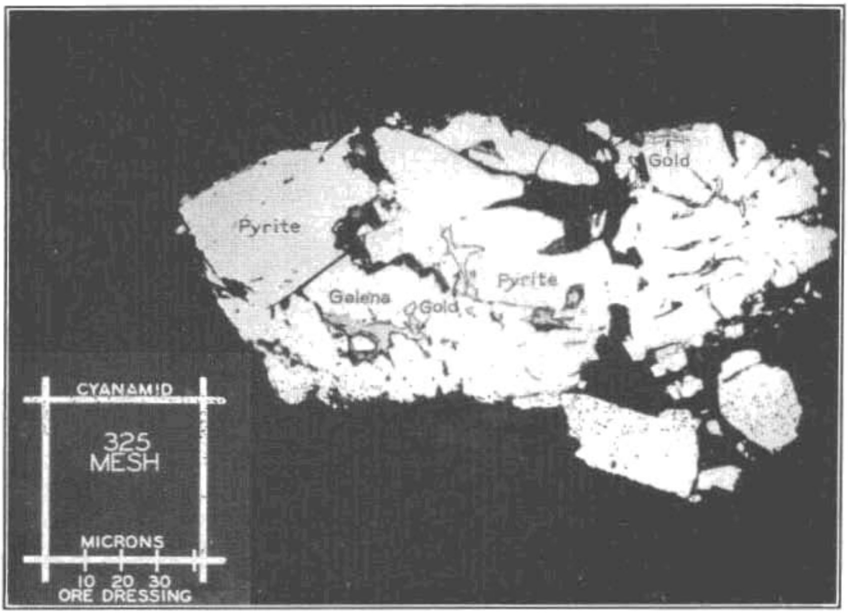
A. PYRITE CRYSTAL IN SMALL FAULT THAT HAS OFFSET TINY QUARTZ VEINLET, HIRST-CHICHAGOF MINE.

Photomicrograph by courtesy of American Cyanamid & Chemical Corporation.



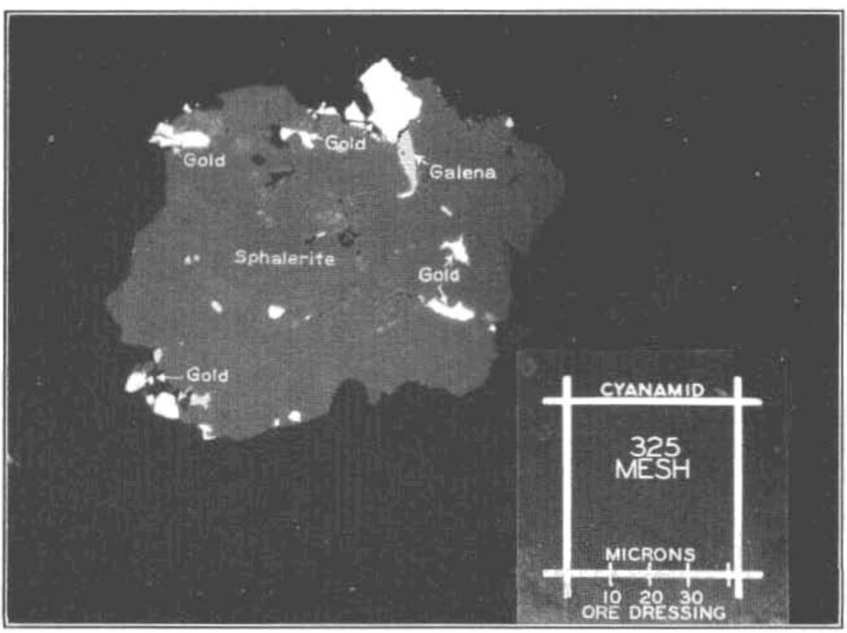
B. PYRITE CRYSTAL CONTAINING GOLD VEINLETS AND DISSEMINATED GOLD PARTICLES, HIRST-CHICHAGOF MINE.

Small mass of sphalerite embays pyrite. Photomicrograph by courtesy of American Cyanamid & Chemical Corporation.



A. GOLD IN PYRITE, HIRST-CHICHAGOF MINE.

Note veinlet of galena cutting pyrite. Photomicrograph by courtesy of American Cyanamid & Chemical Corporation.



B. GOLD DISSEMINATED IN SPHALERITE, HIRST-CHICHAGOF MINE.

Note veinlet of galena in the sphalerite. Photomicrograph by courtesy of American Cyanamid & Chemical Corporation.

At the prospect farthest south a tunnel about 12 feet long has been driven northwestward along the hanging wall of a dike about 10 feet thick. (See fig. 15.) The country rock is massive graywacke, which strikes about N. 35° W. and dips about 65° SW. Some shaly graywacke is interbedded with the more massive rock. The footwall of the dike appears to be an intrusion contact, but the hanging wall is a fault contact. Both walls strike about N. 72° W. The dip of the hanging-wall fault and of some small associated faults is about 80° SW. The dike itself is partly silicified. It contains much granular and interstitial quartz. The feldspar laths have been greatly altered to calcite, sericite, and chlorite. Locally the dike is cut by quartz-calcite-albite veinlets. Arsenopyrite and pyrite, accompanied by a little quartz and carbonate, are present in considerable abundance in the dike near the hanging wall. Lesser concentrations of the sulfides were noted near the footwall. That at least part of the movement on the hanging-wall fault was later than the sulfide mineralization is shown by the presence on the fault of smeared-out and pulverized pyrite. In detail much of the mineralization appears to have been controlled by joints in the dike. Locally the sulfide minerals are present also, with quartz, in the graywacke of the hanging wall.

The prospect just described is a few hundred feet south of a feature that shows distinctly on an airplane photograph and is believed to be the trace of one of the persistent faults of the district. This fault is shown on plate 9.

At a point about 1 mile north of the prospect just described a trench on a steep slope about 30 feet above the beach follows a strong fault that trends N. 5° E. and dips 62° W. The fault zone is several feet thick and carries as much as 1½ feet of vein quartz. The walls of shaly graywacke, into which small splits make off from the fault, strike N. 50° W. and dip steeply SW. A tunnel 48 feet long has been driven from a point about 10 feet above sea level. (See fig. 16.) About 42 feet from the portal the tunnel cuts a fault, probably the same as the one described above. Drifts have been driven in both directions on the fault. The drift to the north is 10 feet long, the one to the south about 15 feet. A winze has followed the fault for 14 feet along its dip. At the face of the northern drift the fault strikes about N. 17° W. and dips 41° SW; in the southern drift it strikes about N. 3° W. and dips 48° SW. At the bottom of the winze the fault strikes about N. 5° E. and dips 51° NW. As much as 3 inches of gouge and from 2 to 12 inches of banded quartz are present on the fault at the tunnel level. At the bottom of the winze an inch of gouge is present on the fault, and a lenticular mass of quartz, 2 feet in greatest thickness and containing angular fragments of graywacke, lies on the footwall of the fault. Irregular quartz veinlets cut the graywacke footwall of the lens. The footwall of the fault zone is sheared parallel to the bedding. At the portal of the tunnel the country rock is massive and splintery graywacke that strikes N. 45° W. and dips 72° SW. A specimen of quartz from the trench above the tunnel consists of coarse-grained interlocking crystals. The quartz contains a few small fragments of silicified and sericitized graywacke. The quartz in the tunnel is vuggy and locally contains considerable galena and sphalerite.

About 400 feet southward along the shore from the prospect described above another small fault was observed. This fault trends

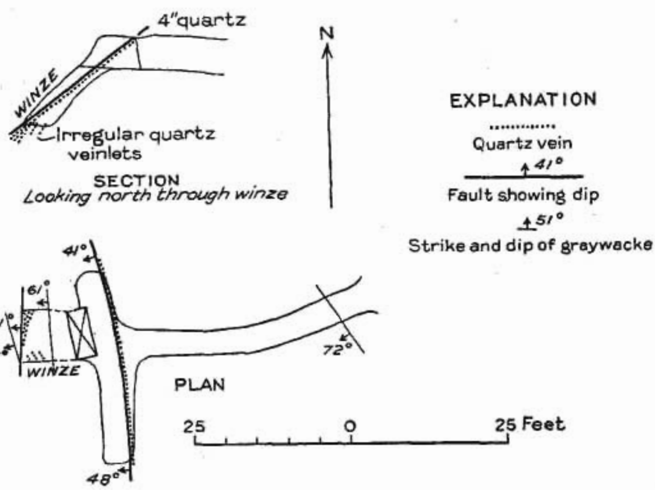


FIGURE 16.—Sketch plan and section of Woll prospect about 1 mile north of Woll cabin.

N. 10° E. to N. 10° W. and dips 58° W. It carries as much as 6 inches of vuggy quartz with pyrrhotite and arsenopyrite. The quartz also contains many inclusions of graywacke and a few of greenstone (?).

