Iron and Copper Deposits of Kasaan Peninsula Prince of Wales Island Southeastern Alaska

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By L. A. WARNER, E. N. GODDARD, *and others*

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IRON AND COPPER DEPOSITS OF KASAAN PENINSULA, PRINCE OF WALES ISLAND, SOUTHEASTERN ALASKA

By L. A. Warner, E. N. Goddard, and others

ABSTRACT

Copper-bearing magnetite deposits and associated copper deposits on Kasaan Peninsula, Prince of Wales Island, southeastern Alaska, have been known for many years and have been mined to some extent for their copper content. Total production has been over 670,000 tons of ore valued at more than $6,200,000. At the beginning of World War II, the development of war industries in the Pacific northwest focused attention on the deposits as possible sources of iron ore. From 1942 through 1944 the U.S. Geological Survey made detailed studies of most of the ore deposits, and at a few of the more promising localities diamond-drilling operations were carried on by the United States Bureau of Mines.

The deposits are mostly small and irregular but of relatively high grade. The chief ore minerals are magnetite, pyrite, and chalcopyrite, and the gangue is largely tactite consisting of garnet, epidote, diopside, and hornblende. Total reserves for the area are estimated at about 4 million long tons of iron ore containing an average of 50 percent of iron and 1.5 million short tons of copper ore, most of which contains less than 2 percent copper. Only small quantities of phosphorus and titanium are present, but the sulfur content may average between 1 percent and 4 percent, the amount being roughly proportional to the copper content. The reserve figure includes only a small amount of high-grade copper ore. Recoverable amounts of gold and silver are in many of the deposits.

Most of the country rock on the peninsula is greenstone of andesitic composition and probable Mesozoic age. Included in the greenstone are rocks of sedimentary origin believed to be of Paleozoic age. These consist of limestone and various clastic rocks, including siltstone, graywacke, quartzite, and conglomerate, some of which are calcareous. All the sedimentary rocks have been somewhat metamorphosed, the limestone having been completely recrystallized. Structural relationships suggest that the andesitic material is mainly in the form of huge sills that intruded the sedimentary sequence. It is believed that the intrusive material was far more abundant than the host rock, and the sedimentary rocks are thought to have been broken into discontinuous slabs which now appear as crenulated lenses and layers in the greenstone. The greenstone and included sedimentary rocks were later folded and fractured and were intruded by numerous dikes and stocklike bodies of igneous material ranging in composition from gabbroic to keratophyric types. At the close of the intrusive sequence the region was faulted and ore-bearing solutions, percolating upward along faults and dikes, replaced brecciated greenstone and lenses of calcareous clastic material; limestone was replaced in only a few places.

The ore deposits are commonly associated with areas in which rocks of sedimentary origin constitute a substantial part of the country rock. Only small pods and stringers of ore have been found in areas where such rocks are not exposed or cannot be reasonably assumed to be present.

During the orogeny that preceded and accompanied the intrusion of the many dikes and stocks, the greenstone doubtless yielded with difficulty to the forces of deformation. However, in places where the greenstone contained abundant layers of sedimentary material, zones of weakness existed and rock failure was more common. These zones of weakness became zones of principal deformation in which the rocks were folded, faulted, and brecciated. Such zones of principal deformation were best suited to receive the mineralizing solutions. The extent to which the rocks were replaced presumably depended upon their composition and their accessibility to the solutions. The limestone, having been deformed by plastic flow and recrystallization, is much less permeable than the foliated clastic sediments and the fractured greenstone, and contains little ore. Low-grade ore with tactite is found in broken greenstone within and adjacent to the major ore bodies. Where the greenstone was pulverized sufficiently replacement was practically complete. The more calcareous of the foliated and broken lenses of clastic sediments were probably the rocks most commonly affected by the mineralizing solutions. Much of the ore and tactite shows a banding similar to that found in certain of the clastic rocks, and nearly all stages of replacement between the partly altered clastic rocks and the banded ore and tactite have been found.

The largest magnetite deposits on the peninsula are in the Mount Andrew-Mamie area, which is estimated to contain more than one-third of the total reserves. Most of this is in the so-called compound ore body just south of the Mount Andrew mine workings. This deposit was trenched, sampled, and explored by diamond drilling during 1944 by the U.S. Bureau of Mines. A considerable tonnage of magnetite remains in the vicinity of the Mamie mine; however, other deposits in the area are small and virtually no high-grade copper ore remains. The deposits of this area appear to have replaced contorted lenses of sedimentary rocks in greenstone. The rocks are intricately folded, faulted, and intruded with numerous dikes.

The Poor Man iron deposit, second largest on the peninsula, contains about half as much high-grade magnetite ore as the Mount Andrew compound ore body. The deposit was trenched, sampled, and drilled by the U.S. Bureau of Mines in 1944. The ore formed largely through replacement of brecciated greenstone in a large fault zone that terminates against a thick lens of marble. The fault is part of a larger en echelon fracture zone that extends southward across the peninsula from the head of Tolstoi Bay. No other ore deposits have been found in the fracture zone.

The magnetite deposits at Tolstoi Mountain, formerly thought to be of considerable size, proved to be small and of relatively low-grade. They are of interest mainly for the information they provide regarding genesis of other deposits on the peninsula. The magnetite replaced banded calcareous siltstone and other rocks that occur in lenticular masses in greenstone. Large exposures of unreplaced sedimentary rocks were found in the area, and structural and genetic relations are somewhat better defined than at Mount Andrew where replacement was more complete.

Many smaller magnetite bodies occur elsewhere on the south side of the peninsula and all contain some copper, however, the only remaining copper reserves of any consequence are at the Rush and Brown mine and the Rich Hill mine and the amounts of better grade ore are not large. The deposits at the It mine are said to be virtually exhausted; the main workings were not accessible at the time of examination.

The Kasaan Peninsula ores may furnish support to ferrous industries on the west coast, although they are not large enough to play a major role. There may be metallurgical difficulties because of the relatively high sulfur content, but byproduct recovery of copper, gold, and silver might serve to offset the cost of special treatment. It seems likely that further exploration may reveal additional deposits of the kind and size already known.

INTRODUCTION

SCOPE OF REPORT

Iron and copper deposits containing recoverable amounts of precious metals have been known on Kasaan Peninsula, Prince of Wales Island, southeastern Alaska, for many years. They were worked intermittently for copper and precious metals, but until recently little attention was paid to their iron resources. Interest in a west coast ferrous industry during World War II led the U.S. Geological Survey to make detailed investigations of virtually all known deposits on the peninsula. Particular attention was paid to the iron ores, but several copper deposits were examined in the course of the fieldwork.

Reports describing several of the ore deposits were issued for limited distribution during the war. At the close of the war it was felt that all the material pertaining to the geology and ore deposits of the peninsula should be brought together in convenient form and made available to the public. The present report has been prepared with this end in view.

FIELDWORK AND ACKNOWLEDGMENTS

Since 1900 several geologists of the U.S. Geological Survey have examined the ore deposits on Kasaan Peninsula. A. H. Brooks visited the area in 1901 in connection with his studies of the deposits of the Ketchikan district. F. E. Wright and C. W. Wright examined the deposits on Kasaan Peninsula in 1904 and 1905 and C. W. Wright, assisted by Sidney Paige, made a more comprehensive study during 1907 and 1908. During the latter period, D. C. Witherspoon, J. W. Bagley and R. H. Sargent made a detailed topographic survey of the peninsula. The area was visited subsequently by Adolph Knopf in 1909–10, P. S. Smith in 1913, Theodore Chapin in 1915–16, and J. B. Mertie, Jr., in 1917 and 1919. In 1941, J. C. Reed and G. O. Gates visited the more important iron deposits on the peninsula and recommended that detailed studies of these ore bodies be made.

Fieldwork that served as a basis for this report was begun in the summer of 1942, under the direction of E. N. Goddard, and was continued in the summers of 1943 and 1944 under the direction of L. A. Warner. In the vicinities of the ore bodies geologic, topographic, and dip-needle surveys were made. In the larger areas less detailed dip-needle surveys were made in conjunction with the geologic mapping.

The fact that the magnetic compass could not be relied upon in the vicinities of the magnetite deposits required the use of a plane table almost exclusively in these areas, despite the fact that the dense underbrush and heavy timber make plane-table surveying extremely difficult. For the most part, outcrops are scarce and the geology is rather complicated, requiring fairly close control in order to insure adequate coverage. At safe distances from the magnetite bodies, pace-compass and tape-compass traverses were made to supplement the planetable control.

Lake Superior type dip needles were used in making all of the dip-needle surveys, and Brunton compasses and sundial compasses were used in obtaining horizontal magnetic anomalies. During 1942 a grid system was used in making the dip-needle surveys, but owing to the rough topography and heavy timber, this system proved cumbersome because many of the grid stations fell at points that could not readily be located with the plane table. Consequently, during 1943 and 1944 the dip-needle stations were located at random by radial shots taken from each of the plane-table stations. Care was taken in laying out the plane-table control so that the dip-needle stations were not more than 100 feet apart. Additional stations were established where needed by turning compass angles from points on the radial lines leading from the plane table and measuring or pacing to desired locations. The number of dip-needle observations in any particular area was controlled by the complexity of the magnetic field in that area. Where great range in the magnetic anomalies was noted, many stations were established, and where the anomalies were fairly consistent or rather small, relatively few observations were made. Because of its flexibility, this system of dip-needle surveying seems well adapted to regions of rough, wooded, terrain.

During 1943 and 1944 the U.S. Bureau of Mines sampled and drilled the Rush and Brown and Salt Chuck deposits; trenched, sampled and drilled the Mount Andrew and Poor Man deposits; and trenched and sampled the Iron Cap deposits at Tolstoi Mountain. The Bureau also sampled many of the smaller deposits on the peninsula. Many courtesies were extended to the geologists in the field by Bureau of Mines engineers, particularly S. P. Holt, A. W. Tolonen, and E. L. Fosse.

Thanks are due many of the local citizens, businesses, and agencies for their helpful cooperation. The officials of the Pacific Amer-

ican Fisheries at Kasaan made their facilities available to the field parties on many occasions. The McKay Transportation Company and the West Coast Transportation Company of Ketchikan extended many favors beyond their regular services. The U.S. Forest Service in Ketchikan furnished storage space for the field equipment and assisted the Survey personnel in many ways. Mr. A. L. Howard, manager, and Mr. and Mrs. Otto Lindemann, caretakers, at the Salt Chuck mine extended many courtesies to the fieldmen working in that vicinity. Mr. Axel Carlson of Ketchikan furnished much helpful information about the Mount Andrew mine, of which he was formerly superintendent.

The task of organizing the material of this report has been difficult, because the work of many men is involved, some of whom were called into the armed forces or assigned to other duties, leaving their field data to be interpreted by others. Contributions of individuals have been included under their names where possible, but certain changes in the original manuscripts have been necessary for clarity and unity.

The results of the work done by H. R. Gault, assisted by Clyde Wahrhaftig, at the Salt Chuck mine during the winter of 1942–43 are not included here. The geology and mineralogy of the Salt Chuck deposit seem to mark it for special consideration and the report on this work is being prepared separately. The studies by Gault and Wahrhaftig have, however, contributed much to an understanding of the general geology of Kasaan Peninsula.

HISTORY AND PRODUCTION

Copper ore was discovered on Kasaan Peninsula by the Russians about 1865 (Wright, 1915, p. 88). Most of the ore bodies now known were located between 1895 and 1900 and mining was begun during that period. Mining was done intermittently until shortly after World War I. Since then, with the exception of that from the Salt Chuck Mine, there has been little production from the peninsula. Total production has been over 670,000 tons of ore valued at more than $6,200,000. Copper has accounted for most of the value, but there has been appreciable income from precious metals.

The Salt Chuck, It, and Mamie mines have each produced more than $1 million in copper ore and together account for more than two-thirds of the production. Many prospects have produced little or no ore. These include the Venus or Iron Creek, Copper Center, Haida, Brown and Metzdorf, Alarm, Poor Man or Iron King, Charles, Copper Queen, Uncle Sam, and the Tolstoi Mountain prospects. Little is known of their history. Descriptions of all the deposits that were examined in detail are included in the report.

GEOGRAPHY

Kasaan Peninsula is on the northeast side of Prince of Wales Island (fig. 1), about 30 miles northwest of Ketchikan and 750 miles northwest of Seattle, Wash. The peninsula is bounded on the south-

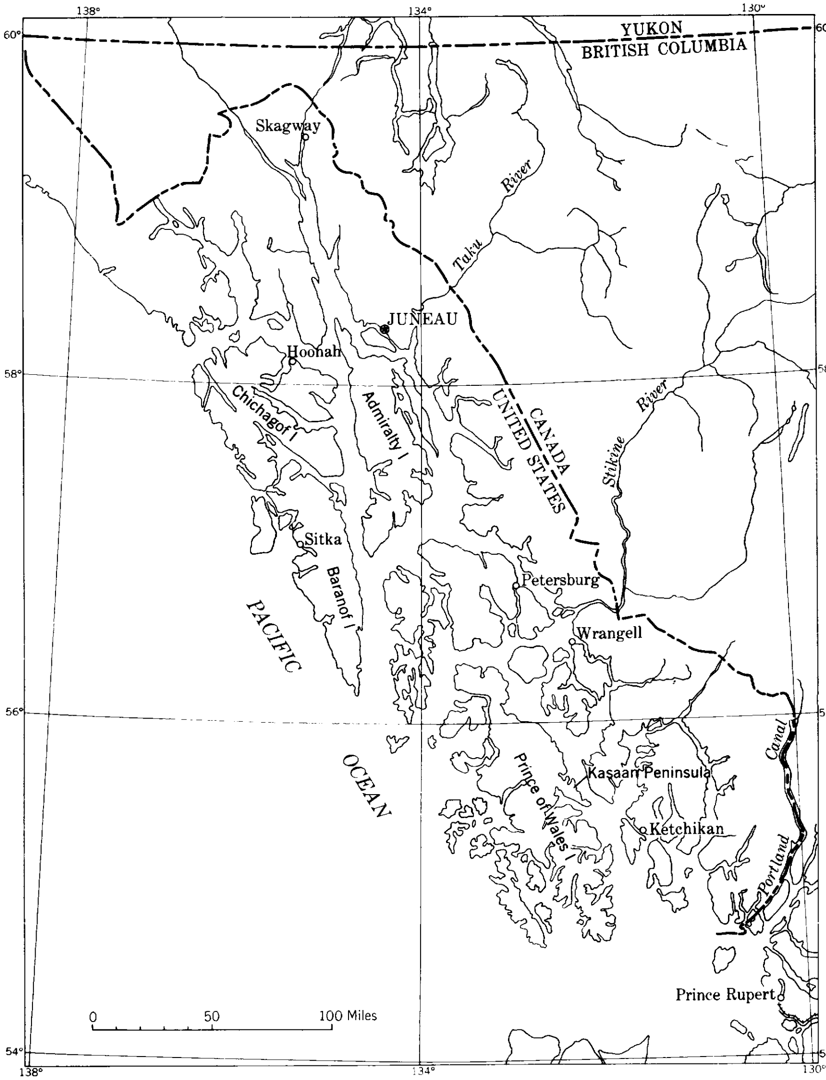

FIGURE 1.—Index map of southeastern Alaska showing location of Kasaan Peninsula.

west by Kasaan Bay (fig. 2), which is accessible to deep-water shipping, and on the northeast by Clarence Strait, a main waterway for most shipping in southeastern Alaska. The region is sparsely inhabited. Kasaan, the only town, is a small fishing village with about 50 residents. Ketchikan, a city of about 8,000 people, is a port of call for most of the Alaska shipping. A small boat makes weekly trips to Kasaan, carrying freight, passengers, and mail. There are no roads on the peninsula but a Forest Service trail, in poor condition, extends from the Salt Chuck, at the head of Kasaan Bay, to Hadley, an abandoned village at Lyman Anchorage.

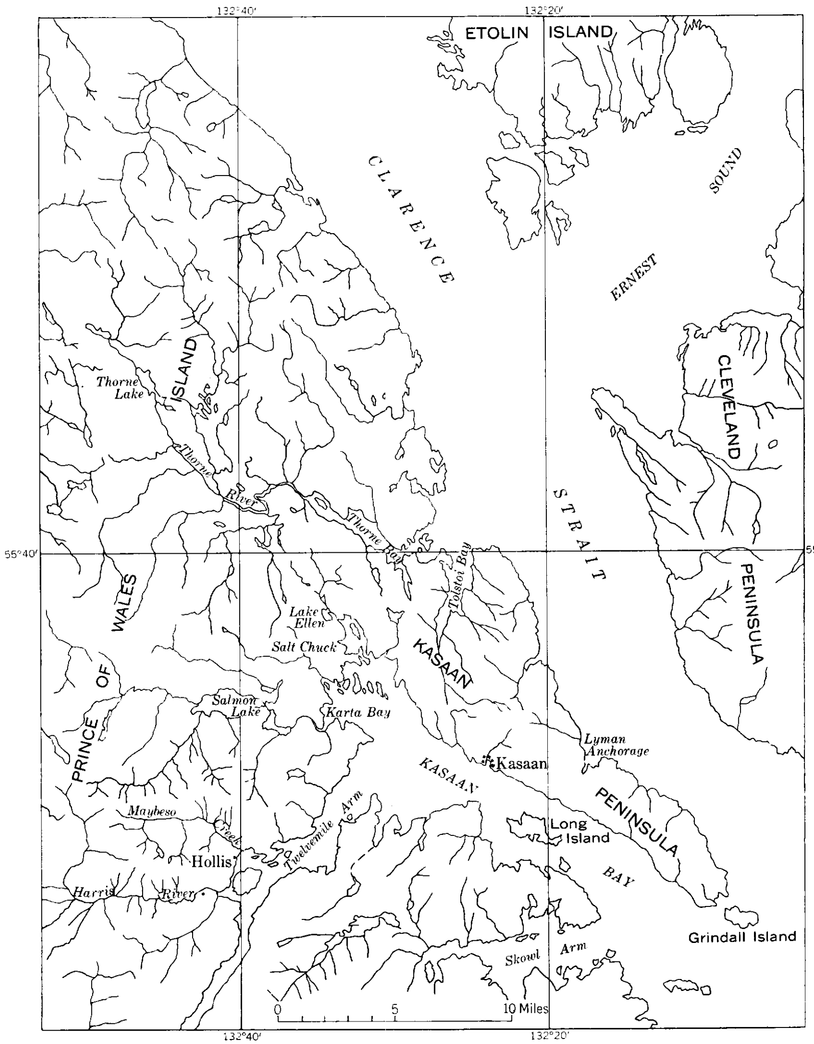

FIGURE 2.—Map showing relationship of Kasaan Peninsula to adjacent areas.

The peninsula is a long tapering mountainous ridge culminating in Kasaan Mountain, the highest peak, which has an altitude of 2,840 feet. The southwest slopes of the peninsula tend to be steeper than those on the northeast and in many places rise precipitously from Kasaan Bay. The peninsula is separated from the main part of

Prince of Wales Island by a broad topographic depression extending south from Tolstoi Bay. The entire peninsula was glaciated, as shown by the rounded hills and by glacial erratics and till.

Stream erosion is at its earliest stage. Small lakes are scattered over the area at various altitudes and the streams seep sluggishly through muskegs in high glacial valleys and descend precipitously to the sea through narrow, steep-walled canyons.

The climate on Kasaan Peninsula is mild and wet. The mean annual temperature, as recorded by the United States Weather Bureau at Ketchikan is about 45°F and ranges from an average of about 32°F in the winter months to about 57°F in July and August. The mean annual minimum temperature is about 13°F and the mean annual maximum about 78°F. Mean annual precipitation is about 151 inches, most of which is drizzling rain. Rainfall is fairly well distributed throughout the year but reaches a monthly high of about 22 inches in October and November and a monthly low of about 6 inches in May and June. Heavy thunderstorms are uncommon. The snowfall above altitudes of 1,000 feet is likely to be heavy during the winter months. Kasaan Bay is open to navigation throughout the year but low fogs are frequent. The streams on the peninsula are too small for water power.

The terrain is covered with a thick growth of vegetation. Hemlock, spruce, and cedar predominate but a few pines are in the uplands. Much of the timber is not of marketable quality but in most places an adequate supply for mining purposes is within easy reach of the mines and prospects.

GEOLOGY

The general geology of the peninsula is shown on plate 1. The older rocks include a great thickness of greenstone containing layers and lenses of metamorphosed sedimentary rocks. The greenstone is mostly altered andesite with some basalt and monzonite. The metamorphosed sedimentary rocks were originally limestone, calcareous siltstone and sandstone, graywacke, and conglomerate. The true relationship of the greenstone to the sedimentary rocks is not known but field and laboratory evidence suggest that the greenstone is in part intrusive into the sedimentary rocks and that the two may be of widely different ages.

The greenstone and metamorphosed sedimentary rocks are folded and faulted and are intruded by many dikes and stocks ranging in composition from pyroxenite to granite aplite. Many of the later dikes are rich in albite. In the vicinity of the Salt Chuck most of the intrusive rocks are gabbro and pyroxenite. At Mount Andrew, 14 miles to the southeast, more acid types predominate. A progressive difference in the composition of the dike rocks was noted between these two places.

Quaternary deposits of glacial debris and alluvium fill many of the valleys and lowlands. This material commonly forms a thick mantle along the beaches but is generally absent in the uplands.

GREENSTONE AND ASSOCIATED ROCKS

METASEDIMENTARY ROCKS

Rocks of sedimentary origin form lenses and layers in the greenstone and are widespread on the peninsula. Too little of the peninsula is mapped in enough detail to obtain an accurate picture of the character and distribution of these rocks, and the character of the original rocks is obscured in many instances by dynamothermal and hydrothermal metamorphism.

Rocks of sedimentary origin are estimated to constitute as much as 25 percent of the older bedrock, which is largely greenstone. The metamorphosed sedimentary rocks can be divided roughly into three categories based on their original composition: limestone; calcareous beds of mudstone, siltstone, and fine sandstone; coarse sandstone, graywacke and conglomerate. Each of these types probably formed about a third of the original sedimentary section.

The limestone, in part dolomitic, has been metamorphosed to rather coarsely crystalline marble. It is white or gray and, where impure, is foliated parallel to the original bedding. It forms discontinuous lenses that are mostly tightly folded. Near Tolstoi Mountain, some marble layers contain siliceous pebbles, some of which are an inch or more in diameter.

The fine-grained clastic rocks are, for the most part, somewhat calcareous. The colors are commonly pale green, blue gray, or buff. The rocks are either massive or thin bedded, the bedding in some instances being of a rhythmic character similar to that in varved clays. In many places bedding is well preserved (figs. 3, 4). The massive varieties are easily confused with fine-grained greenstone. Originally the principal constitutents of the clastic rocks were probably lime, clay, silt, and quartz sand. Near the ore deposits, the clastic rocks are largely altered to tactite and virtually all rocks of this this type show some alteration to garnet, epidote, and diopside or amphibole.

The coarser grained clastic rocks in places form rather thick continuous layers, as at Tolstoi Mountain. They consist mainly of poorly sorted siliceous material with minor amounts of feldspar and mafic minerals. Some of these rocks contain fragments of older igneous and metamorphic rocks in a heterogeneous matrix and are

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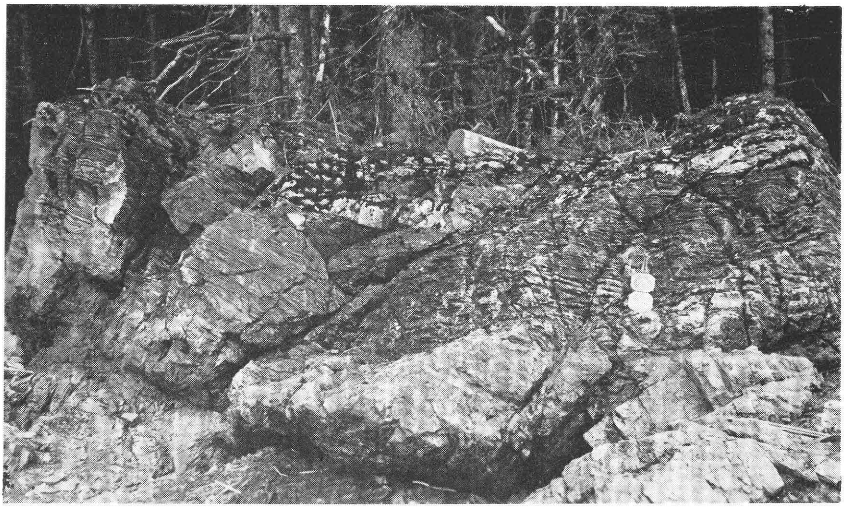

FIGURE 3.—Thin-bedded calcareous siltstone in contact with greenstone (massive material in lower foreground) on beach three-fourths mile southwest of Poor Man iron deposit.

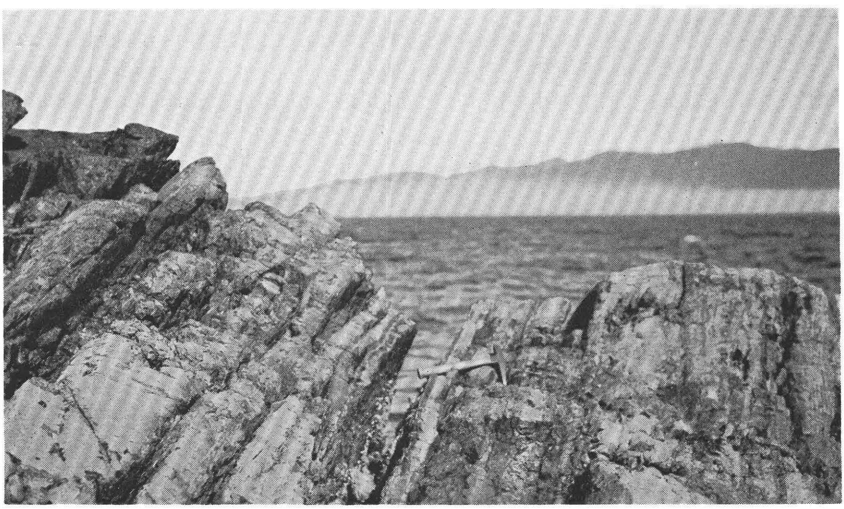

FIGURE 4.—Interbedded sandstone (light) and calcareous mudstone, south side of Palmer Cove, Tolstoi Mountain area.

probably graywacke. Others contain a fairly high percentage of detrital feldspar and are probably arkose. The conglomerates contain flattened and elongate quartzitic pebbles which are oriented parallel to the bedding.

Limestone containing an abundant Devonian fauna (Wright, 1915, p. 70–72; Buddington and Chapin, 1929, p. 97, 99–101) crops out on Long Island and adjacent small islands in Kasaan Bay, about 1 mile off the southern coast of the peninsula. (See pl. 1.) These rocks, though folded and faulted to some extent, have been affected little by metamorphism. They are in sharp contrast to the recrystallized limestone on Kasaan Peninsula, where no fossils have been found.

GREENSTONE

The greenstone on Kasaan Peninsula was described first by Brooks (1902, p. 40, 49–50) as an effusive rock having the general character of an andesite. He states that "rhyolites, trachytes, and basalts were also noted at a few localities." Wright (1915, p. 68–69) refers to these rocks as "graywackes," using the term to indicate somewhat metamorphosed sedimentary rocks consisting "largely of igneous material worked over mechanically, but not greatly decomposed before deposition." It is now known that part of the rocks grouped with the greenstone were originally sedimentary deposits but that most of the material is of igneous origin.

The term "greenstone" probably is appropriate for much of the country rock on Kasaan Peninsula and in this report is used to refer to altered andesitic rocks related to igneous activity that took place prior to the emplacement of the dikes and stocks. The greenstone constitutes at least 75 percent of the older rocks of the peninsula. Megascopically it is dark gray green, commonly compact and massive, but locally with a mottled appearance where weathered. It is with few exceptions prophyritic and in most instances can thus be distinguished from the clastic sedimentary rocks, which it in part resembles. Local variations in texture and composition are not readily apparent in the field and the various types are not separated on the geologic maps.

Most of the greenstone appears to have been derived from andesite. However, deuteric and hydrothermal alteration in many instances virtually have obliterated the original minerals. The usual texture is porphyritic with a felty groundmass, although aphanitic varieties are noted. The phenocrysts are commonly 1 to 2 millimeters in diameter and consist of sericitized plagioclase, and augite, which is altered largely to hornblende or chlorite. The groundmass consists mostly of laths and needles of plagioclase with numerous crystals of magnetite and rare crystals of apatite and sphene. The plagioclase in these rocks is altered largely beyond recognition but probably was mostly andesine. Much of the greenstone originally may have been monzonite. Some probably was basalt and a little may have been derived from rhyolite or quartz porphyry. Quartz-bearing varieties, however, are exceedingly rare.

AGE RELATIONS

Structural and petrographic evidence suggests that the greenstone is intrusive for the most part into the metamorphosed sedimentary rocks. No greenstone unquestionably of extrusive origin was found in place on Kasaan Peninsula. Boulders of greenstonelike material showing oriented vesicles and amygdules were found on the beach at the head of Tolstoi Bay, but this material may not be indigenous to the area. Material thought to be metamorphosed tuff in the field proved to consist largely of tactite minerals.

In many places the greenstone crosscuts the foliation in the metamorphosed sedimentary rocks and in some instances appears to form dikes in these rocks. Mainly, the greenstone probably represents huge sills that are conformable in general with the attitude of the metamorphosed sedimentary rocks. At Tolstoi Mountain, lenticular bodies of sedimentary rock seem to be included in the greenstone as large xenoliths.

A comparison of the lithologic characteristics of the metamorphosed sedimentary rocks and the greenstone suggests that they are of different ages. The sedimentary rocks are heterogeneous ranging from coarse conglomerate to nearly pure limestone, suggesting that they accumulated over a relatively long period during which the physical environment changed appreciably. The greenstone, on the other hand is homogeneous, consisting largely of altered andesite, suggesting that it was formed during a single epoch of volcanic activity.

About one-third of the sedimentary rocks are limestone and are composed almost entirely of calcite and dolomite. Normally such rocks are thought to have formed in quiet bodies of water at considerable distance from shore. If the greenstone represents flows and ash beds contemporaneous with the sedimentary layers, they should have been formed, in part at least, under water and would be expected to show some of the characteristics of submarine lava. No pillow structure has been noted in any of the greenstone; yet lenses of nearly pure calcite marble are included in it. That such features as pillow structure and vesicles were destroyed by metamorphism seems unlikely as the greenstone has been affected little by metamorphism except for the altered condition of many of the constituents. The outlines of the phenocrysts are clearly discernible and the pilotaxitic texture of the groundmass has been little disturbed.

Wright, (1915, p. 68–73) who described the greenstone sequence as "graywacke," regarded it as Devonian(?) on the basis of Lower Devonian fossils in limestone on Long Island in Kasaan Bay. He also states that

> graywackes and conglomerates which correspond somewhat more closely to those of metamorphosed sediments on Kasaan Peninsula are found on the northwest side of Prince of Wales Island and these lie between limestone beds carrying lower Devonian fossils.

Buddington and Chapin (1929, p. 96–97) point out that "the relation of these beds [sedimentary rocks of Kasaan Peninsula] to the fossiliferous limestone of Long Island is nowhere evident" but suggest that on the basis of structure "these interstratified limestone, conglomerate and tuffaceous beds [on Kasaan Peninsula] are believed to occupy a position just below the massive limestone of Long Island." They assign the massive limestone to the Middle Devonian.

It seems that the implied relationship of the white to gray marble of Kasaan Peninsula with the blue-gray limestone of Long Island is not well supported by evidence. The latter is not associated with any rock resembling the greenstone sequence and metasediments of Kasaan Peninsula and is separated from the peninsula by at least a mile of sea water. As far as the structural evidence goes, the limestone on Long Island could lie stratigraphically far above or far below the greenstone sequence or could be separated from it by a large unconformity or a well-defined fault extending up Kasaan Bay. As yet the only indication of the age of the greenstone is that afforded by the igneous rocks that invade it. These have been assigned by Buddington (1929, p. 252) to the Upper Jurassic or Lower Cretaceous. In the absence of more definite criteria the greenstone could be of any age earlier than Cretaceous.

The sedimentary rocks on Kasaan Peninsula may be related to rocks of Paleozoic age on the main part of Prince of Wales Island and the greenstone to volcanic rocks of Mesozoic age which are widespread in southeastern Alaska and western British Columbia. Eardley (1947) has suggested that the Coast Ranges geosyncline was bordered on the west by a volcanic archipelago during Paleozoic and early Mesozoic time, giving rise to intermingling of volcanic and sedimentary materials along the margin of the trough. In places the volcanic material may have been injected into older rock formations in the form of sills and dikes. This appears to correspond to the situation on Kasaan Peninsula.

IGNEOUS ROCKS

Igneous rocks in the form of dikes and stocks have intruded the greenstone and metamorphosed sedimentary rocks and constitute a considerable part of the regional bedrock of Kasaan Peninsula.

The dikes trend mainly north and northeast and are very abundant in most parts of the peninsula. They range in width from a few inches to a hundred feet or more and in places constitute swarms several hundred feet wide in which the amount of intrusive material is greater than that of the intruded rock. The stocks are for the most part elongate in a northwesterly direction parallel to the regional trend of the bedded rocks. (See pl. 1.)

In composition the igneous rocks range from pyroxenite to granite aplite. They are mainly varieties of gabbro, diorite, granodiorite, and monzonite. Some syenite and granite were reported by Wright (1915, p. 76) but with the exception of small aplitic dikes no true representatives of these types were found by the writers. Mineralogically the rocks are characterized by a lack of quartz and mica. Biotite is relatively abundant in certain early basic intrusive rocks, but augite and common hornblende are generally the dominant mafic minerals. The feldspars are chiefly plagioclase and include labradorite, andesine, and albite; oligoclase is virtually absent. Potassium feldspar mainly in the form of orthoclase, rarely constitutes more than 40 percent of the total feldspar.

On the basis of lithologic character and field relations, the igneous intrusive rocks may be divided into five groups, each of which can usually be differentiated from the others in the field: early diorite, gabbro and related rocks; porphyry dikes; late granodiorite and related rocks; aplite and pegmatite; diabase.

With the possible exception of the diabase dikes, all of the igneous rocks are thought to be related to a single intrusive sequence.

EARLY DIORITE, GABBRO, AND RELATED ROCKS

The oldest igneous rocks on Kasaan Peninsula are mainly diorite and gabbro but include types ranging from pyroxenite to quartz monzonite. In the vicinity of the Salt Chuck the rocks of this group are principally gabbro and pyroxenite. Southeastward toward Mount Andrew they are for the most part more silicic. Gabbro is rare in the Tolstoi Mountain area and silicic types, some of which contain appreciable amounts of quartz and orthoclase, predominate.

Certain textural and structural features are common to nearly all the rocks of this group and serve in part to differentiate them from later intrusive rocks. They are of medium-sized grain and of granitoid texture, being rarely porphyritic. The average diameter of the grains in most instances is between 1 and 2 millimeters. Locally, the larger masses show faint flow banding but for the most part the constituents are unoriented. The intrusions range in size from small dikes to large dikelike bodies several hundred feet wide and a few miles long. The contacts with the surrounding rocks in most instances are irregular and somewhat gradational. The intruded rock is commonly altered and feldspathized and chilled borders are rare. Numerous small apophyses and stringers are associated with the intrusive rocks, which themselves resemble apophyses of a stock or batholith.

The pyroxenite in the vicinity of the Salt Chuck is a dark-greenish-gray rock containing about 75 percent augite, partly altered to greenish-brown hornblende. The remaining minerals are chiefly brown biotite, sericitized plagioclase, and magnetite, the last in some specimens amounting to more than 10 percent of the rock. Dark-gray gabbro is more widespread in occurrence and commonly contains about 50 to 60 percent labradorite, 20 to 25 percent augite, and small amounts of biotite, olivine, and magnetite. Diorite is common in most parts of the peninsula and is characterized by a salt-and-pepper appearance in hand specimen. The samples examined contained from 60 to 75 percent andesine and 20 to 25 percent hornblende. Quartz is locally present in small amount and sphene is a common accessory constituent. More silicic varieties contain appreciable orthoclase and include syenodiorite, granodiorite, monzonite, and quartz monzonite.

PORPHYRY DIKES

The rocks of this group have great variety but appear to be related genetically. The earlier types include gabbro, basalt, andesite, and diorite porphyry. Later types are alkalic varieties of granodiorite, dacite, and andesite, containing an abundance of albite and orthoclase.

Some of the earlier members of this group resemble members of the early diorite group. With the possible exception of certain gabbros, however, they are thought to be entirely later than the rocks of the early diorite group.

The most characteristic feature of these rocks is their porphyritic texture, although some small fine-grained dikes and some very early members of the group are nonporphyritic. In many instances where porphyritic texture appeared to be lacking in the hand specimen, a thin section showed definite phenocrysts.

The rocks form well-defined dikes that are from a few inches to a hundred or more feet wide and from a few feet to a few thousand feet long. For the most part the width is from 5 to 50 feet and the length is several hundred feet. The borders are generally chilled and sharp except where two or more types of relatively the same age intruded the same fracture.

GABBRO, BASALT, AND ANDESITE

Small dikes of gabbro, basalt, and andesite are closely associated, particularly in the Mount Andrew-Mamie area. In texture and composition the gabbro closely resembles that of the early diorite group found at the Salt Chuck mine and is commonly nonporphyritic. Hence, there is some question as to whether these small gabbro dikes should be included with the porphyries or with the early diorite-gabbro group. However, a small gabbro dike cuts the relatively large body of early diorite south of the Mount Andrew ore body. This occurrence and the close relationship of the gabbro in this area to the basalt and andesite suggests that small dikes of gabbro may be early mafic representatives of the porphyry sequence. The basalt may be an aphanitic phase of the gabbro and the andesite a silicic phase of the basalt.

The gabbro dikes are dark-greenish-gray and consist mainly of grains 1 to 2 millimeters in diameter. The major constituents are about 60 percent labradorite and 30 percent subhedral augite, which is partly altered to pale-green hornblende. Magnetite and apatite are the chief accessories and epidote and altered olivine are commonly present. The basalt is a dark fine-grained rock that breaks with a conchoidal fracture. In thin section it shows an ophitic groundmass of labradorite laths with interstitial pyroxene in which the 2V is rather small, suggesting that the mineral may be pigeonite. Fine-grained magnetite is also present. Phenocrysts of olivine, pyroxene, and plagioclase constitute about 30 percent of the rock. The andesite is fine grained and dark gray in hand specimen. Thin sections reveal a felty groundmass of andesine laths and yellow-green hornblende with a few blocky phenocrysts of altered plagioclase.

