Idaho 07-1

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGY OF THE EMPIRE COPPER MINE NEAR MACKAY, IDAHO

by

F. W. Farwell and R. P. Full

Open files
October 1944

CONTENTS

ILLUSTRATIONS (See map crb., library)

(22 pages)

GEOLOGY OF THE EMPIRE COPPER MINE NEAR MACKAY, IDAHO

by

F. W. Farwell and R. P. Full

SUMMARY

The Empire copper mine, principal mine in the Alder Creek mining district, is situated in the White Knob Range, about six miles by road southwest of Mackay, in southeastern Custer County, Idaho. Mackay is the terminus of a branch of the Union Pacific Railroad and is also accessible from the north and south by U. S. Highway 93-A.

The Empire mine was first operated in 1884, and from 1901 to 1942 yielded over 55,000,000 pounds of copper. Over 98 percent of this yield was produced prior to 1931. Several million pounds of lead have been produced from neighboring lead-zinc deposits which have not been developed so extensively as the copper deposits. A carload of tungsten ore was shipped from the Empire mine in 1942.

The copper and lead-zinc deposits are located along the margin of a granite stock, which has been intruded into the Brazer limestone, of Mississippian age. Near the Empire mine the stock has a marginal facies of granite porphyry and an extensive zone of contact metamorphism has been developed in the adjacent limestone. Tongues and dikes of granite porphyry transect the limestone, and several large blocks of limestone are wholly included within the granite porphyry. Irregular masses of garnet-diopside rock, or tactite, lie within the granite porphyry and along the contacts of granite porphyry with tongues and blocks of limestone. The tactite was produced by contact metamorphism, after the granite porphyry had crystallized. Most of it formed from limestone or marble, although some tactite replaced granite porphyry.

The copper deposits are irregular, pipe-like bodies which commonly lie along the margins of tactite masses in contact with marble; some ore bodies lie entirely within tactite. A few of the larger ore bodies have been mined through a vertical extent of 400 feet or more. Many of the pipes do not crop out at the surface. The copper ores are composed of chalcopyrite, pyrite, and pyrrhotite in coarsely granular garnet, diopside, and calcite. Magnetite, fluorite, sphalerite, molybdenite, specularite, and scheelite are less widely distributed. The copper ores have been deeply oxidized by ground waters. Chrysocolla is the principal supergene copper mineral.

Most of the lead-zinc deposits are veins whose hypogene minerals consist of galena, marmatitic sphalerite, pyrite, and some chalcopyrite. Oxidation of these deposits has also been extensive, yielding cerussite, smithsonite, and calamine as the principal products.

Because of the irregular distribution and character of the copper ore bodies, considerable exploration is necessary in order to develop ore reserves in advance of mining. In recent years ore has been extracted nearly as fast as it was found and present reserves of sulphide ore are small. Indicated and inferred sulphide ore reserves, based largely upon drilling and mine sampling by the Bureau of Mines in 1943, are estimated by the Geological Survey to be 23,370 tons of ore averaging 2.67 percent copper. Reserves of oxidized ore cannot be closely estimated, but perhaps 100,000 tons or more of chrysocolla ore exists which is too low in grade for direct shipment to the smelter or treatment by present methods of beneficiation.

The geological studies indicate that the possibilities of finding additional ore bodies at the Empire mine are very good. Thorough exploration of known tactite bodies and search for new tactite masses are suggested. Specific recommendations for exploration are made and indicated on the level maps accompanying the report. It is recommended also that other mineralized areas around the granite stock be prospected and search made for possible undiscovered deposits.

INTRODUCTION

The Empire copper mine, principal mine of the Alder Creek Mining district, is situated in the White Knob Range in Custer County, Idaho, about six miles southwest of the town of Mackay. The mine was investigated by geologists of the Geological Survey during 1942 and 1943 in order to gather information on the nature of the ore occurrences which could be used by the mine operators as guidance in search of additional ore reserves. The surface geology was mapped on topographic base maps prepared from aerial photographs, and the accessible levels of the Empire mine were mapped in detail; drill cores were also logged. To furnish a broader setting, the general geology of an area approximately twelve square miles in size surrounding the Empire mine (designated the Mackay district in plates 1 and 2) was mapped in less detail, and a number of smaller mines and prospects were examined. The senior author spent thirteen months at Mackay, accompanied by C. N. Bozion for nearly eleven months; the junior author was with the party in the field for three months. The authors worked on the report for four months in the Spokane office of the Geological Survey.

From December 1942 until September 1943, Bureau of Mines Project 1406, under the supervision of John W. Taber, operated in the Empire mine concurrently with the study of the Geological Survey. Twenty-one diamond drill holes, totaling 3,863 feet, were drilled from underground stations; nearly 400 mine and dump samples were taken; and new transit surveys were run in different parts of the mine. The Bureau of Mines' assays were used exclusively in the estimation of ore reserves made by the Geological Survey.

The ore deposits of the Mackay district were first described by Kemp and Gunther, 1/ who pointed out that the deposits occurred in a contact metamorphic zone. Umpleby 2/ discussed the deposits in more detail, and in his Professional Paper gave a reconnaissance treatment of the geology of the surrounding area. In 1930, Ross 3/ wrote briefly on the Empire and adjacent mines when the Empire mine had nearly reached its present state of development.

A number of private geological and engineering reports were made available to the authors by the management of the Empire mine. The geological information includes maps of examinations made by geologists of the International Smelting and Refining Company during 1923-26 and April 1942, and maps by geologists of the American Smelting and Refining Company in January 1942. The present authors have drawn on these earlier maps for the geology of mine levels which are no longer accessible. The engineering reports were written by Morton Webber of New York, N. Y. in 1919; H. L. Batten of Vancouver, B. C. in 1929; and J. Ray Weber, present superintendent of the mine, in 1940.

