Bureau of Mines
Report of Investigations 5320

COPPER MINES AND PROSPECTS ADJACENT TO LANDLOCKED BAY, PRINCE WILLIAM SOUND, ALASKA

BY MIRO MIHELICH AND R. R. WELLS

United States Department of the Interior — April 1957

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UNITED STATES DEPARTMENT OF THE INTERIOR
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by

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SUMMARY

The mines and prospects in the vicinity of Landlocked Bay, 25 miles southwest of Valdez, Alaska (fig. 1), were examined, mapped, and sampled in July and August 1955 as part of a comprehensive investigation by the Bureau of Mines of ore deposits adjacent to Prince William Sound. The purpose of the investigation is to establish and record the location, nature, extent, and metallurgical characteristics of copper and associated metallization in the Prince William Sound district and to indicate, if possible, those areas in which additional exploration and development may be justified. Of particular interest are the possibly numerous deposits of massive iron sulfides that were neglected during early mining operations. These deposits may constitute important reserves of sulfur and iron. At Landlocked Bay deposits of copper-bearing iron sulfide minerals have been mined or partly explored through mine workings, which are in a zone about 1 mile wide along the western side of a large overthrust fault known as the Landlock Overthrust. Eight of the principal mines along this zone were examined and sampled. Although only three of the mines have a recorded production of shipping-grade copper ore, all have deposits of copper-bearing iron sulfide minerals that are similar in occurrence. The deposits occur as lenticular masses and disseminations of chalcopyrite, pyrite, and pyrrhotite which replace crushed rock or fill cavities along shear zones in greenstones and in sedimentary rocks that are exposed between sea level and an altitude of 2,500 feet. These lenticular masses of sulfide minerals range in size from small pods to ore bodies that have been stoped to maximum widths of 9 feet, strike lengths up to 70 feet, and dip lengths as much as 350 feet. Where accessible for sampling, the copper content of the deposits ranged from a few hundredths of a percent to over 8 percent; zinc, gold, and silver are present in negligible amounts. Flotation tests of a sample composited to represent typical mine-run ore indicate that 81 percent of the copper is recoverable in a product assaying 28 percent copper at a concentration ratio of 17.5 : 1.

INTRODUCTION

Statistical records indicate that approximately 110,000 tons of metallic copper (about 16 percent of total Alaskan production) was produced from mines adjacent to Prince William Sound during the 40-year period ended in 1938. Although the principal production was from a large-scale mining and milling operation on Latouche Island (Kennecott Copper Corp., Beatson mine), a substantial amount of the total copper was derived from direct-shipping ores selectively mined or hand-sorted from numerous other deposits in the district. No production has been made since 1938; many of the claims have long been abandoned, and mine workings are either caved or deteriorating rapidly.

Much of the selectively mined copper ore was associated with iron sulfide minerals, which often occurred in massive deposits whose copper content was too low for profitable extraction; these deposits were not removed or explored. Because of the increased interest in iron sulfide minerals as a possible source of sulfur and iron and also because of the impending shortage of copper, the Bureau of Mines began a

