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THE ZINC-COPPER DEPOSITS NEAR MOTH BAY, REVILLAGIGEDO ISLAND, SOUTHEASTERN ALASKA

By

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INTRODUCTION

Moth Bay is a narrow inlet on the north side of the entrance to Thorne Arm, a large bay near the southern end of Revillagigedo Island, southeastern Alaska (see insert, fig. 1). It is about 16 miles by water southeasterly from Ketchikan, the nearest port. Moth Bay is locally known as Maiden Bay. The zinc-copper deposits are about three-fifths of a mile north of the head of the bay, at altitudes ranging from 250 feet to 500 feet, and are accessible by a good trail from the bay. The deposits are near the southern end of a low northward-trending ridge which rises above a broad, swampy, lake-dotted muskeg. The muskeg is bordered on the east and west by smoothly rounded, densely wooded hills up to 2,300 feet high. Vegetation and glacial till cloak most of the surface and rock exposures are rare. Small timber and fresh water are available. The climate is mild and humid.

According to Smith 1/ the first development work on the deposits was done in 1911-1913 by the Gold Standard Mining Company. An adit 75 feet long was driven and from it a steeply inclined winze 100 feet long was sunk (see old adit, fig. 2). The adit and the upper 40 feet of the winze are still accessible but the lower part of the winze is now flooded. In later years, the deposits were prospected on the surface by a series of open cuts, and an adit was driven into the ridge about 500 feet northwestward from the old adit (see main adit, fig. 2). This adit encountered ore 180 feet from the portal and an exploratory drift was driven parallel to the strike of the rocks near the footwall of the ore. Nine short crosscuts were made to intersect the ore zone. The aggregate length of these workings, which are still in good condition, is about 800 feet. In 1929-1931 the development work "was undertaken by Mr. Jas. (James L.) Freeburn and associates of Ketchikan and Tacoma who secured for that purpose control of the property from the former owners Messrs. Griswold, McGuire, and Dodge of Ketchikan." 2/

1/ Smith, P. S., Lode mining in the Ketchikan region: U. S. Geol. Survey Bull. 592, pp. 90-91, 1914.

2/ Stewart, B.D., Report on cooperation between the Territory of Alaska and the United States in making mining investigations and in the inspection of mines for the biennium ending March 31, 1931, p. 18.

Seven claims are reported to have been surveyed for patent (U. S. Mineral Survey 1590). No ore is known to have been shipped.

The deposit was briefly examined and described by Smith 3/ in 1913, and by Stewart 4/ in 1930. A more detailed examination was made by Townsend 5/ in 1937. Twenty-one of the analyses of samples taken by Townsend are used in this report, with his permission.

The U. S. Bureau of Mines collected four moil samples from the main workings in 1942, and the analytical results are used herein.

This report summarizes field work done in the period September 8-28, 1943, by G. D. Robinson and R. A. Harris. Detailed maps of the deposit were made and chip samples of ore were taken from numerous localities.

GENERAL GEOLOGY

According to Buddington and Chapin 6/, the principal rocks in the vicinity of Moth Bay are phyllite and quartzite of probable Ordovician to Jurassic age, intruded by quartz diorite of Upper Jurassic or Lower Cretaceous age.

The present investigation indicates (see fig. 1) that the rocks containing the zinc-copper deposits are fine-grained to medium-grained mica schist and quartzite. These rocks are structurally complex in detail, but in general they strike about N. 60° W. and dip from steep northerly to vertical, to moderate southerly. Foliation is generally parallel to the bedding. A sequence of biotite schist, with some muscovite schist and impure quartzite, stratigraphically overlies a sequence of muscovite schist, with some quartz-muscovite schist, biotite schist, quartzite and limestone. The maximum outcrop width of the biotite schist sequence is about 600 feet, and that of the muscovite schist sequence is about 700 feet; because the rocks probably are folded and faulted, these measurements may include some repetition of beds. In the central and northwestern parts of the area shown in fig. 1 contacts between the two sequences commonly appear to be sharp. In the southeastern part, layers of muscovite schist are abundant in the basal part of the biotite schist sequence. Some of the apparent interbedding may be the result of small-scale isoclinal folding.