The authors wish to express their deep gratitude to the officers of the Mackay Exploration Company, particularly Mr. J. Ray Weber, for their wholehearted cooperation. Thanks are due to Mr. J. W. Taber and Mr. S. H. Lorain of the Bureau of Mines for interchange of information. The authors owe sincere gratitude to many of their colleagues on the Geological Survey who guided and aided the field studies and the preparation of the report.

MINING INDUSTRY

Mackay, with a population of about 700, is the principal settlement of the Alder Creek mining district. The town is the terminus of a branch line of the Union Pacific Railroad which connects with the Pocatello-Butte division at Blackfoot, ninety miles to the southeast (see index map, pl. 1), and is also served by U. S. Highway 93-A, one of the major north-south highways. Mackay lies in the broad valley of the Big Lost River at an elevation of 5,900 feet. The White Knob Range rises to the southwest and the rugged Lost River Range lies to the northeast of Mackay. A few miles west of the Empire mine, White Knob reaches an elevation of 10,533

1/ Kemp, J. F., and Gunther, C. G., The White Knob Copper Deposits, Mackay, Idaho: Am. Inst. Min. Eng. Trans., vol. 38, pp. 269-296, 1908.
2/ Umpleby, J. B., The Genesis of the Mackay Copper Deposits, Idaho: Economic Geology, vol. 9, pp. 307-358, 1914.
Umpleby, J. B., The Geology and Ore Deposits of the Mackay Region, Idaho: U. S. Geol. Surv. Prof. Paper 97, 1917.
3/ Ross, C. P., Geology and Ore Deposits of the Seafoam, Alder Creek, Little Smoky, and Willow Creek Mining Districts, Custer and Camas Counties, Idaho: Idaho Bureau of Mines and Geology, Pamphlet 33, pp. 7-18, 1930.

feet and Mackay Peak an elevation of 10,276 feet. The district is not heavily forested and generally the southern and southwestern slopes are treeless. The only perennial stream near the Empire mine is Cliff Creek, which heads against the saddle between Mackay Peak and White Knob and flows easterly into Big Lost River.

The oldest and most important mine in the district is the Empire copper mine, which was first operated about 1884. Other mines in the neighborhood are the Horseshoe, White Knob, Bluebird, Grand Prize, and Champion mines; numerous prospect pits and adits are scattered over the hillsides.

In the early days of the Empire mine high-grade oxidized ores were mined from open cuts and treated locally in a small smelter. From 1899 to 1907 the mine passed through a period of over-capitalization and mismanagement. The Empire Copper Company acquired the property in 1907 and operated almost continuously until 1921, shipping crude ores to Salt Lake smelters. The company paid handsome dividends but apparently toward the end of this period too little attention was directed to underground development and the maintenance of reserves. In October 1921, the Idaho Copper Company succeeded the Empire Copper Company and installed the present mill and tramway. Milling began in 1924, only the low-grade sulphide ores averaging about 2.8 percent copper being treated, and both concentrates and crude ores were shipped to Salt Lake smelters until operations ceased in 1930. From 1928 until August 1930, the mine was worked by Mackay Metals, Inc. which went into voluntary receivership in 1931, at which time the patented claims were taken over by Custer County. A small amount of crude ore was produced by lessees in 1935-1937. The Mackay Exploration Company, present operators of the mine, took over the property in 1939 under lease and bond agreements with Custer County and with Mackay Metals, Inc.

According to Umpleby, 4/ operations on a large scale at the Empire mine were started in 1901. The production since then is shown in Table 1; previous production is not known.

The other mines in the district have primarily been producers of oxidized lead and zinc ores. The Horseshoe mine, which lies one and a quarter miles northwest of the Empire mine, has yielded principally lead ores from oxidized ore bodies in the upper part of the mine. Zinc occurs in both hypogene and supergene ores, but has been only slightly exploited. The production of the Horseshoe mine for the period 1916-1928 is shown in Table 2, which has been taken from Ross. 5/ Mrs. R. A. Strunk of Mackay is owner of the Horseshoe mine.

4/ Umpleby, J. B., Geology and Ore Deposits of the Mackay Region, Idaho: U. S. Geological Survey, Prof. Paper 97, p. 13, 1917.
5/ Ross, C. P., Geology and Ore Deposits of the Seafoam, Alder Creek, Little Smoky, and Willow Creek Mining Districts, Custer and Camas Counties, Idaho: Idaho Bureau of Mines and Geology, Pamphlet 33, p. 9, 1930.

Table 1
Production of Recovered Metals at
the Empire Mine, 1901-1942

Year	Crude ore, dry tons	Concentrates, dry tons	Gold, ounces	Silver, ounces	Copper, pounds
1901	None				
1902	1,721		14.40	607	14,966
1903	15,681		240.95	12,658	441,286
1904	67,850		85.	3,500	2,700,000
1905	13,000		384.74	22,065	684,134
1906	40,838		1,842.	71,854	2,807,926
1907	37,141	3,430	1,823.33	70,222	2,895,881
1908	382		15.89	673	38,698
1909	1,436		27.73	2,236	90,347
1910	7,206		265.24	28,754	919,492
1911	11,057		663.	40,900	1,415,314
1912	26,227		1,766.	69,942	2,854,281
1913	35,950		1,891.61	106,463	3,962,125
1914	17,801		970.99	59,243	2,106,441
1915	54,295		3,155.06	125,134	4,702,119
1916	69,907		2,874.60	123,453	5,006,291
1917	66,808		2,530.	74,645	4,208,401
1918	53,211		2,476.41	56,014	3,404,161
1919	12,904		672.80	31,833	1,300,518
1920	15,755		1,369.	29,888	1,480,678
1921	9,992		1,236.	23,354	1,088,148
1922	16,717		2,019.	33,988	1,843,200
1923	15,791		1,458.	25,908	1,449,838
1924	11,775	319	1,244.92	18,808	1,137,771
1925	29,753	4,760	2,096.43	35,439	2,352,306
1926	3,635	255	234.38	6,453	239,785
1927	13,627	1,297	761.22	9,734	684,154
1928	11,532	1,053	495.	9,776	514,697
1929	66,573	4,273	2,282.45	60,883	2,824,032
1930	26,214	2,379	754.51	22,925	1,121,586
1931	None				
1932	None				
1933	None				
1934	None				
1935	190		10.10	1,510	26,518
1936	173		8.83	639	18,897
1937	22		1.00	306	3,876
1938	None				
1939	996		207.	2,465	175,940
1940	4,484		526.	11,300	632,217
1941	3,169		381.	7,013	380,469
1942	1,274		141.	1,874	104,000
Total*	765,087	17,766	36,925.59	1,202,459	55,630,~~493~~

* In addition a small tonnage of tungsten ore has been produced.

