# MINERAL DEPOSITS OF THE ELLAMAR DISTRICT.

By S. R. CAPPS and B. L. JOHNSON.

## INTRODUCTION.

## LOCATION AND AREA.

The area considered in this report lies along the northeast shore of Prince William Sound between latitude  $60^{\circ}$  48' and  $60^{\circ}$  59' and longitude 146° 28' and 146° 52'. The area mapped comprises about 60 square miles of land and includes the shores adjacent to Landlocked, Boulder, Virgin, and Galena bays and the northern portion of Bligh Island (Pl. IV). Although earlier maps of this region showing the shore line and something of the topography are available, they are all on a relatively small scale. The map used for the base of this geologic investigation will be published on a scale of 1 to 62,500, or approximately 1 mile to 1 inch. This map and a more complete report of the geology and mineral resources of the area are now in preparation and will be published later.

#### PREVIOUS WORK.

The territory adjacent to Prince William Sound is one of the most accessible portions of Alaska. The sound was discovered in 1778 by Capt. James Cook and during the succeeding 16 years was visited by a number of navigators who charted its shores, so that for more than 100 years the major features of this region have been known. Geologic explorations, however, followed much more tardily. Geologists first visited this field in 1898, when Mendenhall<sup>1</sup> reported on the geology of Port Wells and Passage Canal and Schrader<sup>2</sup> examined portions of the shore between Orca and Valdez. In the following year the Harriman Alaska Expedition<sup>3</sup> did considerable geologic work on the sound, and in 1900 Schrader and Spencer<sup>4</sup> visited parts of the region between Orca and Port Valdez. More recently Grant and Higgins <sup>5</sup> prepared a fuller report on reconnaissance work done in 1905, 1908, and 1909.

<sup>4</sup> Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey Special Pub., 1901.

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<sup>&</sup>lt;sup>1</sup> Mendenhall, W. C., A reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898: U. S. Geol: Survey Twentieth Ann. Rept., pt. 7, pp. 265-340, 1900.

<sup>&</sup>lt;sup>2</sup> Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: Idem, pp. 341-423.

<sup>&</sup>lt;sup>3</sup> Gilbert, G. K., Harriman Alaska Expedition, vol. 4, 1904.

<sup>&</sup>lt;sup>6</sup> Grant, U. S., and Higgins, D. F., Geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, 1910.

#### OUTLINE OF THE PRESENT INVESTIGATION.

In all of the previous investigations the great area to be covered within a short summer season has prevented the examination in detail of the geology of any particular locality. The steady production of one mine at Ellamar for a number of years and the recent placing of two other mines in Landlocked Bay on a productive basis have singled out the district in the vicinity of Ellamar as an important copper-producing area. It therefore seemed advisable to secure more detailed information about this area, with the hope of clearing up some of the problems concerning the origin and relations of the ore deposits and the geologic succession in the Prince William Sound region. For this purpose a topographic party in charge of R. H. Sargent, assisted by C. E. Giffin, was detailed to map an area including the territory adjacent to Landlocked, Boulder, Virgin, and Galena bays. The writers were assigned to study the areal and economic geology of this same area. Owing to the late date at which the appropriation for this work was made by Congress, the field work was not commenced until August 25, 1912, and the weather forced it to close on October 17. In this short season a topographic map of an area of about 60 square miles was completed and much information obtained concerning the mining developments, the modes of occurrence of ore, and the areal distribution of the various rock formations.

# GEOGRAPHY.

## SURFACE FEATURES.

The district in the vicinity of Ellamar, as well as all of the Prince William Sound region, is included within the borders of the Chugach Mountain Range. Near Ellamar the highest peak is Copper Mountain, which has an elevation of 3,946 feet. Eight miles northeast of Copper Mountain but outside the area with which this report is concerned Mount Denson, locally known as the "Rooster Comb," reaches a height of 5,886 feet. Farther north, toward the main axis of the range, the peaks become progressively higher, approaching 7,000 feet at the crest of the range. From a distance the peaks of the range seem to have a certain accordance of elevation, which Grant<sup>1</sup> interprets as suggesting an ancient peneplain that has been elevated far above sea level, warped, and eroded. In the area around Ellamar erosion has been so extensive that all suggestions of this peneplain are lacking.

The coast line of this area is very irregular, as is that of the whole of Prince William Sound. The area studied, though comprising only about 60 square miles of land surface, has a coast line 116 miles

<sup>1</sup> Grant, U. S., Geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, p. 15, 1910.

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in length. No part of it is more than 3 miles from tidewater. Notwithstanding the short distance within which any point may be approached by boat, the country in this vicinity is very difficult to traverse. The mountains in most places rise steeply from the shores and are in general densely timbered to an elevation of 1,800 to 2,000 feet. Practically all travel is by boat, and few trails have been cut. There are some less rugged areas, such as those on both sides of the mouths of Landlocked and Galena bays, bordering Tatitlek Narrows, and at the head of Galena Bay, where the timber is in scattered groves, with grassy or marshy openings between, and in these places travel is less difficult.

The irregular and indented shore line gives abundant harbors for small craft, and some of them will admit ocean steamers.

The topography has in places been strongly influenced by the structure of the bedrock, though this influence has in other places been of minor importance. Tatitlek Narrows lies along the strike of an easily eroded slate belt, and Copper and Ellamar mountains are of more resistant greenstone. West Bay, Cloudman Bay, and the head of Galena Bay all lie parallel to the strike of the underlying rocks, as does the shore line east of Graveyard Point. On the other hand, Landlocked Bay and the lower half of Galena Bay cut directly across the strike of the rocks, and in these places other agencies were more powerful than the rock structure in determining the direction of the erosion lines.

#### STREAMS.

The largest stream in the vicinity of Ellamar is Millard Creek, which enters the head of Galena Bay from the southeast. This creek drains a basin about 9 square miles in area, including two good-sized lakes. It fluctuates in volume, as after each rainfall the run-off is rapid from the steep mountains at the head of the basin, but throughout the summer season a good volume of flow is maintained.

A second large creek empties into the lagoon at the northeast end of Galena Bay. Most of its basin lies outside of the area studied, but it is reported to drain a large lake which is fed by an active glacier.

Two creeks of moderate size enter the head of Landlocked Bay, the larger from the northeast and the smaller from the northwest.

In addition to the above-mentioned streams numerous creeks of smaller size reach the coast at short intervals. Many of these creeks are small and intermittent and flow only after heavy rains. Others are permanent and occupy well-defined though short valleys. The deep indentation of the coast and the high relief of the land have prevented the gathering together of numerous tributaries to form elaborate drainage systems, as most streams have been able to find a short direct course to the sea.

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### GLACIATION.

Perhaps the most important single agency which has sculptured the surface of this region to its present form is that of glacial ice. Although there are now no glaciers in the vicinity of Ellamar, other near-by portions of the Prince William Sound region are occupied by vigorous valley glaciers of large size, which are eroding their beds and giving them a characteristic glacial topography. At some time in the not far distant past a great glacier fed by a multitude of valley glacier tributaries filled the Prince William Sound basin and perhaps extended out to sea beyond Hinchinbrook and Montague islands. Near Ellamar the surface of this ice sheet was about 3,000 feet above sea level, for Ellamar Mountain shows glacial scouring and grooving nearly to its top. These grooves were not made by a local glacier which was formed on this mountain but by an ice stream which came from the north and almost if not completely submerged Ellamar Mountain. Copper Mountain also shows glacial erosion to an elevation of at least 3,000 feet. Erosion by this ice sheet was sufficiently strong to shape the mountains up to the highest level to which the ice reached, and its effect upon the lowlands was profound. There fragments of rock, pressed down by the weight of several thousand feet of moving ice, were able to grind away the glacial bed and remove many obstacles to the path of the glacier and to carve out broad troughlike valleys, many of which were excavated far below sea level. Indeed most of the bays and channels of the Prince William Sound region are probably due in an important degree to glacial scour.

At the time when the ice extent was greatest the amount of glacial deepening was more or less independent of the level of the sea beyond the ice edge, so that with the gradual retreat of the glaciers the encroaching sea flooded those parts of the glacier bed which had been eroded below sea level and formed the many irregular bays and channels of the present coast line. Other portions of the rock floor remained at various elevations above the sea. The broad, low pass between Boulder and Galena bays, the low divide between Cloudman and West bays on Bligh Island, and the lowland at the east entrance of Landlocked Bay are portions of the glacier bed which were deepened nearly but not quite to sea level. Landlocked, Boulder, Galena, and West bays and Tatitlek Narrows were deepened below sea level by the ice and were flooded by the sea when the ice withdrew.

It is difficult to reconstruct the drainage system of this region as it was before the period of glaciation, for the ice has done much to destroy the continuity of former stream valleys. It is believed, however, that the principal valleys, bays, and channels of to-day were the valleys of the earlier streams and that the glaciers, although they profoundly changed the shape of these basins and in many places formed new valleys, have in the main only widened and deepened the valleys of preexisting streams.

## TRANSPORTATION.

The district near Ellamar, as compared with most parts of Alaska, is favored with unusually good transportation facilities. As it is bordered by deep water, it can be reached directly by ocean vessels and is on the regular route of the two steamship lines which ply between Seattle and ports on the Gulf of Alaska. During the summer months about one boat a week brings passengers and mail from Seattle, and Ellamar is a regular port of call. In the winter the trips are somewhat less frequent, but even then a satisfactory service is maintained. In addition to the mail and passenger boats several freight boats are kept in service, their schedules depending to some extent upon the amount of ore available for shipment. The regular fare for passengers from Seattle to Prince William Sound ports is \$35. The freight rates depend upon the class of freight shipped and the amount of the consignment. Contracts by large shippers of ore from the mines to the smelter at Tacoma have been made at rates as low as \$3 a ton.

With such favorable conditions for water transportation practically nothing has been done to facilitate land travel. One road about 4 miles long has been built to a prospect on Copper Mountain from the head of Galena Bay, and one about half a mile long to another prospect from the head of Landlocked Bay, but beyond these no roads have been constructed and but few trails have been made. Practically all communication between the camps is by water.

## CLIMATE.

The climate of Ellamar and the immediate vicinity is neither so mild as that of southeastern Alaska nor so cold as that of the interior country. The modifying effects of the Japan current are felt, so that the winter temperature seldom falls many degrees below zero, yet the snowfall is less than on many parts of the coast. Most of the bays remain free from ice all winter, but the head of Galena Bay is said to freeze over at times as a consequence of the considerable quantity of fresh water which flows into it. On the lowlands the snow disappears in the spring in May or early June. The summers are warm and pleasant when the weather is clear, but this is distinctly a rainy country and the majority of days during any summer month may be rainy. No weather records have been kept within this region, but at Orca and Cordova, places having a similar climate, a rainfall of about 191 H

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inches was recorded in 1912. The season of 1912 is reported to have been unusually rainy during the entire summer. Of the 50 days between August 25 and October 13 it rained on 44 days.

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## VEGETATION.