About 1,000 feet north of the prospect illustrated by figure 16 are two small pits in each of which is exposed a quartz vein about 1 foot thick. The pits are about 200 feet from the beach, at an altitude of 100 feet. The veins are poorly exposed but appear to strike N. 15° E. and N. 17° E. and to dip 73° W. and 60° W. respectively.

This most northerly prospect is a very short distance south of what is believed from the photographs to be the Chichagof fault.

ANDERSON PROSPECTS

The two prospects of T. A. Anderson are on the north shore of Sister Lake a few hundred feet east of the southeast end of the salt-water entrance from Lake Anna. This locality is a short distance northeast of the contact between the schist and the graywacke (see pl. 3) and therefore is in the schist.

The Anderson cabin is near the more easterly prospect, which is about 35 feet above sea level and is an open cut 40 feet long driven N. 10° E. into the hillside. The country rock is shaly graywacke with some interbedded greenstone. The strike in the vicinity is N. 50° W. and the dip 65° SW. At the beginning of the cut is exposed a fault that trends N. 10° W. and dips 72° SW. At the face this fault has curved to N. 25° E. with a dip of 75° SE. At the face and about 3½ feet west of this fault is another fault with the same strike but with the steeper dip of 88° SE. The zone between the two faults is considerably broken. As much as 1 foot of quartz is found on the more easterly fault. The quartz is coarse-grained and contains some calcite as well as fragments of silicified and sericitized graphitic graywacke.

The more westerly prospect is in the bed of a small stream 70 feet above sea level. The country rock is shaly graywacke that strikes N. 45° W. and dips 80° SW. Here a 36-foot tunnel has been driven on a strong fault that strikes N. 12° W. and dips 72° SW. About 2 feet of gouge and sheared rock lies against the relatively massive footwall. Intense shearing continued into the hanging wall but appears to have decreased in intensity with increased distance from the footwall. Thin leaves of quartz are present in many places between layers of sheared shaly graywacke. Locally as much as 2 feet of vein quartz is present on or near the footwall of the fault. The quartz appears to be identical with that of the more easterly prospect, several hundred feet away. From the airplane photographs the more westerly prospect appears to be on a strong fault that connects with the Chichagof fault under Sister Lake and with the Hirst fault about 4,000 feet north of the north end of Lake Anna (see pl. 9). The fault therefore appears to link together the Hirst and Chichagof faults.

McKALLICK PLACER PROSPECT

Mike McKallick has staked some placer ground at the head of a small bay on the east side of Ogden Passage, about a mile north of Vein Point. A small dwelling has been erected on the beach. Some prospecting has been done in the bed of a small brook which flows across muskeg. Underneath the peat and muck of the stream bottom is considerable debris, made up mostly of angular fragments of graywacke. This debris may be as much as 8 feet thick 60 feet from the beach. The ground has been opened incompletely for a distance of about 50 feet along the creek, a width of about 20 feet, and a depth as great as 8 feet. The graywacke bedrock is hard and irregular. The gold-bearing material appears younger than morainal material present at the prospect and possibly younger than the ash from Mount Edgecumbe.

The authors panned some of the debris that lies on the bedrock and obtained a concentrate in which considerable gold was visible, as sharp-edged irregular flakes as much as 2 millimeters long. Nearly all the gold grains either enclosed quartz or were enclosed in quartz. One grain enclosed a pyrite crystal. The associated minerals were hypersthene, which was coated with a thin film of vesicular glass, ilmenite, magnetite, augite, and plagioclase feldspar. Most of these minerals appeared to be associated with the volcanic ash rather than with the gold. Little quartz was noted in the muck and rock fragments.

The deposit is evidently eluvial, as shown by the lack of rounding of the rock fragments and still more by the angularity of the gold, which can have traveled but a short distance since it was freed from the enclosing rock. The gold probably came from a nearby lode that is concealed by the dense vegetation and swamps of the vicinity.

AMERICAN GOLD CO.'S PROSPECT

The American Gold Co. is reported to hold a group of 21 claims on the peninsula that extends southward from Doolth Mountain between Ogden Passage and Klag Bay. The claims are about 1 mile south of Chichagof. The stockholders in 1938 were reported to include Messrs. Wallace George, president; Joe Thibodeau, secretary and treasurer; Jack Mullin, and Mike McKallick. The main development on the claims is a tunnel, at an altitude of about 500 feet, which includes about 75 feet of crosscuts and 110 feet of drifts on two faults. (See fig. 17.)

The principal country rock is shaly graywacke. The strike ranges from N. 35° W. to N. 55° W., and the dip is about 72° SW. A dike about 5 feet thick is exposed underground and is offset by faulting. The dike is composed principally of lathlike crystals of albite-oligoclase. It is partly silicified. Alteration products are calcite, sericite, and chlorite.

At 30 feet from the portal the tunnel cuts a fault that strikes N. 50° W. and dips about 77° SW. This fault has been followed for 62 feet. It has displaced the dike 30 feet on the horizontal projection. A few pieces of the dike have been dragged along the fault. The northeast or footwall side has moved southeastward relative to the hanging-wall side. Striae on the fault surface pitch 33° SE.

Another fault that has been exposed by the underground workings about 50 feet southwest of the fault just described strikes N. 40° W. and dips 70° SW. It has been followed for about 50 feet. The dike shows in the footwall, but the drift does not extend far enough northwest to reach the other part of the dike in the hanging wall.

A small open cut about 55 feet above the tunnel has exposed a fault that cuts off a dike, possibly the same one as was seen underground, in a manner similar to that in which the dike is displaced in the tunnel. A little quartz is present on the fault. A speck of gold was seen in a tiny quartz veinlet that is one of several that fill joints trending N. 35° E. and dipping 75° NW.

The prospect, as nearly as can be told from the airplane photographs, is on or very near one of the more prominent faults of the district (pl. 9). Apparently this is the same fault as the one near the most southerly prospect of Mike Woll on Lake Anna. (See pp. 121–122.)

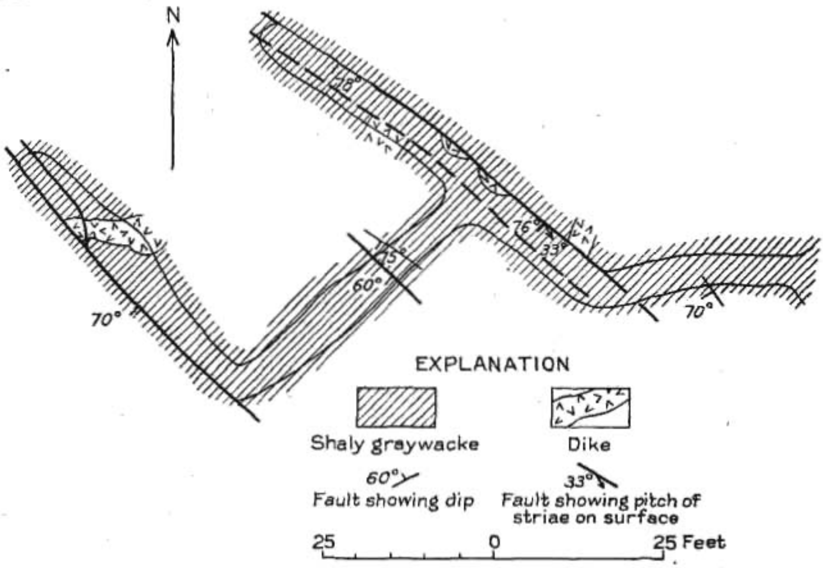


FIGURE 17.—Sketch plan of prospect of American Gold Co.

SMITH PROSPECTS

Louis H. Smith is the holder of four claims, the Jumbo, Duluth, Minnesota, and Gold Reef No. 1, that stretch northwestward from his dock and buildings on the west side of Klag Bay about three-quarters of a mile south of Chichagof. (See pl. 1.) The claims are reported to have been staked in 1909, 1912, 1912, and 1910 respectively. In 1924 these claims and several others were optioned by the Klag Bay Mining Co., which did a considerable amount of underground work before the option was given up in December 1926.

A small tunnel and shaft on the beach on the Jumbo claim have been described by Overbeck [32] as follows:

At the present time [1917] the workings consist of a tunnel about 35 feet long and an inclined shaft 48 feet deep that is now filled with water. In the face of the tunnel there is a small crushed zone about 6 inches wide that is filled with crushed slate and small quartz stringers. Two large quartz stringers cut across the face at an angle to the small crushed zone. Pyrite is fairly abundant in association with quartz and also occurs in stringers that cut the slaty country rock. The country rock is a much-broken argillitic graywacke. The strike and dip of the fault plane are variable. Where measured at the surface it strikes N. 54° W. and dips 62° S. The plane flattens to about 45° S. at the bottom of the incline. The material in the dump shows brecciated slaty particles cemented by quartz in which are rather abundant well-crystallized pyrite, some galena, and some sphalerite. It is said that the quartz which shows rather abundant sphalerite is as a rule not very rich in gold. Some of the best specimens of free gold in the region come from this prospect.