DIORITE PORPHYRY

Diorite porphyry dikes are common in most parts of the peninsula. Their compositions place most of them well within the range of normal diorites but some approach gabbro and others are near to granodiorite. In places, these rocks resemble certain phases of the early diorite, but as the latter is generally nonporphyritic the two types are rarely confused. The porphyritic texture of the diorite porphyry is generally quite pronounced. The dikes are mainly small and discontinuous but in places are a few tens of feet wide and can be traced for several hundred feet.

The typical diorite porphyry is a medium-gray rock showing phenocrysts mainly of plagioclase but some of hornblende, in a groundmass of plagioclase, hornblende, and a small amount of partly uralitized augite. The groundmass is generally subgranitoid but some dikes show a pilotaxitic arrangement of plagioclase laths. The grain size of the groundmass is from 0.1 to 0.5 millimeters. The phenocrysts are lath shaped and commonly a centimeter or more long. The composition of the plagioclase ranges from about An_{32} to about

An_{50}. Most of the plagioclase is sericitized and the hornblende is partly altered to chlorite. The average specimen contains about 55 percent andesine, 25 percent hornblende, and 5 to 10 percent augite. As much as 5 percent quartz is common and a few dikes have small amounts of biotite; some contain a little orthoclase. The common accessory minerals are magnetite, apatite and sphene. Veinlets and aggregates of calcite and epidote are conspicuous.

Some dikes of this group are of lighter color and show a pinkish groundmass. They contain as much as 10 percent orthoclase. The plagioclase is andesine as in the darker diorite porphyry but there is commonly more quartz and less augite.

ALKALIC GRANODIORITE AND ALKALIC DACITE

The rocks of this group are characterized by a pink groundmass that serves to differentiate them from most other rocks in the region. Like the diorite porphyry these rocks form well-defined dikes with sharp contacts and chilled borders.

There are many dikes belonging to this group in the Mount Andrew-Mamie area and in the vicinity of the Poor Man iron deposit but they seem to die out northwestward toward the Salt Chuck mine, where they are exceedingly rare. They are sparsely represented in the Tolstoi Mountain area.

The composition of the rocks is mainly that of granodiorite, although some syenodiorite, monzonite and quartz monzonite are represented, depending upon the content of quartz and orthoclase. As the plagioclase in these rocks is albite, it is thought appropriate to prefix the normal rock names by the adjective "alkalic." The composition of the albite as determined in 20 specimens is rather uniform and is about An_5. Pyroxene and biotite are virtually lacking, chloritized hornblende being the chief mafic mineral. The average specimen contains about 60 percent albite, 15 percent orthoclase, 10 to 15 percent quartz and 5 to 10 percent chlorite. Magnetite, apatite, and sphene are accessory minerals.

Texturally the rocks are of two types; in one the groundmass is of medium-sized grain and in the other it is felsitic. The names alkalic granodiorite and alkalic dacite have been applied respectively to the two types, which are somewhat gradational. They are generally porphyritic and phenocrysts are dominantly albite and hornblende, rarely quartz. Orthoclase is anhedral and fills interstices between the other minerals.

In hand specimen the alkalic granodiorite is commonly gray pink, whereas the color of the alkalic dacite is brick red. The dacite is generally more silicic and is thought to have been intruded later. Some mafic varieties of the alkalic granodiorite resemble the more silicic phases of the diorite porphyry and the two are not readily distingiushable in hand specimen. In thin section the highly altered plagioclase phenocrysts of a few alkalic granodiorite specimens show remnants of andesine, whereas the plagioclase of the groundmass is albite. Fine-grained aggregates of a nearly isotropic mineral, thought to be clinozoisite, are associated with the altered plagioclase phenocrysts. These features were not found in the alkalic dacite nor in the more silicic varieties of the alkalic granodiorite.

Near Hadley and Karta Bay, Wright (1915, p. 76, 78–80) collected specimens of albite-bearing rocks which he described as syenite and granite. The mineralogic compositions which he gives correspond rather closely to that given previously. It seems probable that these rocks are related to the alkalic granodiorite group, although Wright indicates that certain of them form rather large masses, as compared with the dikes observed by the writers.

ALKALIC ANDESITE

Dikes of this rock type are rarely more than 5 feet wide and occur sparingly in most parts of the peninsula. In the field they closely resemble the basalt and andesite described above but are of somewhat lighter color. The contacts are sharp and the borders show the effect of chilling. Although commonly nonporphyritic the dikes are closely associated with the porphyries and are thought to be the latest rocks of the porphyry sequence.

The rocks of this group are mainly alkalic varieties of andesite, trachyandesite and latite, depending upon the orthoclase content which is rarely more than 10 percent. Quartz is generally absent but in some of the dikes amounts to as much as 10 percent of the rock. Albite is present in amounts ranging from 10 to 65 percent and is less sericitized than in the alkalic granodiorite. No calcic feldspar was found. Pyroxene and biotite are absent, the chief mafic mineral being a brownish hornblende that forms most of the phenocrysts where the rock is porphyritic. The content of hornblende ranges from 20 to 70 percent and is much less chloritized than in the rocks of the alkalic granodiorite group. Veinlets and irregular aggregates of epidote and calcite are common and amount to as much as 20 percent or more of the rock. The chief accessory minerals are ilmenite (largely altered to leucoxene), pyrite, apatite, and sphene.

These rocks are thought to correspond to those described by Wright (1915, p. 80) as syenite lamprophyre, which they closely resemble.

LATE GRANODIORITE AND RELATED ROCKS

The large intrusive bodies at Grindall Point, Lyman Anchorage, and Tolstoi Mountain (pl. 1) are thought to be parts of elongate stocklike masses. The Tolstoi Mountain intrusive was the only one studied during the recent work. Wright (1915, p. 74, 75) describes these rocks as diorite and states, "The main diorite mass on Tolstoi Mountain, at the north end of Kasaan Peninsula is almost identical with that at Grindall Point . . .". Although he does not specifically include the body at Lyman Anchorage in this group, it is inferred from his map to be of similar character.

Wright indicates that the rocks contain some quartz and potash feldspar and thin sections of specimens from the Tolstoi Mountain intrusion show these constituents to be considerably more abundant than in the rocks of the early diorite-gabbro group. Although the composition undoubtedly differs considerably from place to place, the name "granodiorite and related rocks" seems appropriate for the group.

Most of the porphyry dikes at Tolstoi Mountain terminate against the contact of the large intrusive body in that area. (See pl. 16.) Near Tolstoi Point a few mafic dikes, determined as alkalic andesite, were found in the intrusive. It is inferred that this intrusive and the similar bodies at Grindall Point and Lyman Anchorage are mostly later than the porphyry dikes.

The Tolstoi Mountain intrusive is composed mainly of a light-gray rock showing medium-grained to coarse-grained granitoid texture. The ratio of light to dark minerals in a hand specimen is generally about 2 to 1. At the contact, rocks resembling the early diorite commonly appear to have been fractured and brecciated, the openings being filled with late granodiorite. Large inclusions of material resembling early diorite or gabbro were also noted in these places. It may be that rocks of the early diorite-gabbro group were emplaced along the zone later occupied by the Tolstoi intrusive. The early diorite in the Mount Andrew–Mamie area may bear a similar relationship to the large intrusive at Grindall Point.

A typical specimen of the Tolstoi Mountain intrusion is medium grained and of granitoid texture. Plagioclase, orthoclase, and quartz constitute about two-thirds of the rock. The plagioclase is calcic andesine (An_{46}) and forms lath-shaped grains that are somewhat zoned and only mildly sericitized. Quartz and orthoclase are largely anhedral and fill interstices. The orthoclase is in part perthitic and quartz forms myrmekitic intergrowths along boundaries between orthoclase and plagioclase. The dark constituents are mainly yellow-green hornblende and brown biotite, the latter somewhat chloritized

Augite occurs sparingly in grains that are largely altered to hornblende. Apatite, sphene and magnetite are accessory minerals. The modal composition of the rock is about as follows: 45 percent plagioclase, 20 percent orthoclase, 10 percent quartz, 15 percent hornblende with some augite, 5 percent biotite, and 5 percent accessories.

APLITE AND PEGMATITE

Aplite and pegmatite are rare on Kasaan Peninsula and generally occur as small pods and stringers rather than as well-defined dikes. Aplite is the more common. Wright (1915, p. 77) describes "veins and dikes, the largest 100 feet wide, of orthoclase-quartz pegmatites or alaskites," but such occurrences are thought to be uncommon.

Petrographically the aplite is of two types. One shows abundant dark constituents and the composition is that of granodiorite. The other shows virtually no dark constituents and the composition is that of granite or syenite, depending on the quartz content. The granodiorite aplite forms small dikes and stringers in the large intrusive at Tolstoi Mountain and in rocks adjacent to the contact. Presumably aplite of this type is related to the late granodiorite. The syenite and granite aplite seems to be of wider occurrence and was noted particularly in the areas where dikes of alkalic dacite are common. In a hand specimen this aplite closely resembles the alkalic dacite and may be a late phase of the deposition of the alkalic granodiorite group. If this is true, the two types of aplite are doubtless of different ages, as the intrusive rocks of the late granodiorite group mainly postdated those of the alkalic granodiorite group.

The syenite aplite is bright pink and appears aphanitic in hand specimen. In thin section the grains are anhedral and show mutual boundaries. The rock consists of about 80 percent orthoclase, in part perthitic, and 20 percent albite. Quartz and mafic minerals are lacking. In contrast, the granodiorite aplite shows many dark grains in a gray-buff sugary matrix. The average specimen consists of about 60 percent andesine (An_{46}) which is virtually unaltered, 10 percent orthoclase, 15 percent quartz, 5 percent green hornblende, and 5 percent yellow-brown biotite which is slightly chloritized. Magnetite is the chief accessory, with some apatite and sphene.

DIABASE

Diabase dikes occur sparingly in most parts of the peninsula and may be the latest of the intrusive rocks. At Mount Andrew they are mainly in fractures which cut the porphyry dikes (see pl. 2), and whereas the porphyry dikes are for the most part highly altered, the diabase dikes are generally fresh. The relationship of the diabase dikes to the rocks of the late granodiorite group was not observed, as diabase was not found in the large intrusive at Tolstoi Mountain. Wright (1915, p. 83, 84) describes diabase and basalt as the latest intrusive rocks at Kasaan Peninsula. The only basalt dikes found during the recent investigation are highly altered and are thought to be early members of the porphyry dike sequence.

The diabase is a dark fine-grained rock and forms dikes that are mostly 10 feet to 25 feet wide and can be traced for several hundred feet with little change in strike. The grains are commonly about 0.5 mm in diameter and the texture is ophitic, the pyroxene being interstitial to the plagioclase. The optic angle of the pyroxene is about 35° and suggests pigeonite rather than augite. The plagioclase is sodic labradorite, the average composition being about An_{55}. Magnetite is a common constituent. The modal composition is rather uniform being about 45 to 50 percent labradorite, 40 to 50 percent pyroxene, and 5 to 10 percent magnetite.

INTRUSIVE SEQUENCE AND DIFFERENTIATION

The igneous rocks of Kasaan Peninsula present many interesting problems, a complete understanding of which would doubtless require detailed geologic mapping and study of the entire peninsula. So far, geologic work on Kasaan Peninsula has centered around the ore deposits and only those areas reported to contain deposits of possible economic importance have been mapped in detail. It can only be surmised that these areas give a fairly adequate picture of the igneous history and its relationship to the ore deposits.

The intrusive sequence, based on field observations, is represented diagrammatically in figure 5. Assuming that the aplite dikes are in part related to the alkalic granodiorite and in part to the late granodiorite, four intrusive series are recognized. Members of the diorite-gabbro group constitute the earliest phase series. These were followed by the porphyry dikes, which in turn were followed by stocks of late-phase granodiorite and related rocks. Diabase dikes constitute the intrusive rocks of latest phase, although their relationship to the late granodiorite is not definitely established.

The periods of intrusion of various rock types are thought to have overlapped somewhat, as indicated in the diagram. Dikes of basalt and andesite in places cut diorite porphyry and both cut members of the alkalic granodiorite group. A few dikes of alkalic andesite cut late granodiorite.

The abundance of igneous intrusions at Kasaan Peninsula suggests that during the intrusive sequence a large mass of molten rock

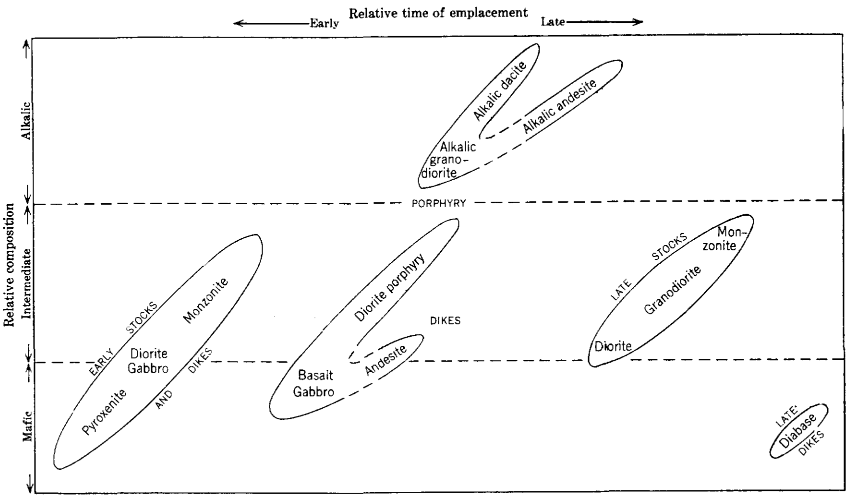

FIGURE 5.—Diagram showing sequence of igneous intrusions.

lay at no great distance beneath the present surface. This magma is believed to have been of gabbroic composition and to have given rise to the many intrusive rock types through differentiation and reaction with the wall rocks. The upper part of the magma chamber probably was irregular, and separate or semidetached intratelluric chambers may have existed in which differentiation progressed more or less independently of the parent magma.

The early gabbro, diorite and related rocks are thought to have been derived from a melt closely related to the original magma. The fact that the largest intrusions of the group are in the vicinity of the Salt Chuck mine (pl. 1) and that these intrusive rocks include the more mafic members of the group may indicate that the rocks of this group came mainly from a source beneath the Salt Chuck area.

The porphyry dikes are thought to have been derived from a melt which differentiated in a chamber separate from that of the parent magma. The earlier porphyry dikes crystallized in part as gabbro and diorite and in part as basalt and andesite. As differentiation progressed, the melt became more silicic and alkalic, as indicated by the occurrence of quartz and orthoclase in some of the diorite porphyries. At about the time these minerals were forming from the porphyry dike melt, it is thought that a part of the liquid rich in silica, potash, and particularly soda, separated from the melt and gave rise to the alkalic porphyry dikes. Some diorite porphyry, basalt, and andesite continued to form, probably owing to incomplete separation of the melt, but mainly the later porphyry dikes are alkalic varieties of granodiorite, dacite, and andesite in which albite is a major constituent.

Stocks of late granodiorite and related rocks, which were intruded after emplacement of the porphyry dikes, are thought to have come from greater depth and may indicate the extent to which the parent magma differentiated during that emplacement. At present the field relations and petrography of these intrusive rocks are not known in detail.

The diabase dikes, thought to be the latest igneous rocks in the area, appear to be unrelated to the other intrusive rocks. Wright (1915, p. 84) regarded them as belonging to a later intrusive epoch. However, they may have been differentiated at depth from the same magma which produced the other igneous rocks and emplaced at or near the close of the intrusive sequence.

ORIGIN OF THE ALKALIC ROCKS

The mode of origin of albitic rocks has been a subject of much discussion among petrologists. Gilluly's excellent studies of this problem (Gilluly, 1923; 1935) leave little doubt that commonly such rocks are of metasomatic origin, resulting from the action of late magmatic or hydrothermal albitic solutions. Parts of some of the early intrusive rocks at Kasaan Peninsula are thought to have been affected by solutions of this type. A notable example occurs in the Mamie mine where a stock of diorite is exposed in workings extending southward and westward from the main shaft. (See pl. 6.) The eastern margin of the intrusive contains large amounts of albite and orthoclase with minor amounts of altered mafic minerals. Similar albitized material was found in association with dioritic intrusions at the east portal of the Stevenstown tunnel and in the vicinities of the It mine and the Rush and Brown mine. In a few instances the thin sections of albitized rock show altered remnants of dioritic material surrounded by unaltered albite. In many thin sections of the greenstone and early intrusive rocks, veinlets were seen of albite and orthoclase with some quartz. (See fig. 6.) In some instances epidote is associated with these veinlets. Pink and green veinlets an inch or more wide, consisting of albite, orthoclase and epidote are exposed in the Stevenstown tunnel. Such features seem to be confined largely to the border facies of the early intrusive rocks and the adjacent country rock.

The majority of the albitic rocks of Kasaan Peninsula, however, are in the form of dikes and are alkalic varieties of granodiorite, dacite, and andesite. Present knowledge seems to favor a primary rather than a secondary origin for the albite in the dikes. Evidence for this point of view is found in the field relations of the dikes to the other intrusive rocks. Granting that albitic solutions of late magmatic or hydrothermal derivation might selectively replace certain dike rocks, it seems doubtful that replacement could

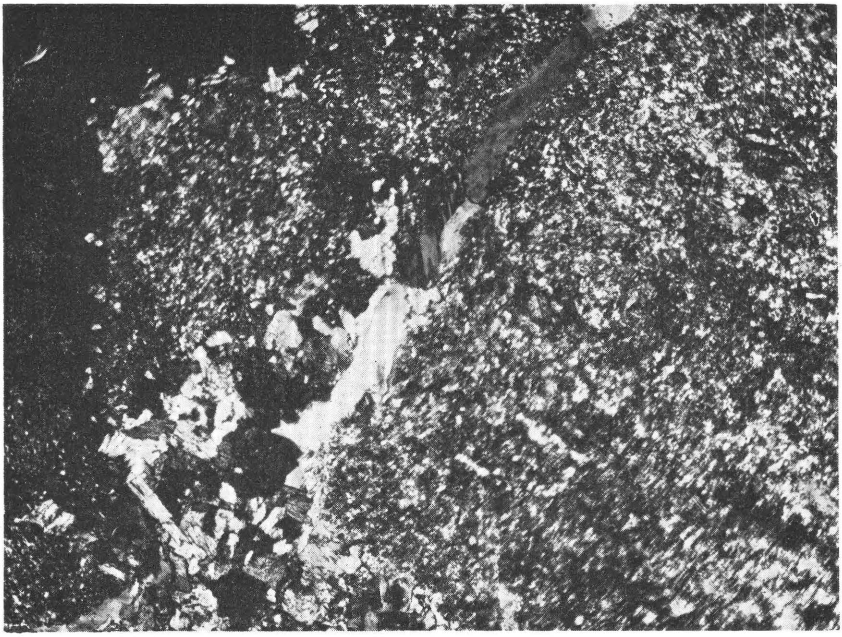

FIGURE 6.—Veinlet of albite in andesite dike, Poor Man iron deposit. Crossed nicols, × 75.

be accomplished without noticeable consequences to the adjacent rocks. Boundaries of replacement bodies are generally gradational and irregular. The boundaries of the dikes in question, however, are sharp and show the effect of chilling. Furthermore, dikes of this group are cut by other intrusive rocks that show no evidence of having been altered by albitic solutions. In the Mount Andrew-Mamie area diabase dikes cut diagonally across numerous dikes of alkalic granodiorite. On the beach 1,500 feet southwest of the Iron King 1 copper prospect, a dike of diorite porphyry cuts alkalic dacite. The many porphyry dikes in the Tolstoi Mountain area terminate at the contact of the large intrusive of late granodiorite. A few dikes of alkalic andesite fill fractures in the granodiorite intrusive but dikes of alkalic granodiorite and alkalic dacite, though present in the area, do not penetrate the mass.

Microscopic data serve to strengthen the field evidence for primary origin of the alkalic rocks. Myrmekitic intergrowths, cataclastic textures, and remnants of unreplaced material, commonly found in albitic rocks of secondary origin, are lacking. Texturally the alkalic granodiorite dikes do not differ markedly from those of diorite porphyry which is thought to have preceded them immediately in the intrusive sequence.

The manner in which the primary albite may have been formed, is not understood, but certain conclusions may be inferred. The composition of the most sodic plagioclase in the diorite porphyry dikes is about An_{30}, that of the most calcic plagioclase in the alkalic granodiorite is about An_{10}. No oligoclase has been found in the porphyry dike sequence. If the albite is admitted to be of primary origin, it follows that normal fractional crystallization of the porphyry dike magma was disturbed during diorite porphyry emplacement. When differentiation had progressed to the state at which An_{30} was crystallizing, the remaining liquid would be relatively rich in soda, as indicated by Bowen's equilibrium diagram for the plagioclase feldspars (Bowen, 1928, p. 34). If at this time a part of the liquid were isolated, it might be regarded as a potential source of albite-rich intrusive rocks. Without such a separation of the liquid and solid phases of the magma, oligoclase-bearing rocks might be expected to result from reaction.

The first plagioclase to form from the albite-rich liquid would be of composition about An_{30}, which, with lowering temperature, would react with the melt to form more sodic plagioclases. If the melt were rich in sodium and poor in calcium, the resulting rocks might be expected to contain albite. Occasional altered remnants of oligoclase or andesine which were not completely destroyed in the reaction process might be anticipated. As mentioned in connection with a description of the alkalic granodiorite dikes, a few such remnants were found.

Events leading to the separation of the soda-rich liquid from the magma can be only surmised. Many writers have postulated that earth movements might squeeze such a liquid from partly crystallized magma through "filter pressing." The fact that the larger intrusions at Kasaan Peninsula conform in a general way to the regional structural pattern of the intruded rocks suggests that intrusion was in part syntectonic. It seems plausible that differentiation of the intrusive rocks may have been affected by crustal movements.

AGE RELATIONS

Buddington is of the opinion that the igneous rocks of Prince of Wales Island are satellitic intrusions of the Coast Ranges batholith which forms much of the mainland of southeastern Alaska and extends into British Columbia and Yukon Territory in Canada (Buddington and Chapin, 1929, p. 173, 183–186). The age of the batholith is reported to be Late Jurassic or Early Cretaceous.

It has been pointed out that the diabase dikes at Kasaan Peninsula may be considerably later than the other igneous rocks. Wright (1915, p. 84) believed these dikes to be of Tertiary age. Diabase and basalt of Tertiary age have been reported from Kuiu,

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Kupreanof, and Zarembo Islands (Buddington and Chapin, 1929, p. 271) but the nearest locality is 50 miles or more northwest of Kasaan Peninsula.

The relation of the ore deposits to the intrusive sequence is not entirely clear. The effect of the ore-bearing solutions upon the igneous rocks affords a possible clue. Although many of the porphyry dikes appear to cut the ore bodies (pl. 8) they were altered by the ore-bearing solutions and clearly antedate mineralization. Veinlets and aggregates of epidote, quartz, and calcite, with some garnet, diopside, and amphibole are common in the porphyry dikes and older rocks. Near the ore deposits these rocks show veinlets and stringers of magnetite and sulfide minerals and in places the dikes were partly replaced by ore (fig. 7).

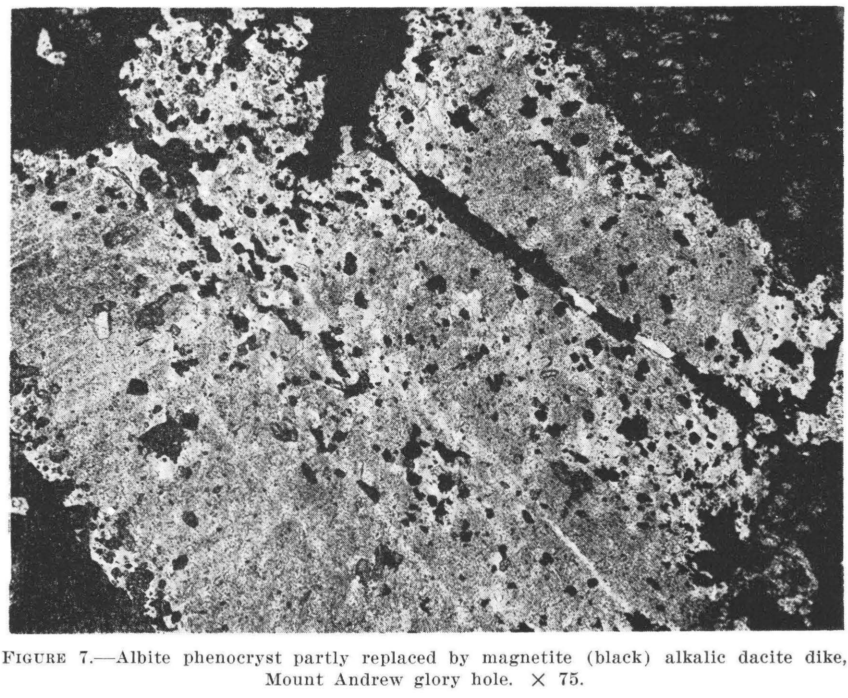

FIGURE 7.—Albite phenocryst partly replaced by magnetite (black) alkalic dacite dike, Mount Andrew glory hole. × 75.

In the Mount Andrew-Mamie area diabase dikes which crosscut the altered porphyry dikes are virtually unaltered and are believed to be younger than the ore. Likewise the large intrusive at Tolstoi Mountain seems to have escaped alteration by the ore-bearing solutions, suggesting that some rocks of the granodiorite group may be postmineralization. The ore-bearing solutions presumably rose from a deep-seated source and are not necessarily related to any particular rock type exposed at the present surface.

METAMORPHISM

In a broad sense, three types of metamorphism are recognized on Kasaan Peninsula. The first is expressed in the folding and recrystallization of the sedimentary rocks, the second in alteration of the greenstone and dike rocks, and the third in replacement of the various rocks by tactite minerals.

Metamorphism of the sedimentary rocks is thought to have resulted in part from dynamic processes, as these rocks are in nearly all instances rather closely folded. The limestone layers are highly contorted and have undergone plastic flow and recrystallization. Certain of the conglomerate deposits contain elongated quartz pebbles that probably originated through the stretching of originally rounded or angular fragments. A few of the metamorphosed sedimentary rocks show a fairly well developed foliation but axial plane cleavage is mostly lacking. The mineralogy of the rocks indicates that the dynamic metamorphism was of a relatively low order. Stress minerals, such as kyanite, sillimanite, almandite, zoi site, and the spinels, are absent. Biotite is rare, the common mica ceous minerals being chlorite and sericite. The lack of high-grade metamorphic effects suggests that deformation of the rocks may have taken place at relatively shallow depth.

The greenstone and dike rocks show virtually no recrystallization or reorientation of their constituents. However, thermal and hydrothermal effects are rather uniform and widespread. Pyroxene phenocrysts have been largely altered to amphibole and amphibole to chlorite. Most of the plagioclase has been sericitized. Secondary epidote, calcite and fine-grained magnetite have developed at the expense of primary minerals. These effects may have been accomplished largely by deuteric action during the emplacement and consolidation of the igneous intrusive rocks.

The pyrometasomatic effects, which are related to the ore deposits, are of rather limited extent. No well-developed aureoles of contact metamorphism surround the major intrusive rocks. The chief minerals formed were andradite, diopside, hornblende, and epidote. The tactite minerals have replaced the rocks, principally those of sedimentary origin, adjacent to the ore deposits and in some instances at considerable distances from the ore. Much of the metamorphosed sedimentary rock shows partial replacement by these minerals. The greenstone and dike rocks, on the other hand, have been less affected by them, except near ore bodies.

STRUCTURAL GEOLOGY

The structure of Kasaan Peninsula conforms in general with the major structural pattern of southeastern Alaska (Buddington and Chapin, 1929, p. 289–292). The regional strike of the metamorphosed sedimentary rocks is northwestward, although locally, because of folding, the strike diverges widely from the regional trend. The attitude of the greenstone is obscure in most places but in general it is thought to conform to that of the sedimentary rocks.

The structures of the larger igneous intrusive rocks are roughly conformable to those of the intruded rocks. The longer axes of the intrusive rocks are parallel to the regional trend of the bedded rocks, and the igneous flow structures, in so far as they have been studied, are concordant with the contacts. These features suggest close coordination between deformation of the intruded rocks and emplacement of the intrusive rocks and the two processes may have been in part contemporaneous.

The bedded rocks on the southwest side of the peninsula for the most part dip northeastward whereas those at Tolstoi Mountain, on the northeast side of the peninsula, dip generally southwestward, suggesting a synclinal relationship. (See pl. 1.) Wright (1915, p. 72) expressed this opinion in his analysis of the structure of the area.

Folds, with radii of curvature of a few feet to more than a hundred feet, have been noted at many places on the peninsula. The strike and plunge of the fold axes is northward or northwestward in some folds, eastward or northeastward in others. The angle of plunge is moderate in all instances, rarely exceeding 30°. Few of the folds have been mapped in detail and the relationship of the two sets of folds is not entirely clear. Buddington and Chapin (1929, p. 306) report two sets of folds in other parts of Prince of Wales Island, one set trending northwestward and the other northeastward. (See also Kennedy, 1953, p. 13.) Folds of both types were observed at Mount Andrew and are described in detail in the section of this report dealing with the Mount Andrew-Mamie area.

The rocks of Kasaan Peninsula have many joints and no doubt fracturing took place through a relatively long period of time during which many forces were operative. For the most part the joints are steep, dips of less than 50° being uncommon. No statistical analysis of the joints has been made but they seem to fall into four major groups trending northward, northeastward, eastward and northwestward. Strike readings obtained on these joint sets vary somewhat from place to place but the four sets are present in most localities. The northward and northeastward trending joints were the first to form and are best developed. Most of the dikes trend in these directions.

Several large faults have been mapped, notably those at Mount Andrew (pl. 2), Tolstoi Mountain (pl. 16) and the Poor Man iron deposit (pl. 12). Apparently displacements on these faults are in most instances more than 500 feet. The fault at Mount Andrew strikes about N. 80° E., that at Tolstoi Mountain about N. 50° W., and the one at the Poor Man iron deposit about N. 10° E. The last may be part of a northward-trending en enchelon group of fault thought to extend across the peninsula to the head of Tolstoi Bay, where a large fault is exposed. (See pl. 1.) Minor faults, with displacements of a few inches to 20 feet or more, are many, particularly in areas of ore deposition. In general the faults are steep and at most places the strike-slip component is larger than the dip slip. The faulting appears to have begun after emplacement of the porphyry dikes and to have persisted until after the period of ore formation.

The fossiliferous limestone of Devonian age on Long Island in Kasaan Bay may be of considerable structural significance, as the limestone is not thought to be related directly to any of the rocks on Kasaan Peninsula or its environs. Buddington and Chapin (1929, p. 97) report rhyolite resting on the limestone. No rhyolite or fossiliferous limestone has been found elsewhere in the Kasaan Peninsula area. The position of the limestone on Long Island seems all the more anomalous in view of the igneous history of Kasaan Peninsula. The area of igneous rock constituting Grindall Point and Grindall Island is thought to be part of a large stocklike intrusion of Mesozoic age, the greater part of which probably lies beneath Kasaan Bay. It seems unlikely that the Long Island rocks were in their present position at the time the stock was emplaced, as they show no evidence of thermal metamorphism.

The fossiliferous rocks of Devonian age forming Long Island may have been thrust eastward from the main part of Prince of Wales Island. Rocks at Coronados Islands, Fish Egg Island, and Port Bagial, 30 miles west of Kasaan Bay, have been correlated with those on Long Island. (Buddington and Chapin, 1929, p. 101). The thrusting need not have been of the magnitude implied by this relationship as similar rocks nearer to Kasaan Bay may have been removed by erosion.

Down faulting may have played a part in fixing the position of the Long Island rocks. The uniformity of the southwestern coast of Kasaan Peninsula and the alinement of this coast with the Thorne River valley, extending for many miles northwest of the Salt Chuck mine, strongly suggest a fault zone. (See fig. 2.) The fact that most of the ore deposits are along the southwestern margin of the peninsula might be explained by such a fault zone, which may have acted as a conduit for the ore forming fluids. A fault of large magnitude may separate the Long Island rocks from those of the peninsula.

No direct field evidence for either thrusting or down-faulting of the Long Island strata has been found thus far. However, the fossiliferous limestone of Devonian age of Long Island seems quite out of harmony with its environment and suggests that the structural history of the region may be more complex than heretofore recognized.

ORE DEPOSITS

CLASSIFICATION

Most of the ore deposits on Kasaan Peninsula are referred to the type known as pyrometasomatic (Lindgren, 1933, p. 696) or contact metasomatic (Bateman, 1950, p. 82–84) although they differ somewhat in detail from the usual deposits of this type. A few of the deposits are hypothermal veins. Similar deposits at Jumbo Basin on the west side of Prince of Wales Island have been described by Kennedy (1953).

The deposits might be classified according to their content as either iron deposits or copper deposits. Each of them might be subdivided according to mode of origin into fissure deposits in which the ore was formed in open fractures and is not confined to any particular rock type or replacement deposits in which the ore minerals replaced certain rock types whose structure and composition favored reaction with the ore-bearing solutions. The various types overlap considerably and the distinctions mentioned here cannot be applied strictly at most places. The iron deposits all contain some chalcopyrite and most of the copper deposits contain some magnetite. Ore deposition was accomplished in nearly all instances by a combination of fissure filling and replacement. However, iron is a major constituent in those deposits that more closely approximate the pyrometasomatic type, and, in these deposits, replacement has predominated over fracture filling. Copper is a major constituent in the deposits that more closely approximate hypothermal veins, and fracture filling has predominated over replacement. Deposits of an intermediate character are common. Certain exceptions to these generalities will be evident from descriptions of the ore bodies.

DISTRIBUTION OF DEPOSITS

The locations of the ore deposits on Kasaan Peninsula are shown on plate 1. Most of the deposits are on the southwest side of the peninsula within short distances of tidewater. They constitute a discontinuous zone of metallization extending northwestward from Mount Andrew to the Salt Chuck mine. The possibility that the zone may continue into the interior of Prince of Wales Island has not been investigated thoroughly. The only significant deposits that have been located so far on the northeast side of the peninsula are at Tolstoi Mountain. Little detailed work has been done in the central part of the peninsula but small deposits, mostly veinlike in character, have been prospected.

A rough zonal arrangement of the ores with respect to the late granodiorite intrusive rocks is suggested. In general, the border zones of the intrusive rocks seem to have been most favorable for the deposition of magnetite whereas the deposition of sulfide minerals extended to greater distances from the contacts. Except for the Poor Man iron deposit, the principal magnetite bodies occur at Mount Andrew and Tolstoi Mountain adjacent to stocklike bodies of late granodiorite and related rocks. These deposits are of replacement origin and closely resemble those of the contact metasomatic type. Northwestward from the Rich Hill mine to the Salt Chuck mine the deposits are principally of sulfide minerals, although small bodies of magnetite are present. Fracture filling is common in these deposits and some are veinlike in character. No rocks of the late granodiorite type were found between the Rich Hill and Salt Chuck mines although they may occur at depth. The Poor Man iron deposit is anomalous in that, although of replacement origin, it occurs in a fault zone and structurally resembles a fissure deposit.

MINERALOGY

ORE MINERALS

Magnetite is the principal ore mineral in the iron deposits and is associated with various amounts of pyrite and chalcopyrite. The sulfide minerals occur as blebs in the magnetite or as thin veinlets and stringers that fill fractures in the magnetite (fig. 8). Pyrite seems to favor the former occurrence, chalcopyrite the latter. Magnetite ore containing laths and needles of pyrite was found at the Poor Man iron deposit. Microscopic examination revealed that the pyrite had partly replaced lath-shaped inclusions of gangue mate-

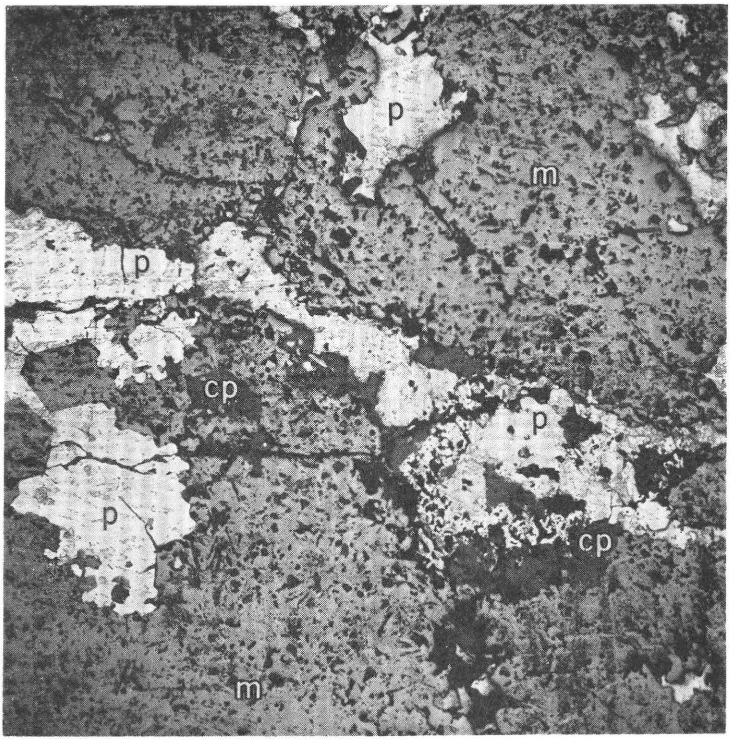

FIGURE 8.—Ore from Haida mine, showing pyrite (*p.*) and chalcopyrite (*cp*) in magnetite (*m*) × 40.

rial in the magnetite (fig. 9). The unreplaced remnants consist of fine-grained aggregates of quartz, calcite, and a little chlorite. The shape of the inclusions suggests that originally they may have been hornblende laths. In some places, principally in the Mount Andrew-Mamie area, chalcopyrite occurs in sufficient quantities in the magnetite to form a fairly high grade copper ore (fig. 10).

Most of the magnetite ore is massive and crystal forms are rare. Magnetite showing a bladed or tabular structure occurs at the Poor Man, Iron Cap and Rush and Brown deposits (figs. 11, 12). This ore simulates the structure of specular hematite, which is sparsely distributed in the region, suggesting that the blades of magnetite may be pseudomorphs.

Replacement bodies of copper ore, such as those at the Rich Hill and It mines ordinarily contain only accessory amounts of magnetite. Pyrite and chalcopyrite are the principal ore minerals, the former being more commonly a replacement mineral than the latter. Minor amounts of molybdenite and specular hematite are associated with these deposits.