The ore deposits are thin layers of schist partly replaced by sulfide minerals. The thickest and most persistent of these layers is at the contact between the two schist types, but thinner layers are present at other places.

3/ Smith, P. S., op. cit.

4/ Steward, B. D., op. cit., pp. 18-19.

5/ Townsend, Harry, Report on the Maiden Bay prospect, Revillagigedo Island, Alaska, private report, 4 p. and map, 1938.

6/ Buddington, A. F. and Chapin, Theodore, Geology and mineral deposits of southeastern Alaska: U. S. Geol. Survey Bull. 800, plate 1, 1929.

The metamorphic rocks are intruded by thin dikes and sills ranging widely in composition and texture, and by larger masses of quartz diorite, with subordinate granite and diorite. The metamorphic rocks are recrystallized and silicified near intrusive masses, and locally lit-par-lit gneiss is present. The metamorphic rocks now form an irregularly bounded body more than 3,000 feet long in a NW-SE direction, and about 1,300 feet wide in the intrusives. Intrusive rocks probably underlie the metamorphic rocks at depths of a few hundred or at most a few thousands of feet.

ZINC-COPPER DEPOSITS

Ore and gangue

The ore minerals in the Moth Bay deposits include, in order of decreasing abundance, iron sulfides (principally pyrite with minor pyrrhotite) dark iron-rich sphalerite, copper sulfides (principally chalcopyrite with minor bornite and covellite), magnetite, galena, silver and gold. The ore minerals are generally in dense, medium-grained aggregates. Magnetite, however, is in minute grains visible only under the miscroscope, and the presence of gold and silver is known only from analyses.

The introduced gangue minerals, which are principally clear glassy quartz and gray calcite, commonly form an insignificant proportion of the ore.

The most common gangue, in many places constituting more than half of the ore beds, consists of inclusions of slightly recrystallized muscovite schist country rock. The inclusions are commonly rod-like or tabular, and their elongate dimensions are in the plane of the bedding of the adjacent country rock. Many of the inclusions are angular, but their parallelism with the bedding indicates that they are not breccia fragments but are unreplaced remnants of schist beds.

The ore has a indistinct mineral banding which is parallel to the boundaries of each mineralized zone and to the adjacent bedding. Locally, sharp-walled veinlets of one or more ore minerals follow and, rarely, cut across the bedding.

The proportions of the sulfide minerals range widely and abruptly within short distances. The proportions of each mineral seem to range independently of the others. Pyrite generally constitutes one-fourth to one-half of the ore; in some places it forms as much as 90 percent of it. As much as 50 percent of pyrrhotite, 30 percent of sphalerite, 10 percent of chalcopyrite and possibly 2 percent of galena are present locally. Commonly, the ore contains less than 10 percent of pyrrhotite, from 3 percent to 15 percent of sphalerite, from 1 percent to 5 percent of chalcopyrite, and only traces of galena.

The ore beds

Although locally the ore may be in isolated pod-like masses, most of it is in layers having all the structural characteristics of the enclosing schist beds. With the exception of pyrite and magnetite, which are widespread in the metamorphic rocks and may in part be primary in those rocks, the ore minerals are rather closely confined to a few thin layers. No zinc or copper mineralization is known in the adjoining intrusive rocks.

Large-scale differences in the mineral proportions of the ore beds along their strike are apparent both from analytical data and by observation. Sphalerite is most abundant in the ore in the central part of the area mapped (see fig. 2), is less abundant in the northwestern part and is scarce in the southwestern part; chalcopyrite is scarce in the northwestern part, is more abundant in the central part and is most abundant in the southeastern part; galena is practically absent in the northwestern and central parts, but is common in the vicinity of the old workings. Both quartz and calcite are most abundant in the southeastern part.