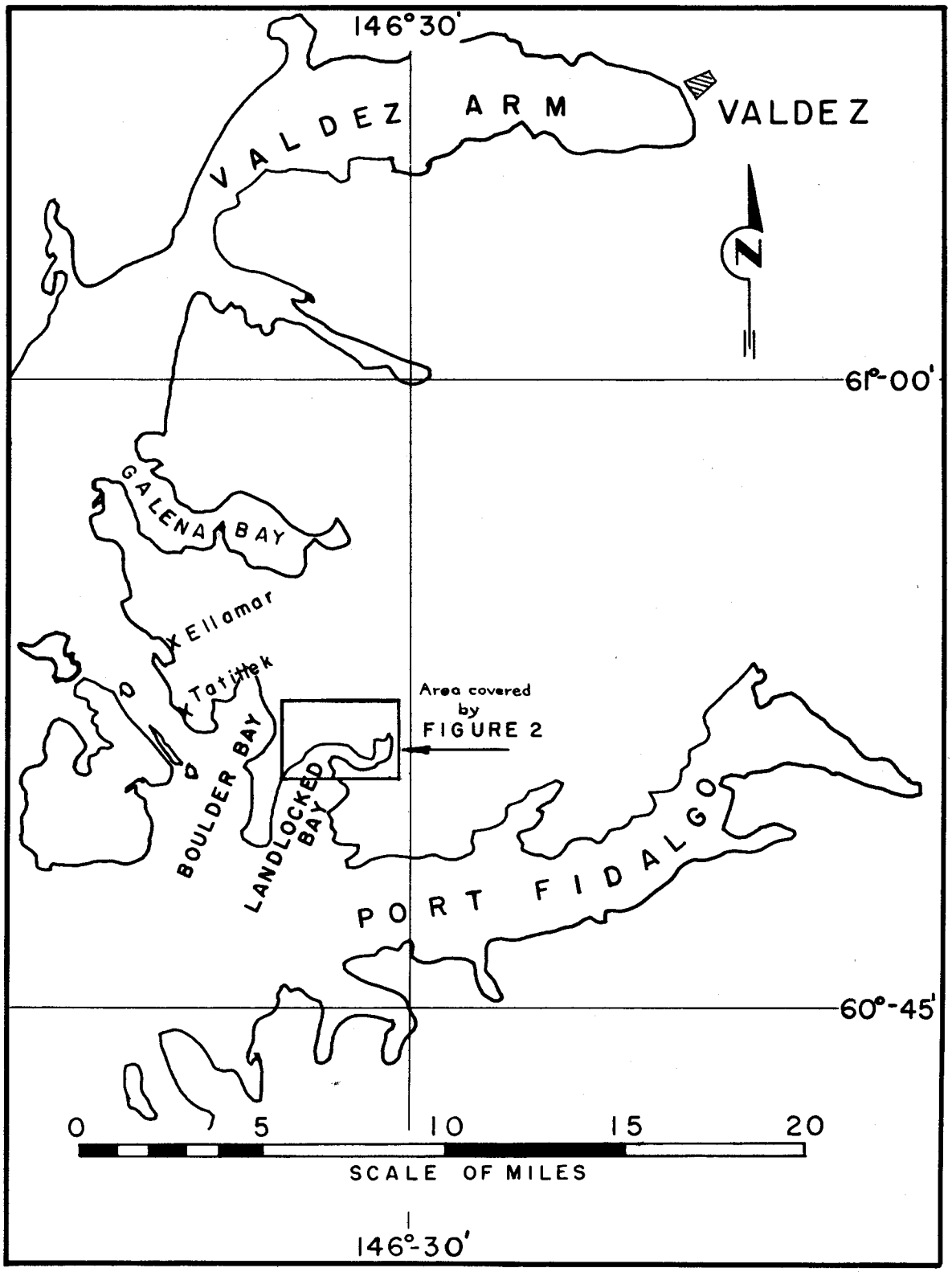


Figure 1. - Landlocked Bay, Alaska.

comprehensive investigation of the district to reappraise the deposits in the light of improved mining and metallurgical practices, higher prices for copper, and the possibility of recovering byproduct iron and sulfur. The work was begun at Landlocked Bay in 1955. This report summarizes general information on the area immediately adjacent to Landlocked Bay and presents factual data resulting from this phase of the Prince William Sound investigation.

ACKNOWLEDGMENTS

Many of the data concerning mining history and regional geology of Landlocked Bay have been obtained from several bulletins published by the Geological Survey.3/

LOCATION AND ACCESSIBILITY

Landlocked Bay is a small embayment on the north shore of Prince William Sound; it is about 2 miles northwest of Port Fidalgo and 25 miles southwest of Valdez (fig. 1). The area described in this report is between latitudes 60°51' to 60°52' N. and longitudes 146°31' to 146°35' W.

Travel to Landlocked Bay may be completed by charter flight of small, pontoon-equipped planes from Cordova, 30 miles southeast of Landlocked Bay, or by boat from Cordova or Valdez; these town are the nearest terminals of scheduled passenger and freight carriers from other Alaskan cities and from the States. A biweekly schedule of airmail and passenger service is maintained from May to November between Cordova and Tatitlek (a small native village 6 miles northwesterly by boat from the head of Landlocked Bay). During the winter months mail and supplies are delivered to Tatitlek and nearby Ellamar by small boat from Cordova.