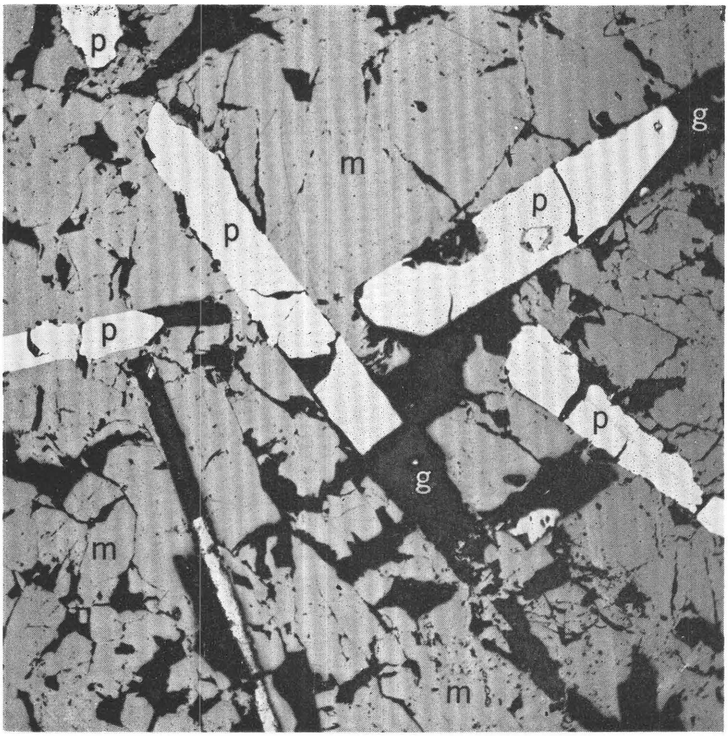

FIGURE 9.—Ore from Poor Man iron deposit, showing laths of pyrite (*p*) which have replaced gangue material (*g*) in magnetite (*m*). × 80.

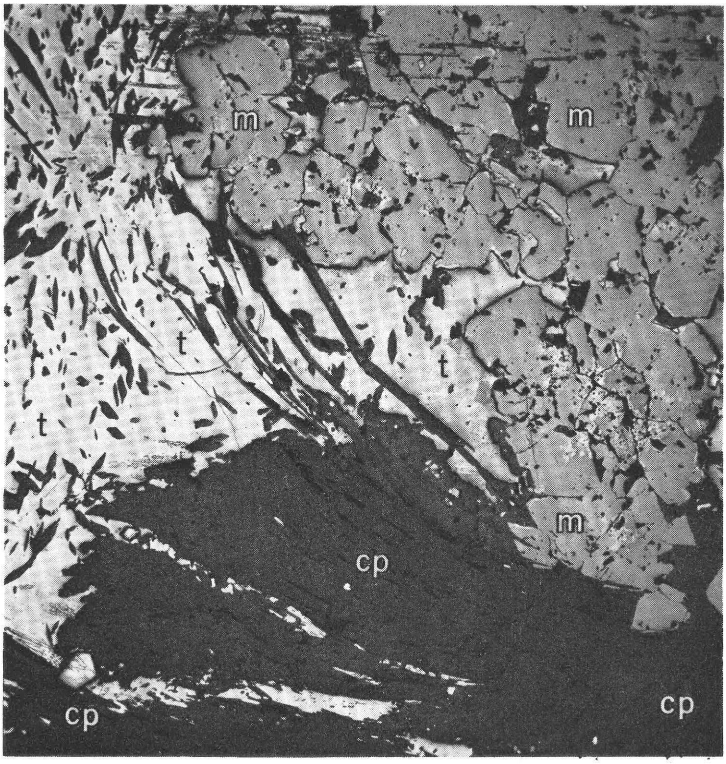

FIGURE 10.—Copper ore from Rich Hill mine, showing chalcopyrite (*cp*), magnetite (*m*), and tactite (*t*). × 40.

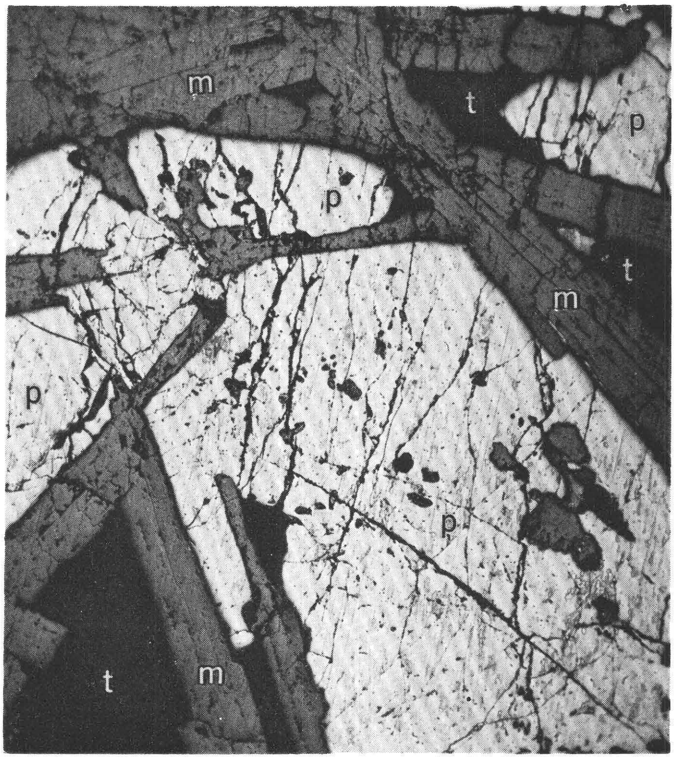

FIGURE 11.—Ore from Poor Man iron deposit, showing tabular magnetite (*m*) with interstitial pyrite (*p*) and tactite (*t*). × 40.

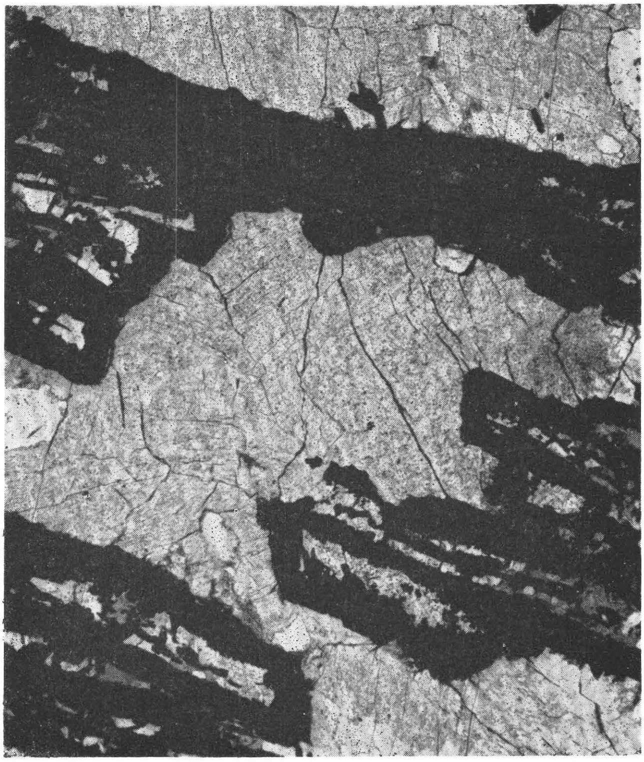

FIGURE 12.—Ore from Rush and Brown glory hole showing tabular magnetite (black) in calcite. × 40.

A few veinlike deposits, in which the ore minerals are mainly sulfides, were prospected, but only one, at the Rush and Brown mine, has been a producer. Pyrrhotite is a common mineral in the deposits of this type, in addition to pyrite and chalcopyrite. Sphalerite was found only at the Venus prospect. A small vein on the east side of Tolstoi Mountain is composed essentially of pyrite and arsenopyrite in broken quartz.

Bornite is the principal ore mineral at the Salt Chuck mine at the head of Kasaan Bay. It occurs as fracture coatings and disseminated grains in gabbro and pyroxenite. Mineralized fault zones containing chalcopyrite are also present.

GANGUE MINERALS

The chief gangue minerals associated with the ore deposits at Kasaan Peninsula are diopside, garnet, calcite, epidote, hornblende, and chlorite. Minor amounts of antigorite, actinolite, idocrase, apatite, orthoclase, and sphene were identified. Late veinlets of quartz and calcite, ranging in width from less than a millimeter to a few inches, are associated with nearly all of the ore bodies. With the exception of quartz and calcite the gangue minerals are for the most part complex silicates of calcium, magnesium, iron, and aluminum and are the characteristic minerals found in deposits of pyrometasomatic origin. The mineral assemblage is herein referred to as tactite, a term proposed by Hess (1919).

The more important optical properties of the tactite minerals are given in table 1. Inference as to the probable compositions of the minerals is based on graphs and tables by Winchell (1951) and Larsen and Berman (1934) which show the relationship of optical properties to chemical composition.

The areas of tactite coincide roughly with the areas of ore deposition. Tactite minerals are, with few exceptions, associated with the ores and, in most places, are found for some distance beyond the boundaries of the ore bodies. Small pods of ore may be virtually without tactite. Of more common occurrence are small bodies of tactite that contain little or no ore.

In general, the ore bodies are enveloped roughly in an aureole of tactite. Whereas diopside, garnet, and epidote are associated with both sulfide and magnetite deposits, hornblende is not abundant except near magnetite bodies. A coarse, bladed variety of hornblende forms large masses in and around the ore bodies at the Mount Andrew, Mamie and Stevenstown mines.

TABLE 1.—*Optical properties of tactite minerals from Kasaan Peninsula*

Mineral	Color or pleochroism	Refractive indices			Birefringence	Orientation		Remarks
		α	β	γ		2V	Z∧c	
Hornblende	X=yellow to yellowish green Y=olive green Z=blue green	1.623–1.655	1.635–1.668	1.645–1.678	0.020–0.023	(−) >60°	17°–26°	Chiefly pargasite and hastingsite.
Diopside	Colorless		1.680–1.690		Moderate	(+)±60°	40°–43°	Diopside 75–85 percent. Hedenbergite 15–25 percent.
Epidote	Pale yellow to greenish yellow	1.735–1.738	1.763–1.765	1.772–1.777	0.037–0.039	Large		$HCa_2Al_3Si_3O_{13}$±65 percent. $HCa_2Fe_3Si_3O_{13}$±35 percent.
Garnet [1]	Colorless, pale yellow, reddish, greenish gray.	n=1.815–1.887			0.0–very low			Largely andradite; probably some grossularite in low index varieties.
Chlorite	Dark green		1.585–1.597		Very low	Near 0		Chiefly penninite and delessite.

[1] Data on garnets furnished by J. J. Glass.

PARAGENESIS AND ASSOCIATIONS

The paragenetic relations of the ore and gangue minerals in the deposits on Kasaan Peninsula are represented diagrammatically in figure 13. Many of the relationships are as yet in doubt. Absolute values for time, temperature, and pressure are, of course, lacking. The scale of the ordinate and the abscissa are, therefore, relative and the pitchs and lengths of the curves representing the periods of deposition of the various minerals are entirely arbitrary.

Among the tactite minerals, diopside and garnet were the earliest to form. At many places diopside appears to be the earlier of the

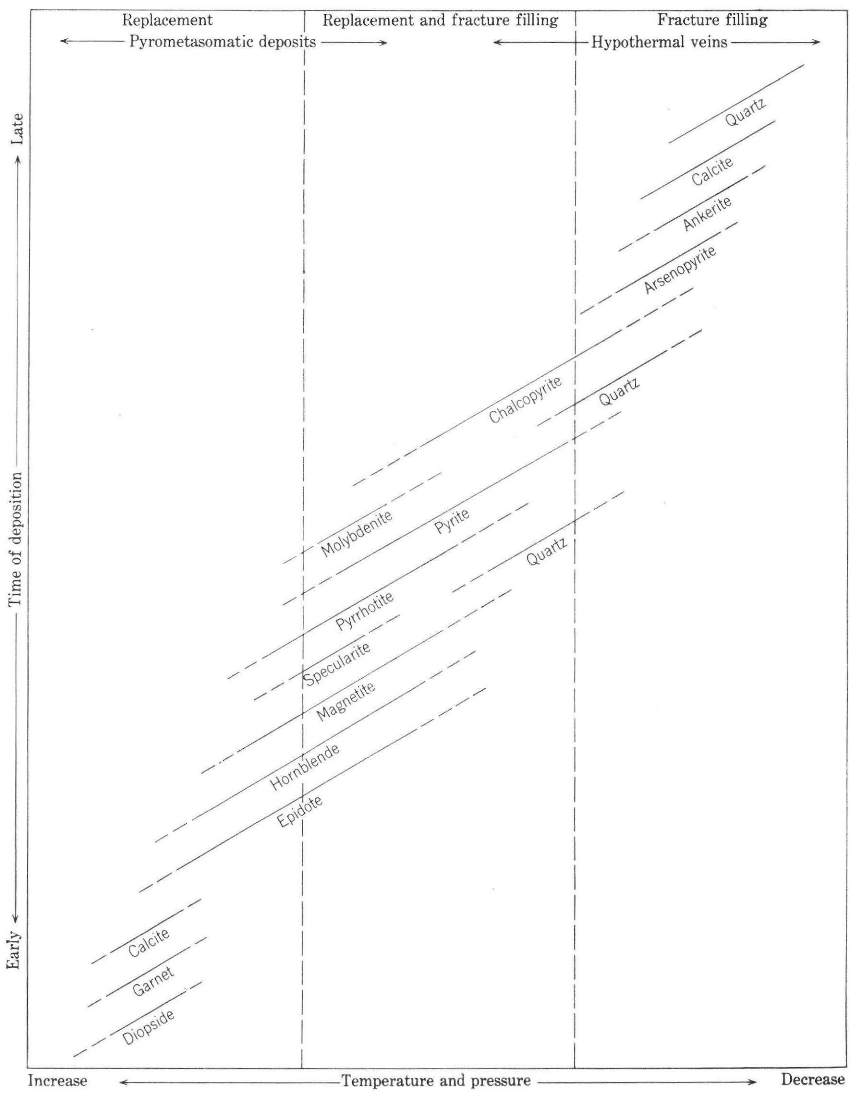

FIGURE 13.—Diagram showing age relationships of ore and gangue minerals.

two minerals, though they commonly show mutual boundaries. Generally the garnet is zoned and weakly birefringent in thin section. Irregular veinlets of pale-red garnet cutting dark massive garnetized country rock were noted at the It mine. Whereas the earliest garnet is chiefly andradite, the later garnet shows properties corresponding more closely to grossularite. The garnets (data furnished by J. J. Glass, U.S. Geological Survey) may have become progressively richer in aluminum at the expense of ferric iron as deposition proceeded. The relationships of garnet, diopside, and other minerals are shown in figure 14.

Epidote formed predominantly later than garnet and diopside and seems to have formed largely earlier than, or contemporaneous with, the magnetite (fig. 15), but veinlets of epidote commonly cut the magnetite (fig. 16). That deposition of epidote continued over a relatively long period is indicated by late veinlets of epidote that cut epidotized country rock (fig. 17). The later epidote shows higher refractive indices and birefringence than that formed earlier, suggesting progressive enrichment in iron.

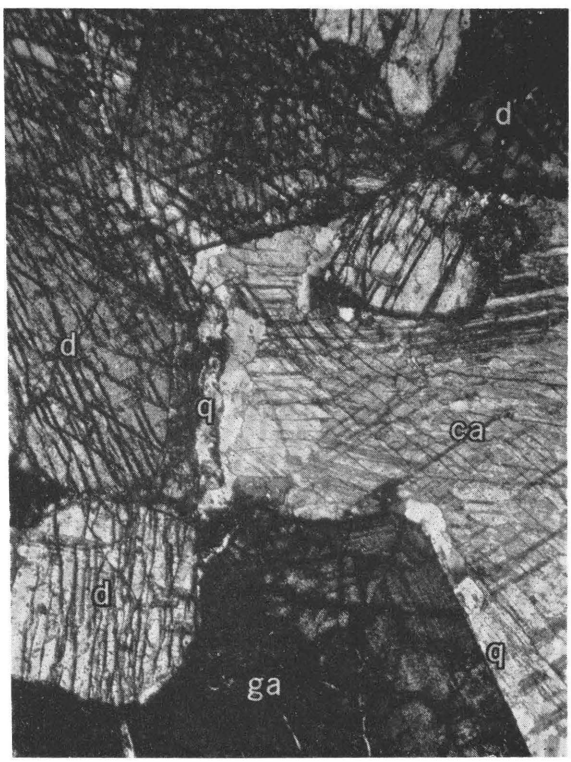

FIGURE 14.—Tactite from It mine, showing relationships of garnet (*ga*), diopside (*d*), and calcite (*ca*). Note late quartz stringer (*q*) along boundary of calcite. × 40.

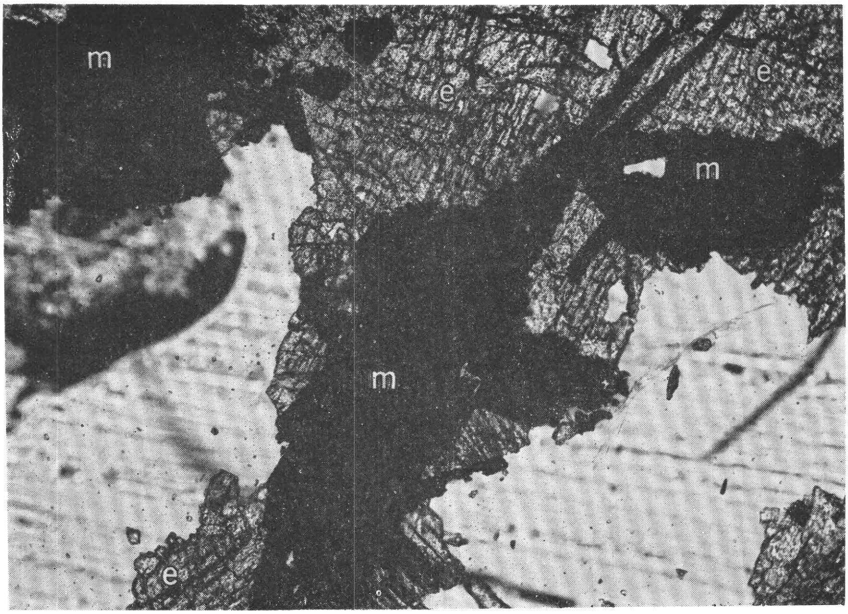

FIGURE 15.—Ore from Mount Andrew mine, showing epidote (*e*) cut by magnetite (*m*). × 75.

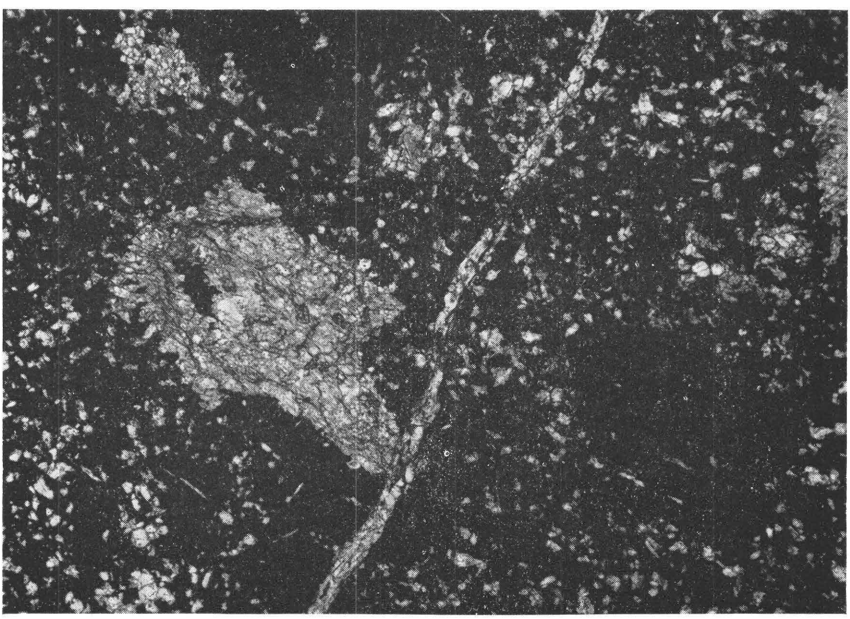

FIGURE 16.—Ore from Mount Andrew mine, showing earlier epidote (light) in magnetite (black) cut by veinlet of later epidote. × 40.

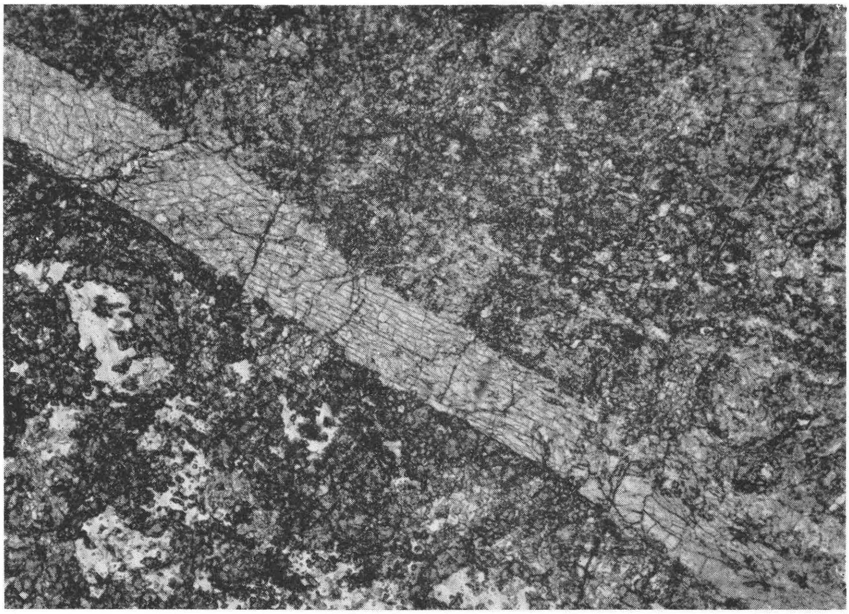

FIGURE 17.—Tactite from Aolstoi Mountain, showing epidotized country rock cut by veinlet of late epidote. × 40.

Part of the amphibole was undoubtedly formed before magnetite, but later hornblende veinlets cut the magnetite. As mentioned above, hornblende is rare except in the vicinity of the magnetite deposits.

The early calcite probably represents recrystallized limestone. This calcite is generally coarse and is interstitial to the early silicates, in contrast to late calcite which occurs in veinlets.

In nearly all instances the sulfide minerals are later than the magnetite, although some pyrite may have been deposited with the magnetite. The relations of pyrite and chalcopyrite to molybdenite are not clear. The relation of pyrrhotite to the other sulfide minerals is also obscure, although it is probably earlier than most of them and may be in part contemporaneous with the magnetite.

Quartz and calcite form veinlets late in the paragenetic sequence cutting the ore and tactite minerals. (See fig. 18.) Quartz generally formed later than calcite. Chalcopyrite commonly is associated with these veinlets. In some places it formed later than the calcite and may be closely related to the quartz. Ankerite is an important gangue mineral in the Rush and Brown magnetite deposit and formed later than the magnetite.

The latest deposits in the region are hypothermal veins in which quartz is the principal gangue. (See fig. 19.) The ore minerals in the veins are mainly pyrrhotite, pyrite, and chalcopyrite, as at the

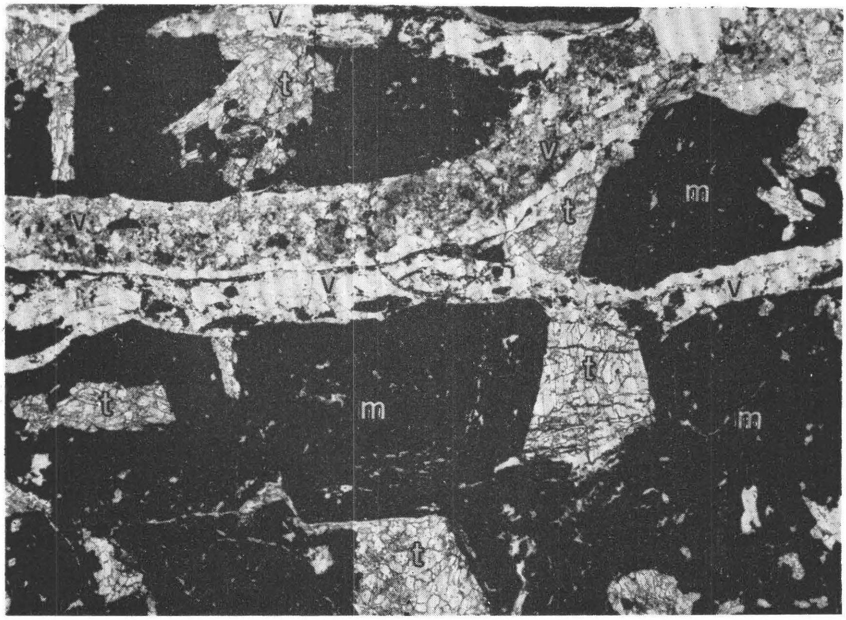

FIGURE 18.—Ore from Mount Andrew mine, showing veinlets (*v*) of quartz and calcite cutting magnetite (*m*) containing tactite inclusions (*t*). × 40.

Rush and Brown mine and the Venus and Copper Center prospects. On the beach south of the Poor Man iron deposit is a small vein containing irregular aggregates of magnetite. A small vein on the east slope of Tolstoi Mountain contains arsenopyrite.

From the paragenetic relations outlined above one may assume that the ore bearing solutions at first deposited rather simple minerals which became increasingly more complex as deposition proceeded. In the beginning the chief constituents were Ca, Mg, Fe and SiO_2. Later Al was added to form garnet and still later H_2O to form epidote and hornblende. At about the time H_2O became a prominent constituent in the gangue minerals, magnetite began to be deposited.

Diopside and garnet occur almost exclusively as replacement minerals. In a few places garnets fill fractures but no veinlets of diopside were noted. Epidote and amphibole occur partly as aggregates in replacement zones and partly as fracture fillings. The veinlets of these minerals are mostly later than the magnetite and the replacement aggregates are earlier. Although fracture filling appears to have begun near the close of garnet deposition it was relatively unimportant until after magnetite deposition had largely ceased.

After the deposition of magnetite and the complex silicates, the mineralogy of the ore and the gangue, as well as the mode of deposi-

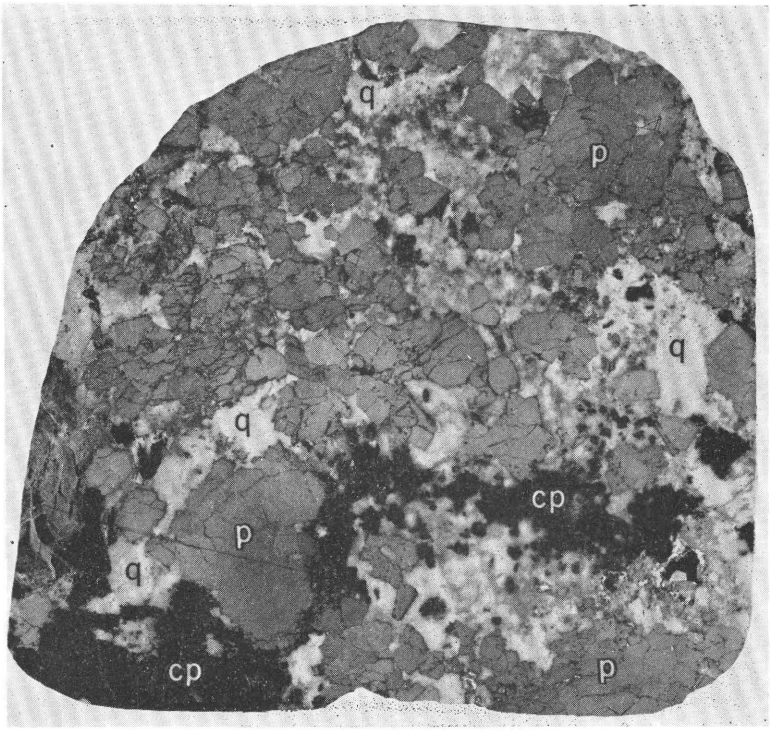

FIGURE 19.—Ore from Rush and Brown mine showing pyrite (*p*), quartz (*q*), and chalcopyrite (*cp*). Natural size.

tion, changed radically. The chief gangue minerals during this later period were calcite and quartz and the ore minerals were sulfides rather than oxides. In contrast to the magnetite and tactite minerals, the later minerals were deposited mostly in fractures. This later phase of metallization culminated in hypothermal vein deposits which are sparsely represented. Although all of the sulfide minerals are of simple composition, the tendency was toward increasing complexity, chalcopyrite, arsenopyrite and bornite being the latest ore minerals in the region.

ORIGIN OF DEPOSITS

On Kasaan Peninsula, lenses of marble included in the greenstone are virtually barren of mineral deposits. In the Mount Andrew-Mamie area, for instance, a zone of crenulated lenses of marble extends across the northern edge of the area (pl. 2). All ore deposits are south of this belt in metamorphosed clastic rocks and greenstone. Some limestone was replaced by ore, but such occurrences are not common. Near the It mine, marble layers are abundant, but all of the copper ore is in tactite, greenstone, and metamorphosed clastic sediments (pl. 24). The Poor Man iron deposit is in a fault zone that cuts a layer of greenstone that lies between two layers of limestone (pl. 12). At Tolstoi Mountain virtually all of the ore is associated with lenses of metamorphosed clastic material in the greenstone. Similar lenses of marble are barren (pl. 16). The ore deposits, however, are mainly limited to areas in which rocks of sedimentary origin are present, no deposits other than small veins having been found in areas where such rocks are not exposed. Lenses of these rocks locally constitute a subtantial part of the country rock.

In connection with the emplacement of the igneous rocks, the entire region probably was subjected to crustal adjustments that formed and fractured the rocks. Much of the effect of this deformation can be assumed to have been absorbed by those parts of the country rock where limestone and clastic rocks were abundant. During deformation, however, the limestone yielded mainly through flowage, whereas, the clastic rocks and intervening layers of greenstone yielded mainly by fracturing. The more fractured zones were best prepared to receive the mineralizing solutions. It is thought that the zones of principal deformation were rather directly connected with the sources of the mineralizing solutions by open channel ways, as tacite and ore minerals are virtually restricted to these areas. Had the solutions permeated all the rocks, searching out the more favorable horizons for replacement, the occurrence of these minerals presumably would be more widespread.

Within the zones of principal deformation, the mineralizing solutions attacked the most chemically favorable rocks to which they had access. The marble should have been favorable for replacement but, having been deformed by plastic flow and recrystallization, was doubtless quite compact at the time of metallization and much less permeable than the foliated clastic sedimentary rocks and fractured greenstone. Small lenses of marble were partly replaced, leaving irregular inclusions of coarse calcite in the ore and tactite as remnants. The more calcareous of the foliated and broken lenses of clastic rocks probably were those most widely attacked by the mineralizing solutions. Much of the ore and tactite shows banding similar to that found in certain of the clastic rocks and virtually all stages of replacement between the partly altered clastic sedimentary rocks and the banded ore and tactite have been found. These relationships are shown on figures 20–23.

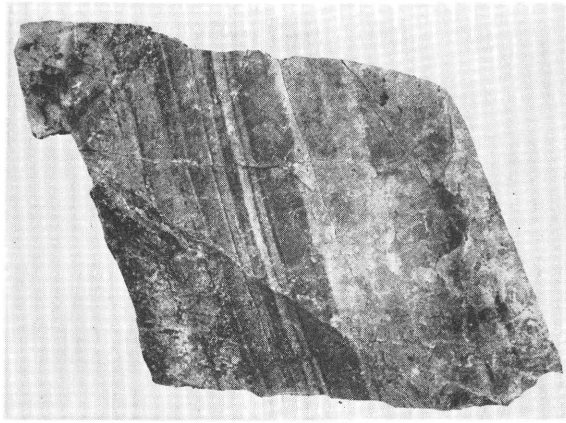

FIGURE 20.

FIGURE 21.

FIGURE 20.—Banded calcareous siltstone from one-half mile south of Tolstoi Mountain. The light bands are mainly quartz and calcite; the dark bands are rich in aluminous materials. Natural size.

FIGURE 21.—Drill core from Mount Andrew mine, showing bands of magnetite (dark) in tactite. Natural size.

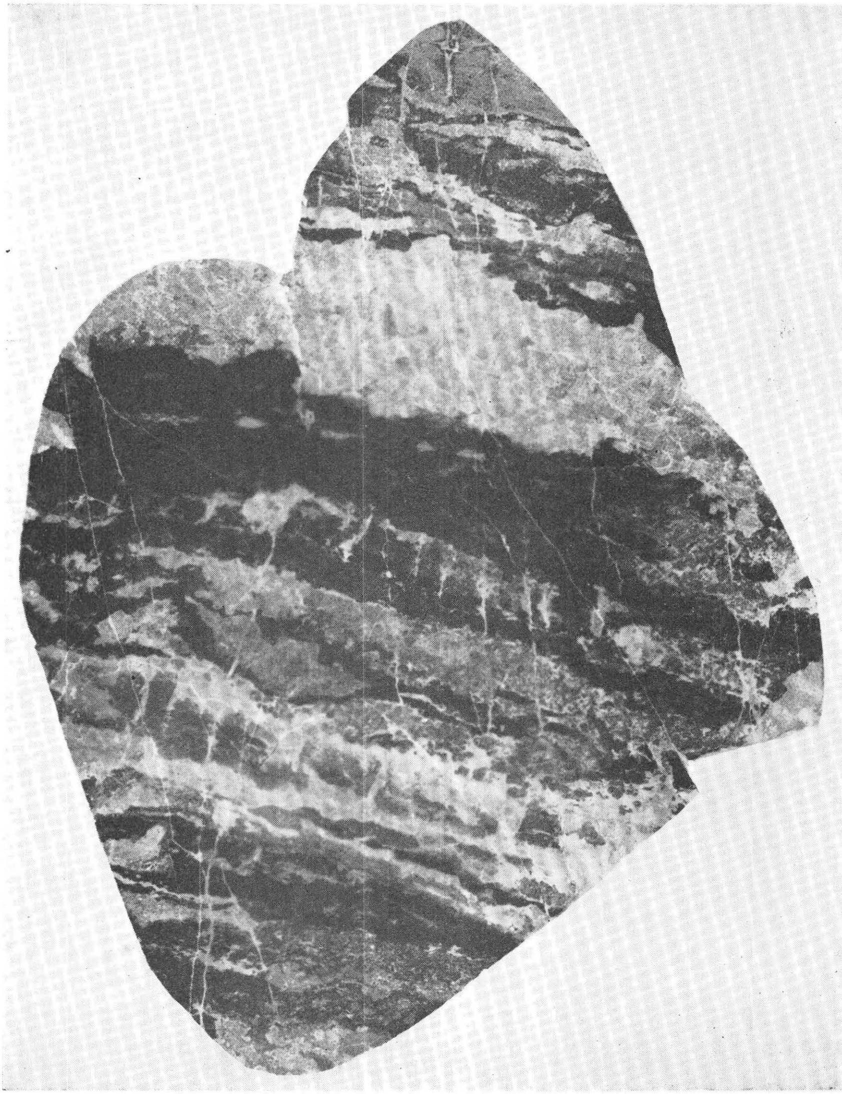

FIGURE 22.—Banded tactite from Mount Andrew mine. The light bands are largely calcite, diopside, garnet, and quartz. The dark bands are mainly hornblende with some magnetite. Natural size.

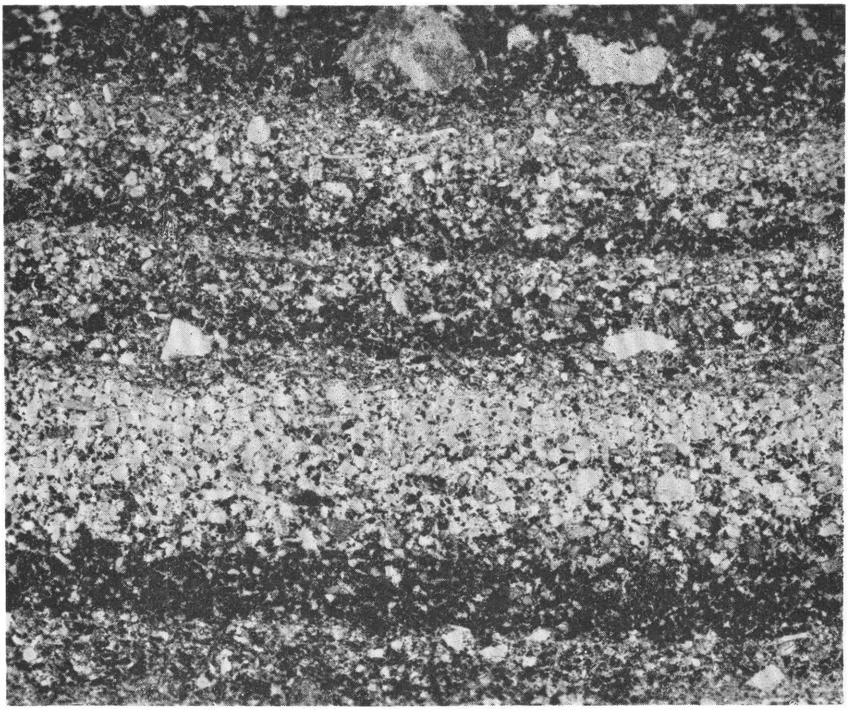

FIGURE 23.—Banded low-grade ore from Mount Andrew mine. The light layers consist of relatively coarse quartz and calcite in about equal amounts. The dark layers are finer grained and consist largely of magnetite and quartz, the calcite having been replaced. × 20.

Much of the ore may have originated through replacement of tactite by ore minerals. Of the tactite minerals, garnet seemingly was least effected by replacement. Drilling at the Poor Man iron deposit penetrated magnetite ore in which altered garnets appeared as inclusions. Presumably the garnets were originally contained in tactite with interstitial diopside, and possibly epidote, which were replaced by magnetite. Garnets were found also in massive chalcopyrite at the Rush and Brown Mine. (See fig. 24.) Aggregates of tactite minerals commonly show partial replacement by magnetite (figs. 25–27).

Thirty samples of magnetite ore of all grades were powdered and subjected to magnetic separation. The minerals in the nonmagnetic residues were examined and in the majority of samples, quartz and calcite were abundant constituents. The results suggest that the most common host rock for magnetite ore was probably an impure calcareous sandstone or siltstone. Greenstone was, for the most part, a poor host rock for the ore and tactite minerals. Within and adjacent to the major ore bodies, however, low-grade ore with tactite

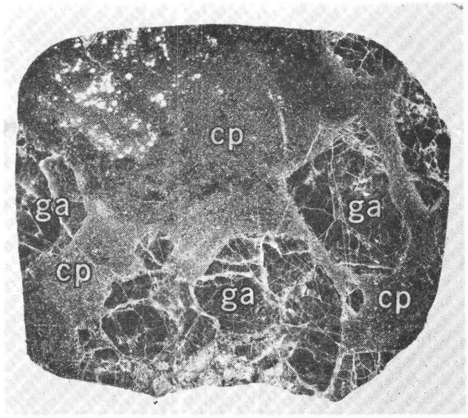

FIGURE 24.—Ore from Rush and Brown mine showing garnets (*ga*) in chalcopyrite (*cp*). Natural size.