The principal underground prospecting of the Klag Bay Mining Co. was done only a short distance from the prospect described above. It consisted of the sinking of a 400-foot inclined shaft from which were turned a 200-foot and a 400-foot level. The shaft is now full of water. The 200-foot level was driven 50 feet S. 53° E. and 200 feet N. 53° W. from the shaft. The 400-foot level was driven about 230 feet southeast and about 1,100 feet northwest from the shaft. A few small crosscuts also were driven. A large number of small open cuts were dug on the surface in a northwesterly direction from the shaft, but these are now sloughed in.

Trenches and pits expose a quartz vein at intervals over a distance of several hundred feet. These prospect openings are believed to be in the northern part of the Jumbo claim and the southern part of the Minnesota claim. At an altitude of about 110 feet a trench exposes for 20 feet horizontally and 10 feet vertically a quartz vein between 1 foot and 2 feet thick that strikes N. 25° W. and dips 60° SW. The quartz is banded and locally has replaced fragments of included shaly graywacke. According to reports this surface quartz assayed between 40 cents and $2.40 to the ton on the basis of gold at $20.67 an ounce.

About 50 feet northwest of the trench just described, on the other side of a low rock knob, another cut exposes the same vein for about 25 feet. The vein here is 2 feet thick, strikes N. 45° W., and dips 75° SW. A short distance farther northwest a pit has uncovered for about 8 feet a vein 14 inches thick. This vein strikes N. 30° W. and dips 73° SW. Striae on a surface of the fault in which the vein lies pitch 25° SE.

About 75 feet northwest of the pit just mentioned is an open cut that crosscuts shaly graywacke in the hanging wall of a fault. The

[32] Overbeck, R. M., op. cit. (Bull. 692), pp. 118–119.

fault is exposed vertically for about 15 feet at the face of the cut. The shaly graywacke strikes N. 45° W. and dips 73° SW. The fault zone, which is 4 feet thick, strikes N. 35° W. and dips 73° SW. In the fault lies a quartz vein 1½ feet thick. The quartz is banded and is pyritiferous. A cross joint that contains a quartz veinlet 6 inches thick, strikes N. 45° E. and dips 46° NW. This joint is in the hanging wall of the fault, and the veinlet is cut off by the fault. Under the microscope the quartz of the 1½-foot vein is seen to be coarse-grained and distinctly banded. The banding is largely due to layers of silicified wall rocks that are somewhat graphitic. The quartz is banded also by crushed zones parallel to the vein walls. Calcite and pyrite were noted in the quartz.

Near the south end of the Gold Reef No. 1 claim, about 2,700 feet N. 42° W. from the 400-foot shaft, is another shaft, now full of water, that also was sunk by the Klag Bay Mining Co. This shaft is reported to be 230 feet deep and to have two short levels turned from it.

HILL & BERKLAND PROSPECT

Charles Hill and Ole Berkland are reported to hold two claims on the east side of Klag Bay about half a mile south of Chichagof. A small tunnel on the beach is said to be on one of these claims. (See fig. 18.) The country rock in the vicinity of the tunnel is argillaceous graywacke that strikes N. 58° W. and dips 62° SW. The tunnel is driven from the beach S. 45° E. for about 50 feet along a relatively weak fault that dips 63° NE. At the face of the tunnel the fault is joined by another fault that strikes N. 20° W. and dips 65° NE.

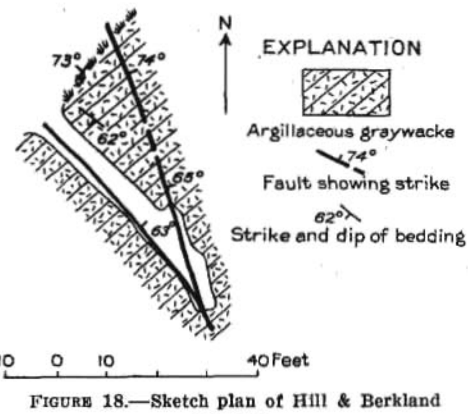


FIGURE 18.—Sketch plan of Hill & Berkland prospect.

This second fault crops out at the beach about 22 feet north of the portal of the tunnel. Each of the faults locally contains a little quartz, in a few places as much as 6 inches thick. A well-defined joint with a little quartz forms a low cliff face near the tunnel portal. This joint strikes N. 31° E. and dips 73° NW.

CHICHAGOF EXTENSION PROSPECT

The Chichagof Extension Mining Co., of which V. V. Tarbull, of Seattle, is said to be the president, was reported to hold in 1938 three claims, the Chichagof Extension Nos. 1, 2, and 4, on the east side of Klag Bay opposite Chichagof. The several pits and open cuts examined are on No. 4 claim, on and near the divide between Klag Bay and the small lake that lies between Chichagof and the head of Lake Anna.

The easternmost prospect opening seen is a trench that exposes a quartz vein for about 30 feet. For about 8 feet of this distance the vein is 3 feet thick. The vein strikes N. 15° W. and dips 80° SW. At the southeast end of the exposure it appears to pass into several cross veinlets. The country rock is shaly graywacke that strikes N. 56° W. and dips 70° SW.

About 65 feet N. 18° W. from the trench just described is another one that opens for about 20 feet a vein from 6 to 14 inches thick. This vein trends N. 8° W. and dips 65° W., but at its north end the strike swings to a more westerly direction.

These two trenches are separated by about 430 feet of swampy ground (muskeg) from a longer trench that exposes for 140 feet a quartz vein as much as 1 foot thick. This exposure is about N. 36° W. from the two smaller trenches. The vein trends N. 29° W. and is vertical. This prospect is very close to the southeast end line of the Andy claim.

HANDY AND ANDY PROSPECTS

The Handy and Andy claims lie on the east side of Klag Bay opposite Chichagof. They are reported to be the property of the Handy-Andy Mining Co. The small tunnel that was visited on the Andy claim is near the beach just south of the base of a small point that extends from the east shore of the bay toward the island near the dock at Chichagof. The country rock is shaly graywacke. The tunnel, which is 57 feet long, has been driven on a small fault. According to reports the tunnel was driven by the Chichagof Extension Mining Co. on what was then its No. 3 claim.

The Handy tunnel (see fig. 19) is at the north base of the small point mentioned above. The tunnel is about 80 feet long and exposes three small faults. The country rock is massive graywacke. What appears to be the principal fault, on which a winze, now full of water, was sunk, strikes in general N. 60° W. and dips 60° SW.

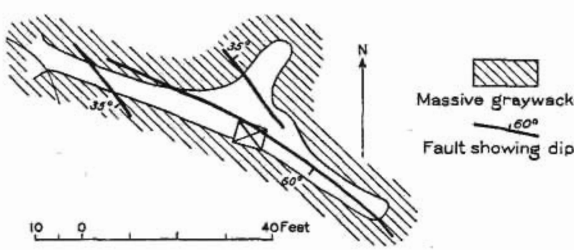


FIGURE 19.—Sketch plan of Handy tunnel.

ALASKA CHICHAGOF MINING CO.'S MINE

The Alaska Chichagof Mining Co. holds a group of claims stretching across the divide between Klag Bay and Ogden Passage. The principal mining and prospecting operations have been carried on in a small mine near the shore of Klag Bay about 2,500 feet south of Chichagof. The chief owner is reported to be Nick Bez. According to reports the tunnel was started by Mike McKallick in 1928, when he claimed the ground. It is said that Bez later bought McKallick out.

Between April and December 1936 mining and milling was done for the Alaska Chichagof Mining Co. by the Chichagoff Mining Co. A total of 302 tons of ore was mined. This ore had an assay value of a little more than $35 to the ton and yielded a little more than $9,000 worth of gold and silver. McKallick reports some production before the mining of the ore by the Chichagoff Mining Co.

The tunnel, which is mostly a drift, was driven about 115 feet to a point from which one branch tunnel, the southerly one, has been driven about 110 feet farther. A more northerly branch tunnel, about 195 feet long, has been driven from the same point, 115 feet from the portal. An inclined shaft, that dips about 65° SW., has been sunk from the surface through this tunnel at about 42 feet from the surface and on down to a depth on the incline of about 142 feet. Below the tunnel the shaft was in 1938 full of water.[33] (See fig. 20.)

The principal country rock is shaly graywacke, but a small dike, offset about 4 feet by a fault; was encountered near the face of the southerly tunnel, and two small dikes were cut in the northerly tunnel, one at the ore shoot and the other about 55 feet from the face. At one place the strike of the bedding is N. 78° W. and the dip 75° SW.; at another the strike is N. 64° W. and the dip 73° SW.