Valdez and Cordova are regular ports of call by freighters of the Alaska Steamship Co. In 1955 ocean freight rates, including wharfage, from Seattle to Valdez ranged from $31.00 to $113.00 per ton, depending on class of freight.

Narrow Landlocked Bay is navigable by ocean-going vessels for almost its entire length. It also affords secure anchorage, protected from storms. The average tide range at Landlocked Bay is 12 feet; the maximum tide range is 22 feet from mean lower low water.

Travel on land is difficult because of the steep slopes or heavy vegetation; no roads or trails are available.

PROPERTY AND OWNERSHIP

The claims shown on figure 2 are those surveyed for patent between 1903 and 1907. At that time claim ownerships were as follows:

(1) The Threeman Mining Co. patented the Redemption, Keystone, Discovery, Scorcher, Jay, Buckeye, Ajax, Cliff, Daisy, and Montezuma claims. Subsequently the Threeman Mining Co. acquired the holdings of the Alaska Commercial Co. which had one patented claim named ACCo (see fig. 2).

(2) The Standard Copper Mines held the Apex No. 1, Apex No. 2, Odelle D, Alice T., Virginia No. 1, and Cornet mining claims and the Apex No. 1 millsite claim.

3/ See footnotes 4, 5, and 6, p. 6.

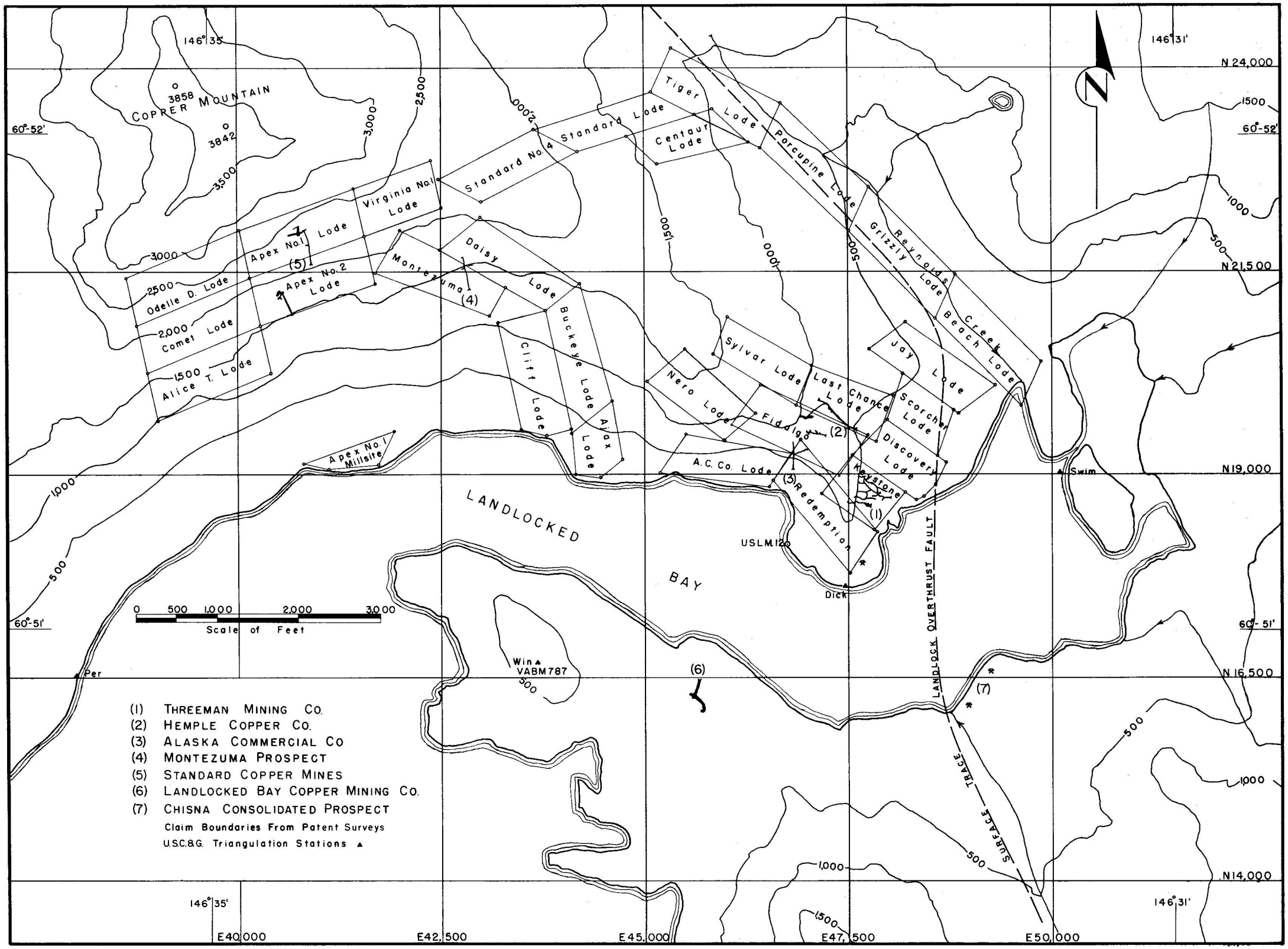


Figure 2. - Copper mines and prospects, Landlocked Bay, Alaska.

(3) Hemple Copper Co. was granted a patent on the Fidalgo, Nero, Last Chance, and Sylvar claims.

(4) The Reynolds Alaska Development Co. held the Standard, Standard No. 4, Centaur, Grizzly, Tiger, Porcupine, and Beach claims.

The present status of the various claims is not known definitely, but it may be assumed that title to many of the unpatented claims has lapsed. Title to the patented claims would remain in the companies that may still maintain a corporate existence, but the legal status of claims that were patented in the name of corporations now defunct is doubtful. All of the above-mentioned companies are listed in the "Mines Register" for 1950 as "inactive," but it is known that the Threeman Mining Co. maintains an office address in New York City.