FIGURE 25.

FIGURE 26.

FIGURE 25.—Drill core from Mount Andrew mine, showing magnetite (dark) replacing tactite. Natural size.

FIGURE 26.—Drill core from Poor Man iron deposit, showing magnetite bordering breccia fragments of epidotized greenstone. Natural size.

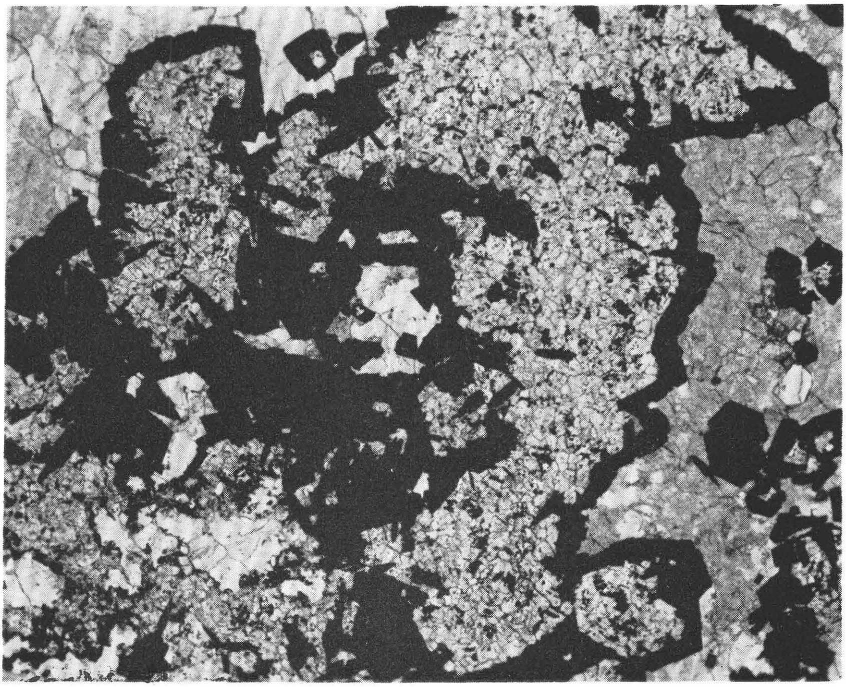

FIGURE 27.—Low-grade ore from Rush and Brown mine, showing magnetite bordering calcite grains in tactite. × 40.

occurs in broken greenstone. In some places extensive deposits of high-grade ore were formed almost entirely by replacement of greenstone. The largest of these is the Poor Man iron deposit in which magnetite replaced finely brecciated greenstone in a large fault zone. Here, evidently, the greenstone was sufficiently pulverized to react readily with ore-bearing solutions which percolated through the fault zone.

Deposits of sulfide minerals, like those of magnetite, are, with few exceptions limited to areas in which sedimentary rocks are included with the greenstone. Sulfide minerals were deposited in all areas containing magnetite, and in many where magnetite is scarce or absent. The tendency toward replacement was stronger, however, with magnetite than with the sulfide minerals. Even in the so-called replacement copper deposits, such as those at the It and the Rich Hill mines, the sulfide minerals are mostly confined to a network of minute fractures. Perhaps the nature of the sulfide-bearing solutions was such that deposition was more rapid than solution so that the openings were filled before replacement had proceeded very far. In certain places particularly favorable to replacement, bodies of high-grade copper ore developed. Elsewhere bodies of relatively low-grade disseminated ore were formed. Some veinlike bodies of fairly high grade copper ore developed principally by the filling of open fissures.

RESERVES

The total ore reserves of the peninsula are estimated to be about 5.5 million tons. This includes more than 4 million long tons of high-grade iron ore, the remainder being in short tons of low-grade copper ore. About three-fourths of the iron reserves and one-fourth of the copper reserves have been prospected sufficiently to be classified as indicated ore; the remaining reserves are inferred ore. More than 85 percent of the iron reserves are in the Mount Andrew and Poor Man magnetite deposits. These are the only two ore bodies in the area that are known to exceed a million tons.

Many of the magnetite deposits contain more than 50 percent of iron and carry gold, silver, and copper in amounts averaging $2.00 per ton or more. The ores are of Bessemer quality, the phosphorus rarely amounting to more than a few hundredths of one percent. The titanium content also is negligible. Sulfur is present in amounts averaging between 1 percent and 4 percent and may, in some deposits, lead to metallurgical difficulties if the ores are used in making steel.

Much of the known copper reserves of the peninsula has been mined. The remaining copper reserves, with the possible exception of those at the Rush and Brown and the It mines, are of relatively low grade, the average copper content being at most places less than 2 percent. The copper ores, however, generally contain more gold and silver than the iron ores.

The grades of ore given in this report are based primarily on analyses by the Bureau of Mines, but in part on samples analyzed by the Geological Survey. The analyses express total iron and copper contents of the samples and no large samples have been processed to determine the amounts of these metals actually recoverable. However, the discrepancies between total and recoverable metals are probably small in the better grades of ore.

FUTURE POSSIBILITIES

GEOLOGIC FACTORS

Most of the Kasaan Peninsula has been rather thoroughly prospected using common methods. Pits, trenches, or short adits have been dug at nearly all places where ore minerals were noted. It is unlikely that many new outcrop discoveries will be made. Because of the dense vegetation, however, some ore bodies of considerable size may have been overlooked. More probably, such bodies are buried at depths of a few feet to several hundred feeet. The search for new deposits in this region is, therefore, thought to be largely beyond the scope of ordinary methods of prospecting and will depend mainly upon modern geological and geophysical techniques.

So far, little attempt has been made at a systematic search for ore deposits on the peninsula. Detailed geologic mapping of the entire area, maintaining sufficient control to insure adequate coverage and using the compass and dip needle to detect magnetic anomalies, might lead to the discovery of new ore bodies. Such mapping should serve, in any event, to block out promising areas in which additional geological and geophysical surveys could be made.

It has been pointed out that most of the known ore deposits are in areas in which lenses and layers of metamorphosed sedimentary rocks are included in the greenstone. In most instances the ore deposits are associated with tactite and outcrops of this material may indicate that an ore body is near. Coarse aggregates of bladed, dark-green hornblende commonly are associated with magnetite and rarely are found with deposits of sulfide minerals. These criteria may be useful if a systematic search for new ore bodies is undertaken.

The localization of ore deposits along the southwestern coast of the peninsula suggests that future discoveries will be more likely in this zone than elsewhere. The alinement of the zone of metallization with the Thorne River valley and other topographic features northwest of the Salt Chuck, hints that it may relate to a fault and may continue for many miles into Prince of Wales Island. Because of the relative inaccessibility of the region the geology of the Thorne River valley is little known. An investigation of this area appears to be warranted.

In searching for new ore bodies on Kasaan Peninsula, the sizes, shapes, and tenors of the known ore bodies should be kept in mind. There is little reason to believe that deposits yet to be discovered differ greatly in these respects from those that are already known. Conversely, there is good reason to suppose that deposits similar to those described in this report are now partly or totally concealed. Whether such deposits can be located and exploited profitably will depend largely upon what use can be made of the known resources of the peninsula.

ECONOMIC FACTORS

Whether the magnetite ores of Kasaan Peninsula can be extracted profitably is dependent on a number of uncertain factors involving market, mining, shipping, and treatment. These, of course, are problems primarily for the mining engineer, metallurgist and economist, but a short discussion here seems warranted from the standpoint of the field conditions involved.

At present no certain market exists for the magnetite ores of the region. Utilization of these ores is dependent on future growth of an iron and steel industry in the Pacific Northwest. The Kasaan Peninsula deposits could not support the industry alone, but from these and other deposits on Prince of Wales Island and similar deposits on Graham, Moresby, Vancouver and Texada Islands, B.C., and in Washington, a sufficient supply might be secured.

The Poor Man iron deposit and the compound ore body at the Mount Andrew mine, which together constitute the bulk of the ore reserves on Kasaan Peninsula, probably could be mined by open pit methods at relatively low cost. The other ore bodies are not well suited to open pit mining and probably would have to be mined by underground methods on a rather small scale. In some instances the cost of mining might be prohibitive. Transportation of the ore from Kasaan Peninsula to a smelter on the Pacific Coast should be fairly simple and relatively inexpensive as the entire trip could be made by water.

Treatment of the ores is a complex problem that must be worked out by a competent metallurgist. The ore probably is of high enough grade to be used directly in a blast furnace, but it is questionable whether magnetite ore alone is suitable. Magnetite ores mined in the eastern United States are mixed with hematite ores for smelting. Electric smelting similar to the process used on the Kiruna iron ores of Sweden has been suggested for the magnetite ores of the Pacific Coast region by several engineers and metallurgists (Stansfield, 1919; Lippert, 1940), but apparently no extensive industry of this type has been established in the United States. The Swedish Kiruna ores are very low in sulfur (Daly, 1915, p. 8). Whether ores as high in sulfur as those of Kasaan Peninsula can be smelted successfully by electrical means is a problem that apparently is not yet solved. The sulfur content of these ores probably could be eliminated in several ways. A simple method might be magnetic separation, but this would require fine grinding. The disseminated sulfide grains in the massive magnetite range in size from 0.01 mm (about 0.0004 inch) to about 5 mm (about 0.2 inch), but most of them are 0.2 mm (0.0078 inch) or larger. To remove nearly all the sulfide content would require a grinding too fine to be practical, but it seems likely that 75 to 80 percent of the sulfides could be removed by grinding the ore to 120 mesh size. Possibly even a coarser grinding would be practical, but this cannot be determined without experimentation on the particular ore. The byproduct of magnetic concentration probably would contain a high percentage of copper and in some instances gold and silver. These byproducts might pay for much of the cost of separation.

Another possible method of eliminating most of the sulfur from the ore would be by roasting. This would convert most of the sulfides to oxides and might even convert some of the magnetite to hematite and thus make a more suitable blast furnace ore. It is possible that the copper could be leached from this roasted ore.

If there is sufficient demand for iron and steel on the Pacific Coast it seems likely that a feasible process for treating the Kasaan Peninsula iron ores can be found.

DESCRIPTION OF DEPOSITS

DEPOSITS OF THE MOUNT ANDREW-MAMIE AREA

By E. N. Goddard and L. A. Warner

The Mount Andrew-Mamie area, so named for the two principal mines, includes several groups of magnetite deposits, some of which have been mined for their copper content. Three mines in the area have been productive, the Mount Andrew, Mamie, and Stevenstown, but no mining or development work has been done since 1918. No ore has as yet been mined for its iron content, although large bodies of magnetite have been known to be in the area for many years.

The area is about 28 miles northwest of Ketchikan and 4½ miles southeast of Kasaan (pl. 1), a small fishing village, which is the site of a cannery. A Forest Service trail in fair condition connects Kasaan with Hadley, an abandoned village on Lyman Anchorage, about 1¼ miles north of the area. Two aerial tramways and a small railroad that operated when the mines were working are in complete ruin. Trails lead into the area from Mount Andrew landing and Bogg's landing on Kasaan Bay.

Most of the area is at the crest of the main ridge near the narrowest part of the peninsula. Altitudes within the area range from 640 to 1,495 feet. The topographic features consist of a number of rather flat surfaces separated by steep slopes. They are believed to have resulted from differential glacial erosion, which tended to smooth the preexisting topography. Most of the area is poorly drained and small ponds are common; a sizeable area of muskeg is in the south-central part. Entrenched streams are few, the most pronounced being one that follows a major fault in the northeastern part of the area. Along the south border are numerous small trickling streams that become precipitous as they leave the area.

The major part of the fieldwork was carried on from June 1 to September 16, 1942. The field party included, in addition to the writers, Matt S. Walton, Jr., geologist, Elder Lebert, and Joseph Llanos. The party prepared detailed geologic, topographic and magnetic maps, on a scale of 1 inch equals 500 feet, of an area about 1 mile long and half a mile wide in the vicinity of the mines. A small area near the Mount Andrew mine was mapped on scale of 1 inch equals 50 feet and the same scale was used in mapping all the underground workings in the area. Goddard did most of the geologic mapping, Warner and Walton mapped the topography, and Walton and Warner, assisted part of the time by Llanos, carried on the dip-needle work. During most of the season, the party worked as a unit and mapped topography, geology and magnetic data at the same time on the same traverses. For the purpose of this survey, a grid was laid out over the entire area with stations 100 feet apart. Magnetic readings were taken at each station and the geology was related to these and to the plane-table stations. The magnetic data were useful chiefly in checking and substantiating the geologic data, but in some places, important additional information was gained by the dip-needle work.

During August and September, the party was serviced by the motorboat, *Clara D.*, operated by James Pitcher. In September G. D. Robinson, geologist, and William Williams, were added to the party.

In the fall of 1943 and the spring and summer of 1944, the U.S. Bureau of Mines trenched, sampled, and drilled the Mount Andrew deposit. C. T. Bressler was assigned by the Geological Survey to log drill cores and to map the geologic features revealed in the trenches.

Warner compiled the topographic maps and did some of the petrographic work. However, it was necessary for him to return to Alaska before the latter was completed and Donald J. Miller made a detailed study of most of the rock thin sections. Walton compiled and interpreted the magnetic data and Bressler compiled the results of the trenching and diamond drilling. Goddard prepared the geologic maps and sections, studied polished specimens of the ores, and wrote most of the original report, which was to have been published separately. Subsequently the manuscript was revised by Warner when it was decided to include the report in the present bulletin. It was not possible to preserve entirely the contributions of the individuals involved, particularly those of Walton and Bressler, parts of whose data have been utilized at appropriate places throughout the report.

HISTORY AND PRODUCTION

The exact date of the discovery of the ore deposits of the Mount Andrew-Mamie area is not known. Prospecting began on Kasaan Peninsula as early as 1870, but it was not until 1898 that the copper deposits at the Mount Andrew property were prospected (Brooks, 1902, p. 37–39). Brooks does not mention the Mamie mine but according to an old map in the files of the U.S. Geological Survey, the property was developed in 1902 by an adit 173 feet long. During 1903–04, a 350-ton smelter was erected at Hadley to treat the Mamie copper ores (Wright, F. E. and Wright, C. W., 1905, p. 63). In 1905, mining developments were begun on both the Mamie and the

Stevenstown mines and on December 5 of that year the smelter began operations (Wright and Paige, 1908, p. 103–106). The first ore from the Mount Andrew mine was shipped during October 1906 to the Tacoma smelter. In the fall of 1907 the Hadley smelter and all the mines of the area were shut down (Wright, F. E. and Wright, C. W., 1908, p. 112–117). The following year the smelter was reconditioned and during 3 months in the fall treated about 360 tons of ore per day from the Mamie and Stevenstown mines (Wright, C. W., 1909, p. 78). The smelter was closed during the winter of 1908–09. In March 1909, the Mount Andrew Iron and Copper Co. commenced operation at the Mount Andrew mine (Knopf, 1919, p. 141–142). Twenty-five men were employed and about 50 tons of copper ore were shipped during the summer months. Production at the Mount Andrew mine was continued during the following year and a long crosscut adit (adit 3) was begun, to explore the ground 300 feet below the working level (Knopf, 1911, p. 100). The Mount Andrew mine continued to produce ore during 1911, but apparently no mine in the area was operated during 1912 and 1913. However, in 1913, the Granby Consolidated Mining, Smelting and Power Co., Ltd. took over the Mamie and Stevenstown mines and in April 1914 began large scale operations (Brooks, 1915, p. 42). During part of 1915 the Granby Company produced about 260 tons of ore per day. The ore was shipped to the Granby Company's smelter at Anyox, B.C.; the Hadley smelter was not operated (Chapin, 1916, p. 83–85). During 1914 and 1915 some development work was done on the Mount Andrew mine but it is doubtful if any ore was shipped during 1915. During 1916 both the Mamie and Mount Andrew mines were in operation. The number 3 adit was completed at the Mount Andrew mine and work was carried on at the Rico, Jem, and Peacock claims east of the main Mount Andrew workings (Axel Carlson, oral communication). During 1918, all mining operations in the area ceased, and there has been no mining activity in the area since. No usable equipment is left at any of the mines. In 1943, the buildings at the Mount Andrew mine were reconstructed by the U.S. Bureau of Mines and used as living quarters for the engineers and workmen during the diamond drilling in 1944.

The total production of the Mount Andrew-Mamie area has amounted to more than 270,000 tons of copper ore, more than half of which has been from the Mamie mine. Both siliceous copper ore and massive magnetite ore were mined for their copper content, but no attempt has been made to mine iron ore in the district, although the large bodies of magnetite ore south of the Mount

Andrew workings were known as early as 1901 (Brooks, 1902, p. 102–103). The amounts of copper, gold, and silver produced in the district are given in table 2.

TABLE 2.—*Production of copper, gold, and silver in the Mount Andrew-Mamie area*

[Compiled from records on file in the U.S. Geol. Survey. No production in 1912–13 and 1919–53. No data for 1914]

Date	Ore sold or treated (short tons)	Copper		Gold		Silver		Total value
		Pounds	Value	Fine ounces	Value	Fine ounces	Value	
1905[1]	20,659	1,194,917	$186,407	932.1	$19,266	5,946	$3,502	$209,175
1906	58,617	2,955,770	570,463	1,708.06	35,309	13,570	9,092	614,864
1907	41,075	2,043,926	408,784	908.28	18,775	11,174	6,375	433,934
1908	17,332	967,711	127,737	544.56	11,257	3,879	2,056	141,050
1909	8,385	711,110	92,444	405.63	8,385	?	?	100,829
1910	9,547	655,567	83,257	261.08	5,397	3,829	2,068	90,722
1911	6,100	418,940	52,368	164.70	3,405	2,440	1,293	57,066
1915	37,775	984,480	172,284	519.21	10,733	5,073	2,573	185,590
1916	51,307	1,856,700	456,748	847,00	17,509	4,254	2,799	477,056
1917	7,529	402,990	110,016	188.92	3,905	2,520	2,076	115,997
1918[2]	12,400	625,264	154,440	460.00	9,509	3,248	3,248	167,197
Total	270,726	12,817,375	2,414,948	6,939.54	143,450	55,933	35,082	2,593,480

[1] Production for Kasaan Peninsula in 1905, principally from Mount Andrew-Mamie area but may include some from Rush and Brown mine (Wright and Paige, 1908, p. 100).
[2] Includes some ore from the It mine.

GEOLOGY

The rocks of the Mount Andrew-Mamie area consist chiefly of greenstone and associated sedimentary rocks on the north border of a large stock of granodiorite and related rocks in the southeastern part of the peninsula. At the edge of this stock, intrusive rocks of early diorite are exposed along the cliffs at the southwestern border of the area. Many porphyry dikes ranging in composition from gabbro to alkalic dacite, trending northerly and northeasterly cut the early diorite and the other rocks throughout the area. Several dikes of diabase trend northeasterly across the area and cut all other rocks. Lenses of marble are interlayered with greenstone in the northern part of the area, and adjacent to these, layers of metamorphosed clastic sedimentary rocks are more abundant than elsewhere in the greenstone sequence. These relationships are shown on plate 2.

Much of the exposed bedrock in the Mount Andrew-Mamie area is greenstone. Most of the greenstone in the central and southern parts of the area reveals little of its true character to the unaided eye. It is a massive, dense, aphanitic, dark-green rock, with no apparent structures. In places, small phenocrysts of feldspar and amphibole are scattered in the groundmass and in other places an indistinct conglomeratic or breccia texture is visible.

In the northern part of the area, south of a prominent easterly trending fault and near the marble layers, rocks of sedimentary origin seem to predominate, but some greenstone is interlayered with them. These rocks are uniformly dense and range from light greenish gray to dark greenish gray. Some are mottled, others banded, but most exhibit little texture or structure to the unaided eye. The rocks have been altered by contact metamorphic effects but microscopic study reveals that they were originally graywacke, shale, arkose, limy shale, and impure limestone. Interlayered with these rocks are beds of nearly pure marble from a few feet to as much as 85 feet thick. North of the fault the greenstone (altered andesite) appears to predominate. It contains some layers of the metamorphosed clastic sediments but no limestone. Slickensides and dike displacements observed along the fault suggest that a component of the movement was reverse, resulting in upthrow of the north side. The relationship implies that rocks of sedimentary origin, which are closely related to the ore deposits, may be more abundant in the upper part of the greenstone sequence in the Mount Andrew-Mamie area.

GREENSTONE AND ASSOCIATED ROCKS

The greenstone is chiefly altered andesite with aphanitic texture. It originally was made up of plagioclase (chiefly andesine), hornblende, augite (largely replaced by hornblende), small amounts of orthoclase, and locally, biotite. Of the accessory minerals, magnetite is fairly abundant, making up as much as 10 percent of the rock in places. Sparse grains of sphene and apatite are present. The original minerals are partially altered to chlorite, sericite, epidote, calcite, and other products too fine grained to identify.

The clastic rocks interlayered with the greenstone are of such great variety that no attempt was made to map them individually. All are either partly or wholly recrystallized and have an uneven mosaic texture. Feldspar (oligoclase and orthoclase) is the most abundant mineral in all types. The metagraywackes also contain biotite and chlorite or hornblende and chlorite as well as small amounts of quartz. Other layers, resembling quartzite, show interlocking grains of quartz and albite and myrmekitic intergrowths of these two minerals; they may represent original arkose. Light-green rocks, found near the ore deposits, are made up chiefly of albite or oligoclase with small amounts of epidote and clinozoisite. Originally these probably were limy shale.

Throughout the area the greenstone and associated metasedimentary rocks have undergone thermal metamorphism which is probably related to the intrusion of the igneous rocks. In the vicinity of the ore deposits, pyrometasomatism was intense and the metasedimentary rocks and greenstone are partly or wholly replaced by a suite of common tactite minerals. Light-green epidote is generally the most abundant of these minerals, but in places dark-green hornblende is the more abundant. Garnet, diopside, chlorite, clinozoisite, pink orthoclase, calcite, and albite are all common.

The marble, because it is so readily distinguishable, was mapped as a separate unit. It occurs in lenticular beds interlayered with greenstone and clastic sedimentary rocks. The beds are much deformed, and thicken, thin, and pinch out abruptly. (See fig. 28.) The marble occurs in at least four, and probably more, different zones, but because of the widespread surface cover and complex structure, the stratigraphic relationships were not determined. The rock is medium grained, white to light gray and weathers light gray to buff. It shows marked effects of solution weathering on the surface. As a result, the outcrops are very uneven especially where deep grooves have been formed along fractures and contacts. The marble in the northeastern part of the area just north of the Mamie mine and at the Stevenstown mine is nearly pure dolomite, but in the rest of the area, it is nearly pure calcite. Both types of marble have been replaced by ore minerals to some extent, but near the magnetite bodies the dolomite is veined and irregularly replaced by both white and pink calcite. Paragenetic relations suggest that the calcite may have formed earlier than the magnetite.

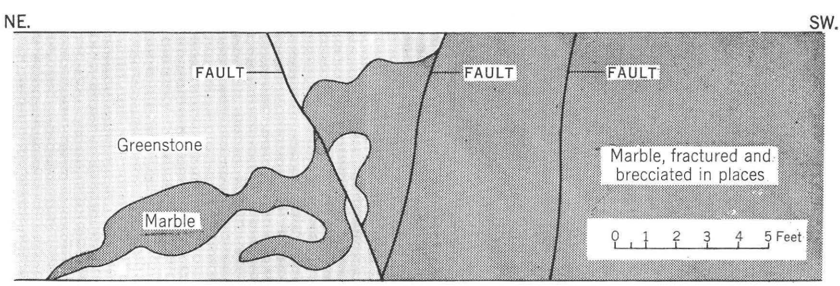

FIGURE 28.—Sketch showing the abrupt pinching out of a contorted marble layer in the Mamie mine, southeast side of main adit, 110 feet from portal.

IGNEOUS ROCKS

The greenstone and associated rocks are cut by many igneous intrusions. The oldest igneous rocks are largely diorite and include an irregular stock that is exposed along the southwestern margin of the area (pl. 2). Small irregular bodies of early diorite and related rocks are exposed elsewhere. The other igneous rocks occur chiefly as porphyry dikes and comprise a magmatic differentiation sequence ranging from gabbro through andesite and diorite porphyry to alkalic varieties of granodiorite, dacite and andesite. These dikes all occupy the same general set of fractures, striking north to northeast and dipping steeply. Compound dikes in which several types were injected along the same fracture, are common. In places, as in the Mount Andrew 3 adit, separate dikes on the surface widen and converge downward to form an almost continuous body of igneous rock with only small slivers of greenstone between. The dikes range in width from a few feet to more than 75 feet and in length from 30 feet to more than 1,500 feet. The porphyry dikes cut the intrusions of early diorite and the alkalic dikes cut those of gabbro, andesite and diorite porphyry. Dikes of diabase trend more easterly than the porphyry dikes and appear to be the youngest rocks in the area.

Except for the diabase, all igneous rocks in the area are more or less altered, particularly near the mineral deposits. Some of the alteration, including sericitization of plagioclase and chloritization of hornblende, may have been accomplished by deuteric action; other effects clearly are related to the ore-bearing solutions. Grains and veinlets of epidote and other tactite minerals are common in the porphyry dikes and are especially abundant near the ore. The dikes have been strongly silicified in places, and some contain veinlets and disseminated grains of magnetite and pyrite. The early diorite and related rocks are in places intensely altered near the ore bodies and along fracture zones are almost completely replaced by epidote and orthoclase. Whereas the porphyry dikes in many places appear to cut the ore, the alteration indicates that they are older than the mineral deposits. The absence of alteration in the diabase dikes, which cut the altered porphyry dikes, implies that the diabase was emplaced after the mineral deposits were formed. Possibly these dikes are related to a distinctly later epoch of igneous activity than that which gave rise to the earlier intrusions.

EARLY DIORITE AND RELATED ROCKS

The early diorite exposed in the southwestern part of the area is part of a large irregular stock that extends to the beach about half a mile to the south. Irregular sills and dikelike apophyses are connected with this intrusive body. In the south-central part of the area, several small lenses of diorite are exposed that may be cupolas of the larger mass. Dikes and sills of diorite are numerous in the eastern part of the area and just south of the Mamie mine a large irregular body that appears to be a combination of dikes and sills is partially altered to epidote and pink orthoclase, as are other small dikes of this rock in the vicinity of ore deposits. The borders of these rocks commonly are gradational with greenstone and greenstone inclusions with gradational borders are common. Apparently there was some assimilation or replacement of the earlier rocks by the diorite magma.

The diorite is a dark- to light-gray speckled rock of granitoid texture with prominent prismatic crystals of hornblende in a light-gray to pinkish-gray matrix of feldspar. Generally andesine (about An_{40}) is the principal feldspar, although perthite and orthoclase are locally more abundant and the diorite probably grades into monzonite and syenite. Quartz is present in small amounts and some augite is found, largely altered to hornblende. In some specimens the andesine crystals have rims of fresh albite and in places albite, apparently of secondary origin, makes up about 65 percent of the rock.

GABBRO AND ANDESITE

Gabbro dikes are most abundant in the vicinity of the Mount Andrew mine and are best exposed in the northern group of Mount Andrew glory holes. Small andesite dikes, in places porphyritic, are intimately associated with the gabbro dikes and are quite similar to them in appearance and composition. In the Mount Andrew glory holes, small andesite dikes appear at various places along the walls of the gabbro dikes. The andesite dikes are slightly younger than the gabbro dikes as indicated in a dike about 1,000 feet south of the Mount Andrew workings where an inclusion of gabbro, with gradational borders, was found in the andesite. Small dikes of andesite, apparently belonging to this same group are found in the eastern part of the area, especially in the Mamie mine. Basalt dikes, associated with gabbro and andesite elsewhere on the peninsula, were not noted in the Mount Andrew-Mamie area.

The gabbro is a medium-grained dark-green rock of granitoid texture, in which augite, plagioclase, and magnetite are visible to the unaided eye. A few round patches of fibrous chlorite and needles of actinolite may represent original olivine crystals. The andesite is a dark-green aphanitic rock composed of about two-thirds calcic andesine and one-third hornblende or augite partly replaced by hornblende. The small andesite dikes in the Mamie mine are intensely altered to a dense dark-brownish-gray rock containing some finely disseminated pyrite.

DIORITE PORPHYRY

Dikes of diorite porphyry are scattered throughout the area and range in width from 10 to 60 feet. Some diorite dikes, whose exact affinities are not known, are placed in this group. The diorite porphyry dikes appear to be remarkably uniform. Abundant lath-shaped andesine phenocrysts, averaging about 5 millimeters in length, are scattered in a fine-grained dark-greenish-gray groundmass and in most places are oriented parallel to the dike walls. In some dikes there are a few small phenocrysts of hornblende.

Diorite exposed in the western part of the Mamie workings is much altered. Parts of it resemble early diorite but in general appearance and composition it seems to be more closely related to diorite porphyry. Much of the body has a faint porphyritic texture but it contains zones of a finer grained nonporphyritic rock with indistinguishable boundaries, and in many places alteration obscures the distinguishing features of both rocks. The porphyritic rock is made up of abundant phenocrysts of andesine, about 1 to 5 millimeters long, in a fine-grained groundmass of andesine and chlorite. The phenocrysts are somewhat embayed by the groundmass minerals causing the boundaries to be macroscopically indistinct. A few quartz grains are scattered through the groundmass, some of which appear to be of secondary origin. Finely shredded chlorite throughout the groundmass is concentrated in places into irregular masses. The nonporphyritic diorite has a fine-grained granitoid texture and is composed chiefly of calcic andesine (about 60 percent) and hornblende (about 25 percent); alteration products comprise the rest. The boundaries between these two facies are too obscure to be mapped. In addition to the prominent chlorite alteration, there are scattered epidote crystals and much finely disseminated pyrite in the diorite. The rock is cut by veinlets of pyrite-quartz-hornblende-epidote and by later-formed veinlets of calcite-prehnite-albite. The latter, where they cut andesine crystals, are commonly bordered by a replacement zone of fresh albite.

ALKALIC ROCKS

Dike rocks containing albite and orthoclase as principal constituents form an almost continuous gradational series ranging from dark-greenish-gray rocks resembling the early diorite and gabbro through mottled dark-green and pink rocks to dense aphanitic pink rocks containing very small amounts of dark minerals. Although there is no pronounced break in this sequence, the end members are so markedly different in appearance and composition that it seems best to distinguish between the darker, more mafic alkalic granodiorite and alkalic andesite and the light-colored, more felsic alkalic dacite. These types are shown separately on plate 2. Persistent dikes of alkalic granodiorite and alkalic dacite occur abundantly throughout the area. Several dikes of alkalic granodiorite are exposed in the Mount Andrew mine workings and a large dike is exposed at the west portal of the Stevenstown tunnel. Pink dacite forms a network of dikes in the west-central part of the area and some of these spread into an irregular body that may be the roof of a small stock. Several of these dikes are cut in the Mount Andrew adit #3. Most of the large dacite dikes are in the central part of the area, but small ones are scattered throughout. One is prominently exposed in the Stevenstown glory holes and the tunnel beneath, and a small one in the Mount Andrew northwest glory hole. Alkalic andesite occurs sparingly in small dikes a few inches to a few feet wide. The dikes are best exposed in the Stevenstown western glory hole. In the Mount Andrew northwestern glory hole, a dike of this type cuts alkalic granodiorite.

The alkalic granodiorite is medium grained and subporphyritic. Phenocrysts of hornblende (in places largely altered to chlorite) and albite are enclosed in a finer grained groundmass of albite and orthoclase. The groundmass has a pinkish cast due to dusty inclusions of hematite in the orthoclase. The dacite is predominantly pink, medium- to fine-grained rock mottled by scattered grains of hornblende. Some of the dacite is porphyritic, consisting of sparse albite phenocrysts in a pink aphanitic groundmass of albite and orthoclase. The alkalic andesite is a dark-gray aphanitic rock containing about 70 percent hornblende, the remainder being mostly orthoclase and albite in about equal amounts. All of the alkalic rocks contain some quartz but it is rarely an important constituent.

DIABASE

Diabase is apparently the youngest intrusive rock in the area and may be unrelated to any of the earlier rocks. Diabase dikes occupy east-northeast fissures and extend en enchelon across the central part of the area. The dikes are 5 to 35 feet wide and 100 to 750 feet long.

The diabase is a dense moderately fine grained, dark-gray rock with ophitic texture. It is made up chiefly of labradorite and pyroxene (apparently pigeonite) and contains about 5 percent magnetite. Small amounts of biotite, chlorite, and actinolite appear to be secondary. This rock is unusually fresh compared with the other rocks of the area.

STRUCTURE

FOLDS

Within the Mount Andrew-Mamie area, the major structural features are asymmetric anticlines and synclines that trend about N. 10° W. and are about 500 to 1,000 feet from crest to crest. Superimposed on these are innumerable minor folds from a few feet to 50 feet in width, and within these are still smaller plications. The minor folds presumably are related to drag resulting from the major folding, but they are commonly more open than the typical drag fold and are not limited to incompetent layers between more competent strata. The minor folds were observed chiefly in the limestone or in ore layers at their contact with greenstone or tactite. Within the limestone itself, rather intricate folds a few inches or less in size were developed in thin shaly layers. Larger folds in the limestone show abrupt bulging in the axial portions and pinching on the limbs, resulting from plastic flow.

The structure of the area is further complicated by another system of folding that is nearly at right angles to the one mentioned above. This system trends about N. 80° E. and is not as pronounced as the N. 10° W. system. It is chiefly indicated by the fact that the axes of the folds trending N. 10° W. are approximately horizontal in the south-central part of the area, but pitch rather steeply northward in the northern part. This is shown by the structure in some of the limestone layers and also by an abrupt northward plunge of the ore in the northern part of the Mount Andrew workings. Folding on a somewhat broader scale than in the N. 10° W. system is suggested. A rather broad anticline is indicated, the axis trending about N. 80° E. across the southern two-thirds of the area and the north limb occupying the northern part of the area. Minor folds, probably caused by drag, are superimposed on this N. 80° E. system of folding and are best exemplified in ore layers in the upper and main Mount Andrew adits (fig. 29) and in the Mamie mine.

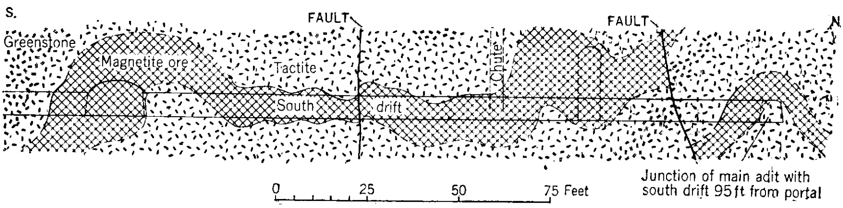

FIGURE 29.—Sketch of contorted magnetite layer in south drift of Mount Andrew adit 1, looking west.

Folds of east-northeastward and northeastward trend, that cross northwestward-trending structural axes have been observed by Buddington and Chapin (1929, p. 306) in other parts of southeastern Alaska. They suggest that "the northwest structure may have been superimposed upon the east-northeast and northeast folds" but admit that the reverse may be true. In the Mount Andrew-Mamie area there is some indication that the intrusions of igneous stocks and dikes have deformed the earlier northwestward-trending folds in places, and it is possible that forces operating in conjunction with the intrusive rocks produced the folds of east-northeastward trend. However, no evidence was found to show whether the east-northeastward folding is earlier or later than the dominant north-northwest system.

Most of the structural interpretation given above is based on the general distribution of the magnetite ore and the limestone layers, on banding in the ore, and on the attitude of contacts between ore and tactite as exposed in the mine workings and, rarely, on the surface. In a few places, bedding in the marble is indicated by thin siliceous layers, but in the greenstone, layering is largely absent. Banding is faintly visible in a few outcrops of the greenstone, but the attitudes are contradictory and cannot be relied on as good evidence of primary structure. It is admitted that the interpretation rests on rather tenuous evidence. However, nearly all of the observed structural data seem to fit satisfactorily into the pattern as outlined and no other interpretation seems to account adequately for the observed facts.

FAULTS

Faults are widespread in the area and undoubtedly are much more numerous than indicated on plate 2. Few faults have been mapped from surface exposures, because of the cover of vegetation, but many are exposed in the mine workings. They appear to belong to four sets that strike northward, eastward, northwestward, and northeastward. Generally, the dip is steep but a few east-trending faults dip gently north or south and some of north trend dip gently east. With the exception of the persistent east-northeast fault in the northern part of the area, the faults are small and displacements rarely exceed a few feet. On nearly all of the faults the strike-slip component of movement is large compared to the dip slip. The faults cut the porphyry dikes and, in places, also the ore deposits. Several faults, however, contain ore and tactite that clearly post date the fault movement. Apparently, the bulk of the faulting took place after emplacement of the porphyry dikes and some faulting persisted until after the period of ore formation.

The only major fault in the area strikes about N. 80° E. and dips 75 to 85° N. In the northeastern part of the area it strikes N. 68° E. and dips steeply southward. It is exposed only at a few places but it is easily traceable because it occupies a topographic depression throughout most of its extent. Where exposed in the stream valley in the northeastern part of the area, the fault zone includes 10 to 15 feet of sheared and chloritized rock containing interlacing gouge seams. Seams of epidote in a few places along the fault indicate that the fault may antedate the ore, but some postmineralization movement is indicated by the fact that a diabase dike (believed to be postmineralization) is sheared in the fault zone. Grooves on a wall of the fault, where exposed in the stream valley, plunge 7° E., but it was not determined whether these were produced by early or late movement. There is fairly good evidence that the north wall moved westward at least 585 feet. This calculation is based on the westward displacement of the steeply dipping northeast-trending alkalic granodiorite dike that passes just west of the Stevenstown glory hole. This dike is conspicuously exposed about 150 feet south of the fault, and again 80 feet north of the fault and about 585 feet farther west, where it has the same character, the same width and approximately the same dip. It is, of course, possible that the dike may pinch out south of the fault and that it fills another fracture on the north side. Elsewhere the evidence for fault displacement is less reliable. In the northwestern part of the area there are three large irregular dikes of alkalic dacite which, if correlated correctly, are displaced about 850 feet to the west on the north side of the fault. Because of their irregularities and the fact that the three dikes do not crop out near the fault, the correlation may not be valid.

If a strike-slip movement on the fault of approximately 600 feet is assumed, with the north side moving west, and if the observed grooving that plunges 7° E. is taken as the direction of net slip, a dip slip of about 75 feet would result, the north side being upthrown. There is a suggestion that the dip-slip component may be considerably greater than indicated by these figures. Just south of the fault are several contorted lenses of marble, some of which appear to be cut off by the fault. The stratigraphic interval represented by the marble lenses is not known but is thought to be as much as 200 feet. Marble was not found north of the fault and is presumed to have been removed by erosion after faulting. A stratigraphic throw, and consequently a dip-slip movement, of considerably more than 75 feet would be required to place the marble strata above the present surface.