As a result of the heavy rainfall in this region the vegetation is very dense. Timber grows to elevations of 1,800 to 2,000 feet, except on the steepest mountain slopes and in some of the marshy lowlands. The most valuable stands of timber are found below an elevation of 1,000 feet, in areas of moderate relief. The rock ridges of the higher mountains are without timber, and considerable areas in the lowlands are poorly drained and support only smaller trees in scattered groves, separated by marshy meadows. The most important timber is spruce, of which there are two varieties. Hemlock, however, is more abundant than spruce. Many spruce and hemlock trees have a diameter at the base of more than 4 feet, and these grow tall and free from knots and make excellent lumber. The spruce is considered more valuable for fuel than the hemlock, and near the larger settlements most of the spruce growing near the beach has been cut, but the total amount of timber which has been removed is insignificant compared with that which remains. Below timber line the ground is generally covered with moss, which retains large quantities of water. The untimbered marshy meadows are full of small ponds and the ground is saturated with water. In the timber alder willow, and other bushy plants grow thickly between the trees, and the spiny devil's-club, familiar throughout the rainy belt of the coast country, is present in abundance. The thick brush, the fallen trees, and the prevailing steep slopes of the mountains make travel through much of the timbered areas slow and laborious, and the mossy covering of the surface renders it difficult for the prospector or geologist to trace the geologic contacts or even to determine the surface formations over considerable areas. Above an elevation of about 2,000 feet, however, there is little timber or other vegetation, and the bare rock is in many places exposed.

## GEOLOGY.

#### CHARACTER OF THE ROCK.

The major features of the geology of the area here considered are shown on Plate IV. As determinable fossils have so far not been . found in this vicinity and as two of the rock groups which are here exposed are of almost identical appearance in some of their aspects, it has been found impossible to map all the rocks as definitely as is to be desired. Earlier workers in the Prince William Sound region included the rocks in two great divisions, the Valdez and Orca groups. The Valdez group is older and more metamorphosed, consisting

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largely of interbedded slates and graywackes. The Orca group is younger and in part consists of interbedded slates and gravwackes. though it contains extensive greenstone flows and agglomerates as well as thick conglomerate beds. The criteria which have been used for the separation of the Orca from the Valdez are (1) the lesser amount of metamorphism of the Orca, (2) the presence in the Orca of extensive greenstones and conglomerates, and (3) the geographic position of the Orca to the south of the Valdez rocks, apparently above them stratigraphically. These distinctions no doubt hold for the Prince William Sound region as a whole, but in individual districts, as that with which this report is concerned, extensive faulting accompanied by local metamorphism has taken place and certain areas of slates and graywackes, which are probably of Orca age, have been more intensely metamorphosed than other neighboring areas of the older Valdez rocks. For these reasons the placing of some areas of the slates and graywackes in one group or the other is open to question, and more detailed work will be necessary before a final assignment to a place in the geologic column can be given them.

# VALDEZ GROUP.

The oldest rocks shown on the sketch map (Pl. IV) belong to the Valdez group. As described by Grant and Higgins,<sup>1</sup> these rocks consist of slates and graywackes, commonly in alternating bands. They have in some places been recrystallized to form schists. The slates range in color from black to grav, and the cleavage is variously developed. The graywackes consist of angular grains of quartz, feldspars, and other minerals, cemented by a matrix of quartz, muscovite, and chlorite, the whole rock having become somewhat schis-As shown in Plate IV, the Valdez rocks lie along the north tose. side of the area here considered. They form much of the Chugach Range to the north and are typically developed around Port Valdez and Jack Bay. A short distance north of the mouth of Galena Bay they come into contact with the Orca rocks, the contact having a general northwest-southeast trend. Northeast of Copper Mountain and Landlocked Bay the Valdez rocks appear to have been overthrust upon the greenstones of the Orca group.

As seen within this area the Valdez rocks consist almost entirely of interbedded slates and graywackes containing a few unimportant dikes of later age. The beds in general strike in a northwestsoutheast direction and for considerable areas seem to be merely tilted but not much folded. This lack of folding is in many places only apparent, and careful study will often show close, sharp folds with the limbs lying parallel to the general strike of the beds. In

<sup>&</sup>lt;sup>1</sup> Grant, U. S., and Higgins, D. F., Reconnaissance of Prince William Sound, Alaska: U. S. Geol. Survey Bull, 443, pp. 22-23, 1910.

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GEOLOGIC SKETCH MAP OF ELLAMAR DISTRICT.

other places several sets of fairly close folds may be observed, with resulting greater metamorphism. In the neighborhood of Copper Mountain, where the contact between the Valdez rocks and the greenstone of the Orca group is the result of a great thrust fault, the slates and graywackes of the Valdez group have been sheared and fractured. In places the shattered rocks have been filled with quartz in tiny veinlets and as a cement in the graywackes, which in some localities resemble massive quartzites.

The Valdez group, where studied, is remarkably uniform in constitution throughout its thickness, and the lack of recognized key beds makes it difficult to measure a reliable section through the group, as the same beds may be repeated by inconspicuous and easily overlooked faults and folds. It seems certain, however, that the group is many thousand feet thick and is very uniform in appearance throughout.

The age of the rocks of the Valdez group is not yet definitely known, for so far no determinable fossils have been found in them. Various authors at different times have assigned them provisionally to horizons from the Silurian to the Tertiary. A more complete review of the literature on the age and correlation of these rocks will be undertaken in the fuller report on this area which is now in preparation, but for the present it may suffice to state that the Valdez rocks are generally considered to be of Paleozoic age.

#### ORCA GROUP.

All the consolidated rocks of this area not included in the Valdez group belong to the Orca group. This group is unlike the Valdez in that it consists of a number of characteristic and dissimilar divisions which, though parts of the same great group, can be differentiated and mapped individually in the field. The Orca rocks consist of black slates, interbedded slates and graywackes, greenstone flows and agglomerates, several conglomerate members, and some thin limestone beds. These rocks in general lie south of the rocks of the Valdez group, but the contact wherever seen was a fault contact and the depositional relations between the two groups could not be determined. As already stated, the Orca rocks have been separated from the Valdez on the basis of their lesser degree of metamorphism, the presence of extensive greenstone flows and conglomerate beds, and their geographic position. In using these criteria in the field there has been no hesitancy in assigning the heavy conglomerates on both sides of the mouth of Galena Bay and the thick greenstone flows and tuffs with their interbedded slates to the Orca. The slates and graywackes of Bligh Island are much less metamorphosed than those north of Galena Bay, and they also appear certainly to belong to the Orca group. In regard to the slates and graywackes and thin conglom-

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erates of Tatitlek Narrows and on both sides of the mouth of Landlocked Bay there is less certainty, for they have been extensively faulted, folded, and metamorphosed, and on this basis might belong to either great group. In general, however, the authors have agreed with the mapping of Grant and Higgins and placed these rocks provisionally in the Orca group. They contain a number of conglomeratic beds which are exposed for short distances along the beach. These conglomerates are altogether different in character from those at Rocky Point and may indicate considerable interruptions in the deposition of the sediments of which the slates and graywackes are formed, but at present too little is known about them to determine their extent or importance.

As far as could be determined, the lowest part of the Orca group near Ellamar consists of a thick division composed of black slates. which reach their greatest development on Bidarky Point and on the north side of Tatitlek Narrows near Tatitlek (Pl. IV). This division is characterized by its freedom from graywacke beds, those found being thin and forming only a very small proportion of the whole The slates are predominantly black or dark gray and have thickness. a well-developed cleavage, which strikes in a northwest-southeast direction and in most places has steep dips. The bedding is inconspicuous but in places could be distinguished as a banding, the adjacent bands having slightly different colors on weathered surfaces. The bedding is less regular in strike and dip than the cleavage but commonly strikes parallel to it and dips at a greater or less angle to the northeast. The regularity of the strike and dip of the cleavage is confusing and care must be exercised to distinguish between the prominent cleavage and the bedding, which is determinable with difficulty.

Structurally above the black slates is a division composed of slates and graywackes, which closely resemble in constitution and structure those of the Valdez group and which in places may have been confused with them. This division appears in certain localities, as on upper Gladhaugh Creek, to be little metamorphosed and merely tilted, with no apparent close folding. In other places, such as the beach near Graveyard Point, the beds stand on edge and have been closely and intricately folded. This division is believed to extend upward to the base of the greenstone but in places is missing between the black slate member and the greenstone.

Above the slates and graywackes is a thick division composed of greenstone flows and some agglomerates, with minor quantities of interbedded slates (Pl. IV). In physical appearance specimens collected from different parts of the greenstone division may differ widely, ranging from aphanitic, cherty-looking rocks to those of granular texture. Some beds are rather massive, but the characteristic feature of the greenstones is the abundance of beds in which the greenstone consists of ellipsoidal forms. Ellipsoidal greenstones have generally been considered to indicate that the basic lava flows from which they were formed were poured out upon the bottom of a body of water, and that the flowing and cooling of the lavas under water induced this unusual type of parting into ellipsoidal or spheroidal forms. Many facts which can not be discussed here point to the conclusion that these greenstones were extruded upon the sea bottom, and that the deposition of the muds which formed the slates continued during the intermissions between the separate flows.

Toward the top of the greenstone division, as seen near Rocky Point, the proportion of interbedded slate increases and thin conglomerates appear. In ascending order the conglomerates increase in importance, until the greenstones and slates disappear and a massive coarse conglomerate, with some finer gritty beds, extends to the west end of the point and forms the many small outlying islands. The conglomerate is conspicuous for the lack of assortment of its materials. Bowlders several feet in diameter are not uncommon, and these are intermingled with smaller pebbles and finer material. Bedding planes are indistinct or lacking in many places, and the angular or subangular character of the included bowlders give the deposit an appearance resembling that of a tillite.  $\mathbf{At}$ other places the unstratified beds are associated with and grade into beds of assorted pebbles and gritty sandstones in which the bedding is distinct. The included bowlders consist mainly of graywackes and banded slates, with scattered greenstones and some granular crystalline rocks.

A mass of similar conglomerate occurs about a mile north of the mouth of Galena Bay and is believed to be a part of the conglomerate just described, though its structural relations to the greenstones are not so clear as near Rocky Point.

What is believed to be the youngest division of the Orca group, as developed in the area under discussion, forms that part of Bligh Island which lies southwest of Cloudman and Busby bays. This division is composed of alternating beds of black or gray slates and graywackes.

The graywacke beds are thicker and constitute a greater proportion of the rocks than in the older Orca group, which has already been described, but the most important difference is that the rocks of Bligh Island, although gently folded and containing some faults, are much less severely metamorphosed. The only rocks with which the slates and graywackes of Bligh Island come into contact are the greenstones on the north side of that island, and this is probably a fault contact. On account of their comparative freedom from metamorphism these beds are believed to be younger than the conglomerates at Rocky Point and therefore to form the top of the Orca group as developed in this vicinity.