The tunnel was driven on a strong fault zone to the place where the branches started. At about 97 feet from the portal quartz appears in the fault, and the northern branch, at 115 feet, follows the fault with quartz to the vicinity of the shaft, where the quartz in a short distance thickens to about 5 feet for nearly 20 feet. Beyond the dike at the ore shoot quartz is present for about 15 feet farther, but this area is now largely concealed. The fault continues, but in greatly decreased strength, to a point about 80 feet from the inclined shaft, where it appears to die out. Another very weak fault is followed by the northern branch tunnel most of the rest of the way to the face.

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[33] This property was again visited briefly in 1939. Prospecting work on the main level is shown in figure 20. The shaft was being pumped out at the time of this later visit, and a lower level was entered, but not enough time was available to study adequately the complex geologic features exposed therein.

Several splits, which appear to curve into the bedding, were seen along the part of the tunnel between the portal and the place where it branches. The hanging-wall side of the fault appears to continue into the ground between the two branches of the tunnel. For about 35 feet from the fork the southerly tunnel is a crosscut. At that distance is encountered another well-defined fault which it followed to the face.

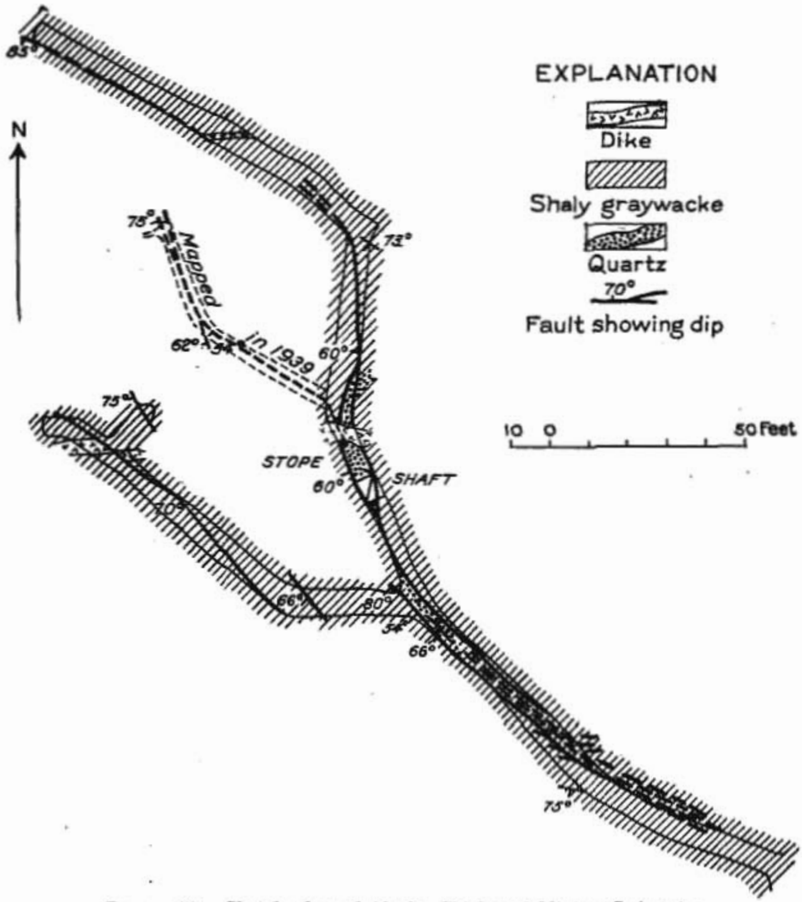


FIGURE 20.—Sketch plan of Alaska Chichagof Mining Co.'s mine.

It seems possible that the ore shoot, from which has come the production and which was mined over a stope length ranging from 10 to 35 feet and from a point 142 feet down the shaft to a point within 15 feet of the surface, is on a split from the main fault that was followed from the portal and that the main fault continues into the unexplored ground between the two branches of the tunnel. Unfortunately the work done in 1939 did not open ground far enough southwest to prove or disprove definitely the continuation of the fault that passes into the tunnel wall at the fork, 115 feet from the portal. (See fig. 20.)

LILLIAN AND PRINCELA PROSPECT

Mike McKallick is said to be the owner of a group of 16 claims that extends from Klag Bay to Ogden Passage between the claims of the Chichagoff Mining Co. on the north and those of the Alaska Chichagof Mining Co. on the south. His company is called the McKallick Chichagof Mines, Inc.

A long veinlet that occupies a joint has been exposed by a trench and several pits for a distance of about 300 feet on the Lillian and Princela claims. The altitude of the prospect is about 250 feet. The country rock is largely massive graywacke, but some shaly graywacke is present also. The rocks strike N. 35° W. and dip 75° SW. The vein, which reaches 1 foot in thickness (see pl. 31), trends N. 42° E. and dips 70° NW. Locally the vein splits, and a small split shows on plate 31. In places the quartz is accompanied by considerable pyrite and galena.

FLORA PROSPECT

The Flora claim is an old claim, reported to be patented, that is now surrounded by ground claimed by the McKallick Chichagof Mines, Inc. A tunnel on the claim is at an altitude of about 680 feet. The tunnel is about 90 feet long and was driven N. 22° W. along a fault that is distinct but not prominent. The wall rock of the fault is shaly graywacke whose average strike is about N. 57° W. and whose average dip is about 66° SW. The fault dips 50° SW. Between 20 and 30 feet from the portal are several veinlets that dip south at different angles. These appear to merge at the fault with a vein, as much as a foot in thickness, that follows the fault to the face. Considerable calcite is present in the vein.

HANLON PROSPECT

The Hanlon prospect is on the west shore of Ogden Passage, about six-tenths of a mile north of Drip Point. According to the location notice, the claim was staked by Hanlon in 1933. An open cut about 25 feet long and 12 feet deep at the face has been driven into the cliff from the beach. About 100 feet northwest of the cut is a trench about 50 feet long, the sides of which are now sloughed in. The country rock in the vicinity is graywacke. In the cut on the beach a fault is exposed that trends about N. 40° W. and dips 80° SW. Quartz a few inches thick is present in the fault at the face of the cut, and quartz about 5 inches in greatest thickness was observed in the dump of the trench. The quartz contains pyrite and arsenopyrite, the latter mostly a replacement mineral in graywacke inclusions. A little carbonate is also present.

TILLSON PROSPECT

Two claims on Doolth Mountain, the Bear Extension and the Lena, are known as the Tillson claims. The Bear Extension claim is reported to have been staked originally in 1912 by Knute Knutson and Ole Berkland and to have passed to Tillson in 1915. The principal prospecting on the claims has been done by means of a tunnel about 95 feet long that lies about 4,300 feet S. 37° E. from the post office at Kimshan Cove. The tunnel was driven N. 47° W. along two faults about 6 feet apart. The dip of the footwall fault is about 50° SW., and that of the hanging-wall fault a little steeper. About two-thirds of the way in the tunnel the hanging-wall fault curves to the left, away from the tunnel, and has not been followed farther. For a distance of 35 feet the footwall fault contains a quartz lens about 1½ feet thick. Quartz is also locally present in the hanging-wall fault.

GLORIA B. PROSPECT

Several prospect pits were examined on the Gloria B. claim of W. D. Baney, on the northwest side of Doolth Mountain. The largest pit is about 200 feet southwest of the small lake shown on plate 1. Several smaller pits N. 25° W. of the largest pit are distributed along a line about 1,000 feet long. The country rock is chiefly graywacke. Many of the smaller pits expose white chert. At the largest pit the graywacke strikes N. 60° W. and dips about 60° SW. A fresh-appearing dike is here cut by quartz veinlets, containing pyrite, and by a small fault that strikes N. 75° W. and dips 50° SW. The amount of displacement of the dike by the fault is apparently less than 10 feet.

CHICHAGOF PROSPERITY PROSPECTS

The Chichagof Prosperity Mining Co. holds nine claims on and near the south side of the entrance of Kimshan Cove. The Hirst-Chichagof Mining Co. optioned the claims in the fall of 1938, sunk a prospect shaft, and did considerable drifting during the winter of 1938–39. This work is shown in plate 30 by dashed lines. The company gave up its option in 1939.

The principal work has been done on the northern part of the Chichagof Prosperity No. 2 claim, where two tunnels and several pits and trenches have been opened. (See pl. 30.) The country rock in the vicinity is graywacke, mostly massive. The general strike approximates N. 65° W. and the general dip is probably about 60° SW. The more northerly tunnel is about 45 feet long and is about 3 feet above high tide level. In this tunnel is exposed a fault that strikes about N. 41° W. and dips 62°–64° SW. Several smaller faults are present in the hanging wall of the main fault, and some of them split from the main fault into the hanging wall. The larger fault locally contains as much as 3 feet of quartz and the smaller as much as 1½ feet. Along a large part of the tunnel the hanging wall of the principal fault contains many quartz veinlets, as much as several inches thick individually, that lie in differently oriented joints.