Two faults of N. 60°–75° W. strike, extend across the north-central and east-central parts of the area, and may be the same fault, although their connection was not traced through the intervening muskeg. These faults dip 75° to 80° S. and are composed of from 1 to 3 feet of sheared rock and gouge. On both faults, the northeast wall has moved northwestward for a distance of 15 to 20 feet. It is believed that they antedate the ore, as small amounts of magnetite and sulfides are segregated along the fissures in places.

Faults having a general northerly strike are the most numerous in the district. They range in dip from 40° E. to vertical and in width from less than an inch to 3 feet. Three faults of this group are exposed in the Mamie adit, 1 in the southeast Mount Andrew workings and 2 in the Mount Andrew 1 adit. Faults and small slips along the walls of some of the dikes probably also belong to this group. On all these faults, except the westernmost one in the Mount Andrew 1 adit, the east wall has moved south, and up or down at a moderate to small angle; the displacements range from a few feet to 30 feet or possibly more. On the fault in the western part of the Mount Andrew workings, the east side has moved downward and to the north at an agle of about 22° and the displacement has amounted to several feet. In the westernmost fault in the Mamie adit small amounts of magnetite, chalcopyrite, and pyrite were deposited in the fissure suggesting that the fault is premineralization. However, there was some postmineralization movement along many of the faults.

Faults of northeast strike are exposed in the Mount Andrew and Mamie workings. They are steeply dipping and appear to be subsidiary to those of north trend. The net displacement does not exceed a few feet.

In the main Mount Andrew workings, there is a group of small faults having a general east trend and a steep but irregular dip. Their widths are at most only a few inches and the displacements amount to only a few feet. On the main fault of this group the north wall has moved east about 3 feet, but on others the north wall has moved west. The faults of northward and northeastward trend appear to be cut by these eastward-trending faults but a small amount of renewed movement on the earlier faults tends to obscure the relationships.

JOINTS AND OTHER FRACTURES

The rocks of the Mount Andrew-Mamie area are intensely fractured. Some persistent joints were noted but the joint pattern tends to be obscured by numerous irregular fractures of random orientation that can be traced for only short distances. For this reason and because of lack of time, no attempt was made to map the joint pattern. Some fracturing is postmineralization. Three fracture sets were observed in a body of magnetite exposed just south of the Mount Andrew southeast glory hole; they cause the magnetite to break into small rectangular blocks.

It will be noted from the map (plate 2) that the dikes have a northerly trend in the western part of the area but trend more to the northeast in the central and eastern parts. This distribution suggests a partial radial pattern with a center lying to the south of the area mapped. The main mass of the early diorite stock lies in this vicinity and it is suggested that the dikes fill radial tension fractures resulting from emplacement and consolidation of the stock. Many of these fractures were reopened shortly after being closed by early dikes and were filled with successively later dikes.

ORE DEPOSITS

GENERAL FEATURES

The mineral deposits of the Mount Andrew-Mamie area are magnetite replacement bodies of a type commonly known as pyrometasomatic or contact metasomatic. Most of the bodies are contorted tabular layers formed by replacement of sedimentary layers in the greenstone sequence. Some of the greenstone is brecciated and was also replaced by magnetite. Small amounts of pyrite and chalcopyrite are disseminated in the magnetite and in the adjacent tactite. Locally rather large irregular masses of chalcopyrite are scattered along the fringes of magnetite bodies, but these are almost entirely mined out. No other metallic minerals were observed in the ores. The wall rocks consist chiefly of tactite. The many dikes that traverse the ore bodies, although premineralization, largely escaped replacement. Marble is in contact with the ore at only a few places and generally was little affected by the ore-bearing solutions.

The distribution of the magnetite deposits in the Mount Andrew-Mamie area is shown on plate 2. There are four groups of deposits, each separated by large areas of barren rock. The Mount Andrew group in the western part of the area includes the largest deposit. It occupies the hill just south of the Mount Andrew workings. Other deposits of various sizes also are exposed in the Mount Andrew workings and in the immediate vicinity. In the central part of the Mount Andrew-Mamie area are numerous small bodies of magnetite scattered over an area about 1,400 feet long and as much as 750 feet in width, that are grouped together and here designated as the east Mount Andrew deposits. The Stevenstown group includes a number of rather small deposits at the Stevenstown mine and on the ridge to the south in the east-central part of the area. The fourth group includes one large deposit and a few small ones exposed in the glory holes and underground workings of the Mamie mine in the northeastern part of the area.

The magnetite deposits range in size from layers a few feet thick and 35 to 50 feet long, to bodies 50 to 100 feet thick and a few hundred feet in length and breadth. These layers are very irregular in detail, thicken and thin in short distances and commonly pinch out abruptly. In most places, several ore layers are interlayered with tactite or greenstone, and on Mount Andrew, south of the main workings, many ore layers of various thicknesses are so intimately interlayered with tactite as to constitute a compound ore body 500 to 600 feet in length and breadth and more than 100 feet thick. Most of the ore layers are much contorted by drag folding, and many of the deposits have a synclinal shape. (See sections on plate 2.) It is believed that all of this folding took place before the deposition of the ore, because the premineralization dikes appear to be undeformed.

There has been very little leaching of the ore deposits in the Mount Andrew-Mamie area. Magnetite at the surface is practically unaltered, and nearly everywhere, unaltered sulfide minerals are in the ore at the surface. However, in most places at the surface, small amounts of the chalcopyrite and the pyrite have been leached from the ore, leaving small cavities containing limonite and, in some places, malachite. This leaching is very slight, however, and does not extend to a depth of more than 10 feet below the surface. As a result of this slight leaching, samples taken at the surface tend to run somewhat lower in copper and sulfur than at greater depth, but there is no indication of secondary enrichment of the ore at depth.

MINERALOGY AND PARAGENESIS

Magnetite is the principal ore mineral in the area and occurs as massive bodies containing only small amounts of sulfide minerals and gangue. Most of the magnetite is medium to fine grained, but in a few places small amounts of platy or bladed magnetite may represent a replacement of original hematite. However, no hematite appears in the area at present except a few microscopic veinlets in some of the Mount Andrew ore and reddish stains on some of the ore and rocks. Chalcopyrite and pyrite are intimately associated and in most places are finely disseminated through the magnetite. They probably make up between 1 and 12 percent of the ore; chalcopyrite is more abundant than the pyrite. Most of the ore is massive, but, locally, magnetite is banded with epidote and other tactite minerals, and in other places the distribution of the sulfide minerals produces an indistinct banding believed to represent original bedding in the layers replaced by ore. Locally, veinlets of chalcopyrite and pyrite penetrate the magnetite. Along the fringes of the ore bodies, especially in the northern part of the mineralized areas, chalcopyrite is most abundant and in the Mount Andrew northwest glory holes rather large irregular masses of chalcopyrite, associated with some magnetite and pyrite, were formed. These constituted some of the richest copper ore mined from the area, but very little of this material now remains.

The gangue minerals include a variety of pyrometasomatic silicates of which epidote is by far the most widespread and most abundant. Garnet, hornblende, diopside, chlorite, orthoclase, and clinozoisite are all common associates of the ore. Calcite is common in most of the deposits and occupies lenticular bands, fills cavities, or cuts the ore as veinlets. Small amounts of quartz are found in a few places, chiefly in the upper Mount Andrew adit where it is associated with chalcopyrite in small cavities and is the last mineral deposited. The tactite minerals are intimately associated with the ore and are commonly finely disseminated through the magnetite, but in places are interbanded with it. Banding is also common in the wall rock where dark bands of fine-grained hornblende alternate with light bands of intergrown epidote, garnet and diopside. The tactite minerals are not only the chief constituents of the wall rocks bordering the ore bodies but also are scattered through the surrounding rocks to distances of 50 to 400 feet from the ore bodies.

The paragenesis of the ore and gangue minerals is not readily determinable but a general sequence of formation was observed. Some of the calcite associated with the ore is coarsely crystalline marble not entirely replaced, and it is, therefore, considered to be one of the earliest gangue minerals. Garnet, diopside, hornblende, clinozoisite, and chlorite appear to be the earliest silicate minerals formed and were about contemporaneous, although the exact age relations between them are not clear. Epidote, though intimately associated with garnet, is slightly later, because in places, it intricately veins garnet. In some thin sections of tactite, calcite grains are surrounded by garnet, which in turn is replaced by epidote. Epidote also occupies irregular replacement veinlets in diopside and locally in chlorite. It seems to be more closely associated spatially with the magnetite than are the other silicates and in places, as in the Mount Andrew glory holes, forms nearly pure masses adjoining the ore. Most of it is slightly earlier than the magnetite, for at some places magnetite veinlets connected with massive layers cut epidote. However, locally, epidote veinlets cut the magnetite, and these apparently belong to a second generation of epidote. Pink orthoclase is intimately associated with epidote in places, and the two appear to be contemporaneous. Commonly they form veinlets that cut earlier fine-grained orthoclase.

Magnetite is later than most of the silicate minerals. Veinlets of magnetite are found cutting epidote, and in thin sections magnetite is seen to penetrate along grain boundaries, small fractures and cleavage cracks of garnet, diopside, and epidote. In nearly all the massive magnetite ore, diopside, hornblende, epidote, and some garnet and clinzoisite are finely disseminated and appear to be contemporaneous with the magnetite, or slightly earlier. Some coarse-grained chlorite is associated with magnetite in the Mamie mine and appears to be slightly younger than the magnetite. The sulfide minerals are later than nearly all of the magnetite, although very small amounts of magnetite seem to be contemporaneous with chalcopyrite. Chalcopyrite and pyrite are disseminated in the magnetite as small irregular replacement grains; some appear to have replaced silicate minerals in the magnetite. Minute veinlets of chalcopyrite, in places intergrown with pyrite, are common in the massive magnetite. Though the two sulfides are intimately associated, chalcopyrite appears to be slightly later because it commonly surrounds euhedral grains of pyrite and locally penetrates along fractures in the pyrite grains.

In the Stevenstown glory holes chalcopyrite and pyrite are intergrown with coarse, bladed crystals of dark-green hornblende and some calcite. Veins of this material cut the other silicate minerals, including fine-grained hornblende. Some of the coarse hornblende blades are as much as 4 inches long. Elsewhere in the area, small amounts of this late hornblende are intergrown with chalcopyrite in veinlets. In the Mamie mine, veinlets of coarse-grained chlorite, calcite, and chalcopyrite are found in some fault fissures near the ore. In an opencut, 375 feet S. 40° W. of the portal of the Mount Andrew 1 adit, chalcopyrite is associated with a peculiar finely banded dense green material that cements a breccia of mixed magnetite and tactite. This material is made up of a nearly equigranular mosaic intergrowth of magnetite, quartz, calcite, garnet, epidote, hornblende, chlorite, and chalcopyrite. Dark bands contain a preponderance of magnetite and light bands a preponderance of quartz and calcite. Very small veinlets of the material were also found in the Mount Andrew northwest glory hole, but it was not observed elsewhere in the area.

Calcite veinlets are common in the ore throughout the area and most of them appear to be later than all other minerals except quartz. In the Mamie mine veinlets of pink calcite cut the marble adjacent to the ore and some faults.

Quartz is the latest mineral deposited and is found only in very small amounts in the Mount Andrew mine. It occurs in small veins in the western part of the Mount Andrew workings, and in the no. 2 adit a little quartz is found in the center of small calcite-lined cavities in the ore.

ORIGIN

Most of the ore in the Mount Andrew-Mamie deposits is believed to have been formed through the replacement of calcareous sedimentary layers by magnetite and sulfide minerals. In a few places in the Mount Andrew, Mamie, and Stevenstown mines, magnetite bodies are in contact with marble layers, and the irregular contacts transgressing the bedding, (fig. 30), clearly indicate that magnetite has replaced calcareous material. Also, the occurrence of most of the magnetite in contorted layers that thicken, thin, and pinch out abruptly, as do the sedimentary layers, lends support to this conclusion.

Locally, small lenses of marble were subjected to the ore-bearing solutions and both calcite marble and dolomite marble are replaced by magnetite. However, where dolomite is adjacent to ore, as in the Stevenstown east glory hole and in the Mamie mine, it is partly replaced by calcite; this leads to the surmise that the calcite may have proceeded in advance of magnetite and thus the latter may have replaced calcite. There is considerable indication that some, and perhaps much tactite also was replaced by magnetite. In some of the Mount Andrew workings, breccia fragments of greenstone are enclosed by magnetite with irregular replacement contacts, and in several thin sections of tactite small masses of magnetite irregularly replace grains of silicate minerals. In low-grade ore bodies where

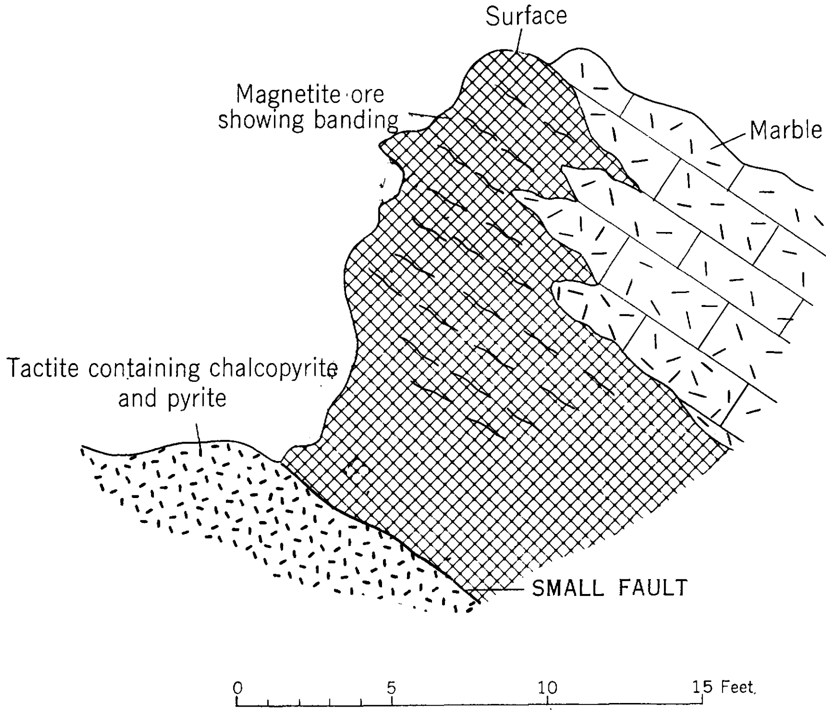

FIGURE 30.—Sketch showing the contact of magnetite with marble, as exposed in the Stevenstown east glory hole.

magnetite is interlayed with tactite, the former irregularly penetrates the latter. It is probable that much of the low-grade ore in the area has resulted from replacement of the tactite by magnetite, but it seems equally probable that most of the high-grade ore has resulted from replacement of calcareous rocks. Of course, it is possible that some layers were first replaced by tactite minerals, which were replaced in turn by magnetite or sulfide minerals. Such may have been the origin of the siliceous copper ore in the Stevenstown glory holes and in parts of the Mount Andrew workings.

Crenulated layers and lenses of nearly pure marble occur in an eastward trending zone just south of the prominent fault bordering the northern margin of the Mount Andrew-Mamie area. As elsewhere on Kasaan Peninsula, the marble contains practically no ore, though in places, as at the Mamie mine, layers of magnetite terminate against marble. Apparently conditions were not favorable to widespread replacement of marble by ore and tactite minerals. The reason may be that at the time of mineralization the marble was undergoing recrystallization and plastic flow and was thus relatively free from fractures along which the ore-bearing solutions would have access to these rocks. However, the ore bodies, which occupy a broad zone south of the marble belt, closely resemble the crenulated marble lenses in shape and structure, suggesting that the ore replaced rocks mainly of sedimentary origin. Diamond drilling in the Mount Andrew area revealed the presence of many brecciated lenses and fragments of fine-textured, banded material in various stages of replacement by ore and tactite. Although the true character of these rocks largely is obscured by alteration products, petrographically they resemble clastic sediments which in part were highly calcareous, as indicated by the presence of recrystallized calcite. In folding, these rocks, unlike the marble, were broken and brecciated and were thus readily accessible to the ore-bearing solutions and therefore more susceptible to replacement. Intervening layers of greenstone were also brecciated and in part replaced by ore. The presence of mapable lenses and layers of calcareous clastic sediments in greenstone elsewhere on the peninsula supports this conclusion.

The solutions that deposited the magnetite probably ascended along the walls of dikes, as well as along crosscutting faults. In nearly all of the magnetite deposits premineralization dikes are numerous and small slips and fractures along the walls are common. Magnetite seems to be more concentrated close to the walls of dikes than farther away, and in the Mount Andrew northwest glory hole some rather large masses of chalcopyrite were concentrated along the walls of the dikes. It is believed that the ore deposits of the area were largely localized at the intersections of dikes and faults with replaceable layers in the country rock.

The amount of chalcopyrite in the ore seems to increase from south to north and most of the copper ore already mined came from the northern edge of the mineralized area. This suggests a zonal arrangement, simulating on a small scale the conditions described by Newhouse (1933, p. 628–633) for the Triassic area in the central Appalachian region. Here magnetite is found chiefly in the central part of the region and copper minerals chiefly at the ends of the mineralized zone and along its margin. Newhouse attributes the arrangement to temperature control with respect to the Triassic land surface. The distribution of chalcopyrite and magnetite in the Mount Andrew-Mamie area might be similarly explained as a function of temperature, if a common source for the ore-bearing solutions is assumed to have been below and south of the area. Magnetite might be expected to be more abundant near the source and chalcopyrite to increase in amount at greater distance from the source. It this event, it is unlikely that copper is concentrated along the underside of the Mount Andrew compound ore body. The chalcopyrite content would tend to decrease southward and with depth.

RESULTS OF MAGNETIC SURVEY

By Matt S. Walton, Jr.

GENERAL FEATURES

A magnetic survey of the Mount Andrew-Mamie area, using the dip needle and Brunton compass, was made in conjunction with the geologic and topographic mapping. The Lake-Superior-type dip needle (Clements and Smyth, 1899, p. 342–343; Hotchkiss, 1915, p 97–107) was used in this survey. The needle was counterbalanced by a weight on the south-seeking pole so that it was approximately horizontal in the normal magnetic field of the earth. In taking observations, the instrument was oriented with the plane of rotation of the needle parallel with the local magnetic meridian. Anomalies in horizontal declination were measured throughout the area at all stations where the dip needle was read. For this purpose a Brunton compass was used where a backsight could be taken along a line with known orientation, but in a few places where a backsight was impractical a solar compass was used.

It was not possible to use a magnetic compass freely for traversing or for making structural observations. Therefore the geologic and magnetic work required close instrumental control. This was provided by the topographic survey which was made by plane table and telescopic alidade. Dip-needle observations were made at 100-foot intervals throughout the area, and for this purpose a grid of 100-foot squares was used. In the vicinity of the Mount Andrew mine, magnetic observations were made at 50-foot intervals, corresponding to a 50-foot grid. The points on the grids were located in so far as possible by rod shots from the plane table, which was oriented with respect to true north. True bearings from the plane table to the grid points were thus established and anomalies in declination were computed from the backsight magnetic bearings obtained with the Brunton compass.

Dip-needle deflections recorded throughout the area are contoured with an interval of 10° on plate 3. Plate 4 shows the distribution of anomalies in declination, also contoured on a 10° interval. On plate 5, magnetic profiles are shown in relation to cross sections on which the major magnetite occurrences have been plotted.

Detection of magnetic anomalies with the dip needle and Brunton compass does not yield data that will permit precise quantative analysis. The magnitude and distribution of the anomalies, however, may be analyzed qualitatively and inferences may be made as to the location, attitude, and probable extent of the magnetic bodies. Both the geologic and the magnetic surveys indicate that the major structures of the Mount Andrew-Mamie ore bodies are relatively simple, but these are complicated by minor folding of discontinuous layers and lenses that pinch out or swell to considerable thickness within short distances. The topography is also irregular and many of the ore bodies are at or near the surface. These complexities result in an irregular pattern of anomalies which, at many places, is difficult to interpret with assurance except in conjunction with detailed geologic and topographic control. The magnetic data were compiled and interpreted prior to drilling in the Mount Andrew area by the U.S. Bureau of Mines, the intent being to furnish all possible information to guide this work. In general there is a rather close correlation between the situation as inferred from magnetic data and that revealed in the drill cores.

INTERPRETATION OF DATA

Any body with high magnetic permeability becomes magnetized by induction in the earth's magnetic field. In the northern hemisphere, particularly in northern latitudes where the inclination of the earth's field is steep, the upper part of the body has induced polarity corresponding to the north pole of the earth. It therefore attracts the north-seeking end of the compass needle and produces north deflections of the dip needle. Thus, in general, north dips are observed in the vicinity of magnetite outcrops. In most cases the "south" pole of the body is buried, but if the body is flat-lying or plunging to the south at a moderate angle, or if the combination of topographic relief and the attitude of the body is appropriate, the south pole may be at or near the surface, near the northern end of the body, and the south-seeking end of the compass and dip needle will be attracted.

Many of the areas of south dip shown on plate 3 may be thus accounted for. The effect is noted particularly where the magnetite bodies are nearly flat and have been dissected by erosion, as in the east Mount Andrew group. At the Mamie mine, south dips were found north and east of the area of high north dips, indicating that the ore bodies form a bipolar magnetic unit, exposed at the upper end to the north and dipping southeasterly. The eastern margin of the Mount Andrew compound ore body, about 500 feet south of the main Mount Andrew dump, is formed by a north-trending ridge of magnetite. The ridge lies mainly within an area of north dip and is bounded on the north and east by areas of south dip (pls. 2 and 3). The south dips obtained east of the ridge perhaps reflect the influence of the under side of the magnetite body, which dips rather steeply westward. The area of south dip at the north end of the ridge suggests a south pole near the surface and indicates that the ore does not extend much north of its outcrop at this locality. Between the main Mount Andrew adit portal and the glory holes, and for the most part south of the line of the main adit, is an area of steep north dips. Immediately north of this area, steep south dips were found. (See section *B–B'*, pl. 5.) A continuous bipolar body which is fairly shallow in proportion to its length is indicated. Magnetite is exposed at the surface and in the workings below. Elsewhere in the Mount Andrew-Mamie area more complex relationships are found and the effect of polarity is not readily distinguished.

Two northward-trending zones of dikes traverse the Mount Andrew compound ore body (pl. 2) and constitute rocks of low magnetic permeability within the magnetite. These zones are clearly outlined by elongate areas of south dip (pl. 3). The muskeg just south of the Mount Andrew workings appears to be underlain largely by barren greenstone and south dips were indicated throughout. Apparently the dip needle may be relied upon to reveal large masses of waste rock within and between bodies of magnetite. The areas of south dip associated with such masses are similar to those resulting from polarity, and geologic data are needed to avoid confusion.

The area of the Mount Andrew glory holes is one of high magnetic anomalies with south dips prevailing. Steep south dips were also noted in the area of the Stevenstown glory holes. In general, excavations from which much magnetite has been removed appear to be characterized by south dips, and this condition does not indicate the presence or absence of additional ore in the vicinity. Considerable magnetite is found in the workings beneath the Mount Andrew glory holes, whereas none is in the tunnel beneath the glory holes at the Stevenstown mine.

The areas of horizontal (declination) anomaly correspond in a general way to those of dip-needle deflection. The structure of the Mount Andrew compound ore body is somewhat more clearly outlined by the former than by the latter (pls. 2, 3, and 4). At most places there is rather close correlation between areas of westward anomaly and those of north dip, as illustrated by the magnetic profiles (pl. 5). The maxima for north dip and westward declination lie approximately above the ore bodies and are apparently related to the attitudes of the ore bearing layers. Where the layers are steeply inclined or vertical, the profiles for north dip and westerly declination are virtually superimposed. Where the layers are more gently inclined the two curves do not coincide. At most places the slope of a line drawn through the two maxima is in the general direction of dip of the ore body. Where the body is essentially flat this criterion is not applicable, as the maximum for westerly declination generally has a larger value than that for north dip and the line joining the two maxima is rarely horizontal. Close inspection of the magnetic profiles suggests that the horizontal distance between the two maxima at a given locality is in general inversely proportional to the dip angle of the ore-bearing layers. Certain obvious exceptions to these generalizations are noted on the magnetic maps and profiles. These discrepancies may be due in part to local structural complexities and to the influence of topography.

Comparison of the geologic and magnetic maps will show that at most places the magnetic anomalies are in the vicinities of magnetite outcrops and that in areas where such outcrops are absent the magnetic readings are essentially normal. An important exception is in the area about 700 feet west of the main adit portal of the Mount Andrew mine where steep north dips were found although no magnetite is exposed. Immediately north and at a lower elevation is an area of steep south dips. On the basis of criteria outlined above, a buried ore body, tabular in form and dipping southward at a moderate angle, was inferred to lie at shallow depth. Subsequent diamond drilling proved the presence of several flat-lying layers of magnetite at an average depth of about 100 feet. It is extremely doubtful that this ore body would have been detected without recourse to magnetic methods.

RESERVES

GRADE

Ten samples of iron ore, believed to be representative of the deposits in the Mount Andrew-Mamie area were taken by the Geological Survey in September 1942. These samples were analysed in the chemical laboratory of the Geological Survey and the results are given in table 3. Of the 10 samples, 7 are from the

TABLE 3.—*Analyses of iron ore samples taken by the U.S. Geological Survey, Mount Andrew-Mamie area, September 1942*

[Analyses by V. North, U.S. Geol. Survey samples 1–7 from Mount Andrew mine and vicinity, samples 8–10 from Mamie mine]

Sample No.	Fe	Cu	S	Ti	Sample No.	Fe	Cu	S	Ti
1	62.00	0.04	0.06	0.05	6	53.23	0.98	1.29	0.05
2	57.74	.06	.01	.04	7	49.49	.52	1.23	.06
3	50.46	.56	1.50	.05	8	58.37	.26	1.69	.03
4	43.66	.28	.54	.09	9	53.40	.90	3.88	.07
5	41.92	.84	1.08	.11	10	59.18	.48	2.41	.03

LOCATIONS OF SAMPLES

1. 7½-foot sample cut along south side of 12-foot adit in cliff 510 feet S. 8° E. of portal of Mount Andrew main (no. 1) adit.
2. 20-foot vertical sample on cliff 580 feet S. 6° E. of portal of Mount Andrew main (no. 1) adit.
3. 40-foot sample across magnetite body in glory hole, 275 feet S. 20° W. of portal of Mount Andrew main (no. 1) adit.
4. 14-foot sample across cut at south end of stripped area, 625 feet S. 40° W. of portal of Mount Andrew main (no. 1) adit.
5. 10-foot sample taken on footwall of magnetite body in glory hole, 275 feet S. 20° W. of portal of Mount Andrew main adit. Epidote-garnet rock containing rather abundant magnetite, chalcopyrite and pyrite.
6. 15-foot sample cut diagonally across magnetite body in stope 650 feet S. 80° W. of portal, Mount Andrew main (no. 1) adit. Magnetite containing rather abundant chalcopyrite and some pyrite.
7. 11-foot sample across syncline of magnetite ore in small stope 110 feet S. 65° W. of portal, Mount Andrew main (no. 1) adit.
8. 6-foot vertical sample across bedding in drift 250 feet S. 62° W. of portal, Mamie main adit.
9. 6-foot vertical sample taken in drift between two large stopes, 345 feet S. 13° W. of portal, Mamie main adit.
10. 6-foot vertical sample across bedding on west wall of big stope, 365 feet S. 10° W. of portal, Mamie main adit.

Mount Andrew group of deposits and 3 from the Mamie mine. No samples were taken from the east Mount Andrew group or from the Stevenstown group, but these deposits are small and on inspection show no marked differences from the ores sampled.

Extensive sampling was carried on by the U.S. Bureau of Mines in connection with trenching and diamond drilling of the Mount Andrew deposits during the period from September 1943 through September 1944. The adjusted and weighted average for all samples taken by the Bureau of Mine is as follows (Wright and Tolonen, 1947, p. 22):

	Percent		*Percent*
Iron	47.8	Phosporous	Tr.-0.01
Copper	0.32	Sulfur	0.71
Insoluble	25.8		*Ounces per long ton*
Alumina	4.0	Gold	0.011
Calcium oxide	3.5	Silver	0.55

The sampling indicates that the magnetite deposits of the area range in grade from about 42 percent to 62 percent iron, the average being close to 50 percent. The copper content ranges from 0.02 percent to more than 1.0 percent and the average lies between 0.30 and 0.50 percent. The sulfur content ranges from 0.01 percent to 3.88 percent in the samples, being lowest in slightly oxidized ore in the southern part of the Mount Andrew compound ore body and highest in the Mamie mine. The percentage of other constituents is very low. The titanium content is as much as 0.11 percent and traces of phosphorous, nickel, cobalt, chromium and vanadium were found. The gold and silver content of the magnetite ore is very small but considerable amounts of both were recovered from copper ore mined in the past. (See table 2.)

Geological Survey samples 1 and 2 (table 3) were obtained from a cliff of nearly pure magnetite on the southeastern side of the Mount Andrew compound ore body. They probably do not represent a large tonnage but are thought to be typical of the high-grade ore in this vicinity. Samples 3, 6, and 7 are believed to be representative of the better grade ore in the northern part of the Mount Andrew mine workings. Sample 4 was taken from a place where gangue comprises about one-third of the ore, and the iron content is probably fairly representative of the low-grade ore of the Mount Andrew–Mamie area. The sample, taken at the surface, showed a small amount of oxidation and, therefore, the copper and sulfur contents are probably somewhat low. Sample 5 was taken from the footwall of a magnetite body and was intended to represent the copper ore still remaining in some of the workings. However, the copper content is no higher than in some of the magnetite ore, although the iron content of 41.92 percent is high enough to make it a low-grade iron ore. Samples 8, 9, and 10 were taken in the Mamie underground workings and are believed to be representative of the magnetite ore still left in the Mamie mine. In iron and copper content the samples are similar to those obtained from the Mount Andrew workings, but the sulfur content of the Mamie ore is higher, suggesting a larger amount of pyrite.

In the east Mount Andrew group and the Stevenstown group of deposits, the ore bodies are small and interbedded with tactite. It seems likely therefore, that they are of lower grade than most of the Mount Andrew and Mamie ore bodies and probably average between 40 and 50 percent iron. Their copper and sulfur content is estimated to be about the same as that of the samples taken in the Mamie mine, that is, from 0.26 to 0.90 percent copper and from 1.69 to 3.88 percent sulfur.

The grade of the copper ore mined from the Mount Andrew-Mamie area was calculated from information in table 2 and the results are shown in table 4. The ore was of two types (Wright and Paige, 1908, p. 103). One was magnetite ore of the type remaining in some of the stopes and represented by samples 3, 6, 7, 9 and 10 of table 3. It apparently contained between 48 and 60 percent of iron and between 0.5 and 1.0 percent of copper. It was classed as "base ore" because of its high iron content. The other type, classed as "siliceous ore," was made up of tactite containing some magnetite, chalcopyrite, and pyrite. The copper content of this ore ranged from 1 percent to about 5 percent and apparently some ore in the Mount Andrew mine was of still higher grade (Brooks, 1902, p. 102). There is very little of this type and grade of copper ore left in the mine workings. Along the borders of some of the magnetite bodies are zones of tactite from a few feet to about 20 feet wide containing magnetite and small amounts of

TABLE 4.—*Grade of copper ore mined in the Mount Andrew-Mamie area, 1905–18* [1]

Year	Ore (tons)	Copper (tons)	Copper (approx. percent)
1905	20, 659	597	2. 89
1906	58, 617	1, 478	2. 52
1907	41, 075	1, 027	2. 50
1908	17, 332	488	2. 82
1909	8, 385	350	4. 30
1910	9, 547	328	3. 44
1911	6, 100	209	3. 42
1915	37, 775	492	1. 31
1916	51, 307	928	1. 81
1917	7, 529	201	2. 67
1918	12, 400	313	2. 52
Total or average	270, 726	6, 411	2. 37

[1] No production, 1912–14.

chalcopyrite and pyrite. Sample 5 (table 3) taken from the Mount Andrew southeast glory hole is believed to be fairly representative of this type of ore still left in the workings.

TONNAGE

Iron ore reserves of the Mount Andrew-Mamie area are estimated to total about 2,684,000 long tons. About 2,289,000 tons is classified as indicated ore and 395,000 tons as inferred ore. About 80 percent of the total is contained in the deposits of the Mount Andrew group, mainly in the compound ore body south of the Mount Andrew mine workings. The bulk of the remainder is at the Mamie mine. The reserves of the east Mount Andrew deposits and the Stevenstown mine are small.

The reserves were computed largely on the basis of the geological mapping, the interpretation being partly substantiated by magnetic data and locally by drilling. The buried ore body which was indicated by magnetic data is included with the inferred reserves, as data from the drill holes is insufficient to warrant classifying it as indicated ore.

No ore has been accurately blocked out in the Mount Andrew-Mamie area, although considerable ore is exposed in the walls and backs of many of the stopes and was logged in several of the drill holes. Estimates of indicated ore are based in part on measurements and in part on geological interpretation of data from outcrops, diamond drilling, and magnetic observations. The inferred ore is based entirely on geologic interpretation of outcrops, magnetic data, and drill records, and includes some supposed ore bodies that do not appear on the surface.

MINES AND PROSPECTS

MAMIE MINE

The Mamie mine, owned by Granby Consolidated mining, Smelting and Power Co., Ltd., is in the northeastern part of the Mount Andrew-Mamie area, 1¼ miles south of Hadley and 1 mile north of Boggs landing. It can be reached by following the old tramline south from Hadley or by 1½ miles of poorly defined trail from Boggs landing. (See pl. 1.) The main adit portal is at an altitude of 750 feet.

The Mamie mine was first opened between 1898 and 1902. In 1905 a 350-ton smelter at Hadley was put into operation to treat the Mamie ore, but it operated only a little more than a year. The mine was operated intermittently until 1918, when it was finally shut down. Several thousand feet of drilling was done at the Mamie mine prior to 1918 and although some of the cores are still on the property, no data are available as to the location of the drill holes. No usable equipment is left at either the smelter or the mine and nearly all buildings are down. Those still standing are shown on plate 2, but they are too weatherbeaten for use. Between 1906 and 1918, the Mamie mine was one of the most productive copper mines on Kasaan Peninsula.

The Mamie workings consist of 3 glory holes, 3 adits, a shaft and many drifts and crosscuts, which according to Wright (1915, p. 89) aggregated 5,000 lineal feet in 1908. In 1942, only the main adit, aggregating about 2,200 lineal feet, and the Preston adit, 130 feet long, were accessible; the shaft, shown by Wright (1915, pl. 20) as 300 feet deep with 4 levels, was caved and full of water below the main adit level, and an upper adit was largely caved. As shown in plate 6, there are many stopes on the main adit level and some of these connect with the upper workings.

GEOLOGY

Many types of rocks are exposed in the Mamie mine and vicinity, but these are so disturbed by folding and faulting that their relationships are not entirely clear. On the surface, tactite and greenstone are intruded by large irregular dikelike and sill-like masses of early diorite and by smaller dikes of andesite, diorite porphyry, and alkalic dacite. Just north of the workings is a large irregular body or marble that has the general shape of a steep northerly pitching syncline.

In the main adit, (pl. 6) the irregular main ore layer occupies much of the workings. Tactite and greenstone are interlayered with the ore. Marble, cut into many blocks by faults, is exposed chiefly in the northern part of the workings and is in contact with the ore. A large mass of diorite occupies the western part of the adit workings and is bordered on the east by a northward-trending fault. The diorite is much chloritized and in places epidotized. Just east of the main diorite mass, irregular apophyses of epidotized and albitized diorite penetrate the tactite and ore.

The Mamie mine is on the west flank of an irregular syncline. (See sections, pl. 6.) The ore layers dip steeply east from the surface to the main adit, where they flatten to very shallow dips. Minor folding greatly complicates the structure. Just northwest of the northwest glory hole, banding in the ore curves around the nose of a rather tight anticline.

In the main adit the ore and wall rocks are cut by many faults, none of which show large displacements. The fault that borders the diorite mass in the western part of the workings strikes north to N. 20° W. and dips steeply east. This fault also is well exposed in the northwest glory hole, where grooves in the wall indicate that the east side moved southward and down at a rather low angle.

The amount of displacement could not be determined, but it is thought to be not more than 25 or 30 feet. The fault is marked by 1 to 15 inches of sheared rock and gouge. A prominent reverse fault extends through the central part of the Mamie workings but is not exposed at the surface. It strikes from N. 5° W. to N. 12° E. and dips 40° to 65° E.; the fault zone contains 1 to 3 feet of sheared rock and gouge. Grooves in the walls indicate that the west or footwall side moved down to the north at 35° to 60°. Judging from displacement of the marble layers the amount of displacement on the fault is between 25 and 40 feet. A third fault in the eastern part of the workings strikes N. 15° to 40° W. and dips steeply either east or west. The fault zone ranges from a few inches to a few feet wide, and grooves on the wall indicate that the east wall moved northward and down at 70°. The displacement is probably at least several feet.

Between these three faults are many branched and cross faults that strike either northwest or northeast, dip steeply, and interlace. Displacement on most of them is not more than a few feet. The faulting began earlier than the later stages of ore deposition, as many of the faults contain fracture fillings of magnetite, pyrite, chalcopyrite, and some of the later tactite minerals. However, the ore layers have been displaced along some faults, indicating that movement continued after much of the ore had been deposited.

ORE DEPOSITS

Most ore in the Mamie mine appears to consist of one contorted layer that dips steeply eastward from the surface through the upper stopes to the main adit level. Here it flattens and, in the northeastern part of the workings appears to give place to marble. (See pl. 6.) This layer ranges from 15 to 50 feet thick, averaging about 30 feet, is at least 500 feet long in a north-south direction, and extends from the surface to the eastern part of the main adit. Whether it extends much below the main adit level has not been ascertained, but from the structure it appears probable that most of the ore is above that level. On the magnetic map (pl. 3) lines of rather steep north dips in the vicinity of the Mamie ore body flare out southward and suggest that the main ore body may plunge to the south and may extend 200 to 300 feet south of the ore on the main adit level.

Four other small lenticular bodies of magnetite are exposed in the Mamie workings and vicinity. On the surface, 50 to 75 feet east of the main layer, is a lens of low-grade magnetite ore about 125 feet long and 10 to 30 feet thick. Its depth is not known. The lens lies stratigraphically above the main ore layer. A very thin lens of magnetite that lies nearly parallel to the surface is exposed in the two southern glory holes, and is largely mined out. It is about 10 to 15 feet thick, 125 feet long, and 60 feet broad. Another flat, thin lens of magnetite, about 5 feet thick and more than 50 feet long, is exposed in the Preston adit just below the glory holes. A fourth lens of magnetite underlies the main ore layer in the main adit. It is exposed in the western part of the Mamie adit workings just southeast of the shaft where it is about 125 feet long and 20 to 30 feet thick. The ore above the adit level has been mostly mined out but a comparable amount of ore may lie below this level.