## UNCONSOLIDATED DEPOSITS.

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No consolidated rocks younger than the Orca occur in this vicinity. The only younger deposits consist of unconsolidated glacial materials, a small amount of talus, and the sands and gravels of the present streams. This area was as a whole one of glacial erosion rather than of deposition, and most of the material removed by the ice was carried to the south and deposited in the sea. In some places, however, there are deposits of glacial till left by the ice during its retreat. The till is found especially in the lowland areas of slight relief. In the more rugged mountains it was either never deposited or has since been removed by erosion. The till areas in general are heavily covered with vegetation, so that good exposures are scarce. The best exposures are at points on the beach where wave cutting is active, such as the southeast side of Bidarky Point. There cliffs show 30 feet or more of bluish clav, inclosing bowlders and fragments of a large variety of rocks. A till mantle covers the surface of the underlying rocks on the lowlands north of Gravevard Point. near Tatitlek and Ellamar, east of the head of Galena Bay, and at many other places.

The gravels of the present streams are of small surface extent and are unimportant. The amount of erosion by streams since the retreat of the glacier uncovered this area is very small, and only a few streams have been able to cut well-defined channels into the rock. The larger streams have naturally been able to erode most vigorously, but the steepness of their gradients has prevented the accumulation of extensive gravel deposits along their courses, and the amount of material handled by them can best be estimated by the size of their delta deposits. Thus Millard Creek, although remarkably free from gravels along its channels, has built out a rather extensive delta at the east end of Galena Bay. The head of Landlocked Bay is also shallow, owing in part at least to the sediments brought down from two good-sized creeks. The greater number of streams, however, are small and empty into tidewater on exposed portions of the coast, at places where the action of waves and currents has carried away the stream-brought materials as fast as they were deposited.

#### THE ORE DEPOSITS.

# RELATION OF THE ELLAMAR DISTRICT TO THE PRINCE WILLIAM SOUND COPPER DISTRICT.

The copper deposits of the Prince William Sound district fall geographically into three large groups—(1) those of Latouche, Elrington, Bainbridge, and Knight islands, (2) those of Glacier Island and the mainland to the northwest, and (3) those of the mainland along the eastern shore of the sound from Valdez Narrows to Copper River. The Ellamar copper district, as considered in this report, is a small area in the northeast part of Prince William Sound and within the third group outlined above. As already pointed out (p. 87), it is of economic interest because it contains three producing copper mines. Purely scientific interest naturally centers here in a search for the causes which resulted in the localization within this portion of the Prince William Sound copper belt of bodies of sulphide copper ores of sufficient size to be economically important.

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## DISTRIBUTION OF DEPOSITS WITHIN THE ELLAMAR DISTRICT.

#### AREAL DISTRIBUTION.

The numerous copper deposits thus far found during the extensive prospecting which has been carried on in the district all lie within the area bounded by Port Fidalgo, Tatitlek Narrows, Galena Bay, and a line connecting the heads of Galena, Landlocked, and Fish bays. The mineralized belt trends in general northwest and southeast, but within the area outlined above there is a marked grouping of the prospects on the flanks of Copper Mountain and along the ridge between Millard Creek and the Galena Bay-Boulder Bay gap. The Ellamar mine, on Virgin Bay, occupies an isolated position, quite apart from the other known copper deposits.

#### VERTICAL DISTRIBUTION.

The known vertical range of the copper-bearing lodes is over 3,000 feet. The relief within this district is but 3,860 feet and copper prospects are distributed through nearly the entire range of elevation from sea level to places high on the flanks of Copper Mountain, and at Ellamar the mineralization has been traced nearly 600 feet below sea level. Several prospects have been located on Copper Mountain between elevations of 1,500 and 2,500 feet, and copper showings are reported at still greater heights on this peak.

#### DISTRIBUTION OF PRODUCTIVE MINES.

The productive mines of the area are located at or close to sea level on Virgin and Landlocked bays. The producing mines in 1912 were the Ellamar mine at Ellamar, on Virgin Bay, and the mines of the Three Man Mining Co. and the Landlock Bay Copper Mining Co., on Landlocked Bay (Pl. IV).

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## MINERAL RESOURCES OF ALASKA, 1912.

## GEOLOGIC RELATIONS OF THE ORE DEPOSITS.

#### GENERAL FEATURES.

The geographic distribution of the ore deposits of the Ellamar district is the result of a combination of definite geologic conditions, partly structural and partly geochemical. The ore bodies are apparently impregnation and replacement deposits of sulphide ores. The channels necessary for the circulation of the mineralizing solutions were furnished by the numerous faults which traverse the area, and favorable conditions for the deposition of the metallic sulphides contained in the mineralizing solutions were supplied by the crushed filling of the greenstone shear zones and by certain sheared and shattered sedimentary beds (slates and graywackes) of the Orca group.

## STRUCTURAL RELATIONS OF THE ORE DEPOSITS.

The area is complexly faulted and the distribution and relationships of the various formations shown on Plate IV are largely the result of this faulting. The major fault of the area is the Landlock overthrust, the trace of which within the area mapped extends from the divide between Landlocked Bay and Fish Bay to Valdez Arm across the heads of Landlocked and Galena bays. By this fault the slates and graywackes of the Valdez group have been overthrust from the northeast upon the younger and less metamorphosed Orca group of interbedded slate, argillite, graywacke, conglomerate, and greenstone. During the dynamo-metamorphism of the district the thinbedded slates and graywackes of both groups were closely folded. The more massive argillites and graywackes and the greenstones of the Orca group, however, yielded by fracturing and were extensively sheared and faulted. This shearing and shattering of the Orca group is observable over a wide area bordering the trace of the Landlock overthrust fault on the eastern slope of Copper Mountain, on the ridge between Millard Creek and the gap between Galena Bay and Boulder Bay, and on the northeast slope of Ellamar Mountain.

Faulting is prevalent in other parts of the area. One large shear zone is found on the southeast shore of Landlocked Bay near the lower end of the bay; another underlies the Ellamar ore body on. Virgin Bay. Numerous shear zones visible on the north and south flanks of Copper Mountain are traceable over considerable distances as shallow troughs where erosion has removed some of the soft sheared material. Topographic and geologic evidence suggests the presence of many faults whose contacts can not be definitely located because of the extensive cover of vegetation. As an example may be cited the probable fault between West and Cloudman bays on Bligh Island, which separates the greenstone series of the eastern peninsula from the gently folded slates and graywackes of the main part of the island.

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Two fairly well defined systems of shearing and faulting are recognizable, one system striking a little east of northeast, whereas the strikes of the other trend west-northwest.<sup>1</sup> The latter system of fissuring, paralleling in a general way the strike of the Landlock overthrust fault, is the more prominent and contains the larger number of shear zones and faults. The dips of the fractures of both systems are steep, generally from 55° to 90°.

The copper deposits are abundant in the highly faulted and sheared portions of the area bordering the overthrust fault; none are known in the comparatively little disturbed sections, such as Bligh Island and the region between Gladhaugh Creek and Galena Bay.

# RELATION OF THE ORE DEPOSITS TO THE COUNTRY ROCK.

The ore deposits occur in both igneous and sedimentary rocks of the Orca group. They are chiefly associated with the basic lavas (greenstones) but are not entirely restricted to them, as is evident at Ellamar, where the sulphide ores are found in sedimentary beds.

Within the greenstone area the copper lodes are most abundant in the more highly sheared portions. The intense shearing produced numerous passages which afforded easy access to the mineralizing solutions and the crushed filling of the shear zones exposed far greater surface in proportion to its mass than that afforded by the less shattered portions. It was consequently more susceptible to chemical attack by the mineralizing solutions and was replaced by the sulphides with greater readiness than the more massive rock.

Within the areas of sedimentary rocks conditions appear to have been less favorable for the deposition of the sulphides from solutions of the character of those circulating through the rocks at the time the mineralization of the area took place. No copper prospects have been found within the conglomerate areas, within the slate and graywacke areas of Bligh Island, or within the black slate belts of the mainland. It is only at Ellamar, where calcareous strata, interbedded with the slates and graywackes, have been sheared and shattered, that solid sulphide ore bodies have yet been located.

The argillites and graywackes bordering the trace of the great Landlock overthrust fault have been minutely shattered over a considerable area and the fractures filled with tiny reticulating mineralized quartz veinlets, in which, however, the sulphides are widely scattered. Several prospects have been located on deposits of this type but have not been proved to be of commercial importance. The similarly shattered areas in the greenstones of the north spur of Copper Mountain are more highly mineralized.

<sup>1</sup> All bearings given in this report are corrected for magnetic variation.

## CHARACTER OF THE ORE DEPOSITS.

The economically important ore bodies of this district, classified as to metallic content, are copper deposits. The ore bodies appear to be impregnation and replacement deposits of sulphide ores, generally in shear zones in the greenstone or, as at Ellamar, in sedimentary beds. Only two sharply defined quartz-filled fissure veins have been noted. and one of these changes along its strike to a mineralized shear zone that carries considerable sulphides and but little quartz. Large masses of low-grade ores are found on the north and east slopes of Copper Mountain, where the Orca rocks bordering the trace of the Landlock overthrust fault were minutely shattered by the faulting. In the argillites and graywackes the fractures were cemented by tiny reticulating mineralized quartz veins with little sulphide replacement of the country rock. Within similarly shattered greenstones, however, a certain amount of metallization of the wall rock occurred together with the cementation of the fractures by the quartz veinlets. Considerable areas were thus slightly mineralized. These bodies of low-grade copper ores in the minutely shattered greenstone areas on the northeast slope of Copper Mountain are not profitably workable under existing conditions but will undoubtedly prove a source of copper at some future time.

The Ellamar type is represented by but one example, the ore body of the Ellamar mine, which, however, is the largest body of massive sulphide ore yet found in this district. Erosion has removed the upper portion of the ore body, but the greatest horizontal dimension of the ore lens appears to have been on the 200-foot level, where the major axis of the elliptical cross section is about 240 feet and the minor axis 90 feet in length. The ore body pinches out between the 500 and 600 foot levels. As no other deposits of this type are known within this district, no definite conclusions can be drawn regarding the probable sizes of this type of ore body should other deposits of similar origin be found later.

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The greenstone shear zone type of copper deposit is by far the more numerous, and most of the prospects in this area have been located on deposits of this character. The width of the greenstone shear zones varies from a few inches to several feet. The exact width, however, is in many places hard to determine because of cover, lack of sharp boundaries between sheared and unsheared rock, or the inclusion of horses of unsheared rock within the shear zone. Many of the shear zones are of considerable length. The metallization within the shear zone varies vertically, laterally, and along the strike. Masses of nearly solid sulphides, lenticular both in plan and section, are irregularly distributed within the sheared material. Other portions of the zones are less completely replaced. The size of these massive sul-

phide lenses appears to be restricted in this type of deposit not only by the width of the shear zone but also by the amount of crushing which the material of the shear zone has undergone previous to the introduction of the sulphides. The more highly crushed material is the more completely replaced.

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Development work on the shear zones has not yet outlined many large sulphide lenses. The width of the known lenses ranges from mere films to several feet, but at most of the prospects thicknesses of more than 5 feet are not common. The maximum width reported is  $9\frac{1}{2}$  feet on an ore body, largely sulphides, the maximum stope length of which as developed is about 60 feet and that portion of the pitch length of the ore body now exposed is about 200 feet. The smaller lenses are much more common.

Because of the nearly vertical position of the shear zones it naturally follows that the lodes of the greenstone shear zone type of deposit are also nearly vertical. Their strikes also correspond with those of the containing shear zones. Many of the ore lenses, however, pitch steeply within the plane of the shear zone.