PHYSICAL FEATURES AND CLIMATE

Landlocked Bay is a narrow indentation on the southern border of Chugach Mountain Range. The area is one of high, sharp relief; in most places the land rises steeply from the shores, which, in many places, are border by vertical cliffs. The top of Copper Mountain, although only four-fifths of a mile from the beach, is 3,858 feet above sea level.

When not too steep to afford a foothold for trees, the slopes up to altitudes of 2,000 feet usually are covered by a dense growth of mature spruce and hemlock. Alder, willow, and bushy plants grow thickly between the trees in the evergreen forests of spruce and hemlock. Lowlands at the head and on the south side of Landlocked Bay support scattered groves of trees interspersed by marshy meadows of sphagnum moss.

As a result of the deep indentation of the coast and of the high relief of the land, the stream gradients are steep everywhere, and the valleys are short, with few tributaries. Adequate fresh water for an operation of almost any size is to be found in Reynolds Creek and in another large, permanent, but unnamed stream that discharges into the head of Landlocked Bay. Numerous intermittent streams are in the area.

Temperatures at Landlocked Bay are modified by the Japanese Current. The winter temperatures seldom fall below zero, and the summers are mild. Mean annual temperature is about 40° F. A maximum of 86° F. and a minimum of 2° F. has been recorded at a temporary weather station 26 miles northwest of Landlocked Bay. Deep winter snows accumulate at all altitudes; even below the perpetual snowline the snow lingers until late in the summer. At Cordova, the nearest source of records, annual precipitation ranges from 140 to 190 inches.

HISTORY AND PRODUCTION

According to old reports the first copper deposit discovered on Prince William Sound was staked on Landlocked Bay in 1897. Between 1897 and 1907 numerous claims were staked on Landlocked Bay; of these, 7 groups were surveyed for patent during the latter part of the period (fig. 2).