No data are available as to whether any other ore bodies lie below the main adit, although several stopes below the adit level have followed the main ore layer possibly to a depth of 20 or 30 feet. Wright's map (1915, pl. 20) shows a few stopes on the lower levels that are now flooded. These indicate that there probably are some showings of ore in these levels.

Nearly all the ore in the mine is massive high-grade magnetite containing finely disseminated chalcopyrite and pyrite. Small amount of gangue minerals also are disseminated through the ore. Chalcopyrite and pyrite are present in the tactite bordering magnetite bodies. Some of this material was mined as copper ore, but that remaining is small in amount and does not contain enough chalcopyrite to constitute ore. The zone of disseminated sulfide minerals commonly extends only a few to several feet from the magnetite layer, but locally it is 20 feet wide. For the most part, the sulfide minerals are disseminated in the tactite along the underside of the main ore layer and between it and the underlying small ore layer.

Three samples taken from the Mamie mine (see table 3) indicate that the magnetite ore ranges in grade from about 53 to 59 percent iron and contains from 0.26 to 0.90 percent copper and from 1.69 to 3.88 percent sulfur. No gold or silver was found in the samples. No attempt was made to sample the tactite containing disseminated sulfide minerals because of the small tonnage available. The average metallic content of the copper ore produced from 1906 to 1918, as calculated from data in the files of the U.S. Geological Survey, is as follows: copper, 1.81 percent, gold 0.0204 ounces per ton, and silver 0.126 ounces per ton.

FUTURE POSSIBILITIES

There are no indications of new, unexposed ore bodies in the Mamie mine. As shown on plate 6, the structure indicates that the ore bodies exposed on the adit level do not extend to any great depth below the adit. It is possible that other ore bodies lie at greater depth, but the complex diorite body exposed in the western part of the adit probably occupies much of the ground beneath.

Before any program is planned for exploration of the Mamie mine at greater depth the shaft should be unwatered and a detailed examination made of the lower workings. However, this procedure is not recommended unless mining is contemplated or actually started in the area.

On the main adit level, the boundaries of the main ore body are fairly well determined except in the southeastern part. Here good magnetite ore is exposed in the walls of two stopes and the structure and magnetic data suggest that this ore may extend for considerable distance to the south. This locality could either be explored by steeply dipping inclined drill holes from the surface or by nearly horizontal drill holes extending south from the south stopes on the main adit level. The latter holes, however, would be nearly parallel to the structure and even though they were to indicate the presence or ore, they probably would not give adequate data as to thickness.

MOUNT ANDREW MINE

The Mount Andrew mine is in the western part of the Mount Andrew-Mamie area, 1.4 miles S. 22° W. of Hadley and 4 miles S. 70° E. of Kasaan. (See pl. 1.) It is reported to be owned by the estate of the late H. Herbert Andrews, represented by Messrs, Jarvis, Barber & Sons, Post Office Box 20, Sheffield, England. The principal mine workings, which range in altitude from 1,290 to 1,392 feet, are in a shallow depression on the northeast side of Mount Andrew, but most of the magnetite ore lies south of the mine workings. In this vicinity magnetite ore is exposed over a range in altitude from 1,270 to 1,485 feet. The mine can be reached by a tortuous route passing through the Stevenstown tunnel from the Mamie mine, or by trail from Mount Andrew Landing on Kasaan Bay.

The Mount Andrew deposits were first prospected in 1898, and in October 1906 the first ore was shipped to the Tacoma smelter. During the next 12 years the mine was worked intermittently and produced a significant tonnage of copper ore. Early in 1918 it was shut down and has not operated since. Considerable diamond-drilling was done in the mine, according to Axel Carlson, former superintendent, and some of the cores are still near the adit 1 portal, but no records of the drilling are available. No equipment is left at the property and two houses still standing were repaired and used as quarters for diamond-drilling crews by the U.S. Bureau of Mines in 1944.

The principal workings (pl. 7) consist of a group of 4 glory holes, 3 adits, several winzes and a sublevel, all aggregating about 3,000 feet in length. The portal of the main (No. 1) adit is at an altitude of 1,338 feet, and the sublevel is 50 feet below this. No. 2 adit is at an altitude of 1,392 feet. No. 3 adit, a long crosscut whose portal is on the west side of the muskeg in the central part of the Mount Andrew-Mamie area, extends N. 65° W. for 1,525 feet and explores the ground at a depth of 300 feet below the main adit. No workings explore the large compound ore body south of the Mount Andrew mine except for one glory hole at the northern edge and a 12-foot adit in the cliff on its eastern border.

GEOLOGY

The geology of the vicinity of the Mount Andrew mine is shown in plates 7 through 11. The chief rock is greenstone, more or less altered to tactite containing epidote, garnet, hornblende, diopside, chlorite, orthoclase, and in places chalcopyrite and pyrite. Small scattered lenses of marble are exposed just north of the Mount Andrew workings and in the sublevel 50 feet below the main adit. Throughout the vicinity of the mine and particularly in the glory holes, the tactite and magnetite ore are intersected by a large number of north-trending, steeply dipping dikes of gabbro, diorite, and alkalic rocks. A large irregular body of early diorite crops out on the south side of Mount Andrew, and apophyses penetrate the bordering greenstone, tactite, and ore.

The major structural feature in the vicinity of the Mount Andrew mine is a syncline that measures about 500 to 600 feet from crest to crest and is bordered on either side by rather sharp anticlines. (See pls. 9 and 11.) The axis of this syncline trends about N. 10° W. and is fairly flat though undulating in the area south of the mine workings, but in the northern part of the workings, it appears to plunge steeply north, apparently on the north limb of a broad anticlinal cross fold. North of this point the surface is largely covered and the structure is obscure. In the area of the large compound ore body, south of the mine workings, the syncline appears to be a broad basin but in the southern part of the Mount Andrew workings it is constricted by a small dome lying between the main adit portal and the southeast glory hole. This constriction seems to continue farther north but the structure is greatly complicated by the many dikes and the faults exposed in the northern group of glory holes. A similar syncline lies just to the west and occupies the west part of the top of Mount Andrew.

Many small faults are exposed in the Mount Andrew workings, but on none does the displacement appear to be more than a few feet. Several faults of northward trend and steep dip parallel the dikes and in places follow their walls. On most of them the east wall has moved northward and down at a low angle. A few faults of northeast strike seem to be related to the northward-trending set, but on these the northwest wall has moved northeastward. Irregular faults of a general eastward trend cut the north and northeast-trending faults and in the vicinity of the north glory holes, form a complex pattern. On some of these the north wall moved eastward, and on others, westward. A few faults of northwest strike are found in the workings, but their relation to the other faults is not known. Beyond the limits of the workings, no faults were observed, probably because the outcrops are sparse.

ORE DEPOSITS

The ore deposits in the Mount Andrew mine and vicinity are composed of massive high-grade magnetite containing disseminated chalcopyrite and pyrite. The ore bodies are contorted layers that range in thickness from a few feet to more than 50 feet and thicken, thin, and pinch out abruptly. The wallrock is chiefly tactite in which epidote predominates, but garnet, hornblende, diopside, orthoclase and other silicates are common. In many places the ore bodies are separated or intersected by various dikes ranging from a few inches to 80 feet in width. In places along the borders of the ore bodies, particularly in the northern part of the workings, there are zones in which the tactite contains disseminated chalcopyrite and pyrite and locally irregular masses of chalcopyrite from a few inches to a few feet in diameter. Some of this material was mined as copper ore and a few such masses are left on the walls of the glory holes.

Most of the magnetite ore near the Mount Andrew mine is localized in one compound ore body that occupies the southeastern part of Mount Andrew. This body is a syncline about 600 feet long in a north-south direction and 550 feet wide. A tongue of this ore extends over into the next syncline to the west. The ore body is made up of many contorted layers of magnetite interlayered and interfingered with tactite and greenstone. On the basis of surface exposures it appears that the magnetite layers are more or less connected and enclose lenticular layers of waste rock, although the reverse could be true. Much of the magnetite ore shown on plate 8 probably contains some tactite that is not indicated, either because the layers are too small or because they are not exposed at the surface. Along the northern border of the ore body, the magnetite layers appear to finger out into tactite and are probably not continuous with other layers exposed in the Mount Andrew workings.

The bottom of the syncline as determined from diamond drill-hole and structural data, is about 200 feet below the surface (pls. 9 and 10). The roof of the early phase diorite stock exposed just south of the compound ore body appears to plunge northward and pass beneath the syncline. Its contact trends southward on the cliffs at the south edge of the area, and the diorite is not exposed in the lower Mount Andrew workings to the north, or in the drill holes. The positions of the many dikes that traverse the ore body are fairly well indicated by surface exposures and by magnetic and drill-hole data, but it is quite possible that there are dikes that were not mapped. The magnetic data suggests that the dikes in the eastern part of the ore body are larger or more numerous beneath the surface than is indicated by outcrops (pls. 2 and 3).

On the basis of the structural, magnetic and drill-hole evidence, it seems probable that the compound ore body has an average thickness of about 125 feet and that about half its volume is magnetite ore, the rest being of barren greenstone, tactite, and dike rocks. There is very little copper ore in this deposit.

The tongue of ore extending west from the compound ore body into the next syncline is separated from the main body by a group of dikes. The tongue is about 300 feet long and on the basis of structural and drill-hole data the ore is assumed to have an average breadth of 150 feet and an average aggregate thickness of 50 feet. The deposit was explored by three drill holes (A–4, A–5, and A–6).

North of the compound ore body are several smaller contorted layers of magnetite that probably can be mined if mining should be undertaken in the area. Most of these layers are partly exposed in the Mount Andrew workings. (See pl. 7 and pl. 9, section *A–A′*.) These layers range from a few feet to as much as 35 feet in thickness and from 50 to 300 feet in maximum dimension. One of the largest of these layers is exposed in the large stope in the main (No. 1) adit 500 feet S. 78° W. of the portal. This layer appears to be the same as that exposed in the upper (No. 2) adit and on the surface above, although in between it is much contorted. If it is continuous, this layer constitutes an ore body averaging 20 feet thick, with a maximum length of 300 feet and a breadth of 150 feet. The layer probably terminates against a wide dike not far below the main adit level. West of this ore body, two other layers of magnetite that offer some promise are exposed in the two small stopes shown in section *A–A′*. They are each estimated to average 15 feet in thickness for a length and breadth of about 100 feet. The layer at the west end of the adit occupies a tight anticline and is partly explored by a drift about 100 feet southward. According to Axel Carlson, good ore was penetrated in these layers below the adit level by a drill hole inclined about 45° SW.

Another ore layer is exposed in the long crosscut that extends south from a point 95 feet west of the portal of the main adit. This layer ranges in thickness from a few feet to about 20 feet and has a length of more than 200 feet. Its breadth is inferred to be 150 feet or more. Magnetite exposed in the central part of the main adit workings, beneath the north glory holes, may be a continuation of this layer, but here it is so traversed by dikes and faults that it probably cannot be mined profitably. Northwest of the main adit portal, magnetite is exposed in scattered outcrops throughout a length of 200 feet, but whether there is one layer or several has not been determined. The average aggregate thickness of ore is probably about 15 feet. In the level 50 feet below the main adit level, several small bodies of magnetite are exposed. These have been partly mined, but here the layer appears to be mainly marble with little magnetite and is so traversed by dikes, that it probably is not minable.

Virtually no ore was found in the lower Mount Andrew (No. 3) adit. Unfortunately, it was placed so that it explored the ground north of the other Mount Andrew workings, where the ore layers are fingering out and the layers of marble are predominant. However, even if this adit had been driven further south, it probably would have passed beneath the large compound ore body. It now is apparent from a study of the structure that no ore could be expected in the Mount Andrew area at that altitude.

Throughout most of the area near the Mount Andrew mine, no magnetite ore is indicated by the magnetic data except at those places where it is either exposed or inferred from geologic data. However, at one place, 700 feet S. 87° W. of the main adit portal, dip-needle anomalies indicate a buried ore body. Structural data suggest rather flat-lying layers of magnetite in the bottom of a syncline, and the magnetic contours imply that the body occupies an area about 200 feet long and 150 feet wide. Where penetrated in 2 drill holes, A–7 and A–8, ore was found at depths ranging between 30 feet and 180 feet below the surface. (See pl. 10.) Several layers of magnetite are indicated, the largest being about 35 feet thick. An average aggregate thickness of about 50 feet is indicated. Just to the northwest of this location, small amounts of chalcopyrite are disseminated in the tactite. This in conjunction with its position at the northern edge of the mineralized area suggests that the buried ore body may be relatively high in copper, possibly comparable to the copper ore formerly obtained from the Mount Andrew mine.

According to Wright and Tolenen (1947, p. 22), the weighted averages for all samples taken by the U.S. Bureau of Mines in trenching and drilling the Mount Andrew deposits are 47.8 percent iron, 0.32 percent copper, and 0.71 percent sulfur. The content of copper, gold, and silver contained in ore shipped from the Mount Andrew mine during the period of 1906–1917, calculated from production figures, averaged as follows: copper 3.09 percent, gold 0.0265 ounces per ton, and silver 0.363 ounces per ton. This material was much richer in copper, and presumably in gold and silver, than most of the magnetite ore remaining in the Mount Andrew mine and vicinity.

RESULTS OF TRENCHING AND DRILLING

By C. T. Bressler

In the summer of 1944, the U.S. Bureau of Mines trenched, sampled, and drilled the Mount Andrew deposits (Wright and Tolenen, 1947). Trenching and drilling operations were based on a plan suggested by E. N. Goddard and disclosed many new data with respect to ore boundaries, dike and waste rock areas, structure and paragenesis of the ore deposits, and reserves.

Six trenches, all trending east southeast, were dug across the main part of the compound ore body of the Mount Andrew group. (See pl. 8.) These trenches were primarily helpful in locating additional dikes and estimating more closely the extent of waste rock in the covered areas, particularly near the pond south of the southeast glory hole. Two trenches were dug across the strike of the "western tongue" of the compound ore body and helped to confirm the general shape and outline of the body as inferred by Goddard. One trench dug near the site of the two drill holes that explore the "buried ore body" 700 feet west of the Mount Andrew adit 1, failed to show any magnetite other than a few small stringers in tactite. Test pits dug elsewhere on the top and flanks of the hill at this locality were similarly barren. Almost all country rock uncovered in this area is tactite. All the trenches disclosed much more waste rock, such as dikes, tactite, and greenstone, than had been mapped previously. In several trenches the boundaries of the ore deposits conformed closely with the contacts inferred from the magnetic surveys in covered areas.

The drilling was confined to the Mount Andrew compound ore body, including the western tongue, and the buried ore body 700 feet west of the Mount Andrew adit 1 portal. Twelve holes were drilled into the Mount Andrew compound ore body and were placed as follows: holes A–1, 7, 14, A–3, and 20 explored the northern part; holes 27, 29, and 31 explored the central part; hole A–2 explored the southern part; hole 23 explored the eastern side; and holes A–4, A–5, and A–6 explored the western tongue. Two holes, A–7 and A–8, were drilled in the buried ore body. Locations of the drill holes are shown on plate 8 and geologic sections through the holes are shown on plate 10.

The compound ore body was explored sufficiently by drilling, to confirm its synclinal shape, and to place the probable lowest limit of magnetite in the ore body at an altitude of about 1.140 feet above sea level, or about 240 feet below the surface at the center of the syncline. Drill-hole data on the western tongue and the buried ore body are not as complete, but indicate that the magnetite may not extend below altitudes of 1,275 feet and 1,315 feet respectively, corresponding to depths ranging from 100 feet to 180 feet below the surface. It is possible, but not probable, that additional ore lies below the levels indicated in the compound ore body and the western tongue. The structural and magnetic data and the lateral extent of the magnetite outcrops suggest ore bodies with dimensions that conform roughly to those shown on plates 8 through 11.

Holes A–7 and A–8, drilled in the buried ore body, disclosed layers of magnetite that appear to be gently dipping and to represent a shallow syncline. They may connect with the layers in the tightly folded anticline exposed to the east in the Mount Andrew workings. (See pl. 9, section *A–A′*.) It is believed that the main magnetite layer has an average thickness of about 35 feet throughout the distance of 106 feet between holes A–7 and A–8. Additional drill holes, however, are needed to explore the deposit adequately.

The drill penetrated many of the numerous dikes in the ore bodies and cores yielded information regarding attitude and size of the dikes at depth. Most of the dikes are nearly vertical but the gabbro, basalt, and andesite dikes tend to dip steeply east, whereas the alkalic dikes dip steeply west. Several dikes penetrated by the drill do not appear at the surface and in general the volume of dike rock tends to increase with depth.

EAST MOUNT ANDREW GROUP

The east Mount Andrew group includes a number of small magnetite and copper deposits under the same ownership as the Mount Andrew mine but 600 to 1,500 feet east of the main group of deposits. They are covered by the Peacock, Rico, Jem, Glory, Goodluck, and Commonwealth claims and some are on the North Star and Mayflower claims, which cover the main Mount Andrew deposits. The deposits are scattered over an area about 1,500 feet long and 750 feet wide in the central and south-central parts of the area (pl. 2). Small tonnages of copper ore, some high in iron, were shipped from some of these deposits. They might contribute a small tonnage of iron ore if mining were under way at the Mount Andrew mine, but they do not seem to warrant exploitation by themselves. In the following pages, the deposits will be described briefly in the order of their location from north to south. Insofar as possible, they are discussed under their claim names, although some lie on the boundary between two claims.

PEACOCK CLAIM

On the Peacock claim, from 700 to 1,100 feet east of the Mount Andrew 1 adit portal, is a group of short adits, shallow shafts and opencuts aggregating about 400 lineal feet. They explore a number of small magnetite bodies in which layers of magnetite a few inches to a few feet thick are interlayered with tactite containing some chalcopyrite and pyrite. A lower adit, 250 feet long, explores ground 60 to 100 feet below some of the upper workings, but no magnetite is exposed in it. A fault striking about N. 60° W. and dipping steeply south, is exposed in some of the workings, but it has little influence on the distribution of magnetite. Displacement on dikes indicates that the north wall moved west about 15 feet. Small tonnages of copper ore were mined from these workings, but no mineable bodies of magnetite ore are indicated, and the remaining copper-bearing rock does not seem to be of sufficient grade or tonnage to warrant further exploration.

RICO CLAIM

At the southeast end of the Rico claim, about 1,500 feet east of the Mount Andrew adit 1 portal, a small opencut and a 100-foot adit explore a small body of magnetite. The magnetite body, where exposed above the adit portal, is nearly flat and about 15 feet thick, but westward it steepens and pinches out in the adit. It appears to be only about 100 feet long and 50 feet wide. This ore is estimated to contain 45 to 50 percent iron and less than 0.5 percent copper.

On the surface, a few scattered outcrops of magnetite and of mixed magnetite and tactite are found as far as 300 feet west of the adit portal. Moderately high dip-needle anomalies were noted in this area, (pl. 3) indicating either a buried body of magnetite or an extension of the body overlying the adit portal.

NORTH STAR CLAIM

In the eastern part of the North Star claim, 850 feet S. 57° E. of the portal of the main (No. 1) Mount Andrew adit, a body of magnetite is exposed partly in an opencut and partly by small surface exposures. This body appears to be in the shape of a shallow syncline. It is about 150 feet long, 50 to 75 feet wide, and 10 to 25 feet thick. It is estimated to contain 40 to 50 percent iron.

About 300 feet north of this surface magnetite body, there is a locality of rather high magnetic anomaly (see pl. 3), but only small amounts of magnetite are exposed at the surface. The lines of high dip cover an area about 250 feet long and 125 feet wide, which suggest that magnetite is abundant within these limits. However, this small area is intersected by many dikes at the surface (pl. 2), and in the Mount Andrew adit 3, which passes 200 feet below the surface at this place, dike rock is almost continuous and no ore is exposed. The magnetite, therefore, apparently lies between the surface and the adit level and is probably cut by many dikes. The locality does not seem to warrant exploration.

GLORY AND GOOD LUCK CLAIMS

Along the boundary between the Glory and Good Luck claims, about 1,400 feet S. 52° E. of the portal of the Mount Andrew adit 1, magnetite is exposed in a small opencut and in several small outcrops. These occupy an area about 250 feet long and 150 feet wide. The local structure indicates that two or more layers of magnetite are present in a shallow syncline. The layers range in thickness from 5 to 20 feet and appear to merge on the eastern side. (See section *D–D'* of plate 12.) The ore probably contains 40 to 50 percent iron and less than 1 percent copper.

GOOD LUCK–MAYFLOWER GROUP

Near the northern end of the Good Luck claim, about 1,250 feet S. 39° E. of the Mount Andrew adit 1 portal, is a group of 4 adits that aggregate about 750 lineal feet and range in altitude from 1,030 feet to 1,180 feet. The two upper adits of this group extend into the Mayflower claim and connect with a few shallow shafts and opencuts. They explore small layers of magnetite, and some copper ore was mined from these workings. An intermediate adit 175 feet long and 50 feet below the upper workings exposes a small body of magnetite and some interlayered magnetite and tactite. The lowest adit, 325 feet long, passes 150 feet below the upper workings and exposes only greenstones and several dikes.

In the upper workings, 3 layers of magnetite are exposed which range from a few feet to 6 or more feet in thickness and are separated by 3 to 6 feet of sulfide-bearing tactite. These layers are flat-lying and appear to be on the east limb of a gentle syncline. Because of local structural irregularities, the layers, as exposed in the northern of the two upper adits, dip 15° to 34° S. to SW., but southward they change to a gentle west dip. As exposed in the workings, the layers measure at least 50 to 60 feet in length and breadth but they may be more extensive underground.

An area of high magnetic anomalies extends 150 to 200 feet west of these workings, suggesting that the exposed magnetite layers may thicken or coalesce to the west and northwest to form a sizeable ore body. It is inferred that magnetite is abundant in a block about 250 feet long, 150 feet wide and 20 feet thick. On the basis of the workings, it is assumed that this block is half ore and half waste. It is estimated that the ore averages about 50 percent iron, 0.2 to 0.9

percent copper and 1 to 2 percent sulfur. The ore body probably lies in a shallow syncline within 100 feet of the surface and could be tested readily by three or four vertical diamond-drill holes.

COMMONWEALTH CLAIM

At the north end of the Commonwealth claim, about 1,200 feet S. 25° E. of the main Mount Andrew adit portal, are several small outcrops of magnetite. The magnetite layers dip 17° to 55° NE. and appear to be on the west limb of a syncline. The layers range in thickness from a few feet to 15 feet and can be traced for lengths ranging from 25 to 100 feet. Two of these layers might be large enough to mine if mining were being carried on in the area. On the basis of outcrops, it is estimated that this group of layers contains 45 to 50 percent iron. The copper content probably is negligible.

STEVENSTOWN MINE

The Stevenstown mine, owned by the Granby Consolidated Mining, Smelting and Power Co., Ltd., is on the crest of the divide, 1.3 miles S. 4° W. of Hadley and 4.3 miles S. 72° E. of Kasaan. It can be reached by following an old tramline up a steep slope from the Mamie mine. The mine was first opened prior to 1905 and was active from 1906 to 1908. There was no production between 1909 and 1915. During the period 1915–18 it was worked with the Mamie mine by the Granby Company. The chief value was in copper, but minor amounts of gold and silver were recovered. The ore produced during these 3 years contained an average of 2.88 percent copper, 0.0308 ounces per ton of gold, and 0.264 ounces per ton of silver.

The chief workings consist of two large and two small glory holes and a 550-foot tunnel (altitude 1,065 feet) which passes through the ridge about 50 to 60 feet below the glory holes. Several chutes connect the glory holes with the tunnel. About 375 feet S. 7° E. of the west portal, is an adit with about 575 feet of workings from which no ore has been produced. On the ridge east of this adit are many small pits, trenches, and a shallow shaft. The main workings are shown on figure 31.

GEOLOGY

Greenstone and associated metasedimentary rocks, largely altered to tactite, are the chief country rocks in the Stevenstown mine and vicinity. Small bodies of marble are exposed at the northern edges of the glory holes, where they are in contact with magnetite bodies. Early diorite, apparently belonging to an irregular stock, is the chief rock in the tunnel under the glory holes, (fig. 31) and also is exposed on the surface in the vicinity of the east portal. Small ir-

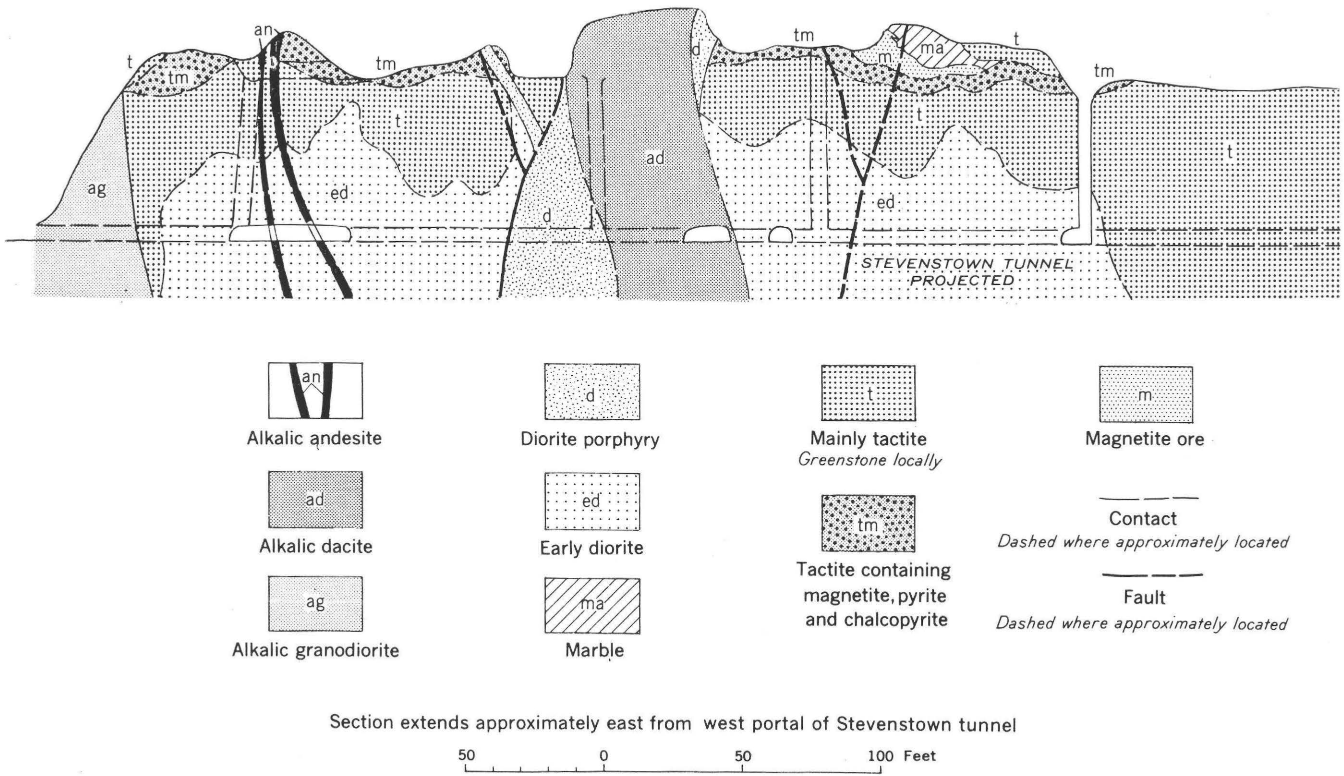

FIGURE 31.—Geologic section of Stevenstown mine.

regular dikes of early diorite are exposed in the glory holes. Persistent dikes of diorite porphyry and alkalic rocks are exposed in the workings; between the two large glory holes, an alkalic dacite dike cuts irregularly through a dike of diorite porphyry. In the western glory hole a group of steeply dipping alkalic andesite dikes from 10 to 18 inches wide strike about N. 15° E.

A few small faults are exposed in the main workings, but the displacements on them are, at most, only a few feet. A fault exposed in the southern adit strikes about N. 75° W. and dips 85° S. Displacement on a dacite dike indicates that the north wall moved west 15 to 20 feet.

ORE DEPOSITS

The ore mined from the Stevenstown mine was siliceous copper ore and contained very little magnetite. However, on the ridge south of the main Stevenstown workings, are exposed two magnetite bodies that might be minable.

The siliceous copper ore body (now mostly mined out) is in the form of a nearly-flat, gently undulating layer on the top of the ridge (fig. 31). This layer ranges from 8 to 25 feet in thickness and is about 300 feet long and 200 feet wide. Dikes of diorite porphyry and alkalic dacite totalling about 50 feet in width intersect the central part of this body. Chalcopyrite and pyrite are irregularly disseminated through this layer and scattered pockets, lenses, and pods of magnetite, chalcopyrite, and pyrite are common. These segregated masses of metallic minerals are commonly intergrown with coarse hornblende or with chlorite, and they range from a few inches to a few feet in length. In places they show a banding of chalcopyrite and pyrite in magnetite. Small amounts of ore remain around the walls of the glory holes. Above and below the ore layers are layers of tactite in which epidote predominates. This rock is exposed at several places in the floors of the glory holes and no ore was found in the tunnel below the glory holes.

The two bodies of magnetite exposed in the glory holes (pl. 2) are probably too small to warrant mining. The one exposed at the north border of the eastern glory hole lies on top of the copper ore and under a small body of marble which it partly replaces. This magnetite body is 5 to 15 feet thick, about 50 feet long, and probably about 30 feet wide. The magnetite body at the north side of the western glory hole underlies the siliceous copper ore and overlies marble with a very irregular contact. This layer is 5 to 8 feet thick, 100 feet long and 30 to 40 feet in breadth. In both these layers, chalcopyrite and pyrite are fairly abundant, but the copper content is probably less than 1 percent.

The two magnetite layers south of the main Stevenstown workings, are exposed on the sides of the ridge near its southern end. The ore layer on the west appears to be about 100 feet stratigraphically above the one on the east. (See pl. 2, section *C–C'*.) The one on the west, as exposed in a shallow shaft, a cut, and a trench, appears to be 5 to 12 feet thick and to average 8 feet. Magnetic data indicate that this layer extends through the ridge to the east, where it splits and narrows to a few feet. The bottom part of this layer is exposed at one place in the underlying adit, where it consists of mixed magnetite and tactite with some sulfide minerals. If this layer is continuous, it measures about 250 feet in length and 200 feet in width. The lower or eastern magnetite layer is not so well exposed, but scattered outcrops and magnetic data suggest that it is a few feet to 12 feet thick with an average of 8 feet, about 250 feet long, and about 50 feet wide. The magnetite in these bodies is mixed with some tactite and contains irregularly disseminated pyrite and chalcopyrite.

No samples were taken of the magnetite ore at the Stevenstown mine. The ore is estimated to be of somewhat lower grade than most of the ore at the Mount Andrew and Mamie mines but may contain from 40 to 50 percent iron. The copper and sulfur content is probably comparable to that of the ore sampled at the Mamie mine, that is, 0.26 to 0.90 percent copper and 1.69 to 3.88 percent sulfur. The reserves of magnetite in the vicinity of the Stevenstown mine are small.

POOR MAN IRON DEPOSIT

By L. A. Warner and Matt S. Walton, Jr.

The copper-bearing magnetite deposit, known as the Poor Man prospect, is 2 miles northwest of the village of Kasaan. (See pl. 1.) The deposit is within 2,000 feet of tidewater in an area ranging in altitude from 50 to 200 feet. Outcrops are confined to stream valleys and to prospect cuts and trenches. Most of the area is covered with a veneer of vegetation, glacial drift, and alluvium. The deposit is explored by 3 short adits on the west side, 4 shafts along the east margin, numerous pits and trenches, and 13 drill holes. There has been no production.

Geologic, topographic, and magnetic surveys of the deposit were made by the Geological Survey in September 1942. The field party consisted of E. N. Goddard, Matt S. Walton, Jr., G. D. Robinson, and L. A. Warner, geologists; Elder Lebert, and William Williams. The Bureau of Mines trenched and sampled the deposit in November 1942 and drilled it during April and May 1943 (Holt and Sanford 1946).

GEOLOGY

The geology in the vicinity of the Poor Man deposit is shown on plate 12. The principal bedrock is greenstone. Within the greenstone are layers of quartzite and graywacke and lenses of crystalline limestone or marble that range in thickness from a few inches to more than a hundred feet. The regional strike of these rocks is in general northwesterly, although locally their attitude is complicated by folding and faulting. The greenstone and associated rocks are cut by many dikes, including early diorite, alkalic granodiorite, alkalic dacite, diorite porphyry, gabbro, andesite, and basalt. Most of the dikes strike from north to N. 45° W., but a few dikes strike northeasterly.

A north-trending en echelon set of faults and shear zones is suggested by the mapping. The iron deposit occupies one such fault zone and a smaller fault about 1,000 feet south of the deposit contains some sulfide ore in quartz. The large shear zone exposed in the creek northwest of the iron deposit contains no ore. Reconnaissance in the area to the north suggests that the en enchelon fault set may extend across the peninsula to Tolstoi Bay (pl. 1) but no further indications of ore were found. Near the iron deposit, smaller faults of east, northeast, and northwest trend, were found, and presumably such faults are more numerous than is indicated by the mapping, as much of the area is covered with vegetation.

ORE DEPOSIT

EXPLORATION

The ore minerals have replaced and cemented greenstone breccia fragments in a large fault zone which trends about N. 7° E. and dips from 55° to 75° W. At the surface the deposit is about 1,500 feet long and 50 feet to 150 feet wide. It has been outlined fairly well by many trenches which extend across it. At some places the ore boundaries have been inferred from the results of the magnetic survey.

Prior to the drilling, the only underground openings consisted of four shafts and three adits (pl. 13). Ore is exposed at the collar of shaft 1, which is 15 feet deep and full of water. The dump indicates that ore was found throughout most of this depth. Shaft 2 is 60 feet deep and is probably mostly in ore. Shaft 3 is 20 feet deep and is reported to have been in ore throughout. The north end of the deposit is covered with glacial drift and shaft 4 was sunk to a depth of 10 feet in this material.

Adit 1 is 25 feet long and exposes irregular blocks of greenstone, some of which are several feet in diameter, in a matrix of ore. Adit 2, which connects with shaft 3, cuts through 60 feet of ore and exposes epidotized greenstone at the face. The greenstone is separated from the ore by a north-trending fault that dips 70° W. The adit exposes several large blocks of greenstone in the ore. Adit 3 cuts through 45 feet of greenstone and penetrates the ore for 40 feet.

The hanging-wall contact of the ore strikes north and dips about 55° W. The greenstone is much altered and cut by many small faults, some of which are nearly parallel to the contact.

The Bureau of Mines originally planned drill sites 100 feet west of the deposit, but the shattered wall rock adjacent to the deposit made drilling difficult and these sites had to be abandoned for set-ups closer to the west contact. Because the deposit dips westward, this arrangement was unfavorable for prospecting the body very far below its outcrop.

Cross sections of the ore body in the planes of the drill holes are shown on plate 14. With two exceptions (holes 2 and 21) the drill holes were either vertical or inclined eastward across the ore body from near its western margin. Hole 21 strikes N. 15° E. nearly parallel to the eastern boundary of the ore. It was intended to prospect the body at its northern end. This hole was directed too far eastward and passed into the footwall of the ore at a slight angle before reaching the north end of the body.

In some holes dikes were cut at such angles as to furnish inadequate information regarding the ore body in that vicinity. For example, hole 19 (pl. 14, section *C–C'*) penetrated the chilled hanging wall of a dike, passed through the porphyritic central part and ended in chilled-border material on the footwall. The dike footwall probably would have been cut and the presence or absence of ore beneath the dike determined had the hole been only a few feet longer. The hole was abandoned because of bad drilling conditions.

The fault zone in which the ore was deposited contains faulted segments of several north-trending dikes (pl. 13). Most of these segments were not replaced by magnetite. Blocks and lenses of greenstone, similar to those exposed in the adits, were found in most of the drill holes.

Observations of magnetic anomalies were made with a dip needle and Brunton compass at 50-foot intervals over the mapped area. The magnetic data are shown on plate 15. The limits of the deposit are rather closely defined by the area of north (positive) dip-needle deflections. Surrounding the area underlain by ore is an area of low to moderate south (negative) dips. The horizontal anomaly (the amount of deflection of the compass needle from its normal declination), is westerly along the east margin of the ore body and is easterly along the west margin. Near the center of the magnetic disturbance caused by the ore body the horizontal anomaly is zero. The locus of all points of no horizontal anomaly is shown on plate 15 as the "median line of no horizontal anomaly."

At the time the magnetic survey was made, no drilling had been done and the body was poorly exposed. Several inferences were made on the basis of the magnetic data regarding the continuity, attitude, depth, limits, and character of the deposit which have since been largely substantiated by drilling and additional trenching.

The fact that the area of north dips forms an elongated zone corresponding closely to the outcrop of the deposit and the regularity with which the median line of no horizontal anomaly follows this zone indicate that the deposit is roughly tabular and that its dip is probably greater than 45°.

South dips of 5° or more are almost entirely confined to the western side of the deposit. Positive (westerly) horizontal anomalies, which characterize the eastern side of the magnetic disturbance, are greater throughout than the negative (easterly) horizontal anomalies. These data indicate that the deposit dips westerly.

Wherever a contact between ore and country rock was observed it is generally within the area of north dips. Therefore, it is probable that the deposit does not extend beyond the area of north dips. No conclusive evidence was obtained by trenching or drilling as to the termination of the deposit at either of its apparent ends, but the magnetic data practically eliminate any possibility that it extends appreciably beyond the boundaries shown.

Several discontinuities in the deposit are suggested by the magnetic data. Along section *E–E'*, plate 15, there is a sharp offset in the median line of no horizontal anomaly as well as two distinct areas of high north dips. Drilling and trenching indicate that these data reflect the presence of a large segment of dike rock in the deposit. The low dips north of section *C–C'* probably indicate a large lens of greenstone and a segment of a dike in the ore, both of which are partially exposed, as well as a distinct narrowing of the ore.

Between sections *B–B'* and *C–C'* is another sharp offset in the median line of no horizontal anomaly and a break in the area of north dips. Surface exposures indicate another thick segment of dike rock in this area.

North dips are closely confined to the area actually underlain by ore. If the deposit extended to considerable depth without substantial loss of width, positive dips would be found over an area considerably larger than that of its outcrop. Drilling reveals that the body becomes narrower with depth. The fact that the area of horizontal anomalies does not extend more than a few hundred feet on either side of the ore body suggests that the body does not continue to great depth, but specific estimate of depth cannot be made on the basis of present magnetic data.