The intense glacial scouring to which all of this district has been subjected has exposed the primary ore bodies at the surface. Any preglacial enriched zones or weathered parts of the lodes which may once have existed were removed by the glaciation, the recentness of which has moreover afforded little opportunity for surface alteration of the ore deposits. Recent weathering has extended a few inches to a few feet below the surface and in most places the alteration is only partly complete. There is thus no considerable leached zone in the upper portions of the lodes and consequently no enriched zones. Though chemical agents have altered the deposits but little, physical processes have been more active. The soft filling of the shear zones is readily removed by the degradational agents and the shallow troughs formed are traceable over considerable distances.

## THE ORE MINERALS.

The primary metallic minerals found in the copper deposits of the Ellamar district are chalcopyrite, pyrrhotite, pyrite, sphalerite, arsenopyrite, galena, gold, silver, and an unknown mineral, presumably a copper-iron sulphide, which is found intimately associated with chalcopyrite on the property of the Three Man Mining Co. on Landlocked Bay. Galena is found in small amounts at some of the prospects about Landlocked Bay, and assays of ore from the Ellamar mine show the presence of lead, probably present as the sulphide, galena. Chalcopyrite is the principal copper-bearing mineral of the district and is found at all of the copper prospects. It is usually intimately intermixed with pyrrhotite, the relative proportions of these two minerals varying greatly. Sphalerite is abundant at Ellamar and at prospects on the north slope of Copper Mountain.

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Polished specimens of these ores studied under the metallographic microscope show an early deposition of pyrite, followed by the deposition of chalcopyrite, pyrrhotite, and sphalerite, partly at the expense of the pyrite, which was not stable in the presence of the later copper-bearing solutions. These later sulphides appear to have been deposited contemporaneously. In ore from one of the deposits a soft pale brass-yellow mineral occurs intergrown with the chalcopyrite. This mineral has not yet been determined. It is possibly a new species, apparently a copper-iron sulphide with a low copper content.

Secondary copper minerals are of little importance in this district. Green malachite stains are visible at many prospects and native copper has been found at the property of the Three Man Mining Co. on Landlocked Bay.

The nonmetallic gangue minerals include quartz, calcite, epidote, and chlorite and other minerals derived from the shearing and hydrothermal alteration of the greenstone and other country rocks of the ore deposits.

#### SUMMARY AND CONCLUSIONS.

The study of the data obtained during the field season of 1912 has resulted in conclusions regarding the distribution and genesis of the copper deposits of the Ellamar district considerably at variance with those of earlier investigators. The data upon which these conclusions are based, however, can not be presented in detail within the limits of this preliminary report, but the evidence at hand appears to warrant the conclusions as now stated, and a more complete discussion of the distribution and genesis of the ore bodies will be included in the final report now in preparation.

Abstract of the geology.—The Orca group of interbedded slates, argillites, graywackes, conglomerates, and basic lava flows was folded and faulted in Mesozoic time, apparently at a considerable depth below the surface, and the Valdez group was overthrust from the northeast upon the Orca. Though no granitic intrusives are found within the Ellamar district, the presence of "knots" at the head of Landlocked Bay is suggestive of their nearness to the surface, and a large granite mass is known to be intrusive into the Orca rocks between Port Gravina and Sheep Bay.

Distribution of the metallization.—The Ellamar copper district is a portion of the Prince William Sound copper district. In the Ellamar district the mineralized area is definitely outlined. The ore bodies all lie west of the trace of the Landlock overthrust fault and east of Tatitlek Narrows. North of Ellamar Mountain the slightly deformed

Orca group is not known to contain any copper deposits. South of Landlocked Bay the copper belt is narrowed by the overlapping Valdez group, but it extends beyond the divide between Landlocked Bay and Fish Bay toward Port Fidalgo. A marked concentration of the deposits is noticeable in the highly faulted and sheared strip bordering the trace of the great overthrust fault. The present known vertical range of the metallization is over 3,000 feet. Structurally the ore bodies occur only in close association with faults and are most abundant in areas of the most intensely localized faulting and shearing.

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Time of metallization.—The metallization of the Orca group probably took place in Mesozoic time, subsequent to the folding and faulting referred to above and presumably somewhat later than the intrusion of the granitic rocks of the Prince William Sound region, which probably took place at some time during the Jurassic or Cretaceous. There was but one period of metallization.

Character of the ore deposits.—The studies so far made appear to the writers to indicate that the important ore bodies are primary impregnation and replacement deposits by sulphides of (1) the crushed filling of shear zones in greenstone and (2) certain sheared and shattered sedimentary rocks, presumably those of a calcareous character. The deposits of the greenstone shear zone type are the most abundant.

Attitude of the ore bodies — The ore bodies occupy or are related to two well-marked systems of shearing and faulting, one system striking east-northeast and the other west-northwest. The dips of both systems are steep, generally from  $55^{\circ}$  to  $90^{\circ}$ . There has been no marked metamorphism of the rocks or ore bodies, as the ores and the deposits stand in the positions in which they were originally formed.

Mineralogy of the ores — The primary metallic minerals of the ores are chalcopyrite, pyrrhotite, pyrite, sphalerite, arsenopyrite, galena, gold, silver, and an undetermined mineral, apparently a copper-iron sulphide. Chalcopyrite is the principal copper-bearing mineral. The association of the metallic minerals is the same as that found in the gold quartz veins of the surrounding regions. The gangue minerals include quartz, calcite, epidote, chlorite, and other alteration minerals.

Character of the metallizing solutions.—The association of metallic minerals in these copper ores is that characteristic of ore bodies of deep-seated origin deposited by alkaline solutions <sup>1</sup> under conditions of moderately high temperature and pressure, at a depth of several thousand feet below the surface.<sup>2</sup> Such hot alkaline solutions are usually ascending waters.

<sup>&</sup>lt;sup>1</sup> Allen, E. T., and Crenshaw, J. L., Sulphides of zinc, cadmium, and mercury; their crystalline forms and genetic conditions: Am. Jour. Sci., 4th ser., vol. 34, pp. 341–396, 1912.

<sup>&</sup>lt;sup>2</sup> Lindgren, Waldemar, The relation of ore deposition to physical conditions: Econ. Geology, vol. 2, pp. 105–127, 1907.

Source of the metallizing solutions.—The metallizing heated alkaline solutions were presumably of magmatic origin and probably circulated shortly after the intrusion of the Mesozoic granitic rocks. This conclusion was suggested by the results of the field work of 1912 but can not be considered as proved because of the small portion of the Prince William Sound copper district examined and the lack of granitic intrusives closely associated with the copper deposits in the Ellamar district.

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Course of the ore solutions.—The ore-bearing solutions apparently circulated in the channels furnished by faults and shear zones and penetrated but little into the massive rock. The larger faults were naturally the main passageways for these solutions. They appear to have risen principally along the Landlock overthrust and associated large faults and circulated through a group of rocks containing crushed and shattered calcareous beds and greenstone.

Source of the copper and other minerals.-Earlier writers have concluded that the copper deposits of this district were formed either by the concentration of disseminated copper minerals of the greenstones <sup>1</sup> or in connection with the intrusion of basic igneous rocks.<sup>2</sup> An alternative and to the present writers an apparently more probable hypothesis accounts for the presence of the ore minerals-chalcopyrite, pyrite, pyrrhotite, sphalerite, galena, arsenopyrite, gold, and silver-by assuming that they were introduced by magmatic waters, which rose after the cessation of the Mesozoic granitic intrusive activity along the major faults and shear zones and which impregnated and replaced the sheared and crushed greenstones and certain of the sedimentary beds. 'The metallic mineral association of these copper ores is, moreover, similar to that of the gold quartz veins of the Pacific coast belt of Alaska, which are generally believed to have been formed by deep-seated deposition from magmatic waters, which followed the Mesozoic granitic intrusions. The greater abundance of the copper deposits in the greenstone than in the sedimentary areas appears to be best explained by the more ready replacement of the crushed filling of the greenstone shear zones than of most of the sedimentary beds.

Continuity of the metallization in depth.—The continuity of the metallization in depth is dependent upon the existence of material capable of impregnation and replacement, either shattered calcareous sediments or sheared greenstone, in the path of the mineralizing solutions. The deep-seated origin of the ore deposits, their probable deposition from ascending heated waters, the character of the min-

<sup>&</sup>lt;sup>1</sup> Grant, U. S., Copper and other mineral resources of Prince William Sound: U. S. Gecl. Survey Bull. 287, p. 81, 1911.

<sup>&</sup>lt;sup>2</sup> Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, p. 58, 1910. Brooks, A. H., Geologic features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, p. 82, 1911.

eralization, and the known extensive vertical range of cupriferous metallization above sea level are all indicative of the persistence of the metallization to considerable depths, provided the material capable of being impregnated and replaced lay within the path of the rising solutions.

*Enrichment.*—Enriched copper deposits of economic importance are not found within this district.

Relation of the ore deposits of the Ellamar district to metallogenetic epochs and provinces.—Classified as to age the copper deposits of the Ellamar district probably belong in the late Mesozoic metallogenetic epoch as established by Lindgren. They form, moreover, a part of the metallogenetic province of which gold is primarily and copper secondarily the characteristic metal, associated with the petrographic province characterized by the intermediate quartz monzonite or granodiorite magmas of the great batholith of the Pacific coast, the intrusion of which in late Mesozoic time was immediately followed by intense metallization along its borders. These copper deposits appear to correspond, therefore, in both age and genetic relations with most of Alaska's gold lode deposits and with certain of the copper deposits and belong to the same metallogenetic epoch and province as those of the western coast of the United States.

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## MINES.

Comparatively little development work has been done, except at the mines now producing, since the region was visited by Grant in  $1909.^1$ 

The writers are indebted to Mr. L. L. Middlekamp, Mr. W. A. Dickey, and Mr. W. A. Rystrom for information furnished and for permission to examine the workings of the mines of the Ellamar Mining Co., Three Man Mining Co., and Landlock Bay Copper Mines Co., respectively. The writers' thanks are also due to Messrs. Peter Steinmetz, Guy Banta, W. B. Hancock, and George Walentine, who acted as guides and furnished considerable information regarding the prospects. The absence of anyone familiar with the underground development at many of the prospects prevented as complete a study of the deposits as might otherwise have been possible. The producing mines are arranged in order of their present importance as producers. The prospects are described in geographic order from north to south.

#### ELLAMAR MINE.

Location of property.—The Ellamar mine is situated at the town of Ellamar, on the east shore of Virgin Bay, about 20 miles southwest of Valdez. The ore body outcrops on the beach between high

<sup>&</sup>lt;sup>1</sup> Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, 1910.

and low tide marks. The workings are on the Copper King and Gladhaugh claims, the original discovery being on the end line between these two claims, which were staked along the lead.