The mineralized layers, or ore beds, are rarely more than 15 feet thick and generally less than 5 feet thick. A few ore beds may be continuous or nearly so for several hundreds of feet in length and depth; others probably do not persist for more than a few tens or scores of feet.

The total number of ore beds is not known. Three beds are known from closely-spaced exposures, and single exposures may indicate additional beds.

The greatest amount of ore in the area is in ore bed 1 (see fig. 2), which includes all the ore shown on fig. 3. In the main workings the ore, although regarded as a single layer, in detail comprises a number of closely spaced, staggered or en échelon bands separated by schist partings a few feet thick. The ore bed is as much as 17 feet thick in the crosscuts near the southern end of the drift; in the crosscuts near the northern end the ore bed is little more than 2 feet thick. Ore is exposed in the most northerly crosscut, and presumably the ore bed exposed in the side of the cliff about 100 feet northwest of the end of the drift is a continuation of the same bed. The southern end of the ore bed in the drift is cut off by a fault. In this report, the ore bed in the old workings is correlated with bed 1. On the surface, bed 1 has been exposed at intervals for 600 feet by a series of open cuts from the cliff mentioned above to the portal of the old adit. The ore in the cuts northwest of the cliff probably should not be correlated with bed 1. The best evidence that the unconnected ore exposures labelled bed 1 are parts of a single ore zone is the similarity of their relation to the enclosing country rock; all the ore occurrences grouped in bed 1 are at, or within a few feet of, the contact between the muscovite schist sequence and the biotite schist sequence.

In the main workings bed 1 is exposed for 440 feet. In the old workings it is exposed for 75 feet and in the ridge cuts it is exposed for 200 feet. The bed is absent from the most northerly of the ridge cuts and presumably is absent through much of the distance between the ridge cuts and the cliff to the northwest. Whether the bed is continuous on the surface between the ridge cuts and the old workings is not known, but it is present in the only open cut between them.

The known vertical range of bed 1 is about 200 feet. The dip distance between the ridge cuts and the main workings is 140 feet. The winze in the old adit is flooded below 40 feet; the bed is continuous to at least that depth, and certainly somewhat farther, although the winze is not in ore for its entire length of 100 feet because, according to Smith 7/, "the winze is driven at a flatter inclination than that of the vein."

Bed 2 is stratigraphically below bed 1. It is definitely known only in the ridge cuts, where three cuts expose it 10 feet to 15 feet upslope from bed 1. It is probably continuous for at least 80 feet along its strike, and has an average thickness of 4 feet. In the last 20 feet of the adit, where it would seem bed 2 should be (see section, fig. 2), the muscovite schist sequence is interrupted by a tongue or lens of biotite schist which does not reach the surface; bed 2 may be stratigraphically below the biotite schist on the adit level or bed 2 may not extend to this level. The ore in the cuts northwest of the cliff perhaps may be correlated with bed 2.

East of the old adit dump, two cuts 50 feet apart (see fig. 2) expose ore as much as 3 feet thick on the crest of a southeasterly-plunging anticlinal drag fold. This ore bed, which stratigraphically underlies bed 1 and bed 2, is designated bed 3.

A number of relatively isolated exposures of ore other than those discussed above are shown on fig. 2. Only local concentration is assumed for the ore at each exposure but future development may indicate extensions. Considerable uncertainty exists regarding the location and number of open cuts about 1,000 feet east of the old adit (see fig. 2), because time was not available for mapping in the vicinity. Townsend's sample T2 may not have been taken from the same cut as that from which the Geological Survey's sample G315 was taken, but may represent a nearby cut not seen by the writer, who also did not see the cut from which Townsend's sample T1 was taken.