In a pit about 10 feet deep that lies at an altitude of about 69 feet, 192 feet S. 38½° E. from the portal of the tunnel just described, are exposed three quartz veins, each 14 inches thick. One of these veins trends N. 41° W. and dips 60° SW. and appears to lie in a fault zone. The others appear to be splits into the footwall of the fault zone. About 60 feet farther southeast a vein 2 feet thick shows in a small prospect opening. This vein appears to lie in a fault that strikes N. 25° W. and dips 50° SW. In a large, partly sloughed pit about 90 feet S. 60° W. from the portal of the southern tunnel 8 inches of quartz in place is exposed. About 55 feet southeast of the pit is a small, old tunnel, now caved.

The southern tunnel (1938) is a crosscut about 150 feet long. Near the face it cuts a fault that strikes N. 13° W. and dips 69° SW. A quartz vein from 1 foot to 2 feet thick occupies the fault. A winze, full of water when the tunnel was surveyed in 1938, has been sunk on the vein. Whether or not the veins seen in the two tunnels and in the prospect pits are all parts of one and the same vein is not known. Probably they are either parts of the same vein or at least occupy closely associated faults and splits of one fault zone.

The prospect openings made in 1939 have not been visited by the authors.

MARINOVICH PROSPECT

The Marinovich prospect lies at an altitude of about 250 feet along the small stream that enters Kimshan Cove about 1,000 feet northeast of the Hirst-Chichagof Mining Co.'s dock. The country rock at the prospect is shaly graywacke that strikes N. 75° W. and dips 65° SW. A 27-foot tunnel has been driven S. 52° E. from the bed of the stream along a small but definite fault that dips 80° SW. No quartz was seen on the fault. Near the portal of the tunnel and in the footwall of the small fault mentioned is another fault that strikes N. 75° E. and dips 85° SE. This fault contains as much as 4 inches of quartz. Quartz as thick as 1 inch is present in many joints in the vicinity.

McKALLICK PROSPECT

Mike McKallick is reported to own eight claims that cover the divide between Black River and the stream and small lake about 2 miles northeastward up the Hoonah Sound trail from Chichagof. The principal developments consist of two short tunnels about 500 feet northwest of the northwest side of the small lake. The upper tunnel is at an altitude of about 710 feet. The tunnel is 35 feet long and runs N. 15° W. along two closely associated faults that dip 55° SW. The country rock is shaly graywacke. On and between the two faults near the tunnel portal is about 5 feet of quartz. The quartz continues for only about 10 feet into the tunnel. Directly toward the lake from the upper tunnel and at an altitude of about 620 feet is another tunnel about 55 feet long. This lower tunnel exposes a small fault that cuts massive graywacke.

BAUER PROSPECT

Joe Bauer holds four claims, Radio Nos. 1, 2, 5, and 6, on Herbert Graves Island near its east end. Bauer and Soni are also reported to own two patented claims and to hold two unpatented fractional claims on the opposite side of Ogden Passage southwest of the Chichagof Prosperity Mining Co.'s group of claims. On the claims of Bauer and Soni there are reported to be an open cut 50 feet long, which exposes a face 35 feet high, and a 20-foot tunnel on the beach. On the Radio No. 1 claim on Herbert Graves Island there are two tunnels (fig. 21). The lower and longer tunnel starts about 10 feet above high tide and extends for about 467 feet in a general N. 48° W. direction. The tunnel runs principally along a well-defined fault that dips 40°–75° SW. Quartz as much as 1 foot thick is present in places on the fault. From the portal for about 270 feet the tunnel exposes also a split from the main fault that trends N. 53° W. and dips 74°–85° SW. In some places the main fault zone is narrow, but in others it occupies the full width of the drift. Striae on the fault surface pitch 25° to 33° SE. This fault is about 150 feet northeast of a well-defined fault trace that may be the trace of the Chichagof fault.

The principal country rock is massive graywacke, and the general strike is about N. 65° W. and the prevailing dip about 70° SW. Near the face of the tunnel a dike with a maximum exposed thickness of about 6 feet is present in the footwall of the fault but was not seen in the hanging wall. The fault is about 2 feet thick at the present face (1939). The dike is locally mineralized with pyrite and arsenopyrite. The dike and the graywacke are cut by cross joints, some of which contain quartz veinlets. The veinlets contain pyrite and arsenopyrite.

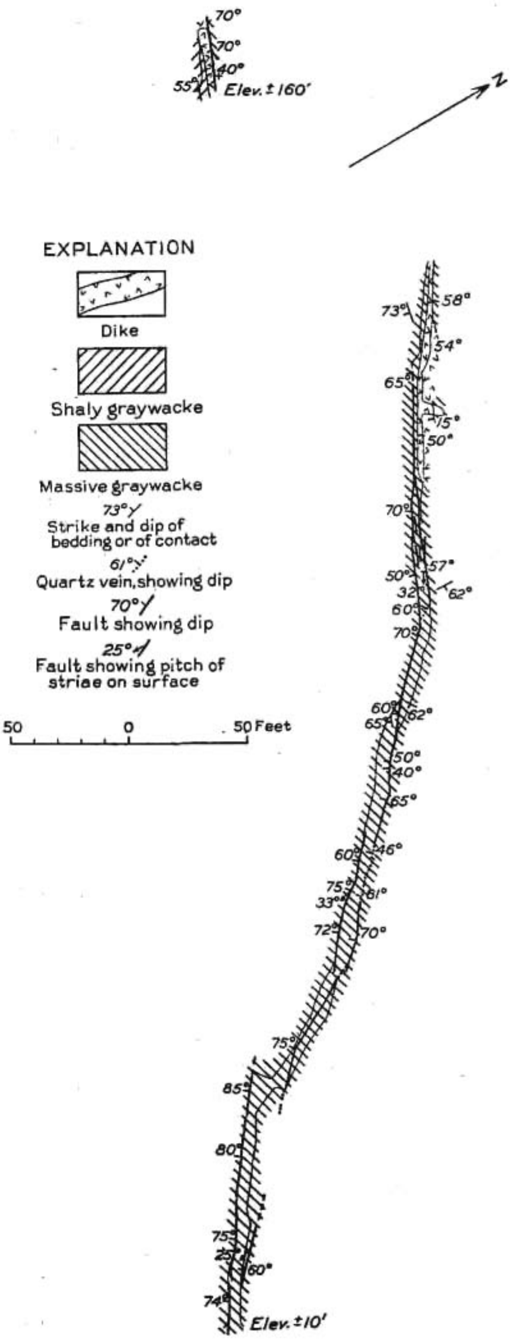
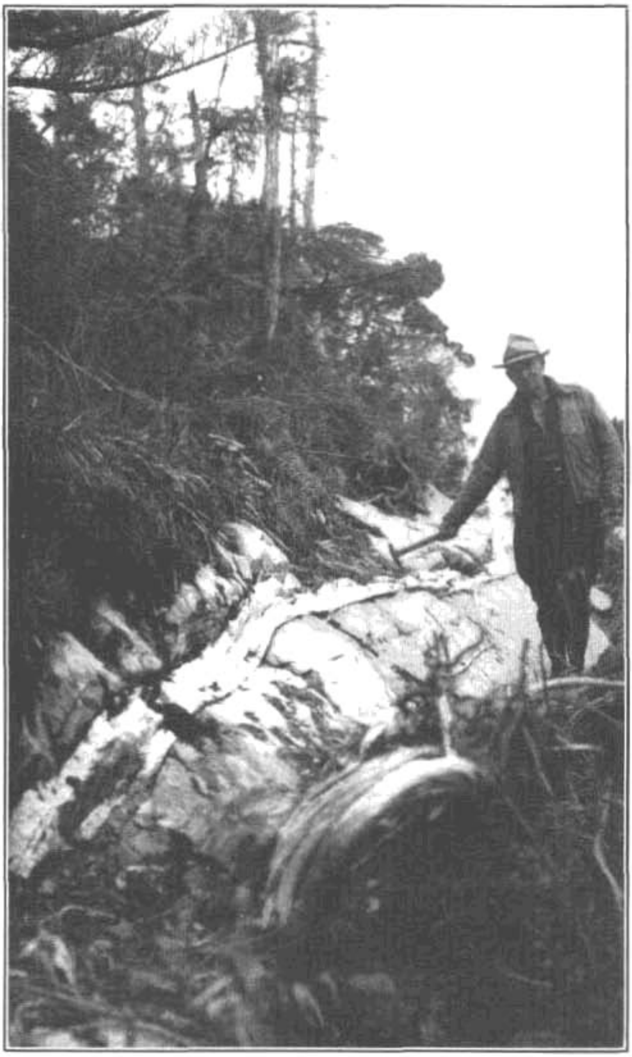


FIGURE 21.—Sketch plan of prospect tunnels on Radio No. 1 claim.