The statistics in Table 1 have been furnished by the Metal Economics Division of the Bureau of Mines. Comparison with company records indicates that the crude ore figures include only crude ore shipped or smelted and not crude ore concentrated.

Table 2

Production of the Horseshoe Mine, 1916-1928
(From records of the U. S. Bureau of Mines)

Year	Crude ore, tons	Concentrates, tons	Gold, ounces	Silver, ounces	Copper, pounds	Lead, pounds	Zinc, pounds
1916	196		.88	1,468	3,093	55,587	
1917	1,462		6.99	17,293	2,997	678,074	
1918	1,087		8.64	11,440	1,522	446,628	
1919	1,128		4.76	12,011	2,333	361,937	
1920	2,319		5.96	21,165	2,021	386,352	
1921	116		2.25	1,811	376	55,902	
1922	651		7.61	9,297	902	246,659	
1923	660		6.98	5,014	1,603	169,872	
1924	79		4.33	1,012	287	36,538	
1925	75		1.50	1,776	348	59,310	
1926	865	32	11.72	10,236	3,198	332,597	18,942
1927	182	53	1.52	2,275	495	58,256	18,163
1928	49	5	.43	123	1,159	791	2,366
Totals	8,869	90	63.57	94,917	20,334	2,888,503	39,471

The White Knob mine, about three-quarters of a mile northwest of the Empire mine, has produced mostly oxidized lead ores in the past, but in 1941 and 1942 yielded over 2,100 tons of oxidized zinc ores carrying 17 percent zinc. The White Knob Mining Company of Salt Lake City is owner of the property.

Mining at the Grand Prize mine, just south of the Empire property, was resumed in the winter of 1943-44. The Champion mine, which lies two and a half miles south of the Empire mine and just off plate 1, produced four carloads of oxidized lead ore in 1943. Both properties are controlled by Joe and Louis Ausich of Mackay.

The Bluebird mine, just east of the White Knob mine, has been idle for several years and is completely inaccessible at present. Mr. J. Ray Weber of the Empire mine is agent for the owner.

GEOLOGY

Nearly half the area shown in plate 2 is underlain by limestone which is the oldest formation known in the region and is correlated with the Brazer limestone of upper Mississippian age. On the east the limestone is bordered by a group of volcanic rocks correlated with the Challis volcanics of Oligocene or Miocene age; these volcanics appear to be the youngest rocks in the district. The limestone has been intruded by a roughly circular stock of granite about four miles in diameter, most of which lies south and west of the map area. The granite is very porphyritic in places along the edge of the stock and numerous dikes of granite porphyry extend northeasterly from the stock into limestone near the Empire mine. The limestone is intruded also by dikes and small bodies of diorite, quartz monzonite, aplite, andesite porphyry, quartz diabase porphyry, and porphyritic granodiorite. The granite and granite porphyry are believed to be related to the Idaho batholith of late Cretaceous or early Eocene age.

A zone of contact metamorphism has been developed in the limestone along the edge of the granite stock. Large blocks of limestone included in the granite porphyry border phase of the stock have been partly or completely converted to masses of garnet-diopside rock, known as "tactite", and a zone of white marble up to 100 feet in width has been developed in limestone adjoining the igneous bodies and tactite masses. The ore deposits, irregular pipe-like bodies composed of chalcopyrite and other sulphides mixed with garnet, diopside, and other lime-silicate minerals, occur in the contact metamorphic zone and are most commonly localized at the contact of tactite and marble.

The limestone has been rather strongly folded, the strike of its bedding being most commonly to the northwest. Fractures and faults, most of which trend northeast, have been developed in the limestone, and many of them are occupied by dikes of igneous rocks. A north-trending fault marks the contact between limestone and the volcanics in places. East of the Empire mine a large mass of jasperoid, derived from limestone, occurs between the limestone and volcanics.

Sedimentary rocks.-- The limestone varies from thin-bedded, black argillaceous types to blue, medium-bedded limestone. Considerable chert is present, particularly in the more argillaceous limestone in the lower part of the formation, occurring as nodules, and as irregular beds and lenses several inches to a few feet thick. The limestone formation has been correlated with the Brazer limestone 6/ on good faunal evidence in nearby areas. The full thickness of the formation cannot be determined in this area, but it is probably to be measured in thousands of feet.

Igneous rocks. -- All the intrusive rocks are probably later than the folding of the limestone and most, if not all of them, are earlier than the volcanic rocks. The oldest intrusive rock in the area is diorite which is present as two small bodies northwest of the Empire mine. The diorite is light to medium gray in color, fine-grained, and is composed of sodic plagioclase, augite, biotite, accessory apatite and a little quartz, and rare phenocrysts of plagioclase and augite.

Quartz monzonite has been observed only on the deepest level of the Empire mine and in diamond drill cores. It is a massive, coarse, even-grained, gray rock containing oligoclase, orthoclase, chloritized biotite, quartz, hornblende, and minor accessory minerals. The relative age of the

6/ Ross, C. P., Oral communications.
Ross, C. P., Geology and Ore Deposits of the Seafoam, Alder Creek, Little Smoky, and Willow Creek Mining Districts, Custer and Camas Counties, Idaho: Idaho Bureau of Mines and Geology, Pamphlet 33, pp. 10-13, 1930.
Umpleby, J. B., Geology and Ore Deposits of the Mackay Region, Idaho: U. S. Geol. Survey Prof. Paper 97, p. 28, 1917.

quartz monzonite is not well established.