History and development.-The Gladhaugh and Copper King claims were located early in 1897 by M. O. Gladhaugh and C. Peterson. The first shipment, of about 225 tons of ore blasted from the outcrop of the ore body, was made late in the fall of 1900. The sinking of the shaft was started in that year, about 150 feet land ward from the outcrop of the ore body. The following year the Ellamar Mining Co. was formed. In 1902 a crosscut was driven from the shaft and the ore body was hit on the 100-foot level. In 1905 the shaft had reached a depth of 500 feet and the 500-foot level had been opened, but the ore body had not been found on that level. By 1908 it was known that the ore body pinched out before reaching the 600-foot level. The cofferdam was started in 1909 to exclude the tides from the outcrop of the ore body, so that the portion of the ore body between the 100-foot level and the surface could be removed. In 1910 the cofferdam was completed and since then all the mining has been done between the 200-foot level and the The workings at present comprise a large glory hole, a surface. 600-foot three-compartment vertical shaft, and about 4,000 feet of drifts. In 1912 the lower levels were flooded, and the water stood several feet deep on the station at the 400-foot level. The mine has been a regular producer since 1900.

Equipment and ore treatment.—The mine is equipped with steam plant, air compressor, and drills. Its buildings include machine shop, laboratory, store, smithy, mess house, large ore bunkers, and several other buildings. A large wharf extends from the ore bunkers across the glory hole and out into the bay. The plant is electrically lighted. The average number of men employed in 1912 was 25, working one eight-hour shift a day.

The present method of ore treatment is as follows: The ore mined from the glory hole and stopes falls to the 300-foot level, where it is trammed to the shaft, raised, partly hand sorted, stored in the ore bunkers, and finally shipped to the Tacoma smelter. The cost of mining is reported to average \$3 a ton. The transportation charges from Ellamar to the Tacoma smelter are also \$3 a ton.

Country rock.—Bedrock outcrops are scarce near the ore body. To the north, south, and east are till-covered flats, and to the west Virgin Bay. All the bedrock to be seen at present is inclosed by the cofferdam, except at extreme low tide, when small additional exposures are visible just outside of the cofferdam along the strike of the ore body. The country rock of the ore deposit consists of interbedded soft black slate, black limestone, argillite, and a few bands of finegrained graywacke. The nearest known igneous rocks are the greenstones north of Gladhaugh Creek, nearly one-half mile away. All these rocks are of Orca age. The strike of the sedimentary beds at the mine is northwesterly; the dip is about 80° NE. The rocks were much crushed and sheared by faulting and shearing movements previous to the formation of the ore body. The strike and dip of the faults are approximately parallel to those of the bedding. A large fault, which strikes about S.  $60^{\circ}$  E. and dips 55° NE., has been found below the ore body on the 400 and 500 foot levels. The plane of this fault crosses the plane of the ore body between the 500 and 600 foot levels and is found again on the 600-foot level. The upper levels of the mine were not extended westward far enough to intersect this fault. Considerable movement has also taken place along the belt inclosing the Ellamar ore body, subsequent to the formation of the ore body, but apparently has resulted in only slight displacements.

The ore deposit.—The ore deposit is a large lenticular mass of sulphides. The major horizontal axis strikes about N. 35° W. The ore lens dips 80° NE. and pitches steeply toward the southeast. The strike and dip of the ore body appear to be the same as those of the bedding of the country rock. The maximum horizontal dimensions of the ore body are on the 200-foot level, where the major axis of the elliptical cross section is about 240 feet and the minor axis about 90 feet in length. The more highly mineralized portion of the outcrop of the ore body measured 80 by 130 feet and is now inclosed by the cofferdam. Less mineralized portions extend outside of the cofferdam along the strike of the ore body. The ore lens is reported to have pinched out between the 500 and 600 foot levels.

The ore body consists of two distinct parts—(1) a large lens of solid pyrite, forming the hanging wall for (2) smaller, closely packed parallel lenses consisting largely of other sulphides. These two parts are separated from each other by a thin but continuous band of black slate, which averages about 2 feet in thickness. Development work has not completely outlined the hanging-wall pyrite lens. It outcrops on the surface and is known to extend at least to the 300-foot level, where the horizontal dimensions of the lens are 160 by 20 feet. Its maximum thickness of 35 feet is on the 100-foot level. Its greatest stope length appears to be about 250 feet.

The distribution of the sulphides—chalcopyrite, pyrrhotite, sphalerite, and pyrite—within the second part of the ore body is irregular, and considerable country rock is included in the ore. This portion of the ore body contained the rich chalcopyrite shoot from which most of the copper ore mined in the past has come. In that portion of this second part of the ore body southeast of the copper shoot there is a gradual but marked increase in the amount of sphalerite present in the ore, a decrease in the copper content, and an increase in the gold and silver to such an extent that this portion of the ore body is

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referred to as a gold ore shoot. Most of the ore mined in 1912 came from this shoot.

The ore.—The metallic minerals in the ore include chalcopyrite, pyrrhotite, pyrite, and sphalerite. Small amounts of galena are probably also present, as lead has been found in some of the assays. Chalcopyrite is the only copper-bearing mineral in the ore. A close association of sphalerite and gold is shown in the gold ore shoot, specimens of solid fine-grained sphalerite from which have assayed \$22, \$45, and \$90 gold to the ton. The rich copper ore and the hanging-wall pyrite have a very low gold content.

The gangue minerals of the ore body include the country rock, quartz, brownish-black calcite, and white calcite. The black calcite is usually marked by fine striations, which are not seen on the later white calcite.

The order of deposition of the metallic minerals, as determined under a metallographic microscope, is (1) pyrite, (2) pyrrhotite, chalcopyrite, and sphalerite, all three contemporaneous and all later than the pyrite. The sulphides are later than the silicate minerals of the gangue. The black calcite is apparently contemporaneous with the pyrite and earlier than the white calcite and the other sulphides.

Ore genesis.—The Ellamar ore body is the only one of its kind within the Ellamar district. It has apparently resulted from the sulphide impregnation and replacement of shattered sedimentary strata by mineral-bearing solutions which probably obtained access to these beds along a faulted zone and deposited their sulphide content, impregnating and metasomatically replacing portions of the strata. The pyrite was deposited first with the black calcite, which may represent recrystallized limy portions of the original sediments. The pyrite and black calcite were then shattered. Further replacement took place by mineralizing solutions of slightly different character from those depositing the pyrite. Chalcopyrite, pyrrhotite, and sphalerite were deposited, partly at the expense of the pyrite. White calcite carrying these later sulphides recemented the fractures in the strained black calcite. The hanging-wall pyrite lens maintained its individuality, being but little affected by these later changes in the mineralizing process.

#### THREE MAN MINING CO.'S MINE.

Location of property.—The Three Man Mining Co. has a number of claims, locally known as the Dickey claims, about the head of Landlocked Bay. Most of the development work has been on the north side of the bay, and according to Mr. Dickey all the present productive workings are on the Keystone claim.

*History and development.*—The Keystone claim was staked about 1903. The only development on the property at that time was an

open cut close to the edge of the bay. After finding prospects there work was started on what is now tunnel No. 1 and ore was found within a few feet of the surface. A shipment of 124 tons of ore, assaving a little over 12 per cent copper, from this tunnel was made in the fall of 1904. The developments in July, 1905, consisted of two 50-foot tunnels with some short drifts, one 20-foot tunnel, and a few open Forty-five tons of ore, assaying a little less than 13 per cent cuts. copper, are reported to have been shipped in 1906. Considerable development work was done in the following years, and a few irregular shipments of ore were made. In 1912 the mine became a regular producer. The present workings comprise 2,000 feet of adits and drifts on five levels, at elevations of 282, 235, 168, 122, and 57 feet. Considerable stoping has been done in a large sulphide ore body opened on levels 3, 4, and 5, and most of the ore shipped in 1912 came from this lens. A little development work was also in progress on the second and fifth levels.

Equipment and ore treatment.—No hoisting machinery has been necessary in the underground workings on account of the development of the property by adit tunnels. Hand drilling only is used in the exploration and exploitation of the ore bodies. There are several buildings on the property, including the manager's house, miners' eating and sleeping quarters, ore bunkers, and ore-sorting shed. A long wharf was completed in 1911. A short aerial tram extends from the mouth of No. 3 adit to the ore bunkers. The average number of men employed in 1912 was 25. Two 8-hour shifts were worked. Four of the men were employed in hand sorting the ore. The ore after sorting is stored in the bunkers until shipped to the Tacoma smelter.

The ore deposit.—The country rocks of the ore bodies are the greenstones, graywackes, and slates of the Orca group. The geology is complex on account of the extensive faulting. The trace of the Landlock overthrust fault crosses the head of Landlocked Bay just east of the present workings, and the rocks west of the fault plane and consequently below it have been intensely shattered, sheared, and faulted. A few of the shear zones are of considerable extent; many are short and narrow. Their strikes vary considerably, but most of them lie within the west-northwest system of fissuring. The dips are steep,  $45^{\circ}$  to  $90^{\circ}$ , and are principally to the north.

Much of the sheared material is mineralized. The ore bodies of workable size and shipping grade, however, are lenticular masses of nearly solid sulphides within the larger shear zones. Recent underground work has been confined to the exploitation of two ore bodies found in two of the larger shear zones. The two upper tunnels, Nos. 1 and 2, have exposed an ore body in the more northerly zone, and tunnels Nos. 3, 4, and 5 cut one in the southerly zone.

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These two shear zones are but 20 feet apart on the level of tunnel No. 2. The northern zone strikes N.  $60^{\circ}$  W. and dips  $35^{\circ}$  N.; the southern zone strikes N.  $75^{\circ}$  W. and dips  $65^{\circ}$  N. The northern shear zone is thought to have been cut in 1912 in tunnel No. 5, 60 feet north of the other zone.

The dimensions of these ore bodies are not fully known. The width of the northern shear zone is 18 feet at the level of tunnel No. 1. The thickness of the ore body ranges from 1 to 6 feet of solid sulphides. The stope length has not been determined, and but 50 feet of the pitch length, that portion between the first and second levels, is known. The continuation of this ore shoot is thought to have been found in the end of tunnel No. 2, 140 feet northwest of the present stopes. Stoping has been confined on this shoot between the second and first levels, and only a small amount of ore has been removed.

The ore body in the southern of these two shear zones ranges from 2 to  $9\frac{1}{2}$  feet thick and has been cut on the second, third, fourth, and fifth levels. The present stopes would indicate a maximum stope length of about 80 feet. The pitch of the ore body is eastward at an angle slightly greater than the slope of the hill. On the fifth level at an elevation of 57 feet the ore body is 140 feet from the surface; on the third level only 20 feet; and above the third level erosion has removed a portion of the eastern edge of the ore body, which extends still farther up the slope. Considerable stoping has been done on this ore body between the fifth level and the surface cropping, and an outdoor stope has been started on the second level. A considerable portion of these ore bodies is solid sulphide ore.

The ores are partly replacements by sulphide minerals of the crushed material of the shear zones and partly the cementation of small fractures in the shattered rocks by solid sulphides. The sulphides present in the ore are chalcopyrite, pyrrhotite, sphalerite, and pyrite. A soft pale brass-yellow metallic mineral occurs intergrown with the chalcopyrite. This mineral has not been determined. It appears to be a new species, apparently a copper-iron sulphide with a low copper content. Specks of native copper are found in the weathered surface croppings of the lodes. The gangue minerals are quartz, calcite, and the sheared and altered country rocks.