The upper tunnel on the claim is at an altitude of about 160 feet. It lies about 530 feet N. 58° W. from the portal of the lower tunnel and is about 25 feet long. For 10 feet near the face is exposed a small fault that strikes N. 71° W. On the northwest end the fault dips 70° NE. and on the southeast end 70° SW. On the southwest side of the fault lies a dike about 6 feet thick. The shaly graywacke that lies southwest of the dike strikes N. 70° W. and dips 55° SW. Like the dike in the lower tunnel, the 6-foot dike is locally mineralized with pyrite and arsenopyrite. The dike and shaly graywacke are crossed by joints that trend N. 9°–25° E. and dip 70°–80° NW. Some of the joints contain quartz veinlets as much as 4 inches thick. The upper tunnel appears to be on or very close to the trace of the fault that may be the Chichagof fault.

GOLDEN HAND PROSPECTS

The Golden Hand prospects, which are reported to be owned by H. J. Armstrong and Joe Nyland, comprise six claims in the drainage basin of the creek that enters the head of



QUARTZ VEIN AT LILLIAN AND PRINCELA PROSPECT.

Pinta Bay from the east. The Nyland cabin is near the creek and about 2,500 feet east of its mouth.

The highest prospect examined is at an altitude of about 420 feet, about 2,050 feet S. 76° E. of the cabin. At this place a small open cut exposes limestone that is intruded by biotite-albite-quartz diorite. The intrusive rock is a small mass, a few outcrops of which are shown on plate 3. The mass is probably somewhat larger than indicated on that plate, as it is partly concealed beneath a cover of glacial moraine and vegetation. Microscopic examination of the intrusive rock shows that the plagioclase has been partly saussuritized and the biotite chloritized. This alteration may be due in part to the effect of the mineralizing solutions. The contact of the intrusive rock with the limestone, as exposed in the cut, is a minor fault that strikes about N. 30° W. and dips 86° SW. Close to the fault the limestone has been replaced by vuggy rusty quartz. Interlocking quartz grains enclose wisps of sericite. A specimen taken somewhat farther away from the fault is limestone breccia stained by limonite and cemented by interlacing small prisms of quartz. Still farther from the contact the limestone contains veinlets and kidneys of coarsely crystalline calcite. A few specks of gold in quartz veinlets were seen at the prospect.

Another prospect is at an altitude of about 305 feet about 1,660 feet S. 62½° E. from the cabin. There several pits penetrate the moraine. One of them exposes an intrusive rock similar to that at the prospect just described. The other pits expose limestone. The limestone is cut by two weak faults, which may be continuous beneath the morainal cover for a distance of 20 or 30 feet and which strike about N. 14° E. and are nearly vertical. Along these faults brecciated rock is cemented with calcite and quartz.

A third prospect is at an altitude of about 100 feet in the bed of a small creek. It is about 670 feet S. 59½° E. from the cabin. Here a small cut has exposed schistose limestone that strikes N. 50° W. and dips 51° SW. A strong fault is parallel to the foliation of the schistose limestone. Other prospect pits of this group, indicated on plate 1, were not examined.

NEW CHICHAGOF MINING SYNDICATE'S PROSPECT

A stock company, called the New Chichagof Mining Syndicate, is reported to hold 17 claims in the vicinity of the head of Pinta Bay. The officers are said to be George Osborn, president; Louis Delabeque, secretary; and Joe Stocker, treasurer. The manager on the property during the summers of 1938 and 1939 was Max Behrmann. A cabin, owned by the company, has been built a short distance up the creek that enters the head of Pinta Bay from the east. At the portal of the longer tunnel are a compressor and a small blacksmith shop.

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The principal underground development is a tunnel about 795 feet long from which have been turned a few short crosscuts. (See pl. 32.) This tunnel is about 1,500 feet east of the mouth of the creek above mentioned and at an altitude of about 180 feet. A shorter tunnel, about 145 feet long, has been opened about 85 feet above the lower tunnel. The property was examined in 1938 and was visited briefly in 1939, but the map and the description represent conditions in the summer of 1938.

Both tunnels are principally drifts on a strong fault zone that trends in general about N. 36° E. but ranges from about N. 20° E. to about N. 40° E. The fault zone dips about 55°–85° NW and the average dip is probably about 65° NW. In some places the fault movements apparently were largely confined to a narrow zone only a few inches thick; in other places the fault zone is several feet thick. Locally splits diverge from the main fault. Some of them pass into the footwall and others into the hanging wall. Here and there the fault divides into several smaller faults that diverge a few feet from each other, continue for 50 feet or less, and then come together again. In the horizontal projection the displacement along the fault zone has been about 22 feet. Locally the displacement appears to be as little as 10 feet. At one place, however, about 560 feet from the portal, it is 40 feet, but here the structure is complicated by smaller faults and is not well understood. The northwest or hanging-wall side of the fault has moved northwestward relative to the footwall side. The vertical component of the movement is not known.

The country rocks exposed in the principal tunnel include thin-bedded limestone, limy shale, graphitic shale, greenstone schist, schistose limestone, massive limestone and marble, massive to intensely sheared diorite, and dike rock. The first rock in place encountered in the tunnel is foliated siliceous greenstone. This rock prevails to a point about 300 feet from the portal except for interbedded layers as much as 26 feet thick of shale, limy shale, and thin-bedded limestone, which are mapped as a unit on plate 32. The shale, limy shale, and thin-bedded limestone are the principal rocks from 300 feet to about 390 feet from the portal. A band of interbedded more massive limestone about 6 feet thick is present in that part of the tunnel. From 390 to 715 feet from the portal the predominant wall rocks are relatively massive limestone and marble. This calcareous section begins with about 11 feet of schistose marble that contains considerable muscovite (or talc). From about 578 feet to about 637 feet from the portal on the hanging-wall side of the fault zone is massive albitized diorite. The diorite is locally intensely sheared near faults and is indistinguishable from the rock mapped as greenstone. A dike that attains a maximum observed thickness of about

8 feet is intruded into the massive limestone and marble at the end of a small crosscut about 80 feet from the face and in the main tunnel about 50 feet from the face.
was observed to range from N. 10° W. to N. 80° W. and the dip 64° SW. Their attitude is not very uniform however, and the strike was observed to range from N. 10° W. to N. 80° W. and the dip from 40° to 82° SW.

Locally brecciated zones have been developed near the main fault zone. The massive limestone and marble appear to have been particularly susceptible to brecciation. The brecciated zones are very irregular and are present in both the hanging wall and the footwall of the fault zone. Some zones were seen to continue at least 10 feet from the fault zone, and they may extend farther. These irregular breccia zones are distinguished on plate 32. The breccia fragments are from a small fraction of an inch to more than 1 foot across. Quartz is the common cementing material, but some calcite is present also. Locally masses of coarse calcite several feet across lie in the brecciated zones.

In many places the solutions that traveled through the fault zones have altered the wall rocks and changed their appearance. The dark-colored siliceous greenstone is the most conspicuously changed and has taken on a light buff color. The principal mineralogic changes appear to be the addition of silica as quartz and the removal of chlorite. The altered zones are in places 2 feet thick on each side of the fault. Altered zones 1 foot thick were noted along some relatively small splits from the main fault zone.

Quartz about 3 inches in greatest thickness is present locally along the main fault zone. Much more quartz, however, is present as the cementing material of the breccia. The quartz-cemented breccia is said to constitute the ore at the property.

The geology of the upper tunnel is similar to that of the lower tunnel, but the variety of rocks is not as great because the tunnel is much shorter. The upper tunnel appears to lie on the same fault zone as the lower.

MINES AND PROSPECTS IN ADJACENT AREAS

COBOL PROSPECT

The Cobol prospect includes a group of claims on the north side of Island Cove, a small bight on the northeast side of Slocum Arm, 6 miles southeast of the entrance to Ford Arm and therefore outside of the district as mapped. The claims are reported to be owned by Frank Cox and George Bolyan. The prospect was visited in June and July 1939.

Several dwellings and other buildings have been erected on the beach near the foot of the tramway and near the two tunnels. The lower tunnel, at an altitude of about 555 feet, is about 1,330 feet long; the upper, at an altitude of about 860 feet, is about 540 feet long. The portal of the lower tunnel is about 1,530 feet N. 32° E. of the buildings on the beach. The greater part of both tunnels is driven along a fault zone (see pl. 33) that has an average trend of N. 5° E. and is nearly vertical. The fault cuts graywacke which has an average strike of about N. 25° W. and dips about 75° SW. A light-colored dike (see pp. 44, 45), which has apparently been intruded along the fault, has been sliced into lenses of different sizes by renewed movements on the fault. Much dike rock has been dragged in the fault zone. The direction of motion on the fault was such as to offset the west side to the north, relative to the east side.

The vein material consists chiefly of gouge and milky quartz. Locally the quartz has a ribbon structure due to films of graphitic material. The maximum observed thickness of the quartz vein is about 1 foot. The metallic minerals visible in specimens of the ore are pyrite, galena, and gold, but they form a very small percentage of the ore. Gold was observed locally in fractures in the dike rock. That some of the fault movement was later than the deposition of the ore minerals is shown by pyrite and gold smeared along fault surfaces.