The granite is light pinkish in color and is composed of orthoclase, oligoclase, quartz, chloritized biotite, and accessory magnetite, apatite, and zircon in a very subordinate groundmass of finer quartz and feldspar in graphic intergrowth, biotite and some hornblende. The granite porphyry is white and contains abundant phenocrysts of orthoclase, plagioclase, and rounded quartz, which average from one-fourth inch to one-half inch in size, and sparse biotite and rarer hornblende in a dense groundmass of quartz and feldspar. The granite is relatively uniform in texture and composition, but the granite porphyry varies widely in nearly all its characteristics except color. It is believed that the two rocks are genetically related because of the close similarity in mineral composition and the position of the granite porphyry along the margin of the stock. Contacts between the two types are not exposed, but the texture of the granite porphyry seems to approach the texture of the granite by gradual changes near the contact. The granite is far more resistant to weathering than the granite porphyry and forms craggy peaks and pinnacles. Both the granite and granite porphyry, as well as some bodies of tactite, are cut by small irregular bodies and dikes of white to pale pink, sugary aplite, composed of quartz and orthoclase.

A few scattered dikes of andesite porphyry, ranging in width from 1½ to 80 feet, cut limestone, tactite, and granite porphyry. The andesite porphyry is a medium-grained, green and white rock containing phenocrysts of andesine, albite, a ferromagnesian mineral completely altered to chlorite, and corroded quartz in a groundmass of feldspars, chloritized biotite, calcite, and alteration products. Scattered dikes of quartz diabase porphyry up to 10 feet in width are present; they cut ore bodies in the Empire mine, as well as limestone, granite, and granite porphyry. The rock is greenish-gray to black in color, and carries phenocrysts of augite, strongly resorbed quartz, and rare plagioclase in a fine diabasic groundmass.

The porphyritic granodiorite, locally known as "trachyte porphyry", commonly occurs in northeast-trending dikes as much as 120 feet wide. The rock is light gray where fresh and is composed of phenocrysts of oligoclase, partly resorbed quartz, pink orthoclase, and biotite and hornblende almost completely converted to chlorite, in a fine-grained groundmass of oligoclase and micropegmatite. The rock contains inclusions of andesite porphyry and possibly of quartz diabase porphyry. Chilled margins of slightly porphyritic obsidian are common along the dikes, and have been observed against garnet-chalcopyrite ore, granite, granite porphyry, and some of the earlier rocks. The porphyritic grandiorite slakes rapidly where exposed underground, requiring timbering in most places.

The volcanics exposed along the east edge of the mapped area have not been studied in detail, but a reconnaissance indicates the formation is made up of reddish and purplish brown porphyritic andesites and dacites, with some tuffs and agglomerates present higher in the section. On the west side of Tuscarora Gulch, just south of the mapped area, fresh angular fragments of granite are present in agglomerate, indicating that the granite was emplaced before the agglomerate was formed.

Metamorphic rocks. -- Zones of marble have been developed throughout the area at the contacts of diorite, quartz monzonite, granite, and granite porphyry intrusions into the limestone. The marble is composed almost entirely of calcite with scattered crystals of lime silicates. Near its contacts with igneous rock or tactite, marble is coarse-grained and white or blue in color, and becomes finer-grained and bluer away from the contacts. In places the marble zone is more than 100 feet wide.

Irregular bodies of tactite occur along a part of the border of the stock in the vicinity of the Empire mine. The tactite bodies have sharp contacts with the marble and commonly with the igneous rocks, although in places tactite passes gradually into granite porphyry. Stringers of garnet commonly extend 100 feet or more into the igneous rock but have not been observed cutting the calcareous rocks. Evidently some tactite has been formed by replacement of the igneous rocks as well as by replacement of marble. Garnet and diopside in varying proportions make up at least 90 percent of the tactite. The garnets are grossularite to andradite in composition and range in color from brown through amber to pale honey-yellow. Diopside is greenish white to bottle-green in color. Epidote, actinolite, scapolite, wollastonite, and orthoclase are present in smaller amounts.

In the central and southeastern part of the limestone area, ribs, pods, and irregular masses of hard, dense, rusty jasperoid have been formed. Much of the jasperoid is made up of angular fragments of chert, silicified limestone, and earlier jasperoid in a ferruginous matrix of very fine-grained quartz. The rock is cut by many curved and slickensided fracture surfaces. In some smaller masses the fragmental character is absent and relict bedding of the limestone is preserved. The jasperoid bodies seem to be the result of repeated periods of brecciation and silicification along fractures in the limestone. The largest body of jasperoid lies on the projection of the fault between the limestone and the volcanics. The formation of the jasperoid seems to have been earlier than the intrusion of the granite porphyry and development of tactite, but later than folding of the limestone. In a surface ore body above the Brown adit on the Empire property, jasperoid is surrounded by tactite and cut by garnet stringers. Wherever jasperoid has been found in contact with granite porphyry, the granite porphyry seems to be unsilicified.

Structure. -- The limestone has been deformed by strong folds trending in general to the northwest. In the 1600 adit of the Empire mine the axes of the folds also plunge to the northwest. Faults and fractures striking to the northeast and northwest are common. Many are now occupied by dikes, but some are marked by gouge or breccia, or filled with calcite, garnet, or fluorite. Northeast-trending fractures of all sizes predominate in the Empire mine, but at the Horseshoe mine the most prominent veins and some of the dikes have northwesterly strikes. Displacement along these faults seems to have been small. On the other hand, the strong north-trending fault separating the limestone and the volcanics in the northeastern part of the mapped area must have at least 300 feet, and perhaps much more, of vertical displacement. The fault may continue farther south than shown on plate 2, but the evidence is not clear. Repeated periods of movement have taken place along this fault.