# LANDLOCK BAY COPPER MINING CO.

Location of property.—The property of the Landlock Bay Copper Mining Co. is situated on the south side of Landlocked Bay, on a narrow greenstone ridge projecting northwestward into the bay about one-half mile southwest of the Three Man mine. The property includes several claims, but the development work has been confined  $\cdot$  to three of the claims. The present workings are on the northeast side of the ridge on the Moonshine claim.

History and development.—The discovery of copper ore on this property was made in 1898. The present owners took hold of the property in 1903, and the Landlock Bay Copper Mining Co. was incorporated in 1906. All of the underground development work has been done since 1903, and the present mine workings are reported to have been driven since the incorporation of the company. The present mine workings comprise about 500 feet of drifts, a 25-foot winze, and three short raises. There are three other tunnels on the property that total a little over 400 feet in length.

Equipment and ore treatment.—The mine has been developed by an adit tunnel 80 feet above sea level and by sinking and raising on the ore bodies from the tunnel level. No hoisting machinery is needed and only hand drilling is used in obtaining the ore. In October, 1912, four men were employed in mining and one in hand sorting the ore. Ore bunkers of a capacity of 800 tons have been built near the mine mouth. The living quarters are on level ground close to shore on the southwest side of the ridge. Seven men were employed on the property in 1912.

The ore deposit now being developed lies in a shear zone in a greenstone and black slate country rock. A crosscut tunnel was started 80 feet above sea level. The lead was cut 180 feet from the mouth of the tunnel, and 260 feet of drift has been driven along the shear zone, the strike of which changes from N. 76° W. in the western drift to north-south at the southeastern end of the present workings. The dip flattens from  $65^{\circ}$  N. to  $30^{\circ}$  E. along the drift. The width ranges from 4 to 15 feet. Two ore shoots have been found, each of which has a stope length of 25 to 30 feet and a thickness ranging from 1 to 7 feet. A 20-foot raise has been driven on one shoot and a 25-foot winze sunk on the other. The pitch lengths of these shoots have not been determined. Ore from the winze is said to average at least  $7\frac{1}{2}$  per cent copper. Another 20-foot raise was driven in the shear 25 feet west of the winze on 10 to 12 inches of ore which is said to assay 4 per cent.

A copper-bearing shear zone on the south side of the ridge, 300 feet above sea level, strikes S.  $60^{\circ}$  E. and dips  $67^{\circ}$  N. Its width ranges from 2 to 5 feet. The outcrop is traceable for some distance east and west of a shaft which has been sunk on the shear zone. The country rock is greenstone and hard blocky slates. The ore is bunchy. A crosscut tunnel has been started northward to intersect this lead. Other undeveloped mineralized shear zones are reported on the property.

The ores are chiefly replacements by sulphide minerals of the crushed material of the shear zones. To a much less extent the sul-

phides fill small fractures in shattered black slate. The sulphides include chalcopyrite, pyrrhotite, sphalerite, and a few specks of an undetermined sulphide resembling the sulphide found at the Three Man mine. The gangue includes quartz, calcite, slate, and greenstone. Much of the calcite has a fine white sugary appearance.

## GALENA BAY MINING CO.

The prospects of the Galena Bay Mining Co. are situated on the north slope of Copper Mountain near the head of a southerly tributary of Millard Creek and are about 3 miles from the head of Galena Bay.

The principal underground development is a long tunnel 916 feet above sea level driven S.  $54^{\circ}$  E. to intersect a large shear zone which outcrops on the eastern side of the valley. In 1905 the tunnel was being driven by the Prince William Sound Mining Co. and had a length of more than 300 feet. The property was later taken over by the Galena Bay Mining Co. In August, 1908, the tunnel had reached a length of over 1,500 feet. In 1909 this tunnel was extended to 1,800 feet and some diamond drilling was done from the end of the tunnel. Further drilling was done on the Sunnyside claim on the west side of the valley. The tunnel has since been extended, according to reports, to a length of 2,200 feet. Several other shorter tunnels have been driven on the various claims. Only assessment work was done in 1912.

Considerable money has been expended in the development of this property. Several buildings have been erected at the head of Galena Bay and at the mine, a road built between the bay and the mine, and a telephone system installed connecting the mine, power house, and buildings at the bay. A dam erected on Millard Creek about a mile from Galena Bay gives a 52-foot head of water. The current generated at the power plant installed here was used to operate an air compressor at the mine tunnel and to light the entire camp. Material for an aerial tramway from the mine to tidewater was on the ground in 1908, but the tram has not yet been erected.

The principal ore bodies upon which development work has been done are the Vesuvius, Copper Crown, and Sunnyside claims. The country rock is predominantly greenstone, with some graywacke and slate. The greenstones are ellipsoidal in places.

The 2,200-foot crosscut tunnel was started north of and beneath the shear zone on the Vesuvius claim, which it was intended to intersect and which outcrops on the east side of the valley. The tunnel was started on a small iron-stained shear zone carrying a few small stringers of chalcopyrite, pyrrhotite, pyrite, and quartz. Seventeen hundred feet from the mouth the tunnel forks. The right branch was driven forward until a wet strip (possibly the Vesuvius shear zone) was reached. The left branch was swung a little to the north and was then continued for 500 feet. At the end it separates into three branches, each about 50 feet in length. The main shear zone was not recognized in the tunnel.

On the surface the Vesuvius shear zone passes between the mouth of the crosscut tunnel and the steep rock bluff a short distance to the south. To the west it heads for the low saddle on the Sunnvside To the east it extends up the steep east wall of the valley toclaim. ward the Landlock overthrust fault. At an elevation of 1.060 feet a 15-foot adit tunnel has been driven on a poorly developed shear zone which strikes N. 75° W., dips 60° N., and contains a few lenses of chalcopyrite, pyrrhotite, quartz, and calcite, 4 to 5 feet in length and up to 14 inches in width. At 1,180 feet a 20-foot tunnel has a long, narrow epidote-bearing quartz vein in the face but contains no ore. At 1.400 feet a 15-foot adit tunnel is driven on the Vesuvius shear zone and the ore which has thus far been found on this claim is said to have been found in this tunnel and above it. The shear zone is about 20 feet wide, strikes N. 50° W., and dips steeply to the south. Some ore is found in this tunnel but no solid masses of sulphides. At an elevation of 1,450 feet the shear zone splits. The south fork strikes N. 30° W. and dips vertically. The north fork strikes N. 50° W. and dips 70° S. The shear zone has a width of 12 feet at 1,500 feet elevation and is heavily iron-stained.° Quartz, calcite, pyrrhotite, and chalcopyrite occur in narrow irregular stringers in the sheared and shattered greenstones and slates. The principal sulphide is pyrrhotite.

The lead on the Copper Crown claim is located at an elevation of 2,250 feet on the east wall of the circue at the head of the valley. Where best developed 4 feet of solid sulphide ore is contained in a shear zone striking N. 75° E. and dipping 80° S. The country rock is massive unsheared greenstone. The width of the shear zone ranges from 3 inches to over 4 feet. The mineral content also varies and in places there are only a few narrow stringers of sulphides. The shear zone is traceable to the northeast about 250 feet and then appears to pinch out. In this portion the lead changes to a fairly well defined quartz vein carrying small amounts of sulphides. The quartz is frozen to the walls. An open cut has also been made on the shear zone 200 feet southwest of the 4-foot sulphide open cut referred to above. Here the lead strikes N. 65° W. and dips 75° N. The width ranges from 2 to 5 feet and some good ore is exposed. The walls are sheared ellipsoidal greenstone. Average assays of 12 per cent copper are reported on ore from this shear zone, but so far the only development work done has consisted of a few open cuts.

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The Sunnyside claim is located on the ridge west of the cabins. The country rock is principally greenstone, much shattered, cemented by a fine network of quartz veinlets, and extensively mineralized. There are numerous small shear zones with different strikes, the majority of which, however, lie within the east-west system of fissuring. No large continuous shear zones have been found. The distribution of the mineralization is irregular and bunchy. Α 28-foot tunnel has been driven at an elevation of 1,550 feet on a shear zone that strikes S. 70° E. The ore is principally pyrrhotite with small amounts of chalcopyrite in the sheared and shattered greenstones. The upper and longer tunnel, which has about 400 feet of drifts and two winzes, one of which is 60 feet deep, is at an elevation of 1.700 feet. Two ore bodies, containing ore said to average as high as 12 to 14 per cent copper, were struck in this tunnel. The larger ore body is said to have measured approximately 75 by 20 by 12 feet.

Other short tunnels have been driven on small and not very extensive shear zones carrying a few small bunches and stringers of ore. A shallow shaft on the crest of the ridge, which is sunk on a 5-foot shear zone that strikes N. 10° W. and dips 85° E., contains a 20-foot lens, 8 inches wide in places, of solid sulphides.

The ores, with the exception of a portion of the Copper Crown lead, are believed to be partly replacements of the sheared and shattered greenstones and partly the filling of tiny fractures in the shattered rocks by solid sulphides. The sulphide minerals comprise chalcopyrite, pyrrhotite, pyrite, and sphalerite. The gangue minerals are quartz, calcite, and the sheared and altered country rock. A portion of the Copper Crown lead is plainly the filling of an open fissure by a siliceous sulphide-bearing solution. The sulphides deposited in this portion of the lead are the same as those in the replaced portions.

## FIELDER & HEMPLE PROSPECT.

The Fielder & Hemple prospect is situated at the northeast corner of Boulder Bay, a short distance northeast of the property of the Reynolds Alaska Development Co. The lower and longer tunnel is at an elevation of 350 feet above sea level.

The development work consists of two tunnels and some surface stripping. The lower tunnel, which has 260 feet of drifts and a 25-foot raise, was driven to intersect a shear zone which outcrops about 100 feet above the tunnel mouth. The upper tunnel, 20 feet long, at an elevation approximating 450 feet above sea level, is driven along the shear zone.

The country rock at the lower tunnel is greenstone with some hard black slate, fractures in which are filled with quartz. No welldefined shear zone or ore body was seen in this tunnel. At the adit tunnel the country rock is all greenstone. The ore deposit consists of a poorly mineralized shear zone in greenstone lying at the foot of an overhanging ellipsoidal greenstone bluff. This shear zone strikes N. 45° E., dips  $65^{\circ}$  N., and is from 25 to 30 feet wide. The shearing is poorly developed. The ore occurs in small bunches up to 10 inches thick and consists of much fine-grained pyrite with only a little chalcopyrite, pyrrhotite, and quartz.

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# PROSPECTS OF REYNOLDS ALASKA DEVELOPMENT CO.

The Landlocked Bay property of the Reynolds Alaska Development Co. is situated near the head of a small northerly tributary to Landlocked Bay and is about a mile from the head of the bay.