Structure

A generalized statement of the structure of the ore beds and the country rocks is given under General Geology, and it has been convenient to introduce some structural data in the preceding discussion of the ore beds. Additional structural data and interpretations are given below.

The areal map and section on fig. 2 show the writer's interpretation of the meagre data available. It is expected that any future development of the area will demonstrate much greater complexity than is illustrated on fig. 2 or discussed herein.

The metamorphic rocks and the ore beds dip southwestward throughout the mapped area, except in the vicinity of the ridge cuts and near the main adit portal, where there are vertical and steep northeasterly dips. The reversal of dip in the ridge cuts appears to indicate local overturning or drag folding of the beds. Data are insufficient to determine the significance of the reversal of dip near the main adit portal. The interpretation favored (see section, fig. 2), is that the reversal indicates a minor drag fold. On this basis, the beds including bed 1 and any other ore beds, in at least the western part of the schist mass,

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7/ Smith, P. S., op. cit., p. 91.

dip southwestward to the contact with quartz diorite or related igneous rock, which is not far distant to the west and downward.

It is possible, however, that the reversal of dip near the adit portal indicates the trough of a major syncline. If this interpretation is correct, the contact, presumably dipping northeastward, between biotite schist and muscovite schist should be repeated within a few hundreds of feet westward from the portal; an ore bed equivalent to bed 1 might be present along the contact. This possibility should be tested by trenching in any future exploration.

The relative ages of the intrusive masses and the ore deposits are not known. If the intrusive masses are younger, an interpretation which the scanty evidence favors, the ore beds obviously terminate at intrusive contacts; if the mineralization is the younger, it might persist within the igneous rocks beyond their contacts with the metamorphic rocks. However, no zinc or copper mineralization has been noted in any of the intrusive masses or in their apophyses, even where they are close to ore beds, as in both the old and the main workings.

The ore bed near the southern end of the main workings terminates against a fault of unknown displacement which strikes N. 20° W. The fault is filled with gouge as much as 1 foot thick. The gouge has slumped or been mucked out for 20 feet updip; the dip is eastward, flattening from 80° at the floor to 65° at the back. Several minor faults branch from the main fault. Displacements of dikes by these faults can be measured accurately and do not exceed a few feet either vertically or horizontally. One minor fault, which departs from the attitude of the principal fault and in part follows the bedding, has been traced throughout the drift. The fault appears to be a hinge-fault, the west wall having moved down relative to the east wall near the north end of the drift, and up relative to the east wall near the south end of the drift. The observed displacements are most simply explained as being due to vertical rather than horizontal movement. Perhaps the movement on the principal fault was likewise mostly vertical rather than horizontal. The south end of the main workings is within a few tens of feet of the surface; exposures are relatively abundant on the surface above, but no evidence of faulting was found there, nor was any ore bed found which might represent the offset part of bed 1 on the east side of the fault. If the structural interpretation shown on fig. 2 is correct, the contact between the schist sequences swings sharply to the northwest in this vicinity. Presumably bed 1 swings with the contact, and it is likely that only a small part of the ore bed could have been affected by the fault described above.

The country rocks had been altered and deformed essentially to their present state before ore deposition. The ore-bearing solutions probably rose up fault-, joint-, and bedding-fractures, and spread outward from the openings to replace the country rocks with ore and gangue minerals. The contact between the relatively dense, massive and little-fractured biotite schist sequence and the muscovite schist sequence apparently provided a principal channel for the rising solutions.

The ore in bed 3 is localized at least in part by an anticlinal drag fold. Other occurrences of ore, in which the attitude of the bedding is markedly different from the prevailing attitude, may be localized in part by openings on drag folds.

RESERVES

The results of the analysis of 39 samples are shown on figs. 2 and 3. Samples taken by Townsend are only approximately located. The grade averages computed are weighted according to the length of each sample. All the samples were taken horizontally, with the exception of Townsend's sample T26, crosscut E, taken vertically; therefore, none represent the true thickness of the ore beds.