ORE DEPOSITS

The ore deposits of the Mackay district lie in the contact metamorphic zone of a granite stock and associated igneous intrusions. Ore bodies are known to occur in an arc-shaped belt that is at least three miles long and about 1,000 feet wide. The deposits have been mined most extensively at the Empire mine in the center of the belt where copper minerals are dominant. To the north and south lead-zinc bodies have been developed at the Horseshoe, White Knob, Bluebird, Grand Prize, and Champion mines. A small copper prospect lies on the ridge north of the Horseshoe mine. The distribution of lead-zinc deposits on either side of the major copper deposits is somewhat suggestive of zoning. The copper deposits differ from the lead-zinc deposits in their structural form as well as in mineral association, and the two types are discussed separately below.

Copper deposits. -- The copper-bearing ore bodies, whose nature is known almost exclusively from developments in the Empire mine, are typically irregular pipe-like bodies associated with masses of tactite. The ore bodies commonly occur along the margins of the tactite masses in contact with marble, although some of them lie entirely within tactite. The pipes usually have an elliptical shape in horizontal plan, and the direction of their longer dimension may change from level to level. The strike length of the ore bodies ranges from 15 to 200 feet and their width from 5 to 55 feet. One ore body has been mined almost continuously throughout a vertical extent of 600 feet; two other ore bodies or chains of ore bodies, have been mined for over 400 feet vertically. Most of the pipes pitch to the northeast, east, or southeast in a direction nearly at right angles to the strike of the pipe. Gunther 7/ described some of the ore bodies as branching upward; at least one is known that branches downward. A few flat ore bodies, occur, particularly beneath marble hanging walls.

7/ Kemp, J. F., and Gunther, C. G., The White Knob Copper-Deposits, Mackay, Idaho: Amer. Inst. Min. Eng. Trans. Vol. 38, p. 290, 1908.

The hypogene copper ores are composed of garnet, diopside, and other lime silicates that carry disseminations and sponge-like aggregates of metallic minerals. Chalcopyrite is the principal sulphide and is accompanied by pyrite, pyrrhotite, calcite, and quartz. Magnetite, fluorite, scheelite, molybdenite, sphalerite, specularite, and rare bornite are less widely distributed. In places, however, magnetite and fluorite are rather abundant and extend beyond the ore bodies into barren tactite. Scheelite is present in the copper ores in minable amounts at only a few places. The average assay of four samples from selected broken tungsten ores awaiting shipment, and the assay of one carload shipped to the Metals Reserve Corporation in 1942 from a winze stope beneath the 1000 level are given below.

Scheelite-bearing copper ores from the Empire mine

	Ounces per ton		Percent	
	Au	Ag	Cu	WO_3
4 samples 8/	0.24	1.75	3.28	4.28
Carload	0.105	1.35	2.45	2.08

Combined gold and silver values of the copper ores range from $1 to $15 per ton and seem to be associated chiefly with the chalcopyrite.

The copper ores have been deeply oxidized, and much of the ore mined in the early days consisted of oxidized ores. Chrysocolla, accompanied by some malachite, is the principal supergene copper mineral, and in the oxidized portion of the ore bodies it occurs as disseminations and stringers through the tactite. The copper sulphide mineral in the tactite masses appears to have been oxidized more or less in place with minor migration of copper-bearing ground waters. However, small deposits of supergene ore have been mined along some of the faults and open contacts. These vein-like deposits are richer than the supergene ores in tactite and are composed of chrysocolla, malachite, tenorite, azurite, and occasional copper sulphate minerals. They were evidently deposited along open channelways and have been found as deep as the 1000 level, whereas the oxidized portions of the tactite bodies lie principally above the 600 level. Beneath the oxidized tactite ores is a shallow zone in which the sulphides are strongly tarnished and accompanied by small amounts of chalcocite and covellite. The extent of development of supergene copper sulphides has been very minor and they are of no economic importance.

8/ Lemmon, D. M., The Empire Copper Mine, Mackay, Idaho: Memorandum report for U. S. Geol. Survey, June 29, 1942.

<u>Lead-zinc deposits</u>. -- The lead-zinc ores occur in veins controlled by single fractures or shear zones which usually follow or parallel contacts between marble and granite. The hypogene ores consist of galena, marmatitic sphalerite, pyrite, some chalcopyrite, and calcite. Chalcopyrite is practically absent in the ores of the Champion mine; pyrrhotite is relatively abundant in the deeper portions of the Horseshoe deposit. The supergene ores comprise cerussite, smithsonite, calamine and limonite. In the White Knob deposit cerussite has been mined to a depth of more than 400 feet, and no hypogene ore has yet been encountered. Ferruginous smithsonite-calamine ore lies in the footwall of the White Knob cerussite bodies. Similar oxidation products have been formed in the other deposits, but hypogene ores have been found at much shallower depths. The White Knob shear zone seems to be more persistent and permeable than the shear zones of the other lead-zinc deposits.

THE EMPIRE MINE

<u>Mine development</u>.-- The workings of the Empire mine are distributed along a north-trending, arcuate zone for a distance of about 3,500 feet and over a maximum width of 400 feet. The large ore bodies near the southern end of the property were mined by surface methods in the early days. Because of the favorable local topography, underground development of the Empire deposits has been carried out chiefly from adits. The Clark and Darlington shafts at the south end of the property are the largest of several early shafts. The relative position and pattern of the levels is apparent on the composite level plan of plate 6. The total length of all horizontal workings is well over 60,000 feet, of which some 35,000 feet were accessible when mapped by the Geological Survey. Six of the nine major levels are now open over considerable distances. The main portal of the mine is at the 700 level, the longest level, which serves as a tie between the older parts of the mine to the south and the more recent, deeper development to the north. About sixty-five percent of the total mine output to date has come from stopes above the 700 level. An interior vertical shaft extends 330 feet below the 700 level to connect with the 800, 900, and 1000 levels. The Cossack Tunnel, or 1600 level, lies 600 feet beneath the 1000 level but has no connection with the upper workings.