The first discovery on the property is reported to have been made by Joseph Putz and Peter Steinmetz about 1899. Other claims were located later. The Reynolds Alaska Development Co. was formed in 1903 and is reported to have obtained control of the Landlocked Bay claims in 1904 or 1905. There is about 900 feet of underground development work on the property at the present time, including two long tunnels, which have 600 and 220 feet of workings, respectively, several short tunnels, open cuts, and a shallow shaft. Surface improvements include a trail from tidewater to the mines, a small warehouse at the bay shore, and a few buildings near the upper workings. No development work has been done on the Boulder Bay property since Grant's visit.<sup>1</sup>

The ore bodies comprise several small shear zones lying close to but a little to the west of the Landlock overthrust fault. The country rock is interbedded greenstone, graywacke, and blue-black slate. At the lower tunnel, 600 feet above sea level, a shear zone 5 feet in width was cut 60 feet from the tunnel mouth and a drift was carried 110 feet N. 35° W. along the shear, which dips 55° N. This shear zone is reported to average 5 per cent copper, though some highergrade ore is said to have been obtained in a 6-foot winze sunk on the lead where the shear zone was first struck in the tunnel. This shear is reported to be traceable on the surface for a considerable distance. A shaft 16 feet deep was sunk near the upper cabins in an ironstained outcrop of much-jointed greenstone showing small patches of chalcopyrite-pyrrhotite ore, which have a maximum thickness of 2 inches, and considerable disseminated sulphides in the more highly shattered portions. A sample taken across 20 feet of this outcrop is said to have averaged 1 per cent copper.

At an elevation of 845 feet a 600-foot tunnel has been driven toward Copper Mountain on an iron-stained shear zone, 3 to 4 feet

<sup>&</sup>lt;sup>1</sup> Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, p. 61, 1910.

wide, which has been traced up the slope by open cuts for a short distance. Sixty feet above the tunnel mouth the shear zone contains 4 feet of solid sulphide ore. No well-defined continuous lead or zone was observed in the tunnel, although numerous well-defined joints exist. Very little ore was seen. Sulphide stringers, having a maximum thickness of 3 inches and showing more pyrrhotite than chalcopyrite, are found in places, and the sulphides also occur disseminated in the greenstone.

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At an elevation of approximately 1,000 feet two short adit tunnels, 30 and 35 feet in length, have been driven on parallel leads in greenstone 100 feet apart that strike N.  $60^{\circ}$  E. and dip  $60^{\circ}$  N. Considerable ore, some of which is reported to average 8 per cent copper, is exposed in the workings. Some of the sulphide lenses are 8 to 10 inches wide.

The ores are believed to be replacements and impregnations of sheared greenstones by the sulphides, chalcopyrite and pyrrhotite. Pyrrhotite is the more abundant. The percentage of chalcopyrite present is indicated by the fact that the best assay reported, on picked specimens, showed between 9 and 10 per cent copper. The average copper content of the ore is much less. The gangue material comprises quartz, calcite, and sheared greenstone. Unreplaced fragments of the dark sheared greenstone are scattered through the masses of solid sulphides.

## STANDARD COPPER MINES CO.

The underground workings of the Standard Copper Mines Co. are on the steep south face of Copper Mountain between 1,400 and 2,100 feet above Landlocked Bay. The present company was organized in 1906 and most of the development work on the property has been done since that date. The tunnels are connected by an aerial tram, with 500-ton ore bunkers on a wharf on Landlocked Bay. Other surface improvements include the manager's house, office, and a large bunk house, all in good condition, on the shore of Landlocked Bay, and camp buildings near the upper end of the tram line. A few tons of ore are reported to have been shipped between 1906 and 1911. The property was idle in 1912.

The underground workings total about 1,300 feet in length and consist of five tunnels, in which the lengths of the workings are about 660, 290, 175, 85, and 28 feet, respectively. A 50-foot winze has been sunk in the longest tunnel at a distance of 54 feet from the mouth.

The ore bodies consist of lenticular masses of sulphides, of variable length and width, and of bunches of sulphides at the intersection of shear zones. The country rock of the shear zones is principally greenstone but includes some graywacke and black slate. The geology is complex, on account of much shearing and faulting. The ore bodies, however, all lie within the greenstone division of the Orca group.

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Tunnel No. 1. driven at an elevation of 1,820 feet, is 175 feet long and is situated at the head of the short branch of the aerial tram. Several lines of shearing intersect in the vicinity of this tunnel, and the following bearings have been recorded on these shear zones: Strike N. 90° E., dip 60° N.; strike north-south, dip 60° W.; strike N. 45° W., dip 65° NE.; strike N. 70° E., dip 60° N.; strike N. 75° E., dip 35° N.; strike N. 55° E., dip 50° N. Their width ranges from 1 to 20 feet. The linear extent of most of the shear zones is not The zone which crosses this tunnel 30 feet from the mouth known and strikes N. 75° E., with a 35° dip to the north, is traceable on the surface for over 100 feet. A 10-foot raise on this shear zone shows considerable chalcopyrite in the face. In a gulch a short distance east of this tunnel about 11 feet of solid sulphide ore is reported in a 5-foot shear zone which strikes N. 55° E. and dips 50° N. Stringers of mixed chalcopyrite and pyrrhotite having a maximum thickness of 1 inch fill cracks in the overlying ellipsoidal greenstone. Thirty feet farther east this shear zone is much less mineralized.

A short tunnel, driven at an elevation of 1,800 feet just west of the long branch of the aerial tram, crosscuts a shear zone about 20 feet wide, possibly the same as the one mentioned above, and is then driven 8 feet along the shearing. This shear zone strikes approximately N. 60° E. and dips 60° N. A little good ore is piled in front of this tunnel.

Tunnel No. 2, at an elevation of 2,070 feet, has 660 feet of underground development work. This tunnel was driven to intersect three ore-bearing zones outcropping on the mountain above. The lowest zone, encountered 45 feet from the mouth of the tunnel, strikes N. 55° E. and dips 45° N. A winze 50 feet deep has been sunk on this lead. Tunnel No. 4, driven along this same shear zone, crosses tunnel No. 2 at this point. Several hundred tons of ore, most of which has been shipped, are reported to have been mined from this zone. Two hundred and thirty feet from the tunnel mouth a 33-foot drift has been driven on a narrow 13-foot mineralized shear zone. Three hundred and fifty feet in a drift has been driven 260 feet S. 60° W. along a narrow mineralized shear zone, 3 to 6 feet wide, which dips 40° N. Numerous small quartzcalcite stringers are inclosed in the shear. The ore is reported to assay 4 to 5 per cent copper.

Tunnel No. 3, at an elevation of 1,450 feet on the short branch of the aerial tram, is 290 feet long: The greenstone at this tunnel as a whole is massive and not badly sheared. The face is in blocky black limy slate. A short distance inside of the tunnel a wide shear

zone, which strikes N.  $40^{\circ}$  W. and dips  $60^{\circ}$  N., is crossed. The sheared portions are 2 inches to 2 feet thick and are separated by several feet of solid greenstone. Joints at the mouth of the tunnel strike N.  $15^{\circ}$  W. and dip  $55^{\circ}$  W. A shear zone 50 feet west of the tunnel strikes N.  $10^{\circ}$  W. and dips  $80^{\circ}$  W. Malachite staining is abundant at the mouth of the tunnel.

Forty-five feet from its mouth tunnel No. 2 is crossed by tunnel No. 4, which is driven on a shear zone, 3 to 15 feet in width, that strikes N.  $55^{\circ}-80^{\circ}$  W. and dips  $60^{\circ}$  N. Tunnel No. 4 was started in a gully 30 feet east of tunnel No. 2, which it crosses, and extends about 50 feet beyond to the west. The shear zone is stoped to the surface, except for the last 25 feet. Lenses of sulphides and sheared greenstones lay within the shear zone. The average sulphide content of the entire zone is estimated to be equivalent to a band of solid ore 20 inches thick. The relative proportions of the sulphides vary. The copper content of this ore is not known.

The ores are probably replacements of the crushed filling of the shear zones combined with the cementation of numerous small fractures in the shattered rocks by sulphide minerals. These comprise chalcopyrite, pyrrhotite, and sphalerite. The gangue includes calcite, quartz, and the sheared and altered country rock.

# PROPERTY OF HEMPLE COPPER MINING CO.

The property of the Hemple Copper Mining Co. lies just north of the Three Man Mining Co.'s ground near the head of Landlocked Bay. The company was organized in March, 1910, and its holdings are reported to consist of six claims, all patented, and a 2-acre mill site. The claims are timbered. Surface improvements include camp buildings near the lower tunnels and a good trail to the property from Landlock. There is about 1,350 feet of underground development work, comprising four tunnels, whose workings are 800, 450, 65, and 18 feet in length, respectively; two shallow shafts, 10 to 15 feet deep; and numerous open cuts. At the lower tunnel, 450 feet above sea level, a Fairbanks-Morse gasoline engine, belt-connected to a small fan, is used to ventilate the workings. The property was idle when visited in 1912.

The country rock consists of greenstone, black blocky slate, and graywacke. Only one copper lead is reported on the property, a shear zone that is of variable width but is said to average 24 feet. Measurements of 5, 9, 10, 15, and 35 feet were made during the present investigation at different points across the sheared zone, which has been traced, by stripping, open cuts, shallow shafts, and tunnels, for over 1,500 feet. The strike of the shear zone changes gradually from N. 55° W. near its eastern end to east-west at its western end. The dip remains constant at about 60° N.

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The distribution of the metal content of the shear zone as a whole is decidedly irregular. Within the more highly mineralized portions the metallic ore minerals are irregularly distributed as stringers, lenses, and bunches of solid sulphides or occur disseminated through the crushed material. Some of the calcite stringers and bunches in the sheared greenstone also carry small amounts of sulphides. Stringers and lenses of pyrrhotite and chalcopyrite 2 to 18 inches thick lie parallel with the shearing, and a few large irregular masses of solid sulphides are occasionally found. The entire width of the shear zone may be mineralized in some places, whereas in others but little evidence of metallization is visible-for instance, at the west end of the lead, where above the 65-foot crosscut tunnel the iron-stained outcrop of the shear zone has been exposed for over 100 feet. At this locality the ore body shows a maximum width of 10 feet at the center, narrowing at both ends, beyond which but little metallization is The mineralized mass shows a lenticular cross section and evident. contains long, narrow lenses and stringers of solid sulphides up to 1 foot thick, irregularly distributed throughout the ore body, as well as considerable quantities of disseminated sulphides.

The ores are probably chiefly replacements by sulphide minerals of the crushed and altered material of the shear zone and fillings of numerous small fractures in the shattered rock by solid sulphides. The sulphide minerals include pyrrhotite, chalcopyrite, and sphalerite. Pyrrhotite is much more abundant than the other sulphides. The gangue minerals are calcite, quartz, and the sheared and altered country rock. Average assays of the mineralized portions of the shear zone are reported to show from 3 to 6 per cent copper. One assay of a sample taken previous to 1905 across a former face of the lower tunnel showed 6 per cent copper, \$1.20 in gold, and \$1.50 in silver. The copper content of the solid sulphide lenses is reported to be about 6 per cent.

# PROSPECTS OF THE THREE MAN MINING CO.

Besides the producing mine at the head of Landlocked Bay the Three Man Mining Co. has several prospects at which considerable work has been done. These include the ground formerly owned by the Alaska Commercial Co. on Landlocked Bay, the Montezuma claim on Copper Mountain, some claims on the south side of Landlocked Bay, and others near the summit on the Fish Bay side of the divide between Landlocked Bay and Fish Bay. These will be described briefly.