Only bed 1 is sufficiently well known to permit estimation of measured and indicated reserves. Of the 39 analyses, 36 are of samples taken from bed 1; 30 of samples taken from the main workings. The following table summarizes the grade data from the main workings:

	from	to	strike	sampled	percent of		Ounces/ton	
	crosscut		length (feet)	width (feet)	Zn	Cu	Au	Ag
Townsend 8/	B	H	340	7.5 9/	8.23	1.30	0.02	0.21
Mines 10/	B	G	290	6.4	8.41	not determined		
Survey 11/	B	H	340	8.4	7.26	0.83	negligible	

A number of lead determinations were made. The lead content was consistently negligible. Lead is therefore omitted from the table.

With regard to zinc and copper content, the divergences between Townsend's results and those of the Survey are probably due to differences in sampling. The Bureau analyses are too few to be significant but they confirm the indicated zinc and lead tenor of the ore.

The writer cannot explain the divergences in precious metal content reported. Only two precious metal analyses of samples from the main workings were made by the Survey and they do not provide an adequate check on Townsend's results, which are accepted for present purposes.

8/ Seventeen analyses by A. L. Glover, Inc., Seattle, Washington. Analyses T4, crosscut A, and T26, crosscut E, omitted because not representative.

9/ Sampled width only approximate. Spacing of samples not known in crosscuts from which more than one sample taken.

10/ Four analyses by Bureau of Mines Technical Service, Reno, Nevada.

11/ Nine analyses for Zn, Cu, and two analyses for Au, Ag, by S. H. Cress and Victor North, Geological Survey.

A majority of the Townsend and Survey analyses are grouped in the southern one-third of the workings, which contains the highest-grade ore. The true grade is therefore probably lower than the mean between that of the two groups (7.835 percent of zinc, 1.065 percent of copper). The entire 400-foot strike length of bed 1 in the main workings is assumed to have an average thickness of about 7.5 feet, and to contain about 7.5 percent of zinc, 1.0 percent of copper, 0.02 ounces of gold per ton, and 0.20 ounces of silver per ton.

The few analyses of bed 1 samples taken outside the main workings indicate that the zinc content near the limits of exposure (G314, from NW end; G313, from old workings, SE end) is much lower than the average in the main workings. The zinc and copper contents up the dip from the main workings (T6, T7, G312, G311) are of the same order as in the main workings. The copper content is much greater in the old workings than elsewhere.

For estimating tonnage, the ore has been divided into high-grade zinc-copper ore, low-grade zinc-copper ore, and high-grade copper ore. High-grade zinc-copper ore is exposed for 200 feet in the ridge cuts and for 400 feet in the main workings. The ore on the surface presumably connects with that underground to form an ore body with a dip length of 140 feet between the levels of exposure, and an average thickness of about 7.5 feet. The ore body outlined has a volume of about 315,000 cubic feet. Assuming a factor of 9 cubic feet to a ton, the mass comprises about 35,000 short tons of measured high-grade ore, containing about 7.5 percent of zinc, about 1.0 percent of copper and small quantities of gold and silver. The body is assumed to persist down the dip from the main workings for at least half the strike length in the workings; an additional mass of ore 400 feet by 200 feet by 7.5 feet is indicated. This indicated high-grade ore mass has a volume of about 600,000 cubic feet and contains about 66,000 short tons.

Northwestward, the high-grade ore passes transitionally into low-grade zinc-copper ore, for thich it is difficult to estimate grade and tonnage. The ore bed is probably continuous on the main working level from crosscut A northwestward to the cliff where the zinc and copper content are considerably lower (sample G314) than underground. This part of the ore bed does not continue to the surface without interruption, being absent from the most northerly of the ridge cuts. For estimating tonnage, a mass of ore of approximately triangular shape in the plane of the ore bed is postulated; the triangle is visualized as having a base 100 feet long and as wedging out about 100 feet up the dip. This part of the bed is assumed to have an average thickness of 3.5 feet, and an average content of 2 percent of zinc and 0.5 percent of copper. The mass has a volume of about 17,500 cubic feet. Assuming a factor of 9.5 cubic feet to a ton, it contains about 1,800 short tons of indicated ore. The ore doubtless continues below the main workings, and it is assumed that a tonnage at least as great as that above the workings is indicated. Bed 1 northwestward from the high grade ore body is therefore estimated to contain about 3,500 tons of low grade indicated ore.