Because of the irregular distribution and nature of the ore bodies, ore has been mined almost as soon as it has been developed. The ground is generally hard and firm, requiring relatively little timbering except in some of the oxide stopes. Shrinkage stoping has been widely used although there are a few square-set stopes. The stopes range in size from enlarged raises to those with floor plans of about 8,000 square feet.

<u>Geology</u>. -- The zone of contact metamorphism in which the Empire ore bodies occur is very irregular because of the numerous granite porphyry dikes extending into limestone from the stock. The dikes converge in depth and the width of the zone becomes narrower. Some of the limestone blocks

that lie within granite porphyry are enormous, having a horizontal length as great as 700 feet and a vertical extent as much as 500 feet. Many of the limestone blocks are believed to be inclusions, but some may be roof pendants. The tactite bodies appear to be restricted to the main mass of granite porphyry on the margin of the stock. They have a tendency to cluster on or near projecting marble tongues or to lie beneath a hanging wall of marble. These tactite masses commonly connect horizontally or vertically with limestone bodies which may be as much as 200 feet or more away.

It has been pointed out above that the hypogene ore bodies are wandering pipes that are commonly situated along the margin of a tactite mass in contact with marble. Some of the pipes lie wholly within tactite; and a few occur at the contact of marble and granite porphyry. One ore body above the 900 level has granite porphyry in both walls.

Sulphide-bearing tactite usually is composed of rather coarse-grained garnet and carries considerable calcite in contrast to much of the barren tactite, which is commonly fine-grained and has only small amounts of sulphides and calcite. The sulphide mineralization ends abruptly along the marble walls of the ore bodies, but diminishes gradually toward the tactite sides. Coarse tactite with interstitial calcite appears to have been more permeable and susceptible to replacement by metallic minerals than either marble or fine-grained tactite. The amount of coarse, calcite-bearing tactite which is free of metallic minerals seems to be small. It is believed that most of the chalcopyrite has replaced calcite, or in some cases pyrrhotite which had previously replaced calcite.

Thus, the present positions and forms of the ore bodies seem to have been largely caused by two factors: the location of the tactite masses, and the presence and structure of coarse, calcite-bearing portions of the individual tactite bodies. Where the tactite bodies were in contact with marble, the susceptible, calcite-rich portion of the tactite usually lay on the marble side of the tactite. On the other hand, the calcite-bearing portion of tactite bodies wholly within granite porphyry has commonly been in the interior of the tactite mass.

A number of strong faults, striking northeast and dipping southeast, persist from level to level in the mine. For the sake of convenience, the faults have been designated by numbers on the mine level maps. They carry gouge consisting of decomposed granite porphyry, clay, and limonite with occasional white calcite, pyrite, and crushed garnet over widths of two inches to six feet or more. Most of the dikes also have a northeast trend, as do some stringers of garnet and sulphides. Recurrent movement has taken place along the faults and some of the dikes. The faults may have been important access channelways for the hypogene mineralizing solutions, but deposition of the hypogene sulphides was practically restricted to the tactite bodies. However, descending groundwater solutions have followed the faults and have deposited chrysocolla and other copper minerals in places along some of them.

Several ore bodies lie against porphyritic granodiorite dikes, which were emplaced after deposition of the ore bodies. It is possible in some cases that the ore body has been separated by the dike and an unexplored segment may lie against the other wall of the dike.

It is appropriate at this point to discuss the methods which were followed in the preparation of the geologic maps and sections accompanying this report. The geology of accessible workings was mapped by Survey geologists, but for the inaccessible workings the geology was taken from the maps of earlier private reports. Using these observations as basic data, the authors then made as much direct interpretation of the geology on each level as seemed obvious and plausible. This geology was then compiled on regularly spaced cross-sections, where known continuations and obvious connections and extensions were drawn through. Where not obvious, the contacts were drawn in accordance with adjacent sections and geologic probability. Finally, the expanded geology was cast back from the sections to the different level maps, where it was plausibly and conservatively connected. The geology was also projected to the elevation of the proposed 1100 level, 100 feet beneath the 1000 level.

Because the hypogene ore occurs in tactite, the authors have been particularly conservative in showing extensions of tactite masses. Jagged bottoms are drawn on tactite bodies a plausible distance below the last known occurrence, and no hypothetical tactite bodies are shown on the plans or sections, although favorable geologic environments for tactite are suggested on the sections. Thus, it is highly probable that more tactite bodies exist than the maps or sections indicate and that those shown may be more extensive.

Although the actual positions of geologic boundaries shown beyond known workings are not definite, the existence of the geologic bodies which they delimit is reasonably certain. The relative accuracy of the different geologic boundaries has been shown as follows:

1. Solid line: known boundary whose continuity is well established.

2. Dashed line: projected boundary of a known formation; or boundary of a formation whose continuity is poorly established.

3. Dashed line with question marks: unknown but generally conservative boundary of a known geologic body.

A further guide to the reliability of a boundary is its distance from mapped workings or diamond drill holes.

Ore reserves. — It is exceedingly difficult to make an estimation of the reserves of the Empire mine because of the irregularities of the ore bodies and because much of the mineralized ground has never been systematically sampled. Only a portion of the mine was sampled by the Bureau of Mines, whose assays have been used in the present estimate. Known reserves are small because very little development has been done in advance of mining.

All the estimated reserves of sulphide ore are contained in one ore body at the north end of the 1000 level (plate 28). Its extension on the 900 level is not known. On the northwest and probably down the dip this body is truncated by a post-mineral dike. The possibility of a continuation of the ore body on the farther side of the dike is promising. Using a cutoff of 2 percent copper, the reserves of indicated and inferred sulphide ore in this ore body are 23,370 tons averaging 2.67 percent copper, 0.066 ounces gold and 0.95 ounces silver per ton; no measured reserves have been estimated. In computing the grade of the ore blocks, the assays of the drift and horizontal drill hole samples were given a weight of 3, and the assays for the raise and down hole samples a weight of 1.