## WORKINGS OF ALASKA COMMERCIAL CO.

The workings of the Alaska Commercial Co. are on the north side of Landlocked Bay near its head and only a short distance west of the Three Man mine. This prospect was located in 1897 by Louis Jacob-

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son and is reported to have been the first discovery of copper ore by white men in this district. Undergro ind development work includes a 412-foot crosscut tunnel driven in 1898–99 at an elevation of 200 feet above sea level and two shorter adit tunnels driven at a later date, having a reported length of 100 and 20 feet, respectively, 250 feet above the lower tunnel. Several tons of high-grade ore are said to have been shipped from the upper tunnels. Since the Three Man Mining Co. has obtained control of the property a drift has been started in the crosscut tunnel about 210 feet from the mouth of the tunnel. In 1912 two men were employed extending this drift eastward.

The country rock of the ore deposit is chiefly greenstone, more or less ellipsoidal, with some interbedded black and gray slates and lightcolored fine-grained graywackes. The strikes and dips of the sedimentary beds vary. In the lower crosscut tunnel a strike of N.  $30^{\circ}$  W. and a dip of  $50^{\circ}$  E. was observed. Near the upper tunnels the strike is N.  $20^{\circ}$  W. and the dip  $70^{\circ}$ - $80^{\circ}$  E. In a gulch east of the upper tunnels and at an elevation of 400 feet a graywacke and black slate band 40 feet or more in thickness strikes N.  $5^{\circ}$  E. and dips  $70^{\circ}$  E.

The ore occurs in a shear zone about 30 feet wide, which carries large lenses of massive unsheared greenstone around which the sheared strips bend. The ore lies in the narrower and more sheared portions and in joint cracks in the massive lenses and the country rock. Some of the smaller sheared strips, 2 to 6 inches wide, are slightly mineralized. The adit tunnels are driven in the more highly mineralized part of the shear zone, a narrow greenstone band ranging from 2 to 10 feet in width but probably averaging only about 4 feet. This band strikes S. 85° E., dips 60° N., and is traceable about 250 feet along the strike. It extends about 75 feet west of the present tunnels but is not well developed. In a gulch at the east end of the known outcrop 2 feet of solid pyrrhotite has been found. In the adit tunnels a few lenses and streaks of chalcopyrite and pyrrhotite, with a thickness of 2 to 8 inches, are present. The largest lens is said to have shown a thickness of 18 inches of solid chalcopyrite and pyrrhotite.

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The long crosscut tunnel was driven to intersect the large shear zone outcropping above, but no ore was found in the main tunnel. Development work in the winter of 1912–13 in the east drift in this tunnel exposed a foot of solid pyrrhotite but no chalcopyrite.

The ore is probably chiefly a replacement of the sheared greenstone, with some cementation of small fractures by solid sulphides. The sulphide minerals present are chalcopyrite, pyrrhotite, sphalerite, galena, arsenopyrite, and the unknown sulphide also found at the Three Man Mine. Gold and silver are reported in assays of the copper ore. The presence of galena and arsenopyrite in this ore is noteworthy.

With the exception of pyrite, which was not observed in the specimens examined, the association of metallic minerals is the same as that in the gold-quartz veins of the Prince William Sound region. The gengue minerals include quartz, epidote, and the products formed by the shearing and hydrothermal alteration of the greenstone.

# MONTEZUMA CLAIM.

The Montezuma claim is situated on the steep south slope of Copper Mountain, a little lower and a little to the east of the workings of the Standard Copper Mines Co. The developments comprise a straight crosscut tunnel 350 feet long at an elevation of 1,300 feet above sea level, one short crosscut tunnel about 10 feet long, an adit tunnel of similar length, and considerable stripping, reported to be about 900 feet in length, along the lead which outcrops at about 1,400 feet elevation.

The country rock of the lead is principally greenstone with a few beds of interlayered black slate which, where seen, have a maximum thickness of 15 feet. The ore occurs in a mineralized shear zone 20 feet in width which strikes due east and dips 65° N. Erosion of the outcrop of this shear zone has resulted in a well-defined shallow trough, which is traceable for a considerable distance eastward toward the head of Landlocked Bay. The mineralization of the shear zone is irregular. Copper ore is reported to have been found in all the pits along the 900 feet for which the lode has been traced by the owners. The ore was formed by impregnation and replacement of the sheared material by chalcopyrite and pyrrhotite. Some quartz accompanies the sulphides. Lenses of solid chalcopyrite and pyrrhotite 1 to 4 inches thick have been found in some of the open cuts. These sulphides also occur disseminated in the sheared material.

Actual development work on the ore body has thus far been confined to surface strippings and the two short tunnels. The 350-foot tunnel was driven to crosscut this lode but has not yet reached the main shear zone. A small copper lead, however, is reported to have been crossed in this tunnel. The main shear zone, which is well defined and of considerable length, is mineralized, and later development may disclose bodies of profitable ore within it.

## CLAIMS ON SOUTH SIDE OF LANDLOCKED BAY.

Four tunnels, 115, 65, 35, and 5 feet in length, have been driven on claims belonging to the Three Man Mining Co. on the south side of Landlocked Bay. These workings are located S. 45° E. of Copper Mountain and between elevations of 450 and 650 feet above sea level. A trail leads from Landlocked Bay to the tunnels, which have been driven at different elevations in slightly mineralized shear

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zones in interbedded black slates, graywackes, and greenstones. The recorded strikes and dips of the various shear zones examined are (1) strike S.  $75^{\circ}$  E., dip  $40^{\circ}-50^{\circ}$  N.; (2) strike N.  $65^{\circ}$  E., dip vertical; (3) strike N.  $35^{\circ}$  W., dip  $35^{\circ}$  N.; (4) strike S.  $85^{\circ}$  E., dip  $52^{\circ}$  N. The stripped outcrops of the shear zones are iron stained in places, with exceptionally a little copper staining. Small lenses of quartz carrying chalcopyrite and pyrrhotite are visible in the lowermost open cut. Very little ore was found in any of the workings. Both greenstones and slates were slightly mineralized, chalcopyrite and pyrrhotite being the sulphide ore minerals.

WORKINGS ON THE FISH BAY SIDE OF BILLY GOAT MOUNTAIN.

The workings on the Fish Bay side of Billy Goat Mountain consist of short tunnels at elevations of approximately 1,150 and 1,750 feet above sea level. The country rock of the ore bodies is massive greenstone. The lower tunnel is driven 30 feet northeastward on a slightly sheared zone along a master joint which strikes N.  $45^{\circ}$  E. and dips  $45^{\circ}$  E., at the base of a 50-foot bluff of massive greenstone. The thickness of the sheared zone ranges from a fraction of an inch up to 6 inches. Slight copper and iron staining appears along the shear zone, which carries a few stringers of chalcopyrite and pyrrhotite and a little quartz. The greenstone beneath the tunnel is much shattered and contains irregular, barren-looking quartz-calcite veins, short and lenticular, the largest ones being 3 feet in width and 10 to 12 feet in length.

The upper workings are in a vertical copper-stained bluff of greenstone. The tunnels are driven along small shear zones, which strike S. 70° E. and dip  $30^{\circ}-50^{\circ}$  N. The largest body of ore is reported to have been not over 8 feet long, with a maximum width of 1 foot, and is said to have contained about 6 per cent copper. The sulphides of the ore are chalcopyrite and pyrrhotite. The ores are of the usual type—sulphide impregnations and replacements of the sheared greenstone.

## HOODOO CLAIM.

The Hoodoo claim is situated on the south shore of Landlocked Bay, a short distance east of the ore bunkers of the Landlock Bay Copper Mining Co. This claim was located January 1, 1904. Thomas B. Grove and the Three Man Mining Co. have each a half interest in it. The workings include considerable surface stripping and three tunnels, 180, 60, and 15 feet long, of which 105 and 45 feet, respectively, of the two longer tunnels were driven in slide. The remainder of the tunnels is in solid rock. A 30-foot raise has been driven to the surface in the long tunnel. The 60-foot tunnel was driven in 1903. Two men were at work on the property in 1912.

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The country rock of the ore bodies is greenstone. The last 75 feet of the long tunnel is driven S. 66° E. on a shear zone in the greenstone, which dips 60° N. The ore is said to have ranged from a thin film to 2 feet in thickness and to have averaged 4 to 5 per cent copper. A 30-foot raise was put in to the surface along the footwall of this lead where it was first struck in the tunnel in 1910. Surface stripping at an elevation of 230 feet above sea level has exposed for about 75 feet a 3-foot band of mineralized sheared greenstone, which strikes N. 45° W. and dips from 60° NE. to nearly vertical. A network of tiny quartz veinlets shows on the iron-stained outcrop of the lode. The 15-foot tunnel, 150 feet above the cabin, is driven S. 60° E. on a lead reported to show 3 feet of copper ore in the face of the tunnel. One hundred feet east of the long tunnel and at the same level stripping has exposed an 18-inch shear zone in greenstone. This lode strikes S. 30° E., dips 55° NE., and carries a little copper.

The sulphide minerals of the ore are chalcopyrite, pyrrhotite, and sphalerite. Native copper is found in the iron-stained surface that crops out above the 15-foot tunnel. The ore carries only a small amount of copper, but assays of \$10 to \$22 gold are reported. Quartz is an abundant gangue mineral.

# GOLD QUARTZ LODES.

A few gold quartz claims have been located in different parts of the Ellamar district on stringers, lenses, and stockworks of gold-bearing quartz, but no prospects of economic importance have as yet been found. Several large low-grade quartz masses are reported on the seaward side of Bligh Island. Near the entrance to Cloudman Bay there is a stockwork of quartz veins in slate 20 to 30 feet wide, containing about equal quantities of quartz and slate. The strike is a little east of south and the dip 65° N. A 4-inch gouge seam forms the south wall and two small faults with gouge were seen at the left edge. Most of the cropping is below high tide, but the lode is stripped 40 feet back from the beach. The quartz is drusy. The sulphides include chalcopyrite, pyrite, and sphalerite. The ore is reported to average 2 to 4.80 on samples taken across the entire 30 feet.

Just back of this ledge is an old Alaska Commercial Co. prospect on a bunch of gold quartz on which assays as high as \$2,500 are said to have been obtained. The bunch of ore is reported to have been blown out. The shaft is now caved in and there is nothing to be seen.

In a bay at the north side of Graveyard Point Mr. L. E. Banzer has put down a couple of shafts and done several hundred feet of stripping, all now fallen in and covered. The shafts are full of water. The slate and greenstone in this vicinity is much contorted and crumpled, but the general strike seems to be a little south of east with

a steep northeasterly dip. The slates have many stringers and bunches of quartz up to 6 inches thick. In the bottom of one of the shafts a lead 2 feet wide is reported. On the dump is a good deal of quartz carrying sulphides. Chalcopyrite, pyrrhotite, pyrite, sphalerite, and galena are found in the ore and a little calcite is included in the gangue. Assays as high as \$50 in gold to the ton are reported on this ore, but it is not known that this was an average sample. ディアやっちろしたかとないとう

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