CONGRESS CLAIMS

The Congress claims are on the west side of Hill Island a short distance west of the mapped area. A tunnel about 25 feet long is about 1,800 feet northwest of the north side of the entrance to Imperial Passage. According to Overbeck,[34] who described the claims, the property was staked in 1916.

The principal country rock of the vicinity is graywacke that strikes about N. 70° W. and dips about 70° SW. The most prominent joints strike about N. 36° E. and dip about 35° NW. Stretching is present and pitches about 54° SE. At the tunnel a greenstone lens about 25 feet thick lies in the graywacke and is essentially parallel to the local structure. The upper part of the lens is massive, but the lower 10 or 12 feet is schistose. The schist contains numerous quartz lenses and rodlike bodies an inch or so thick and several inches long. Most of these parallel the foliation, but some cross it. The schist is a quartz-chlorite-magnetite rock that has been partly replaced by a mosaic of clear quartz grains and later by sparse calcite, chalcopyrite, and pyrrhotite. The sulfide minerals

[34] Overbeck, R. M., Geology and mineral resources of the west coast of Chichagof Island: U. S. Geol. Survey Bull. 692, pp. 123–124, 1917.

are in the quartz bodies and on the foliation surfaces of the schist. No ore minerals were observed in the graywacke in which the greenstone lens lies.

KOBY & SHEPARD PROSPECT

The Koby & Shepard prospect is at an altitude of about 100 feet about 1.6 miles S. 53° E. of the southwest side of the head of Lisianski Inlet. A graveled road, 1.8 miles long, constructed by the Forest Service, leads from a house near the head of the inlet to the mine buildings, which are on a small creek. All prospect openings are on the east side of the creek, which is entrenched about 50 feet below a muskeg-covered bench that flanks a broad lowland stretching between Lisianski Inlet and Hoonah Sound. The northernmost prospect is a stripped surface about 60 feet long. Here a large quantity of quartz is exposed, but the attitude of the vein is obscure. The general trend appears to be about N. 30° W.; the dip could not be ascertained. Individual quartz bodies are at least 3½ feet thick, but the walls are indefinite. Locally the vein contains sulfides and green sericite. At another prospect opening about 220 feet to the southeast a 2-foot vein is exposed for a distance of about 4 feet. Its strike appears to be about N. 10° W. and its dip 86° E. A third prospect opening is a tunnel, 10 feet long, in schist. At the portal a lens of quartz 4 feet thick appears to have a flat dip, which may be due to surface slump. The country rock is a soft chlorite-quartz schist that contains a little pyrite near veins.

A longer tunnel (fig. 22) has been driven just above the creek level, in an endeavor to intersect at a greater depth the bodies of quartz seen in the upper pits. About 26 feet from the portal the tunnel cuts a fault that strikes north and dips about 83° E. At 80 feet from the portal is a minor fault that trends N. 22° W., dips about 50° NE., and contains quartz lenses as much as a foot long and 8 inches thick. This may be the same as the one on which lie the quartz lenses exposed above on the hillside. The quartz bodies seen on the surface are apparently cigar-shaped, with their longest dimensions lying nearly horizontal in the fault zone. At 90 feet from the portal, on the north side of the tunnel, is exposed a zone of quartz lenses that contain chalcopyrite and reach a thickness of 6 inches. At 107 feet is exposed a minor fault that strikes north and dips 80° W. This fault contains a little quartz. At 115 and 122 feet from the portal are irregular zones that contain lenses of glassy quartz with a little pyrite. At 160 feet is a fault zone, with a little quartz, that trends north and dips 67° E.

COX, BOLYAN & LOBERG MINE

The Cox, Bolyan & Loberg property consists of nine claims in an airline distance of about 4 miles N. 4½° E. of the head of Goulding Harbor. These claims, according to George Bolyan, were discovered and located in 1921 by Frank and Ed Cox, Ollie Loberg, and Mr. Bolyan. The claims were bonded to the Pinta Bay Mining Co., which in 1923 built a light-rail tramway, now in a state of disrepair, between the prospect and the head of Goulding Harbor. This tramway is about 5 miles long.

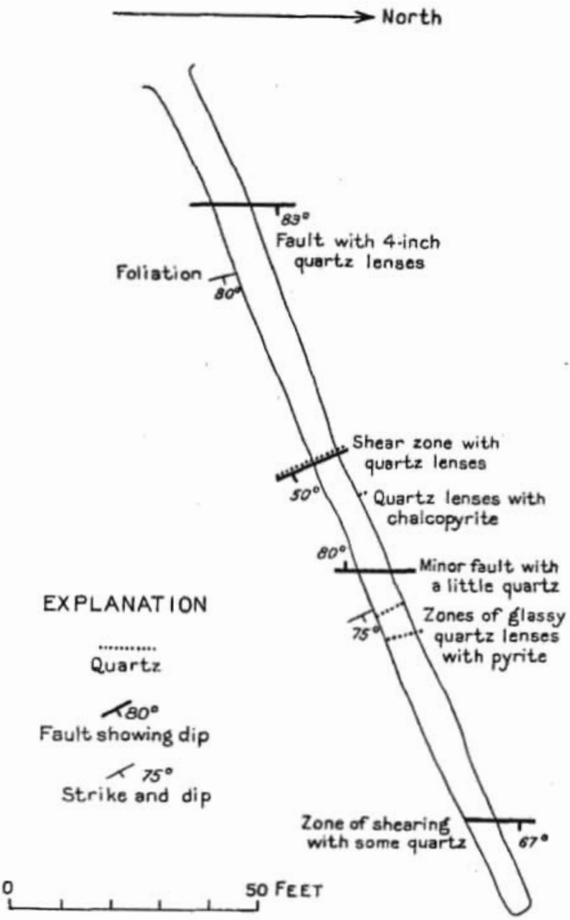

FIGURE 22.—Sketch plan of tunnel at Koby & Shepard prospect.

The veins and the development work up to the fall of 1923 have been described by Buddington.[35] Since his visit further work has been done on the No. 1 vein. According to Mr. Bolyan, the claims reverted to the partners mentioned above, and in 1933 these men purchased and installed a Gibson mill, which was operated for 25 days in that year. The mill was also operated during parts of the summers of 1934 and 1935. The mill and machinery were removed in 1936. Mr. Bolyan estimates that about 135 tons was milled and that about $3,500 in gold was recovered.

Figure 23 is a geologic sketch map of the part of the workings on vein No. 1 that has been productive. The portal of this tunnel is

[35] Buddington, A. F., Mineral investigations in southeastern Alaska: U. S. Geol. Survey Bull. 773, pp. 122–123, 1925.

about 100 feet behind the mill. The length of the stope, measured along the drift, is about 70 feet. The height of the stope was estimated at 40 feet. Near the edges of the stope the vein is about 2 feet wide. The portion stoped is almost entirely in albite-quartz diorite. The vein is much narrower where one or both walls are greenstone.

A specimen of the diorite shows it to be composed of albite, quartz, biotite, and hornblende, with a little titanite and apatite. The biotite has been partly replaced by chlorite. Feldspar has been partly replaced by sericite and epidote. Chlorite, pyrite, and calcite veinlets cut the rock. The albite-quartz diorite has invaded greenstone made up largely of an aggregate of uniform-sized grains of albite and quartz, with interspersed flakes of biotite, oriented roughly parallel to each other. The biotite has been partly replaced by chlorite. The quartz and feldspar have been irregularly replaced by aggregates of fine mica, with calcite and epidote. Both rocks have been intruded by a fine-grained dike, composed of albite, quartz, and biotite. The biotite is bleached and the feldspar partly sericitized.

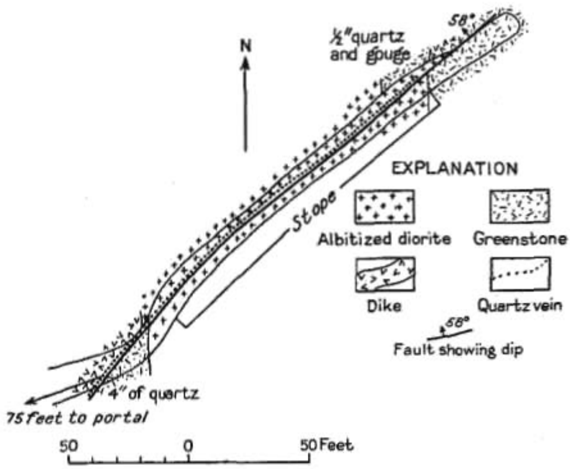

FIGURE 23.—Sketch map of part of workings on No. 1 vein, Cox, Bolyan & Loberg mine.

APEX-EL NIDO MINES

The property of the Apex-El Nido Mining Co. is on Cann Creek, which enters the southwest side of Lisianski Inlet about 5 miles southeast of Miner Island. It includes 26 unpatented claims. The company is controlled by Mrs. J. H. Cann, of Seattle.