This small tonnage of reserves of sulphide ore is hardly an adequate measure of the immediate prospects for the mine. In the authors' opinion the unknown ore will probably exceed the known ore for some time to come, regardless of exploration technique. Ore bodies now known on and below the 1000 level will continue for some distance in depth, at least to the proposed 1100 level, but the authors do not feel that they have sufficient geologic or statistical information to include them in the ore reserves. The chances of discovering extensions of known ore bodies on the opposite sides of transecting porphyritic granodiorite dikes are good, but not certain enough to be included in the ore reserves. The 14 feet of ore and associated mineralized tactite cut between 143.5 feet and 184.5 feet in Bureau of Mines' Hole 2, drilled downward at 45° from the 1000 level, probably connects along the strike with showings of mineralized tactite penetrated between 144 feet and 170 feet in similarly inclined Hole 1. This mineralized tactite probably is peripheral to a heretofore unknown ore body. These and other possibilities indicated by the assay maps should be kept in mind in evaluating the ore reserves. At a conservative guess, at least 50,000 tons of sulphide ore could be realized from these sources.

No estimate of oxide ore has been prepared because no group of oxide samples attained shipping grade. Possibly 100,000 tons or more of low-grade chrysocolla ore exists and awaits an adequate metallurgical process. This tonnage is chiefly between the 300 and 700 levels, but cannot be confirmed by available information.

RECOMMENDATIONS FOR EXPLORATION

Although the deposits of the Empire mine have been extensively explored and mined and the developed reserves are small, the authors believe that the chances of finding additional ore are very good. Probably the continued life of the mine will depend on the discovery of new ore bodies rather than extensions of known ore bodies. The full width of the contact zone has not been systematically determined or explored, nor has the full length of the copper-bearing zone. It is thought that the possibilities for exploration on the 1600 level have not been exhausted.

Since the ore deposits are associated with tactite, the discovery of new ore bodies is chiefly dependent upon the thorough exploration of known tactite bodies and the discovery and exploration of new tactite masses. All tactite bodies should be well explored, for an ore body may be completely enclosed within barren tactite, or weakly mineralized tactite may lie on the margins of a good ore body. A sulphide-bearing stringer, no matter how narrow, may lead to an ore body, particularly if the stringer is cutting tactite.

Situations considered to be favorable for exploration are presented below:

1. Projections of known ore bodies.

2. Where an ore body is cut by a post-mineral dike of porphyritic granodiorite, the separated and unexplored portion of the ore body may be along the farther wall of the dike.

3. Known tactite masses which carry lean sulphides, to determine whether low-grade material is peripheral to ore.

4. Known tactite masses which locally appear to be barren, to determine whether ore lies within.

5. Projections of known tactite bodies.

6. Limestone-granite porphyry contacts, particularly where limestone might form the hanging wall above a mass of granite porphyry, in search for tactite bodies along the contact.

Some specific recommendations for exploration by drilling on the 700, 800, 900, and 1000 levels and by drifting and drilling on the proposed 1100 level are listed below. The proposed drill holes have been given numbers prefixed by the letter S and are shown on the level plans. The holes listed first on each level are considered most promising. The type of geologic environment to be explored is indicated. Most of the holes are less than 200 feet in proposed length, and all have definite objectives. Conditions encountered in the holes should determine the actual length, once the original objective has been reached. As far as possible the holes have been laid out either to avoid large faults or to intersect them at a large angle.

700 Level (plate 15). --

Drill Hole	Depth, feet	Bearing	Inclination	Approx. collar
S1	± 180	N 25°W	0°	25180 N, 26085 E
S2	± 50	S 62°E	0°	25180 N, 26085 E
S3	± 120	N 10°W	0°	24690 N, 26295 E
S4	± 350	N 56°W	0°	25650 N, 25900 E
Total	± 700			

The drift from which holes S1 and S2 are suggested has followed a narrow quartz diabase porphyry dike which cuts mineralized tactite. Near the face this body of tactite has not been explored above and is only partly known on the 700 level. Lateral holes to the northwest and southeast would probably test the adjacent ground most satisfactorily. Exploration type 3.

Hole S3 would collar in barren tactite and prospect a large garnet-diopside body which has produced ore above and farther east. Exploration type 4.

Hole S4 would explore a large tactite mass around a limestone tongue. Ore has been mined from this tactite body at the surface and the 800 level. Some stoping may have reached the 700 level but very little is known about the body as a whole. If the hole enters limestone, it should be continued to test the tactite on the farther side. Exploration type 1.

800 Level (plate 17). --

Drill Hole	Depth, feet	Bearing	Inclination	Approx. collar
S5	± 50	S 50°E	0°	25540 N, 25890 E
S6	± 75	N 45°W	+45°	25560 N, 26235 E
S7	± 75	N 40°E	+45°	25450 N, 26185 E
S8	± 75	N 40°W	+45°	25460 N, 26320 E
S9	± 125	S 12°E	0°	25275 N, 26095 E
S10	± 130	S 66°W	0°	25040 N, 26330 E
S11	± 130	N 60°W	0°	24650 N, 26425 E
S12	± 160	S 15°E	0°	24420 N, 26495 E
S13	± 120	N 86°W	0°	25675 N, 25780 E
S14	± 110	N 38°W	0°	25675 N, 25780 E
Total	±1050			

Hole S5 would test unknown tactite from a drift in mineralized garnet-diopside rock. A second hole in the opposite direction from the face of the short crosscut would collar in more highly mineralized rock and might be worthwhile also. Exploration type 3.

Holes S6, S7, and S8 are up-holes intended to test the area under the limestone body shown on plates 33 and 34. The presence of the limestone above the 800 level is well established but the exact position and configuration of its bottom is unknown. Exploration type 6.

Hole S9 would test the same garnet-diopside body as Holes S1 and S2 on the 700 level. Results there might modify the orientation of Hole S9, but this hole should be drilled regardless of the results on the 700 level. Exploration type 5.