CHARACTER OF THE ORE

The principal ore mineral is magnetite. Pyrite and chalcopyrite generally constitute less than 10 percent of the ore, and pyrite is more abundant than chalcopyrite. The ore also contains recoverable amounts of gold and silver, very small amounts of titanium and phosphorus, and traces of manganese.

Magnetite was the first ore mineral to be deposited and it has cemented and replaced greenstone breccia fragments in the fault zone. Some of the pyrite may be contemporaneous with magnetite but most of it was deposited later. Chalcopyrite is commonly associated with quartz and calcite in a network of veinlets that cut the earlier ore minerals. The precious metals seem to be associated with the sulfide minerals. The phosphorus and titanium probably are contained in unreplaced greenstone fragments, which contain accessory amounts of apatite and sphene.

Much of the gangue material in the ore body consists of blocks or lenses of altered greenstone and segments of dikes, which may comprise about 10 percent of the volume of the body. Most of these blocks of waste material are a few feet to several tens of feet in longest dimension. The drill cores reveal, however, that some of the high-grade ore contains minute fragments of partially replaced greenstone. In places, these reduce the tenor appreciably. A few euhedral garnets are in the magnetite. Apparently they were present in the brecciated greenstone prior to ore deposition and were not replaced when the ore-bearing solutions attacked the greenstone. Veinlets of calcite and quartz are abundant but their effect on the quality of the ore is small.

The ore deposit consists essentially of a veinlike mass of high-grade magnetite ore that is bordered on both the footwall and the hanging wall by several feet of low-grade material consisting of mineralized greenstone. The magnetite content of these marginal zones is small but they appear to contain as much chalcopyrite as the high-grade ore and parts of them might be mined for copper. This material consists mostly of veinlets of sulfide minerals and some magnetite in shattered greenstone.

STRUCTURE AND GENESIS

Both geologic and magnetic data indicate that at the surface the ore body pinches out short distances north and south of its outcrop. At its northern end the body terminates just south of a limestone cliff. (See pl. 13.) This outcrop is part of a wide belt of limestone which trends across the mineralized fault zone. (See pl. 12.) Careful search over an area about 1 square mile around the north end of the ore body failed to reveal any more ore. Magnetic readings taken over this area are normal.

At its southern end the ore body disappears beneath a thick cover of alluvium and glacial drift which extends southward for several hundred feet. Magnetic readings indicate that the ore does not continue very far to the south beneath the cover. Scattered outcrops of limestone are found northwest and southeast of this covered area. The projected strike of the limestone passes through the covered area and it is possible that here, as at its northern end, the ore body terminates against limestone.

The fact that the ore replaced brecciated greenstone in preference to the large bodies of limestone nearby is of special interest in that limestone commonly is regarded as the more favorable host rock for deposits of this type. Apparently the fault zone in which the ore occurs does not penetrate the limestone at the north end of the deposit and may terminate against limestone beneath cover at the southern extent of the ore. Probably any fractures in the limestone resulting from the faulting were obliterated by recrystallization of the limestone prior to the time of ore deposition. Possibly the faulting occurred at a time when the temperature and pressure were sufficiently great to cause the limestone to yield plastically without fracturing. The marble may thus have been virtually inaccessible to the ore-bearing solutions.

The brittle greenstone, however, was intensely shattered. Ore-bearing solutions readily migrated into the shattered zone, replacing the breccia fragments and filling interstices with magnetite and sulfide minerals. The relatively large surface area exposed on the finer fragments tended to promote total replacement. Large blocks of greenstone and dike material were little affected.

All sections through the ore body (pl. 14) indicate that the hanging wall is steeper than the footwall and that the body pinches downward. The ore body appears to be widest where the footwall is less steep and to be narrow where the footwall is more steep. This generalization is best illustrated in comparing sections *D–D'* and *E–E'*. Whereas the widths of the ore in the sections vary considerably at the surface, the widths are similar at 75 feet to 100 feet below the surface. It is possible that the width attained at this level may persist downward for many feet.

Probably the deposit is the base of a once more extensive pod-shaped ore shoot which formed in a bulge in the fault zone, the upper part having been eroded away. A fault zone of this magnitude could normally be expected to extend downward for several hundred feet below the surface. It is possible that other bulges occur at depth in the plane of the fault and that ore bodies similar to the one exposed at the surface may be present. If the exposed ore is mined and further prospecting seems warranted, these possibilities might be worth consideration.

SIZE AND GRADE

The total length of the deposit is about 1,500 feet and the average thickness of the main mass at the surface is about 85 feet. By projecting the boundaries of the body downward as shown on the cross sections (pl. 14), the average distance to which the ore extends down the dip below the center of the body at the surface is estimated to be at least 200 feet. The body, therefore, may be treated as a triangular prism 1,500 feet long, 85 feet wide and 200 feet deep. It is assumed that 10 percent of the volume is waste. The deposit may be larger if it widens below the level of the drill holes or continues downward without appreciable loss of width. The geologic data indicates that this is one of the largest single bodies of magnetite ore on Kasaan Peninsula.

Analytical data furnished by the Bureau of Mines (Holt and Sanford, 1946, p. 5) indicate that the magnetite ore body contains an average of 52.4 percent iron. The average copper content is 0.25 percent although some samples contained more than 1 percent. Gold averages 0.032 ounces per long ton and silver 0.071 ounces per long ton. About 0.03 percent phosphorus and 0.04 percent titanium are present. The sulfur content averages 3.72 percent and the copper and precious metals are contained in the sulfide minerals.

Bordering zones of low-grade material are on each wall of the veinlike magnetite body. The iron content of this material is low but the copper content is probably as much as, or more than, that of the high-grade ore. Parts of it may be of sufficient grade to furnish low-grade copper ore in event the magnetite deposit is mined.

IRON KING NO. 1 COPPER PROSPECT

By L. A. Warner and Matt S. Walton, Jr.

The copper prospect on the Iron King No. 1 claim is 0.9 mile N. 63° W. of the village of Kasaan. (See pl. 1.) By Forest Service trail the distance from Kasaan is 1.5 miles. The prospect is at an altitude of 50 feet and is about 250 feet from the shore of Kasaan Bay. Development at the copper prospect consists of a group of small pits, trenches, and stripped areas within an area 200 feet by 100 feet. The vicinity is almost completely covered by glacial deposits, alluvium, and vegetation.

In September 1942 the Geological Survey made geologic, topographic, and magnetic surveys of the deposit and the adjacent country. The Bureau of Mines trenched and sampled the deposit in October 1942 and drilled it in February and March 1943.

The principal country rock at the prospect consists of greenstone and associated rocks which, as elsewhere on the Kasaan Peninsula, are folded and metamorphosed. Northeast- and north-trending dikes of basalt, andesite, and alkalic dacite cut the greenstone. Minor faulting has taken place along northeast and northwest fractures. The rocks are shattered and break readily into small pieces. Close to the deposit both the greenstone and the dikes are epidotized.

Exposures of ore are confined largely to a zone about 150 feet long and averaging between 10 and 15 feet wide. (See fig. 32.) The boundaries of this zone are irregular and poorly exposed. It trends about N. 15° E., but its dip is not definitely known. Trench 1 (fig. 32) exposes a well-defined contact between magnetite and sulfide ore which strikes about N. 15° E. and dips 65° NW. This contact may indicate the approximate attitude of the deposit. It is believed that ore deposition was controlled mainly by faulting as

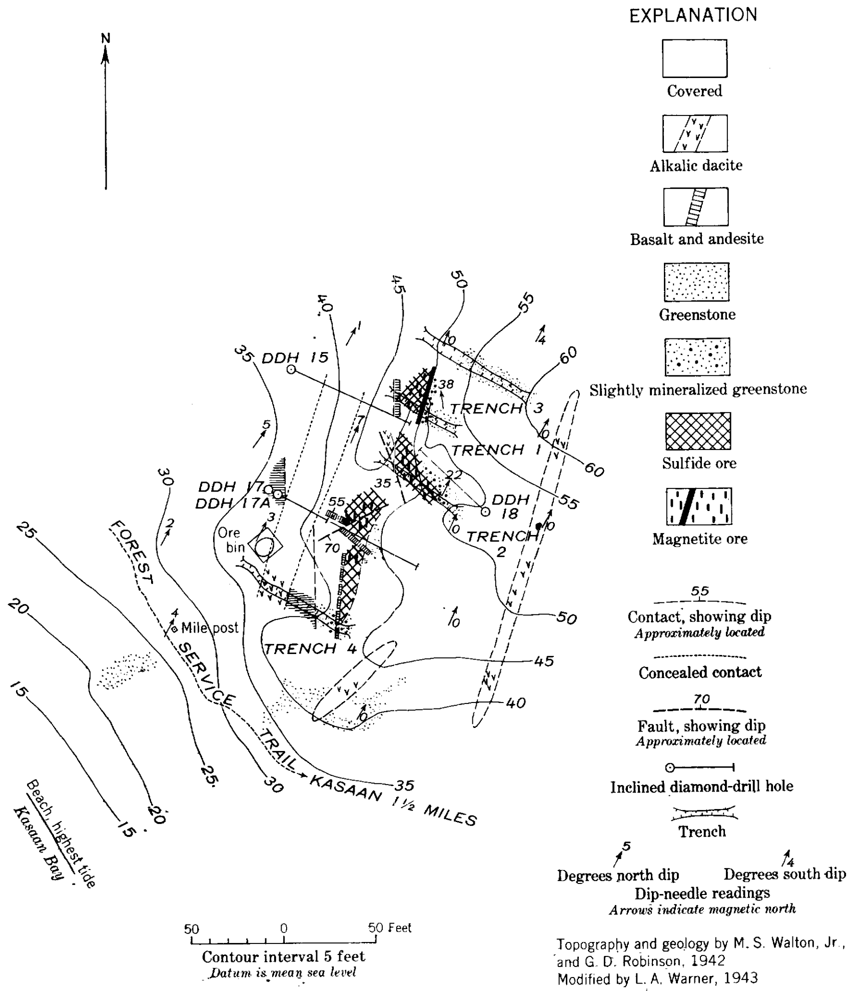

FIGURE 32.—Geologic map of the Iron King No. 1 copper prospect.

the zone of exposed ore strikes nearly parallel to the principal dikes and to other faults and fissure deposits in the region (pl. 12).

A dip-needle survey of the covered area surrounding the deposit, demonstrated that the magnetic attraction of the ore body diminishes abruptly away from its outcrop. Old prospect trenches around the present exposures have largely slumped in, but no ore was observed in the material thrown out. Thus it is inferred that the deposit on the surface does not extend much beyond the area of outcrop.

The principal ore minerals are magnetite, pyrite, and chalcopyrite. Of these, magnetite is the earliest mineral and has replaced the greenstone, whereas the sulfide minerals fill fractures that cut the greenstone and the magnetite. Magnetite is most abundant at the northern end of the body where some ore contains as much as 50 percent iron. The magnetite content decreases to the south and the southern part of the body consists mostly of mineralized greenstone in which pyrite and chalcopyrite occur in a network of veinlets. Here magnetite is found locally as disseminated grains. Judging from the samples taken by the Bureau of Mines at intervals along the body, chalcopyrite, though not evenly distributed, is about as abundant in the northern as in the southern part of the deposit.

The trenches and drill holes of the Bureau of Mines are shown in figures 32 and 33. Trench 1 exposes a band of magnetite ore about 3 feet wide. East of the magnetite for 8 feet is mineralized greenstone containing pyrite and chalcopyrite. Analyses indicate that this material contains about 1.5 percent copper. West of the magnetite is about 8 feet of sulfide ore. In trench 2, magnetite and sulfide ore are rather intimately associated and the ore extends farther east than in trench 1. About 5 feet of mineralized greenstone is exposed at the east end of trench 4. The western part of trench 3 is covered, but mineralized greenstone was found here when the trench was dug. Analyses of 5-foot channel samples from trenches 3 and 4 show that the material contains about 2 percent copper.

Drill holes were inclined southeastward from two places on the west side of the deposit. Two holes (17 and 17A) were put down from the southern location and one (15) from the northern. A fourth hole (18) was inclined northwesterly from a point on the east side of the ore body. None of the cores contain any ore minerals other than a few grains of pyrite and chalcopyrite. Holes 15, 17 and 17A entered a dike at the inferred position of the ore body. Hole 18, if it had been continued about 20 feet farther, would probably have entered the dike below the footwall boundary of the deposit. (See fig. 33.) The dike is exposed only near the west

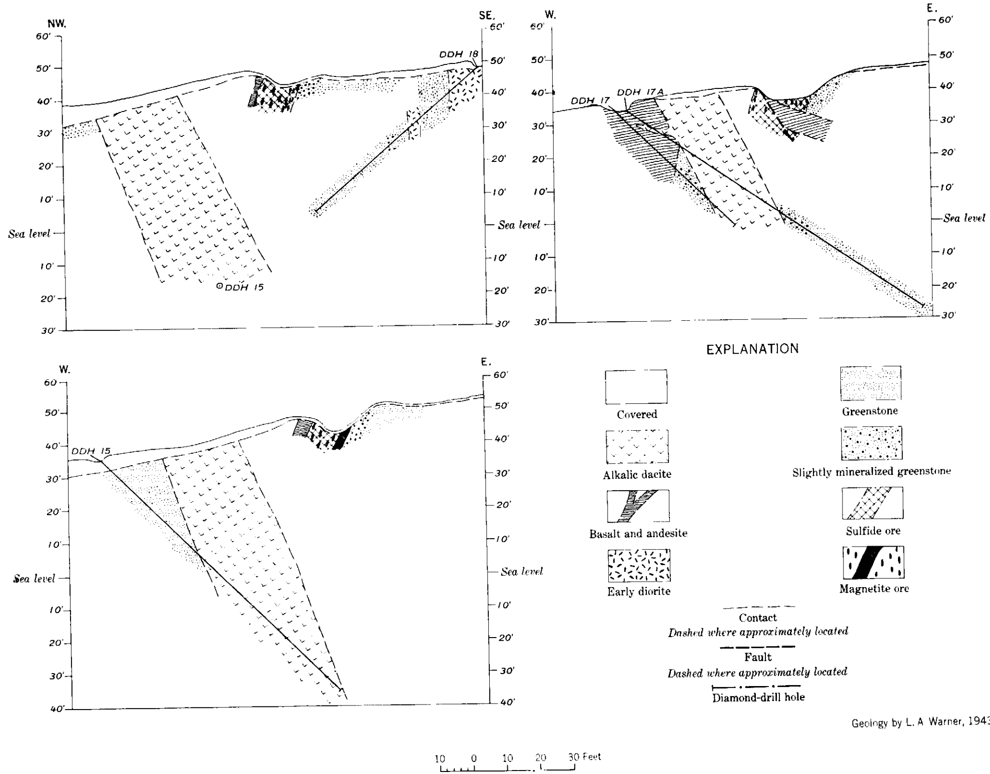

Figure 33.—Sections through diamond-drill holes in Iron King No. 1 copper deposit.

end of trench 4. From the drill-hole data it appears to be about 20 feet thick, to strike approximately N. 15° E., and to dip about 65° SE. Whether or not the deposit extends to or beneath the dike is not shown by the drilling.

Twenty-nine channel samples were cut by the Bureau of Mines from the trenches and outcrops. The analytical data from these samples indicate that the deposit contains an average of about 2 percent copper and minor amounts of gold and silver. On the basis of the surface outcrops the body appears to be about 150 feet long and to average between 10 and 15 feet wide. No data are available on the depth to which the deposit extends.

DEPOSITS OF THE TOLSTOI MOUNTAIN AREA

By L. A. Warner and Karl Stefansson

The Tolstoi Mountain area (pl. 1) is 37 miles northwest of Ketchikan. It is bounded on the east by Clarence Strait and on the west by Tolstoi Bay. Most of the mineral deposits lie on the south and west flanks of the Tolstoi Mountain ridge at altitudes of from 500 to 1,500 feet and are within 1 to 2 miles of tidewater. (See pl. 16.) Two trails lead into the area, one from Palmer Cove on Clarence Strait, and the other from Tolstoi Bay, beginning 1½ miles south of the entrance to the bay.

Most deposits were prospected between 1900 and 1908 and several claims were staked (Wright, 1915, p. 101). On most of the claims only a small amount of development work was done, the aggregate amounting to several short adits, a few shafts, and many pits and trenches. At the Iron Cap or Mahoney property more extensive work was done, including an adit 100 feet long, and several hundred feet of diamond drilling, in addition to pits and trenches. These workings are about one-half mile northwest of Tolstoi Mountain at altitudes of 950 to 1,100 feet. (See pls. 16 and 17.) Apparently no ore has been shipped from any of the prospects.

During March and April of 1944 the Bureau of Mines trenched and sampled the Iron Cap deposits after making preliminary topographic and dip-needle surveys. Later in the season the Geological Survey mapped the geology of the Tolstoi Mountain area. No large bodies of magnetite ore were found. The writers were assisted in the field by David H. Pfeiffer and Frank J. Anderson.

GEOLOGY

The area bedrock consists chiefly of andesitic greenstone containing lenses and layers of metamorphosed clastic sediments and limestone. (See pl. 16.) In many places the greenstone appears to have intruded the sediments, but its relationship to these rocks is not fully understood. In the southeastern part of the area the clastic rocks are mostly siliceous. Here the trend of the beds is mainly north and northeast and the dip is westward. Beds of coarse conglomerate, probably aggregating several hundred feet in thickness, form the south and east flanks of Tolstoi Mountain. Northwestward the sediments become finer grained and more calcareous. Near the western edge of the area a few lenses of nearly pure marble are exposed. In this part of the area the trend of the bedded rocks is northwest and the dip is southwestward.

The greenstone and included sedimentary rocks are cut by many dikes, including diorite, alkalic granodiorite and related rocks, diabase, basalt and andesite. The trend of the dikes is mainly northeastward and the dip in most instances is nearly vertical. In places the dikes are very closely spaced and form a network in which large irregular masses of greenstone are surrounded by dike material.

The northeastern half of the area is composed of coarse-grained granodiorite and related rocks which form a large stocklike intrusive. Dikes in the greenstone adjacent to the stock end at the contact, indicating that the stock was emplaced later than most of the dikes.

Only a few dikes of aplite and alkalic andesite are found in the granodiorite. The contact of the stock with the intruded rocks is not well exposed and is probably somewhat gradational. It trends northwestward and appears to dip steeply to the southwest. Flow structures indicate that the major axis of the intrusive is about parallel to the contact and that the width of the body is probably small compared to its length.

About one-half mile southwest of the granodiorite contact, and trending parallel to it, is a large fault zone that can be traced across the area for nearly 3 miles. Streams flowing northwestward and southeastward from the saddle south of Tolstoi Mountain have developed steep valleys in the fault zone. In many places the zone is more than 100 feet wide and consists of sheared and altered rock with well-defined faults. Many of the faults are diagonal to the main zone and in some instances they extend for many hundreds of feet into the rocks on either side. These faults are in two sets, the one striking about N. 25° W., the other nearly due west. Most of the faults dip more than 70°. Some faults are parallel to the main zone, striking N. 40° W. to N. 60° W. and dipping about 75° SW. They probably indicate the general dip of the fault zone.

Major movement in the zone is thought to have been such that the southwest side moved downward and westward, the plunge of the net slip probably being less than 45°. The thick conglomerate beds southwest of Tolstoi Mountain have been displaced about 600 feet horizontally and the vertical displacement probably is not greater. The parallelism of the fault zone and the stock contact suggests that the faulting was related to the intrusion of the stock.

In the central part of the region between the fault zone and the granodiorite, lenses of fine-grained clastic material are particularly numerous in the greenstone. Many of them are calcareous and bedded. The lenses of clastic rock are limited to several irregular zones, whose approximate boundaries are shown in plates 16 and 17. Outcrops for the most part are poor and outlines of individual lenses are imperfectly known. They probably range from a few to a hundred or more feet long and may constitute roughly 50 percent of the material in the zones. If the greenstone in this area represents huge sill-like intrusions into the sedimentary rocks, the zones containing the clastic lenses may once have been continuous layers that were broken up into numerous pieces during intrusion.

ORE DEPOSITS

All known copper-bearing magnetite deposits in the Tolstoi Mountain area lie between the large fault zone and the granodiorite and are confined to the zones of clastic material in the greenstone. No magnetite was found in those parts of the area where such clastic rocks are absent and only minor occurrences of ore minerals were found southwest of the fault. Much of the host rock for the ore probably was a calcareous shale or sandstone. Locally broken greenstone also was replaced. Lenses of limestone are southwest of the fault zone but contain no ore. (See pl. 16.) The ore deposits are irregular lenticular bodies that approximately simulate the shape of the rock masses they have replaced. They range in size from pods to lenses 200 feet long and 20 to 30 feet thick (pl. 17).

Magnetite is the dominant ore mineral in most of the deposits and is associated with lesser amounts of pyrite and chalcopyrite. A few deposits are composed chiefly of sulfide minerals with accessory magnetite. Pyrrhotite is a common mineral in the deposits of the latter type. The gangue minerals consist of diopside, andradite garnet, hornblende, epidote, and blue-green chlorite. Late veinlets of quartz and calcite cut the ore and the other gangue minerals.

The total estimated reserves of the principal ore bodies of the Tolstoi Mountain area are about 100,000 long tons of magnetite ore. None of this ore has been adequately blocked out and because of the irregularity of the deposits and the poor exposures, the entire amount is classed as inferred ore. The average grade probably does not greatly exceed 40 percent iron and 0.25 percent copper. The sulfur content is estimated to average about 3 percent and small amounts of gold and silver are probably present.

MAGNETITE DEPOSITS

The principal ore deposits are one-half mile northwest of Tolstoi Mountain within an area 1,000 by 2,000 feet (pl. 17). The Iron Cap deposits at the southeast end of this area are the largest. They consist of two groups; the northwestern group is separated from the southeastern by a large northeasterly-trending alkalic granodiorite dike. In aggregate the Iron Cap deposits form an S-shaped zone several hundred feet long in which magnetite has replaced lenses of fine-grained clastic material and fractured greenstone. The shape of the zone probably indicates a broad flexure in the rocks. In general the zone trends northwestward, but locally the ore layers trend northeastward. The ore bodies are not well exposed and their attitudes are not clear. In the southern part of the zone the ore-bearing lenses dip about 50° SW. In the northern part they appear flatter.

The southeastern group of deposits appear to be more extensive. Within an area about 200 feet long and 150 feet wide several lenses of fairly high-grade magnetite ore are exposed in pits and trenches. The ore-bearing lenses are surrounded by altered greenstone and fine-grained clastic rocks; these materials also form inclusions in the ore. Several exposed dikes cross the ore bodies and adjacent rocks and others probably are present. Much of the area near the exposed ore is covered and the ore bodies may extend farther than is indicated by the trenching. However, the dip-needle data indicate that most of the covered area is probably underlain by barren material.

The depth to which the deposits extend below the surface is thought to be relatively shallow. At the northern end of the southeastern group of workings, an adit was driven southeastward for about 100 feet, the last 20 feet being in ore. This ore may represent the downward extension of a southwestward-dipping layer exposed in the bed of a small stream 50 feet southeast of the adit portal. If this is true, the ore in this layer extends below the outcrop for at least 50 feet down the dip. Diamond drilling in connection with early development work at Tolstoi Mountain is thought to have been confined largely to this group of deposits. One of the drill holes was reported to have reached ore at a depth of 70 feet

(Min. and Sci. Press, 1901). The location of this hole and whether it was inclined or vertical is not known. Data obtained from the dip-needle readings indicate that the ore probably does not extend much beyond an average depth of 50 feet.

The northwestern group of Iron Cap workings expose low-grade magnetite ore in an area 300 feet long and 100 feet wide. The ore has not been prospected at depth, but from the dip-needle data it is assumed that most of the available ore is within 40 feet of the surface. About 80 percent of the surface material is waste.

Magnetite ore is exposed 1,000 feet northwest of the Iron Cap deposits at an altitude of 900 feet in an opencut and in stripped areas to the west along the brow of a small hill. The ore-bearing layers dip moderately into the hill. About 1,000 feet farther west and at an altitude of 650 feet, another small body of magnetite ore is partly exposed in an opencut. The deposit seems to trend northwestward and to dip southwesterly at a moderate angle.

Low-grade magnetite ore is exposed 700 feet southwest of the Iron Cap workings in two pits and in outcrops within an area 200 feet long and 75 feet wide (pl. 16). The strike of the ore body seems to be northwestward but the dip is not known. A smaller body crops out 200 feet up the slope to the northeast.

Magnetite is exposed in a pit 1,800 feet southeast of the top of Tolstoi Mountain. The area adjacent to the pit is largely covered, but the ore body probably does not extend much beyond the limits of the pit.

Several other occurrences of magnetite and associated sulfide minerals have been found in the area between the large fault zone and the diorite contact but these appear to be small pods and stringers.

SULFIDE DEPOSITS

On the Big Five claim, 4,600 feet N. 65° W. of Tolstoi Mountain and one-half mile from tidewater, a small pyrrhotite body has been prospected. The deposit is at an altitude of about 250 feet on the southwest bank of a stream following the large fault zone (pl. 16). The body is in impure limestone near the contact of a northeastward trending diorite dike. Adjacent to the deposit, the calcareous rocks have been largely altered to tactite. An adit 40 feet long has been driven in from the stream and a winze about 15 feet deep was sunk near the face of the adit. The deposit consists of small pods and stringers of pyrrhotite with associated magnetite and chalcopyrite in the tactite. The body seems to trend northwestward and to dip steeply to the southwest. Its limits as exposed by the workings show the deposit to be very small.

A quartz vein containing magnetite and chalcopyrite has been prospected 2,500 feet S. 25° E. of Tolstoi Mountain. The vein is exposed in the stream valley that occupies the large fault zone on the southeast side of Tolstoi Mountain. At its outcrop on the north bank of the stream the vein is 8 inches thick. It strikes N. 50° W. and dips 55° SW. The vein material consists of coarse vuggy quartz with massive chalcopyrite filling the vugs. About 100 feet southeast of the outcrop and 60 feet below it an adit 50 feet long has been driven into the vein from the creek. A drift extends northwestward along the vein for 20 feet to where it feathers out into small stringers. Ore on the adit level contains some magnetite and less chalcopyrite than that at the surface.

A small sulfide vein in the granodiorite stock has been exposed by stream erosion a few hundred feet southeast of the outlet of the small lake about one-half mile north of Tolstoi Mountain. The vein strikes N. 50° W. and dips 60° SW. Its maximum width is 4 inches and it is exposed for 8 feet along the strike. The vein consists of stringers of pyrite and arsenopyrite cementing brecciated quartz; it may contain some gold. The vein has not been prospected.

RESULTS OF MAGNETIC SURVEY

Within the area that includes the Iron Cap and adjacent deposits to the northwest, dip-needle readings were taken at closely spaced stations. The spacing of the stations was determined by the anomalies obtained, more readings being taken in anomalous areas than in those showing no anomalies. From these data a contour map showing lines of equal dip-needle deflection has been constructed. (See pl. 18.) For the most part, north, or positive, dips are more indicative of magnetite than south, or negative, dips. Much of the area investigated is covered by muskeg and it was thought that commercial magnetite bodies might be present beneath this cover. The dip-needle survey precludes this possibility.

In the vicinity of the Iron Cap deposits the magnetic anomalies closely approximate the areas in which magnetite is exposed. This condition indicates that the ore bodies probably do not extend much beyond the areas of outcrop and that the ore terminates a short distance below the surface. The complexity of the anomalies further substantiates the assumption that there are several ore-bearing lenses, each with its own magnetic field, the resultant field being very irregular.

At the prospect 1,000 feet N. 40° W. of the Iron Cap deposits the area of magnetic anomaly is considerably larger than the area in which magnetite is exposed. A small body of fairly high-grade ore probably lies within 50 feet of the surface about 100 feet northeast of the opencut.

At the prospect 1,000 feet farther west, some buried ore is indicated but at best the deposit is probably small. No significant anomalies were found north or west of this prospect. Southeastward toward the Iron Cap deposits two small areas of positive anomaly were found. The anomalies are probably produced by small pods of buried magnetite.

Dip-needle readings were taken in the vicinity of the magnetite outcrops 700 feet southwest of the Iron Cap workings. The distribution and magnitude of the anomalies were such as to indicate that only a small amount of magnetite is present. Readings taken at frequent intervals along traverses covering most of the area between the large fault zone and the granodiorite stock failed to show significant anomalies.

RUSH AND BROWN MINE AND VICINITY

By L. A. Warner, R. G. Ray, and G. M. Flint, Jr.

The Rush and Brown mine is near the head of Kasaan Bay about 10 miles northwest of the village of Kasaan (pl. 1) and about 45 miles northwest of Ketchikan. It is in an area of moderate relief in which higher hills attain an altitude of 500 feet or more. Much of the area is covered with glacial drift and dense vegetation. Muskegs are numerous. Outcrops are scarce and are confined mostly to steep slopes, stream beds, and prospect pits. Topographic, geologic, and magnetic surveys of the ore deposits and vicinity were made by the Geological Survey in 1943, and a brief examination of a portion of the underground workings was made in 1944.

The Rush and Brown mine was discovered about 1900 by U.S. Rush and his partner. Development work was begun on the property in 1904 (Wright, 1915, p. 98) and ore was mined almost continuously from 1906 to 1923, first by the Alaska Copper Co. and later by U.S. Rush, the owner. During most of the mine's operation, difficulty was experienced in securing a satisfactory smelter to handle the ore, and according to U.S. Rush this was one of the principal causes, together with a slump in copper prices, for suspending operations in 1923.

In 1929 the Solar Development Co., a subsidiary of the Consolidated Mining and Smelting Co. of Canada, took an option on the mine and reportedly shipped a small amount of ore. The mine was unwatered and 128 ore samples were taken. At present the property is in the hands of the Alaska Gold and Metals Company and is managed by A. L. Howard of Seattle, Washington.

The mine workings consist of a glory hole about 100 feet deep, a 200-foot vertical shaft, an inclined shaft and a series of levels connected by a working winze which extends to a vertical depth of more than 400 feet. (See pls. 19, 20.) All of the mine below the 200-foot level was flooded at the time of examination.

An adit known as the Sawmill adit was driven by the Solar Development Company toward the workings from a point 1,350 feet east of the shaft. (See fig. 34.) The adit, which is 250 feet lower than the collar of the shaft, was designed to intersect the mine workings at about the 300-foot level. It is 1,290 feet long and would have to be extended about 175 feet to intersect the workings.

The country rock on both sides of the Sawmill adit was explored by drilling in the hope of locating additional ore east of the mine workings. Five holes were drilled, 1 by the Solar Development Co. in 1930 and 4 by the U.S. Bureau of Mines in 1943. One of the latter holes, directed westward from the face of the adit, reached an opening, probably in a fault, through which water from the workings drained to the 200-foot level. No ore was penetrated in any of the drill holes.

GEOLOGY

The general geology in the vicinity of the Rush and Brown mine is shown on figure 34. The principal rock is greenstone, thought to have been derived chiefly from andesite. Rocks of probable sedimentary origin were noted in places but are not abundant in outcrop. Limestone apparently is lacking, although masses of tactite exposed in the glory hole are associated with impure calcareous rocks.

Northeast of the mine workings the greenstone is intruded by a large northwesterly trending dike of gabbro and diorite which grades locally into pyroxenite. The southern part of this intrusive is exposed in the Sawmill adit and is cut by three of the diamond-drill holes. A smaller body, probably chiefly diorite, was found in a fourth drill hole but is not exposed at the surface. Another large northwesterly trending dike of gabbro and pyroxenite is exposed from 1,500 to 2,500 feet west of the mine. Mafic dikes, the youngest rocks in the area, are exposed in the Sawmill adit and near the glory hole.

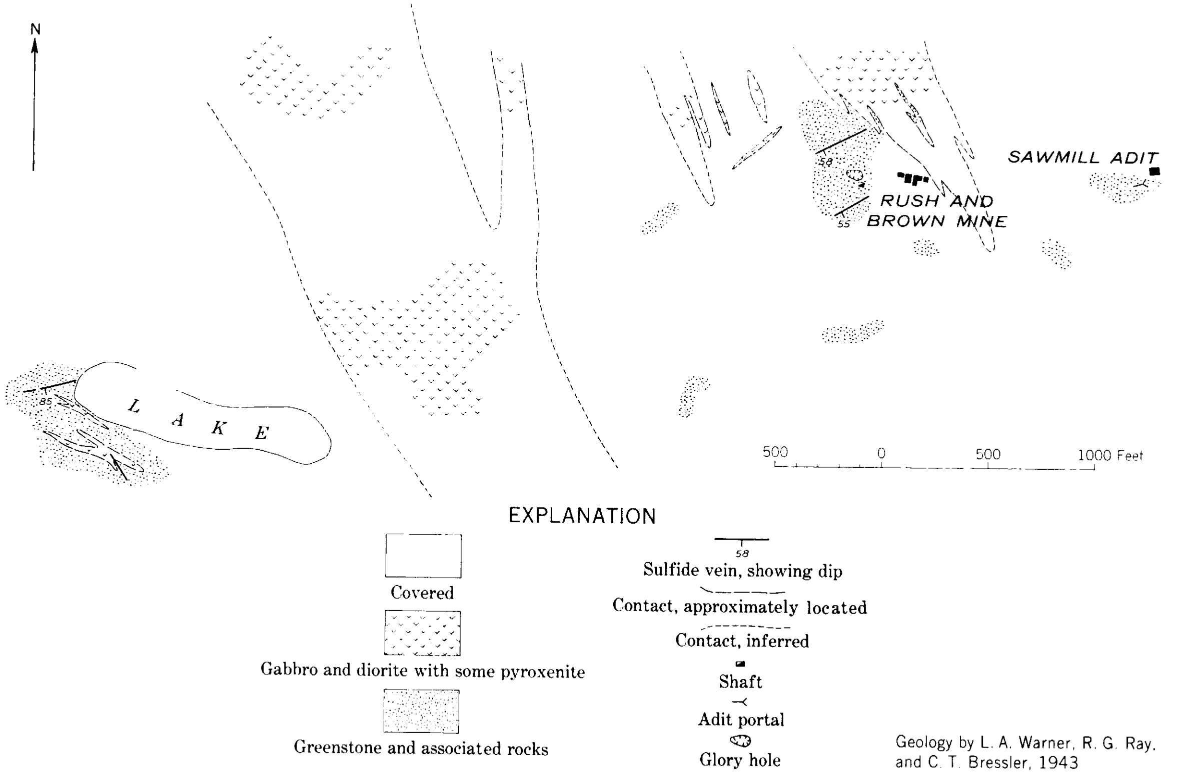

Figure 34.—Generalized geologic map of the Rush and Brown mine area.

ORE DEPOSITS

Production at the Rush and Brown mine has been from two deposits, a magnetite body and a sulfide vein.

The ore mined from the glory hole was essentially magnetite containing small amounts of pyrite and chalcopyrite. Magnetite and tactite replaced brecciated greenstone and calcareous clastic rocks and sulfide minerals were deposited in the network of minute fractures that cut the magnetite. The ore constituted an east-west trending lens with a dip of nearly 90°. A block of ore about 160 feet long, 40 to 50 feet thick, and 100 feet deep has been mined out. Some magnetite, apparently too low in copper to be mined, is exposed at the east end of the glory hole in a short drift 30 feet above the 100-foot level. This body is about 20 feet wide and extends easterly for at least 90 feet. No magnetite was seen in the 200-foot level directly below the glory hole. Dip-needle readings were taken over a wide area around the glory hole and the anomalies decrease sharply within a few feet of the exposed ore.

The sulfide vein, which was the principal source of ore at the Rush and Brown mine, crops out about 150 feet northwest of the glory hole. At the surface the strike of the vein is about N. 60° E. On the 200-foot level near the inclined shaft the strike of the vein is about N. 55° E. A fault trending about N. 20° W., known as Murphy's slip, joins the vein southwest of the shaft, and west of the fault the strike of the vein is about N. 35° E. At lower levels the strike is said to swing to the east and to be nearly due east in places on the 400- and the 450-foot levels. The dip of the vein at the surface is about 60° SE. and decreases downward to about 55° SE. at the 200-foot level; it is reported to be 30° S. at the 500-foot level.

On the 200-foot level Murphy's slip is followed southward for nearly 500 feet. Near the vein it dips about 40° E. Southward the dip increases to about 75° E. No deposits were found along the fault except for a 6-inch calcite vein containing a little chalcopyrite about 35 feet from the face of the drift. West of the junction of Murphy's slip and the sulfide vein there was a small chalcopyrite-bearing magnetite deposit which has been largely stoped out. Magnetite also is reported to occur on the 250- and 350-foot levels.

All of the ore in the vein has been removed from the workings above ,the 200-foot level, the only workings accessible in 1944. In places the stopes are 14 feet wide. According to Mertie (1919, p. 120),

The sulphide ore, chiefly chalcopyrite with some pyrite and pyrrhotite, occurs in lenses and reticulating veins and veinlets within the sheared material, more commonly nearer to the hanging wall than to the footwall. Some solid veins of chalcopyrite have been found, of which the largest so far mined has not exceeded 4 feet in thickness. The gangue material consists of crushed country rock, rather than gangue minerals such as quartz or calcite. The two walls evidently represent the outer limits of movement, for they are slickensided, and the sheared and crushed vein material ends abruptly against them.

A study of analyses of the samples taken in the workings by the Solar Development Co. fails to show any pronounced major trend to the ore shoots. (See pl. 20.) As so far developed, the main shoot is lenticular in form but shows considerable irregularity as to width and stope length. Although the 500-foot level shows a somewhat shorter stope length than the upper levels, the evidence is not conclusive that this represents the final pinching out of the ore body. The few analyses available indicate that the ore at the bottom of the mine is similar in grade to the ore previously mined. The transition from high-grade ore to low-grade material is generally sharp, minable ore grading into ore of less than one percent of copper within a few feet along the strike of the vein.

A small vein is exposed in a trench about 150 feet south of the glory hole. The chief minerals are pyrite and chalcopyrite. The calcite and chalcopyrite found near the face of the south drift of the 200-foot level may represent the downward extension of this vein.

Another sulfide vein is exposed 3,800 feet S. 74° W. of the glory hole and at the west end of a small lake (fig. 34). In general the vein trends about N. 75° E. but at its western end the strike is more easterly. The dip ranges from 85° S. to vertical. The deposit consists of two mineralized shears each about 2 feet wide and separated by 2 to 3 feet of barren greenstone. Ore is exposed intermittently for 200 feet or more along the strike. Pyrrhotite and pyrite are the chief ore minerals. A sample taken and analyzed by the Geological Survey in 1943 contained 0.10 percent copper, 0.07 percent cobalt and a trace of nickel.

A small, poorly exposed sulfide vein trending about N. 35° W. occurs on a hill just south of the lake shown in figure 34. The principal minerals are pyrite and pyrrhotite.