The history of the mine before 1923 has been abstracted by Buddington[36] from reports by B. D. Stewart. According to Mrs. Cann, from 1921 to 1928 the property was operated by the Apex-El Nido Mining Co. under the direction of J. H. Cann. Owing to his sickness the property was not operated from 1928 to 1932. In 1932 the property was optioned by the Condor Mining Co., which did some work but gave up its option in the fall of the same year. In 1934

[36] Buddington, A. F., op. cit. (Bull. 773), pp. 117–121.

and 1935 the property was operated by the Apex-El Nido Mining Co. In 1936 the property was not operated, owing to Mr. Cann's death. In 1937 and 1938 the property was operated, under option, by two different groups, each of which produced some gold.

During the summer of 1939 the property was operated by the Apex-El Nido Mining Co., with W. H. Marquette as manager. In the spring of 1939 three Denver Sub-A flotation machines were installed in the mill. It is reported that during 1939 the mill recovery was better than 95 percent and that about $10,000 was produced.

The principal underground developments have been in two mines, the Apex and the El Nido. (See fig. 24.) The Apex is opened on four levels and consists of about 2,400 feet of tunnels and 1,200 feet of raises. The El Nido is opened on two levels and consists of about 1,500 feet of tunnels and 300 feet of raises.

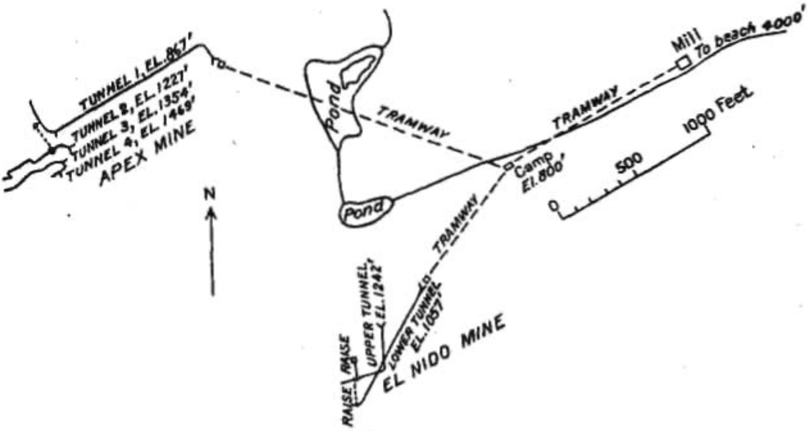

FIGURE 24.—Sketch plan of Apex and El Nido mines.

The country rock at the Apex-El Nido property includes several types of intrusive rocks, which are apparently related to the Coast Range batholith. These include hornblende-bearing pyroxenite, hornblendite, hornblende gabbro, diorite, and aplitic dike rock. Close to the veins the intrusive rocks have been altered to aggregates of coarse quartz, sericite, calcite, chlorite, pyrite, and arsenopyrite.

The Apex vein strikes about N. 42°–60° E. and dips about 45° NW. The vein ranges in thickness from 5 to 48 inches. In places it splits into a stockwork of branching veinlets, which run in all directions. On the high ridge above the mine workings branch veins from the Apex vein were seen; these have similar strikes but generally dip more steeply than the main vein. They are more common in the hanging wall than in the footwall. The Apex vein on the mountain above the Apex mine and more steeply dipping veins in its hanging wall are shown on plate 20, *B*.

The El Nido vein strikes N. 60°–85° E. and dips about 60° SE. Its thickness ranges from about 4 inches to about 60 inches and may average about 10 inches.

Native gold, pyrite, arsenopyrite, and scheelite have been noted, in addition to quartz, in the vein material from the Apex and El Nido veins. One specimen of picked ore from the Apex mine shows numerous small grains of gold in cracks in large crystals of pyrite. Another contains abundant arsenopyrite in veinlets that traverse the quartz vein parallel to its walls. A polished section of ore from the El Nido vein contains a grain of gold and a large amount of arsenopyrite in cracks in the quartz.

GOLDWAN PROSPECT

The claims at the Goldwan prospect were formerly called the Paramount group. This group of 13 unpatented claims lies along a gulch, the mouth of which is on the southwest side of Lisianski Inlet, about 1¼ miles southeast of the point between Lisianski Strait and Lisianski Inlet. Some of the claims were staked in 1920 and were later restaked. All of them are now held by an association, formed in 1938, composed of J. A. Ronning, Joe Repik, August Chopp, A. S. Thompson, and Frank Schotter.

The principal prospect opening is a tunnel at an altitude of about 150 feet. This tunnel is about 138 feet long and runs about S. 30° W. It follows a fault for the entire distance. At the face the fault, which cuts granitic intrusive rock, dips about 40° NW. For most of its length the fault is occupied by a quartz vein. Later faulting along the vein has resulted in its local lensing out or duplication. The vein reaches a maximum thickness of about 2½ feet; at the face it is about 6 inches thick.

At an altitude of about 230 feet along the creek two small veinlets, about 30 feet apart, crop out. These trend east and dip 70°–80° N.

Between altitudes of 950 feet and 1,165 feet, on the west side of the creek, is a quartz vein that reaches a thickness of 2 feet. It strikes about N. 61° E. and dips 85° SE. Both walls of the vein are altered granitic rock. Assays from this vein are said to average $60 to the ton. Two other quartz veinlets are reported to crop out on a cliff that forms the east wall of the main gulch, at about this altitude. One of these is said to be very rich.

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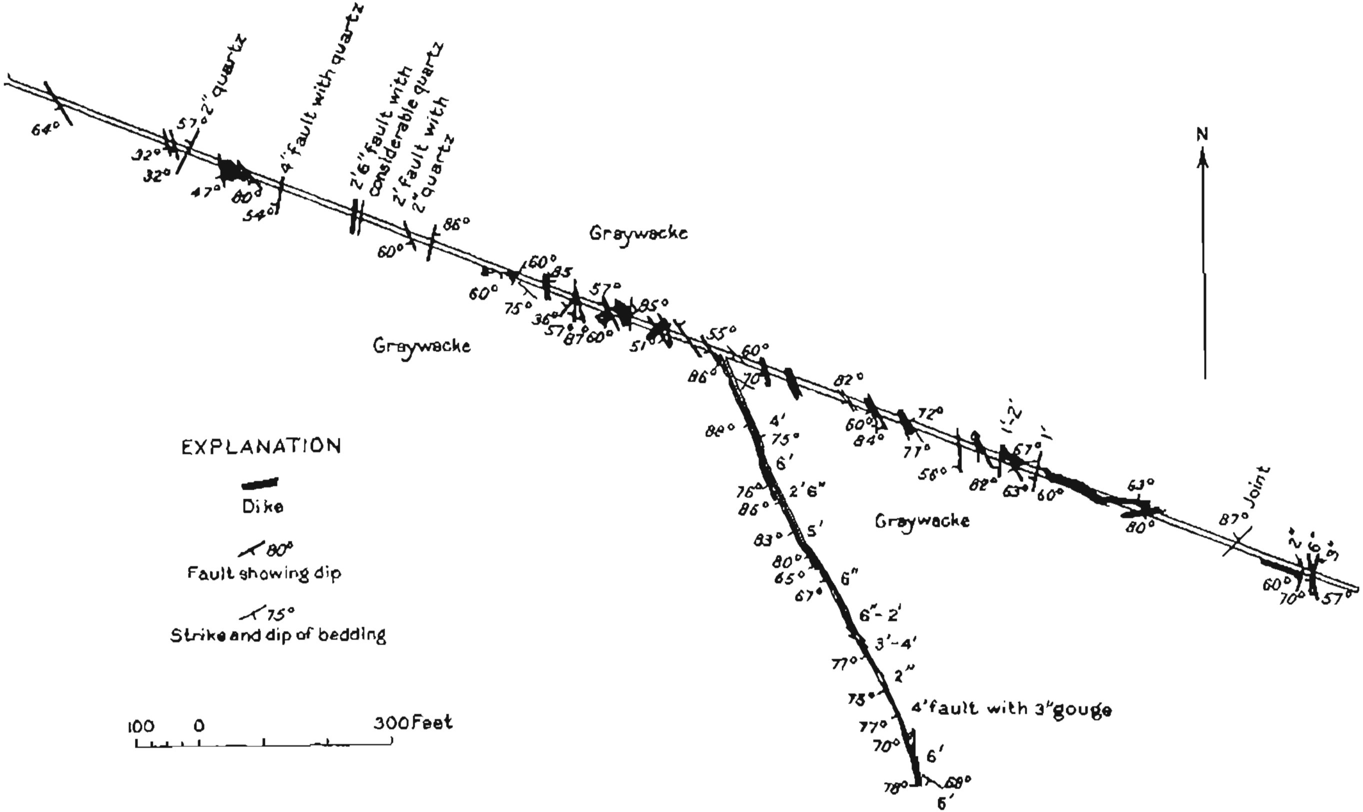

GEOLOGIC SKETCH MAP OF FALCON ARM PROSPECT

1942