Hole S10 would test more distant portions of a garnet-diopside body which has produced ore in places near the limestone on this level. Exploration type 4.

Hole S11 would test more distant portions of another garnet-diopside body, parts of which have produced from this level and the 700 level. Bureau of Mines' Hole 23 cut this tactite farther north on the 800 level, and the first 24 feet averaged 3 percent copper. Because of this good showing, drifting may be more desirable than drilling. Several sulphide stringers enter this tactite from the east and southeast. This body probably connects upward with that in which Hole S3 has been suggested. Exploration type 3.

Hole S12 is designed to investigate a tactite body projected from the 700 level, where it has been stoped. Exploration type 5.

Holes S13 and S14 would penetrate unexplored portions of a large garnet-diopside tactite body near the north end of the level which contains several stopes. This body would be cut by Hole S4 on the 700 level. Exploration type 4.

900 Level (plate 19). --

Drill hole	Depth, feet	Bearing	Inclination	Approx. collar
S15	± 150	N 4° E	0°	25875 N, 25710 E
S16	± 150	S 15° W	0°	25875 N, 25710 E
S17	± 150	S 45° W	0°	25690 N, 25845 E
S18	± 80	S 49° E	0°	25690 N, 25845 E
S19	± 200	S 5° E	0°	25320 N, 26120 E
S20	± 170	S 56° W	0°	25070 N, 26375 E
S21	± 100	S 72° W	0°	24890 N, 26470 E
S22	± 100	South	0°	25560 N, 26040 E
Total	±1100			

Hole S15, from the north face of the level, would explore the mineralized garnet rock northward along the limestone contact. This environment seems sufficiently promising that drifting may be more desirable than drilling. Exploration type 3.

Hole S16 would explore the same body of tactite as Hole S15, nearer the footwall of the porphyritic granodiorite dike. On the hanging wall side of the dike the tactite has been stoped through the 800 level. Exploration type 2.

Holes S17 and S18 would explore in two nearly perpendicular directions the upward continuation of the tactite body which contains the ore body drilled by the Bureau of Mines on the 1000 level. Exploration type 1.

Hole S19 would explore the projection of the same tactite body as Hole S9 on the 800 level. On the 700 level this body would be explored by Holes S1 and S2. Hole S19 should be drilled after Hole S9. Exploration type 5.

Hole S20 would cut a projected tactite body north of the big porphyritic granodiorite dike. This body is continuous upward with that to be explored by Hole S10, which has been located directly above on the 800 level. Exploration type 5.

Hole S21 would collar in slightly mineralized tactite beneath a mineralized area on the 800 level. The extent of this tactite on the 900 level is unknown. Exploration type 3.

Hole S22 would explore an unknown portion of a tactite body which is barren in the main drift but which has produced above. Exploration type 4.

1000 Level (plate 21). --

Drill Hole	Depth, feet	Bearing	Inclination	Approx. collar
S23	± 90	S 12° E	0°	25840 N, 25890 E
S24	± 100	N 40° W	0°	25830 N, 25790 E
S25	± 140	S 22° E	-45°	25225 N, 26480 E
Total	± 330			

Hole S23 would explore the tactite on the opposite side of the porphyritic granodiorite dike from the ore drilled by the Bureau of Mines. Exploration type 2.

Hole S24 would explore tactite beyond the north face of the level. A limestone contact is probably nearby. This underlies ground to be explored by Hole S15 on the 900 level. Exploration type 4.

Hole S25 would further explore the downward extensions of the ore at the south end of the level. At least part of this ore body has been mined from a sill 50 feet below the 1000 level. Exploration type 1.

Proposed 1100 Level (plate 22). -- All the tactite bodies shown on the 1100 level geologic map are known from drilling or stoping to occur or extend below the 1000 level. Their existence at the 1100 horizon, 100 feet below the 1000 level, either has been shown by drilling or has been considered highly probable. The shape and position of these projected bodies cannot be exactly known. In addition, there are probably several other tactite bodies on this horizon.

Drifting. -- A crosscut on the 1100 level should be run due north from the shaft for about 500 feet, with a drift turning out to the northeast at approximately 140 feet from the shaft to follow the tactite delineated roughly by holes B9, B1, and B2. This northeast drift should be driven about 320 feet.

The north crosscut would not only explore a section of ground seldom explored in upper levels but would also give direct access for a few short holes to reach the northern tactite bodies. Five holes have been proposed from this working, but information obtained in the crosscut should be used to revise their locations and orientations.

The northeast drift would explore a body of mineralized tactite that has been indicated by drilling. Holes B1 and B2 cut showings of mineralized garnet-diopside rock over distances of 26 and 41 feet, respectivly, at and below the 1100 horizon. In Hole B2, 14 feet of this mineralized rock immediately below the level averaged 2.58 percent copper. As this ore body has not been encountered on higher levels, the tactite and the adjacent limestone contact should be thoroughly explored.

Geologic conditions seem sufficiently favorable to warrant an exploratory drift into this already-drilled body of garnet-diopside tactite. Ore possibilities should improve toward the limestone contact. Either the drift or subsequent drilling should determine the location of the limestone contact, the attitude of which cannot be predicted.

Diamond Drilling on the 1100 level.--

Drill Hole	Depth, feet	Bearing	Inclination	Approx. collar
S26	± 260	N 72° W	0°	25600 N, 26120 E
S27	± 350	N 72° W	0°	25730 N, 26120 E
S28	± 170	S 62° E	0°	25730 N, 26120 E
S29	± 250	Due East	0°	25790 N, 26120 E
S30	± 110	N 44° W	0°	25820 N, 26120 E
Total	±1140			

Hole S26 would seek the downward extension of the ore drilled by the Bureau of Mines in Holes B10, B11, B12, B13, and B28 on the 1000 level. If the hole reaches the porphyritic granodiorite in tactite, the hole should continue beyond the dike. Exploration type 1.