Data obtained from maps and analyses furnished by the Consolidated Mining and Smelting Co. of Canada indicate that the largest block of remaining high-grade ore at the Rush and Brown mine probably lies below the 500-foot level. The matter of obtaining this ore and the remaining ore in the upper levels involves problems in mining engineering beyond the scope of this report. However, extending the Sawmill tunnel approximately 175 feet to the vein workings would provide a haulage way for the ore and would drain the mine to near the 300-foot level. Drainage below this level would require pumping.

VENUS PROSPECT

By R. G. Ray

The Venus prospect, also known as the Iron Creek No. 1 claim, is on the southwest side of Kasaan Bay, 1 mile south of the Rush and Brown mine. (See pl. 1.) The prospect is about 1½ miles from tidewater at an altitude of 250 feet. The claim is owned by Fred Moeser of Ketchikan. During the summer of 1943 the U.S. Geological Survey made a brief examination of the area. Present development consists of three long trenches totaling 800 feet and a short adit which cuts through 30 feet of glacial drift and about 45 feet of bedrock.

Although largely covered by glacial drift and alluvium, the area surrounding the Venus prospect is thought to be underlain chiefly by greenstone. The greenstone exposed in the area ranges from a dark-gray-green, fine-grained rock to a coarser rock type containing amphibole phenocrysts or metacrysts. Only one outcrop of igneous rock was found and its relationship to the surrounding greenstone is not known. It appears to be a diorite dike.

The deposit is a vein of pyrrhotite containing sphalerite and chalcopyrite. Quartz, pyrite, and calcite are the chief gangue minerals. The vein strikes N. 85° E. and appears to dip steeply south. The vein is exposed for 200 feet in trench 3 (fig. 35) and ranges in width from a few inches at its eastern end to a maximum of 6 feet at the westernmost exposure. The average width is about 2½ feet. The vein does not extend as far east as the east end of trench 3. It probably extends at least 50 feet and may continue 100 feet or more west of the present westernmost exposure. Vein material also is exposed at the face of the adit and in a small fault 40 feet from the adit portal. This fault appears to strike about N. 85° E. and may be the continuation of the vein exposed in trench 3. The exposed portion of the vein at its maximum width is massive sulfide ore although in other places the vein includes many small blocks of greenstone suggesting replacement along multiple fissures. Three samples of the ore were taken and analyzed by the Bureau of Mines. Analyses are given in table 5.

Table 5.—*Analyses of samples from the Venus prospect*

Sample No.	Location	Au (ounces)	Ag (ounces)	Cu (percent)	Fe (percent)	Zn (percent)
1	3-foot chip sample of pyrite and pyrrhotite at face of adit.	0.01	1.00	1.18	33.1	2.01
2	6-foot chip sample of pyrite and pyrrhotite vein (where maximum width of vein is exposed in trench 3).	.01	0	1.78	52.4	.13
3	Grab sample from 50 tons of ore in bin below dump.	.01	.70	.91	41.0	.52

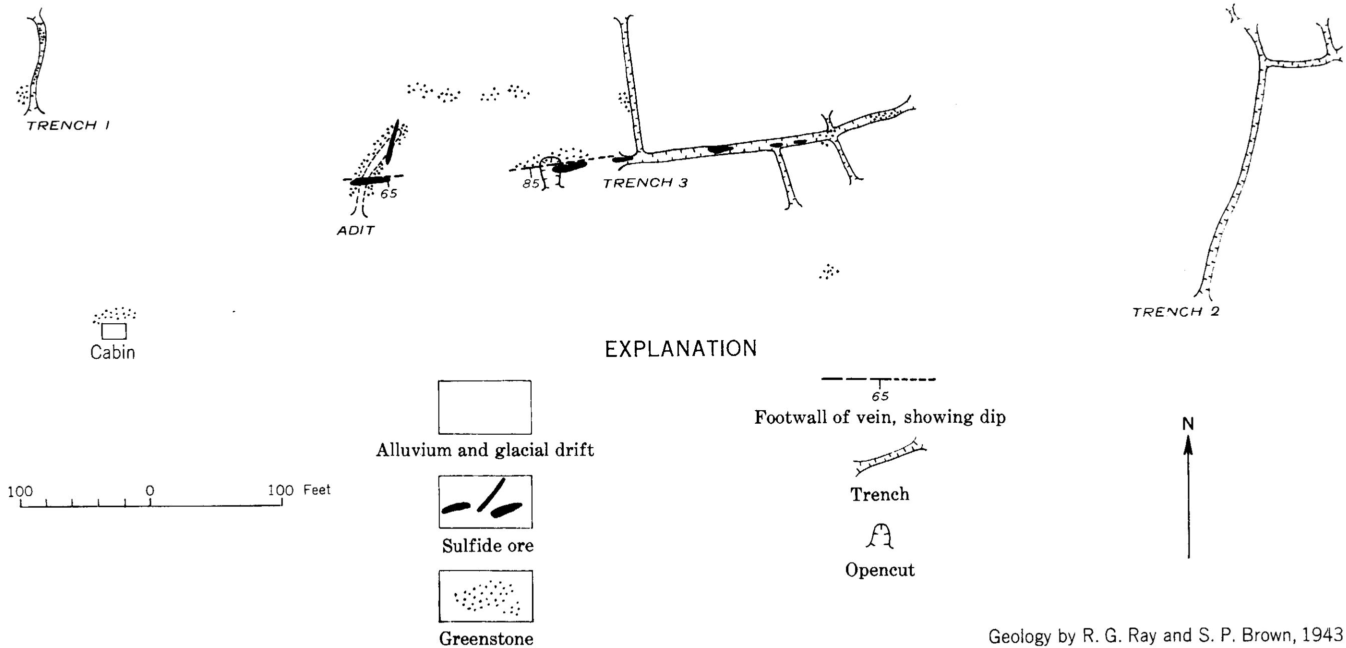

FIGURE 35.—Geologic map of the Iron Creek No. 1 (Venus) prospect.

HAIDA MINE

By L. A. Warner and R. G. Ray

The Haida mine is about 6 miles northwest of the village of Kasaan, near the top of a small hill about 2,000 feet from tidewater and at an altitude of about 500 feet. The ore deposits are explored by several opencuts, pits and trenches, a short adit, and two shafts, one of which was sunk near the face of the adit (pl. 21). The area was examined by the Geological Survey in the summer of 1943, at which time detailed geologic, topographic, and magnetic surveys were made.

Most of the development work at the Haida mine was done in 1904–05 (Wright, 1915, p. 100). In 1907 small amounts of copper ore were shipped to the smelter at Hadley. After a brief period of production, the mine was shut down and little work has been done on the property since 1908. No usable buildings or equipment remain.

The area is largely covered by glacial drift, alluvium, and dense vegetation. The principal rock in the vicinity of the Haida mine is a fine-grained greenstone. Very little igneous rock is exposed in the vicinity of the ore bodies. A large northwestward trending dike of diorite cuts the greenstone 500 feet southwest of the mine (pl. 1). Because foliation in the greenstone is obscure, the attitude of the formations is not clear. No large faults were found but many northwestward trending small faults and fractures are exposed in the workings and these appear to have controlled deposition of the ore.

Magnetite is the most abundant ore mineral and has replaced the greenstone mainly where it was shattered by the northwestward trending fractures. Locally, the greenstone contains lenses of calcareous sedimentary rocks. Remnants of this material are associated with the ore in a few places, suggesting that the magnetite may have preferentially replaced calcareous rocks. The sulfide minerals have the appearance of being disseminated in the magnetite but actually are confined, for the most part, to minute veinlets which cut the magnetite and greenstone. Pyrite appears to be more abundant than chalcopyrite in most places. A few larger sulfide veins, rarely more than a few inches wide, cut the greenstone adjacent to the magnetite deposits. Some of these veins contain minor amounts of molybdenite.

In a few places near the ore bodies the greenstone is altered to garnet and epidote. Remnants of unreplaced greenstone, ranging from minute fragments to blocks and lenses several feet thick, are contained in the ore and locally reduce the tenor appreciably. Late veinlets of quartz and calcite cut the ore and the adjacent country rock.

At least three small deposits of copper-bearing magnetite ore are indicated by development work at the Haida mine. (See pl. 21.) Ore is exposed in an opencut just east of the adit portal. The deposit is apparently thin and flat-lying as the ore does not extend to the adit, which passes about 15 feet beneath the outcrop. The body is estimated to be about 50 feet long, 30 feet wide, and 10 feet thick.

A second ore body is exposed in a small glory hole 75 feet east of the first. The adit intersects this ore body 20 feet beneath the glory hole. The body has been explored below the adit level by a shaft about 30 feet deep, now full of water. The depth to which the ore extends in the shaft is not known. This ore body appears to be confined to a zone of steeply dipping fractures and to be about 50 feet long and 25 feet wide. The ore may follow the fracture zone for several feet below the adit.

A third ore body is partly exposed in pits and trenches 200 feet southeast of the second. The body trends northwestward and appears to dip 55° or more southwest. The ore at the northern end of the body is predominantly magnetite but at the southern end, pyrite is the most abundant mineral. The body is estimated to be about 150 feet long, to average 15 feet wide, and to extend at least 20 feet below the surface without appreciable loss of width.

Ore is exposed in a pit 60 feet east of the third ore body but the amount of ore in this deposit appears to be very small. A similar small lens of ore is exposed in a trench 350 feet N. 15° E. of the adit portal. The pits and trenches south of the main ore bodies disclose only a few small veinlets of ore minerals in greenstone.

Dip-needle readings were taken at closely spaced intervals in the vicinity of the ore bodies and at greater intervals over a wide area adjacent to the workings. The data from the readings were used to supplement geologic observations in delineating the ore bodies. It is inferred from the magnetic data that there is no large body of magnetite near the surface in this area and that the exposed bodies are small isolated pods and lenses.

Samples analyzed by the Geological Survey show that the ore contains an average of about 33 percent iron, 0.88 percent copper, 0.03 ounce of gold per ton, 0.2 ounce of silver per ton, 2.8 percent sulfur, and small amounts of titanium and phosphorus.

COPPER CENTER PROSPECT

By L. A. Warner and R. G. Ray

The Copper Center prospect is about 1 mile from tidewater and 7 miles northwest of Kasaan. (See pl. 1.) The workings are at an altitude of about 400 feet and include several pits and trenches and four shallow shafts. One small building in poor condition is on the property. According to Wright (1915, p. 100), the prospect was discovered in 1907 by means of a dip needle. Most of the development work was done in 1908, and no ore has been produced to date.

The area near the prospect is mostly covered but is thought to be largely underlain by greenstone, outcrops of which are found in and near the workings. (See pl. 22.) The greenstone ranges from fine-grained massive rock to coarse-grained rock containing phenocrysts or metacrysts of amphibole. A single diorite dike is the only igneous rock exposed in the vicinity of the workings, but fine-grained basic dikes, trending northwesterly, crop out north of the prospect and several dikelike bodies of diorite are exposed a few hundred feet to the south.

The ore bodies consist of several small, irregular pods and veins of magnetite, pyrite, and chalcopyrite in greenstone. Most of the ore seems to be localized along small faults which dip steeply and strike nearly east, although a few, as in shaft 3, strike northwesterly (pl. 22). The pods and veins of ore are separated by large areas of barren greenstone.

Magnetite is by far the most abundant ore mineral and chalcopyrite is about as abundant as pyrite. The distribution of these minerals, however, is very irregular. Some of the ore is nearly solid magnetite, but in other places the sulfide minerals are dominant. Garnet and epidote are present but are not as abundant as at most of the other copper-bearing magnetite deposits on Kasaan Peninsula. Minor amounts of quartz and calcite occur as gangue.

Most of the pods and veins of ore are small. One well-defined vein, in which chalcopyrite is the dominant mineral, is exposed in an opencut about 100 feet N. 75° E. of shaft 4. The vein is from 1 foot to 3 feet wide and is exposed for a length of 20 feet. It probably extends for several feet both east and west of the cut. The fact that the footwall dips 70° S. whereas the hanging wall dips 50° S. suggests that the vein may be wider at depth than on the surface.

Dip-needle readings were taken at closely spaced intervals over an area considerably larger than that covered by the workings. Magnetic anomalies are small and are confined to the immediate vicinities of the magnetite outcrops. The magnetic data confirm the geologic evidence that the ore bodies are small discontinuous pods and veins. There is no indication that bodies much larger than those exposed at the surface are present at depth.

Two samples taken and analyzed by the Bureau of Mines contained fairly high percentages of copper and iron. Analyses of these samples are given in table 6.

TABLE 6.—*Analyses of samples from the Copper Center prospect*

Sample No.	Location	Gold (ounces)	Silver (ounces)	Copper (percent)	Iron (percent)
1	Chalcopyrite vein 100 ft N. 75° E. of shaft 4	0.345	2.00	4.72	41.05
2	Trench, 50 ft east of shaft 2	.030	.35	4.08	54.40

The material sampled is of higher grade than the typical ore material at the prospect. Although the average iron content may be between 40 percent and 50 percent, the average copper content is probably less than 1 percent.

Further exploration at the Copper Center prospect does not seem warranted except at the chalcopyrite vein 100 feet N. 75° E. of shaft 4. If this vein widens downward and extends laterally beyond the opencut in which it is exposed it may contain a considerable amount of high-grade copper ore. Short trenches across the strike of the vein east and west of the opencut would determine the length of the vein at the surface. A short shaft, sunk on the vein from the opencut, would show whether the deposit is more extensive at depth.

IT, ALARM, AND BROWN AND METZDORF MINES

By R. G. RAY and L. A. WARNER

The It, Alarm, and Brown and Metzdorf mines are a group of similar copper properties on the southwest side of Kasaan Peninsula about 4 miles northwest of Kasaan village. (See pl. 1.) All these properties are within about one-half mile of tidewater and are at altitudes of not more than 600 feet. A heavy cover of vegetation obscures most of the bedrock.

The principal rocks of the area are interlayered marble, greenstone and tactite consisting chiefly of garnet and epidote; all are cut by irregular dikes of diorite and gabbro. These rocks are cut by smaller dikes of basalt, andesite porphyry, and diabase. The bedded rocks in general trend northwesterly and are complexly folded. Most of the intrusive bodies also trend northwesterly, but some trend northeasterly. The tactite forms irregular zones which are particularly well developed adjacent to the marble, against which it is commonly in sharp contact. For the most part, tactite and greenstone are undifferentiated on the accompanying geologic maps.

The ore deposits at the It, Alarm, and Brown and Metzdorf mines originated in a similar geologic environment. Most of the larger ore bodies in the area formed in fractured tactite close to lenses of marble. The chief ore minerals are chalcopyrite and pyrite, although magnetite, hematite, and minor amounts of molybdenite also are present.

IT MINE

The It mine is 4 miles northwest of Kasaan village and 0.6 mile from tidewater. The property was first developed in 1907, and ore shipments were begun in 1908 (Wright, 1915, p. 94–95). With the exception of the years 1913–14 operations were carried on steadily until 1919, principally by the Granby Consolidated Mining, Smelting, and Power Co., Ltd. Since 1919 the mine has been shut down. From 1908 to 1918 the It mine was one of the three largest producers of copper ore on Kasaan Peninsula. The average metallic content of the ore produced during this period was as follows: copper, 3.99 percent, gold 0.0685 ounces per ton, and silver 0.478 ounces per ton.

The workings at the It mine are in two groups, the main workings and the north workings. (See pl. 23.) The main surface workings are near the top of a hill at an altitude of 600 feet and consist of a few opencuts, several trenches, and two glory holes. The main glory hole (glory hole 1) is about 75 feet deep. Glory hole 2, just southeast of the main glory hole, connects with a large stope, the bottom of which is more than 100 feet below the surface. An inclined shaft between this stope and the main glory hole connects with lower levels which were inaccessible at the time of examination. Adit 5 and one other level are accessible from the main glory hole. (See pl. 24.)

Adit 1, driven from a point 1,100 feet west of glory hole 1, connects with the main workings 370 feet below the surface. The portal was caved at the time of investigation. According to information furnished by the Granby Consolidated Mining, Smelting and Power Co., Ltd., four working levels with several large stopes are between the main adit level and the two upper levels, which are exposed in the main glory hole. Adit 1 was used as a haulage level for the ore mined in the main workings.

The north workings include many opencuts, pits, and trenches, two adits, and a glory hole about 75 feet deep. A short adit (adit 3) intersects the glory hole 40 feet below the rim and a longer adit (adit 2) extends beneath the glory hole 115 feet below the rim. An ore chute connects the bottom of the glory hole and adit 2.

Several hundred feet of surface tramway, now in ruin, originally connected all workings except adit 4 to the main dump where most of the mine buildings are located. The surface tram which connected the mine workings to the beach is also in ruin. None of the mine buildings is usable.

Marble, garnet-epidote tactite, and greenstone form prominent northwesterly trending bands in the vicinity of the It mine. A large irregular band of marble is exposed southeast of adit 1. Elsewhere only small lenses of marble were found. Such lenses are well exposed at the main surface workings and at the north workings. They are commonly enclosed in tactite, which is more abundant in the area than typical greenstone, although there are lenses of greenstone in the marble and tactite. A large irregular body of diorite, which trends northwesterly through the central part of the area, contains many irregular inclusions of greenstone and tactite. Northeasterly trending diabase dikes cut both the diorite and the layered rocks.

At the main workings the chief ore minerals are chalcopyrite and pyrite. The ore is localized along contacts between tactite and the lenses of marble. The marble lenses dip steeply northeast and, according to maps furnished by the Granby Consolidated Mining, Smelting, and Power Co., Ltd., the ore associated with these lenses has been mined downward over a vertical distance of 346 feet to the main adit level. Apparently several large ore shoots were mined.

Similar, though smaller, ore bodies were mined at the north workings. Glory hole 3 was sunk on a nearly north-trending shear zone bounded on the east by a fault striking N. 12° W. and dipping vertically or steeply west. Chalcopyrite, pyrite, and, rarely, magnetite are sparsely disseminated in the wallrock, which is mainly tactite containing irregular fingers of marble and greenstone. The north and south drifts of adit 2 have been driven along a fault that strikes N. 8° W. and dips vertically or steeply west. (See pl. 24.) This fault probably represents the downward extension of the fault exposed along the east wall of glory hole 3. No ore was found in adit 2 except in a small stope off the south drift, where a small lens of rich chalcopyrite ore is exposed just east of the main fault. The chalcopyrite was deposited in fractured greenstone and tactite. Adit 3 exposes no ore, but small sulfide veinlets occur at the adit level in the glory hole.

Magnetite ore is exposed at only two places in the vicinity of the It mine. Adit 4 explores a magnetite deposit 700 feet southwest of the main glory hole. The adit is in tactite which in places contains small pods of sulfide minerals. The magnetite occurs as an irregular mass on the hanging wall side of a northeasterly trending basic dike. Magnetite is also exposed in an opencut 200 feet northeast of adit 4. Here the magnetite occurs in irregular blobs and thin veinlets in tactite and marble. Bedding in the marble suggests that the body dips steeply northeast. Data from a dip-needle survey of the vicinity of these magnetite exposures indicate that the deposits are small.

Very little ore remains in the workings that were accessible at the time the mine was examined in 1943. The Granby Consolidated Mining, Smelting, and Power Co., Ltd. is reported to have exhausted all the ore shoots exposed in the workings and to have done extensive diamond drilling without finding any additional ore.

ALARM MINE

The Alarm mine is about 4⅓ miles northwest of Kasaan and about 800 feet northwest of the north workings of the It mine (pl. 23). The history of the Alarm mine is not known, but probably the property was developed during the period when the It mine was active. Production, if any, was very small. Development at the mine consists of a few opencuts and trenches, and 2 short adits totaling 200 feet in length. A surface tram that connected adit 1 with the main dump of the It workings is now in ruin.

In the vicinity of the Alarm mine the country rock is largely marble containing northwesterly trending lenses of tactite. The bedrock east of the mine is completely covered by muskeg. A mass of diorite and gabbro is exposed 250 feet southwest of adit 1 and is cut by a gabbro pegmatite striking northeastward. Northeast of adit 2, fingers of diorite and gabbro are exposed but are associated with greenstone. Several basic dikes are exposed in the mine workings.

As at the It mine, the chief ore minerals are chalcopyrite and pyrite. Small amounts of ore were taken from adit 1 (pl. 24) in which there are two small stopes. Just inside the portal a pod of ore at the contact between marble and tactite was stoped for 15 feet to the surface. About 50 feet from the portal an east-trending fault dipping 75° S. was found. A short drift west along this fault does not expose ore but to the east the fault zone has been stoped for 25 feet to the surface. In a few places sparsely disseminated chalcopyrite remains, but the copper content is estimated to be less than one-half of one percent. No ore is exposed in adit 2 which is mainly in tactite.

The vicinity of the Alarm mine has been thoroughly prospected by trenches and opencuts, but very little ore is exposed. It is doubtful that any commercial deposits of iron or copper are in this area.

BROWN AND METZDORF MINE

The Brown and Metzdorf mine is 0.5 mile northwest of the Alarm mine and 0.4 mile from tidewater. The mine workings are at an altitude of about 275 feet. The mine was discovered prior to 1908, and it is reported to have produced a small amount of ore (Wright, 1915, p. 97).

Surface developments consist of several opencuts and trenches. (See pl. 25.) Underground workings include two shafts and an adit with 225 feet of workings (pl. 24). The adit is caved about 75 feet from the portal and access to the rest of the adit is gained through a 35-foot vertical shaft (shaft 1). Shaft 2 is inclined and extends for a distance of 15 feet along the footwall of a small basic dike. An ore chute connects the bottom of this shaft to the adit.

A surface tram from the mine connects with an aerial tram 500 feet southwest of the portal of the adit. This aerial tram in turn leads to the beach. Two small buildings in poor condition are near the adit portal.

Much of the area near the mine workings is covered and the geology is not entirely known. North and west of the workings the outcrops are mostly greenstone. Marble is exposed in the southeastern end of the adit and at several places on the surface near the portal. The marble in the vicinity of the adit portal appears to form the nose of a northwestward-plunging anticline, but the structural data are not conclusive. A small lens of marble has been cut near the face of the adit and shows on the surface at the collar of shaft 2. Tactite is exposed in and near the shafts and in the northern end of the adit. The relation of this rock to the marble and greenstone is not clear. It was probably a calcareous sedimentary rock that was replaced by garnet and epidote. Basic dikes, mainly basalt and andesite, are the only intrusive rocks near the mine. The adit is driven along one of these dikes which is sheared by a fault.

A small pod of high-grade copper ore was uncovered in a short drift extending east from the face of the adit. Similar ore is exposed in shaft 2. The ore is in tactite on the footwall side of an easterly trending basic dike near a lens of marble. Chalcopyrite and pyrite are the principal ore minerals, but small amounts of molybdenite also are present. Three samples of this ore were taken and analyzed by the Bureau of Mines, 2 from the shaft and 1 from the adit. Analyses of these samples indicate that the ore contains an average of 0.027 ounce of gold per ton, 0.59 ounce of silver per ton, 3.8 percent copper, and 0.05 percent MoS_2. Pyrite, chalcopyrite, and molybdenite are present in the dike indicating that metallization succeeded the dike emplacement. Disseminated chalcopyrite and pyrite also are found in surface cuts in tactite and greenstone but the copper content is low, probably less than one percent.

Only very small amounts of high-grade copper ore are available, and no large tonnage of low-grade ore is in sight. Although small amounts of molybdenite are present, the molybdenite content of the ore is too low to be significant. The possibility of finding commercial bodies of ore in this area is small.

RICH HILL MINE AND VICINITY

By R. G. Ray

The Rich Hill mine is about 2½ miles southeast of Kasaan village (see pl. 1), near the top of a small hill, at an altitude of 500 feet, and about a quarter of a mile from tidewater. The Rich Hill deposit and several prospects south and west of it (pl. 26) were examined by the Geological Survey during the summer of 1943.

Magnetic surveys were made of the Rich Hill deposit and the surrounding area. Geologic and topographic maps also were prepared.

Surface workings at the Rich Hill mine include many trenches, opencuts, and a small glory hole about 20 feet deep (pl. 27). Two adits explore the ore body underground (fig. 36) and a third was driven for a short distance into an outcrop of slightly mineralized greenstone. Two inclined raises were driven near the end of the main adit (adit 1) for about 50 feet above the adit level. Twenty-five feet from the face of the west drift of adit 2 a 10-foot shaft connects with a sublevel, which in turn connects with the more westerly of the two raises.

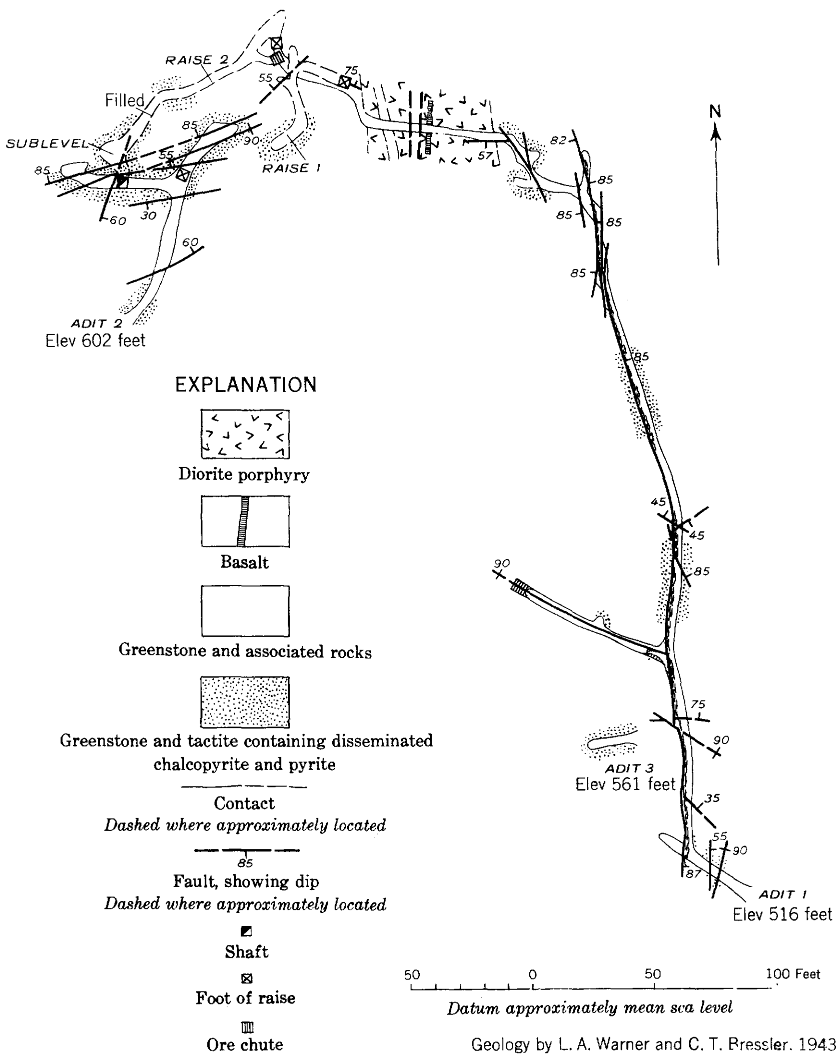

FIGURE 36.—Geologic map of Rich Hill mine workings.

An aerial tramway connects the mine workings and a loading shed near the beach. Several buildings, all in good condition, are on the property, including a small mill and equipment.

Mineralized zone 2, (pl. 26) west of the Rich Hill mine, is prospected by four short adits in addition to surface cuts and trenches. Zone 1, near the beach south of the mine, has been prospected only by a few opencuts and trenches (pl. 28).

The Rich Hill mine was worked during 1917–18, and a small tonnage of ore was mined. The Granby Consolidated Mining, Smelting, and Power Co., Ltd. is reported to have mined a considerable tonnage of high-grade chalcopyrite ore in 1928.

Andesitic greenstone is the principal country rock in the Rich Hill area. It contains lenses of foliated material that may be of sedimentary origin. In general, the formations strike northwestward. Many dikes, including alkalic dacite, diorite, gabbro, basalt, andesite, and diabase have intruded the greenstone (pls. 26 and 27). The dikes dominantly trend to the north or northwest. The largest igneous body in the area is a northerly trending diorite porphyry dike which attains a maximum width of 50 feet and has been traced a quarter of a mile. Both the dikes and greenstone are cut by many faults which do not appear to conform to a definite pattern.

ORE DEPOSITS

Most of the ore in the Rich Hill area consists of disseminated chalcopyrite, pyrite, and magnetite in greenstone, but many irregular pods and veinlets of magnetite and sulfide minerals are present. The main ore body at the Rich Hill mine consisted of a mass of rich calcopyrite ore, with little or no associated magnetite, in a fault zone that strikes N. 77° E. and dips 80° N. to vertical. Most of the high-grade ore has been mined, but a considerable amount of low-grade material remains.

The fault zone is exposed in the glory hole (pl. 27) and also in adit 2 (fig. 36), where the rich chalcopyrite lens pinches out. Low-grade ore is exposed in the north and west drifts of adit 2. Some rich chalcopyrite veinlets are in the low-grade ore but the typical ore is disseminated chacopyrite and pyrite in greenstone. The fault zone also is exposed on the sublevel of adit 2 and contains disseminated chalcopyrite and pyrite in greenstone.

The west drift of adit 1 was designed to explore the ore body 80 feet below the level of adit 2, but the drift may have been placed too far north. The upper ends of the two raises from adit 1, however, expose ore that may be the downward extension of that found in the glory hole and in adit 2. A small amount of ore is exposed in the west drift of adit 1 east of the large diorite porphyry dike; it appears to be localized along a small fault and to be separate from the main ore body.

Disseminated chalcopyrite and pyrite are at places in a pronounced northerly trending fault along which adit 1 has been driven for 290 feet. The copper content of this material is probably less than 0.5 percent, and the mineralization is thought to have been confined to the immediate vicinity of the fault. A well-defined fault, 110 feet from the portal of adit 2, trends N. 70° D. A drift 65 feet along this fault has exposed no ore.

A short prospect adit (adit 3) 75 feet northwest of the portal of adit 1 extends 22 feet into slightly mineralized greenstone that contains magnetite and chalcopyrite in joints and fractures.

Most of the remaining copper ore at the Rich Hill mine is contained in a block about 100 feet long, 35 feet wide, and 80 feet deep, as indicated by exposures in the glory hole, adit 2, and raises 1 and 2 (fig. 36). A chip sample collected and analyzed by the Geological Survey from the north drift of adit 2 contained 1.40 percent of copper. Another sample from near the top of raise 1 contained 2.00 percent of copper.

Detailed studies of the Rich Hill area indicate that ore minerals are limited to definite zones. (See pl. 26.) Three and possibly four mineralized belts are recognized. All these zones trend northwesterly and include low-grade deposits of disseminated chalcopyrite, pyrite, and magnetite in greenstone. Some of the country rock in and adjacent to these zones shows pronounced foliation and is thought to be of sedimentary origin. The specimens selected for laboratory study, however, were so altered as to elude positive identification. Within the mineralized zones are areas of high-grade magnetite and chalcopyrite. The rich chalcopyrite ore body at the Rich Hill mine was a high-grade mass in zone 3. The mineralized area, which includes the mine workings, may represent only a part of zone 3, which has not yet been completely traced. Zones 1 and 2 are well established but zone 4 is questionable. The zones contain much barren greenstone, and probably not all of the ore-bearing material is minable under present conditions.

In the mineralized zones magnetite replaced fractured country rock whereas the sulfide minerals for the most part fill a network of fractures in the country rock and magnetite. The fact that mineralized material is confined mainly to northwestward-trending belts suggests that some structural control was operative during ore deposition. The mineralized zones in general trend parallel to the strike of the formations on Kasaan Peninsula.

At the Rich Hill deposit and at other places in the area northeasterly trending faults have provided local openings in which sulfide minerals and minor amounts of magnetite are concentrated. This appears to be true of the main chalcopyrite ore body at the Rich Hill mine. There is less indication that faults were an important factor in localizing the deposition of the larger masses of magnetite.

The composition of the country rock may have been a factor in localizing deposition. In the northwestern part of zone 1 disseminated magnetite, with little or no associated chalcopyrite or pyrite, is the principal ore mineral, and the country rock is the typical greenstone composed of feldspar, pyroxene, and epidote. In the southeastern part of zone 1, the country rock is largely tactite, and the dominant ore minerals are chalcopyrite and pyrite; magnetite is much less abundant.

Much tactite is in zones 2 and 3. At other places on Kasaan Peninsula bodies of tactite seem to have originated largely through replacement of lenses of sedimentary material included in the greenstone. The fact that the ore-bearing zones in the Rich Hill area are parallel to the regional trend of the formations on Kasaan Peninsula further suggests that stratigraphy and rock composition may have guided the ore deposition. The foliated nature of some of the country rock associated with the zones resembles that of rocks from other parts of the peninsula that are identified positively as of sedimentary origin. Possibly pods of high-grade ore were localized in lenses of more easily replaceable sedimentary material, whereas the larger amount of low-grade ore was disseminated in less easily replaceable rocks.

Zones 1 and 2 probably contain considerable quantities of low-grade copper ore; bodies of better ore, similar to that mined at the Rich Hill glory hole, may be present at depth. Zone 1 is exposed intermittently for a length of 500 feet and averages about 140 feet in width. Zone 2 is at least 1,200 feet long and averages about 100 feet wide. The material exposed at the surface in each of the zones is estimated to be about two-thirds waste. The remainder probably contains about 1 percent copper.

Time did not permit more than casual investigations beyond the area shown in plate 26. It is possible that other mineralized zones may be present, although this was not indicated by reconnaissance.

RESULTS OF MAGNETIC SURVEY

In general, vertical magnetic anomalies in the vicinity of the Rich Hill mine are small. (See fig. 37.) The amount of magnetite associted with the chalcopyrite is not sufficient to affect the dip needle appreciably. However, large deflections were recorded locally where masses of magnetite are known to be present. The largest magnetic anomalies were recorded over a covered area 300 feet south of the glory hole. A maximum dip-needle deflection of 85° N. was noted

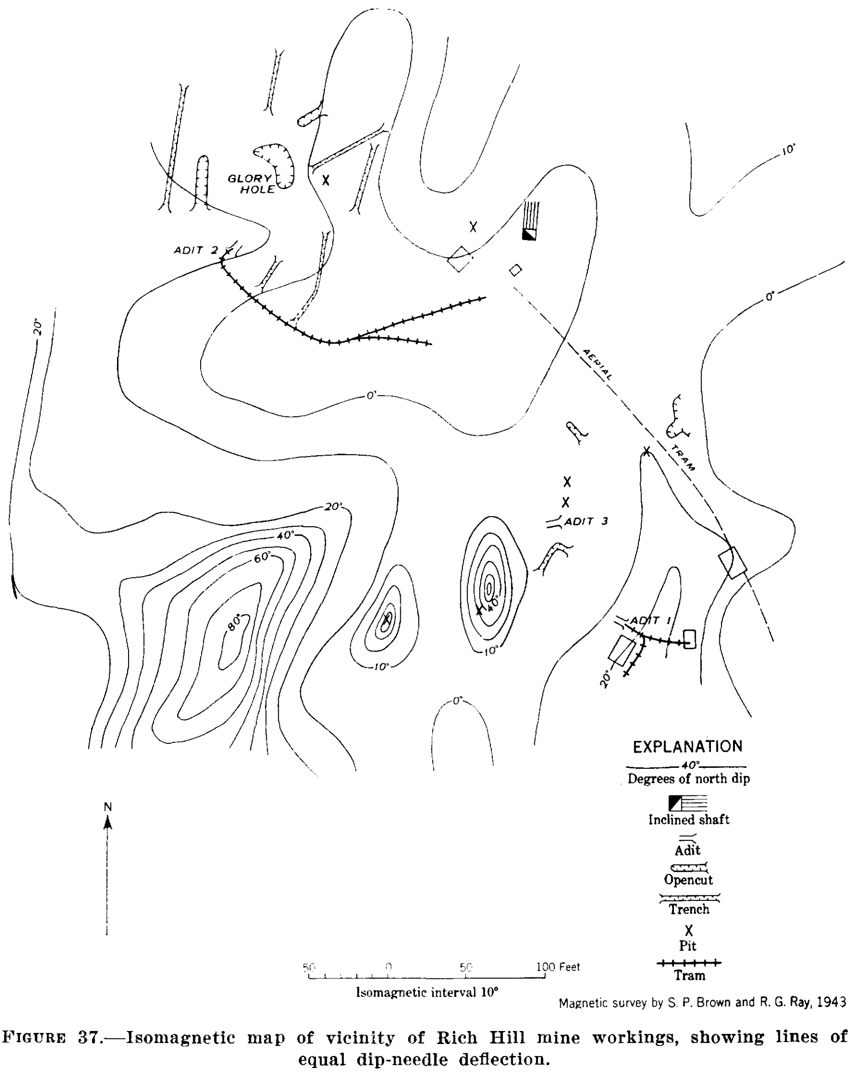

FIGURE 37.—Isomagnetic map of vicinity of Rich Hill mine workings, showing lines of equal dip-needle deflection.

and within a radius of 75 feet of this magnetic high, horizontal magnetic anomalies of as much as 20° were recorded. It is inferred that a body of magnetite is beneath this covered area. The size of this body of magnetite is not known, nor is it known whether the body is high-grade magnetite or disseminated magnetite in greenstone, similar to the material found in zone 1 to the south.

Magnetic data from a survey of zone 1 near the beach (pl. 28) confirm its presence as inferred from geologic evidence. The occurrence of large dip-needle deflections over barren greenstone just northeast of the exposed mineralized belt suggests that the zone dips northeast and that the magnetite content may increase with depth or that the zone persists downward for a distance much greater than its known width.

The large dip-needle deflections in the Rich Hill area might at first suggest that large bodies of magnetite occur in the area, but repeated observations with the Pollard-type dip needle used here indicate that small bodies of magnetite have a considerable effect on the needle. Therefore, the results of the magnetic surveys, although of considerable qualitative value, have but little quantitative significance.

OTHER DEPOSITS

A few other deposits on Kasaan Peninsula have been prospected, including those at the Uncle Sam mine, 1 mile east of Kasaan, and the Charles prospect, three-fourths of a mile east of the Haida mine. (See pl. 1.) These deposits were examined only in a general way, as none appeared to be of sufficient size to warrant detailed study. The Uncle Sam mine, from which some ore was shipped in 1906 (Wright, 1915, p. 95), is the largest of these prospects, consisting of several hundred feet of underground workings and a small open pit. The underground workings were inaccessible at the time of examination. Some magnetite is exposed in the pit, but dip-needle readings taken in the vicinity showed virtually no anomaly. The Charles prospect consists of a small open pit in tactite containing some chalcopyrite, pyrite, and magnetite. Magnetic readings in the vicinity are normal. A few prospect pits were dug on the slope west of Lyman Anchorage. The pits are now caved and exposures in the vicinity are poor, but apparently no ore was found in this area.

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