The ore exposed in the old workings is herein regarded as high-grade copper ore. Hand-specimens contain much pyrrhotite and pyrite, considerable chalcopyrite, a little galena, and less sphalerite. In the single analysis available

(G313), the sample is reported to contain 2.9 percent of copper but no zinc, lead, gold, or silver. The ore bed has an average thickness of about 3.5 feet for the exposed strike length of 75 feet; it probably grades northwestward into zinc-rich, copper-poor ore. The known continuation of the ore down the dip is less than 100 feet but more than 40 feet (see p. 9); a minimum dip length of 70 feet is assumed. Measured ore includes that portion of the bed between the surface and 70 feet down the dip from the adit; this mass has a volume of about 30,000 cubic feet, and assuming a factor of 9.5 cubic feet to a ton, contains more than 3,000 short tons. For estimating indicated reserves, the bed is assumed to be continuous along the strike for at least an additional 75 feet, up the dip to the surface (about 85 feet), and down the dip for at least 105 feet (70 feet of known dip length plus 35 additional feet). About 60,000 cubic feet of ore, containing more than 6,000 short tons, is indicated.

In addition to the measured and indicated reserves estimated above, bed 1 is inferred to contain several tens of thousands of tons of low-grade zinc-copper ore and of high-grade zinc-copper and copper ore in possible extensions of the bed along the strike and down the dip.

Several tens of thousands of tons of low-grade ore, comparable to that at the northwestern end of bed 1, is inferred in the other beds in the area.

In summary, the ore reserves in the Moth Bay deposits consist of about 100,000 tons of measured and indicated high-grade zinc-copper ore, containing about 7.5 percent of zinc and 1 percent of copper; about 3,600 tons of measured and indicated low-grade zinc-copper ore, containing about 2 percent of zinc and 0.5 percent of copper; about 10,000 tons of measured and indicated high-grade copper ore, containing nearly 3 percent of copper but little or no zinc; and possible 100,000 tons of inferred ore, principally low-grade zinc-copper. The ore contains small amounts of gold and silver.

CONCLUSIONS AND RECOMMENDATIONS

The Moth Bay deposits contain moderate tonnages of zinc-copper ore in a geologic and geographic environment favorable to their economical development. Townsend's conclusion is shared by the writer: "The .... prospect is a property of doubtful value under present conditions, but is an attractive prospect if an assured market for zinc concentrates on the Pacific coast is established." 12/

In the event of future development, the following recommendations are made:

(1) The continuity of bed 1 and other beds on the surface should be traced by closely-spaced open cuts;

(2) Bed 1 should be sought at greater depth by an adit driven northeasterly from the western base of the ridge, by a winze driven on the footwall of the bed from the main drift, or by diamond-drill holes;

12/ Townsend, H., op. cit., p. 4.

(3) One or more long, northeasterly-trending trenches should be made west of the adit portal, to investigate the nature of the reversal of dip in the main adit. If a contact is found between biotite schist on the east and muscovite schist on the west, the contact should be traced by closely-spaced open cuts to determine the possible presence of an ore bed equivalent to bed 1;

(4) The old workings should be further explored. The old adit should be extended as far as the continued presence of the ore bed warrants. The winze should be unwatered and an exploratory drift driven at its base if the ore bed is found there;

(5) During exploration, the exposures of ore should be thoroughly and systematically sampled.

May, 1944.