The mining of copper, with small shipments of high-grade ores, began in 1904, soon after the first discovery. Extensive surface installations and underground development at the Threeman, Standard, and Landlocked Bay mines were completed by 1911; by this time a significant amount of hand-sorted ore had been shipped to the smelter

at Tacoma, Wash. The Hemple, Alaska Commercial Co., and Chisna Consolidated holdings were prospected actively by trenching and by underground exploration during the same period; however, no shipments of ore were made from these properties. Mining activity at all of the properties ceased by 1917. Only obscure ruins remain of the buildings, aerial trams, ore bunkers, and piers that existed at the Threeman, Standard, and Lanlocked Bay mines.

Recorded production from Landlocked Bay is summarized in table 1. The massive sulfide ore was upgraded to as high as 13.0 percent copper by hand sorting. The average grade of all hand-sorted ore shipments from Landlocked Bay was 7.5 percent copper. No attempt was made to mine and treat the copper and iron sulfides that remain in the mines as small lenses, minor stringers, and disseminations of sulfides that could not be economically hand-sorted.

TABLE 1. - Ore shipments, Landlocked Bay, Alaska[1/]

Date	Ore, tons	Copper, percent	Metal content: Copper, lbs.	Gold, oz.	Silver, oz.	Mine
1904	12.5	12.0	3,000	(2)	(2)	Threeman.
1906	45.0	13.0	11,700	(2)	(2)	Do.
1907	1,000.0	.4	8,000	36	518	Standard.
1909	100.0	12.0	24,000	(2)	(2)	Do.
1911	739.0	11.8	173,960	14	608	Threeman.
1912	3,300.0	9.1	601,000	48	3,300	Do.
1915	1,500.0	8.3	250,000	39	1,400	Do.
1916	928.0	4.0	74,240	(2)	(2)	Landlocked Bay.
Totals	7,624.5	7.5	1,145,900	137	5,826	

1/ From records, Federal Bureau of Mines, Juneau, Alaska.
2/ Gold and silver content not reported.

GENERAL GEOLOGY

Study of the geology of Prince William Sound by the Geological Survey began almost as soon as the search for mineral deposits. The most comprehensive investigation and detailed description of the regional geology and ore deposits of Landlocked Bay were made by Capps and Johnson[4/] in 1912. Moffitt[5 6/] subsequently contributed to the literature of Prince William Sound geology. The following description of regional geology is based chiefly on the above reports.

The Landlocked Bay area is underlain predominantly by greenstones bounded on the east by a major overthrust fault known as the Landlock overthrust. East of the fault are interbedded slates and greywackes of older rocks that have been thrust from the northwest over younger rocks. The younger rocks are known as the Orca group and the older as the Valdez group. The Orca group is composed of black slates, interbedded slates and greywackes, some limestones, greenstones ranging from rather coarse diabasic intrusives to lava flows, and conglomerates. The presence of greenstones and conglomerates is one of the chief criteria for distinguishing the

4/ Capps, S. R., and Johnson, B. L., The Ellamar District, Alaska: Geol. Survey Bull. 605, 1915, 125 pp.
5/ Moffitt, Fred H., and Fellows, Robert E., Copper Deposits of the Prince William Sound District, Alaska: Geol. Survey Bull. 963-B, 1950, pp. 47-80.
6/ Moffitt, Fred H., Geology of the Prince William Sound Region, Alaska: Geol. Survey Bull. 989-E, 1954, pp. 225-310.

Orca rocks from the more intensely metamorphosed Valdez group. Both the Valdez and Orca groups have been folded and intricately faulted; consequently, accurate determination of the thickness of each group is impossible. The greenstones are several thousand feet thick at Landlocked Bay. The scarcity of fossils and other diagnostic evidence does not permit conclusive assignment of ages to the rock groups; however, the Valdez and Orca groups have been classed as late Mesozoic.7/

The rocks underlying and bordering the major Landlock overthrust fault are extensively sheared and faulted. Numerous shear zones visible on the south flank of Copper Mountain are traceable for considerable distances as shallow troughs or gullies where erosion has removed some of the soft, sheared material. Two fairly well defined systems of shearing, faulting, and fracturing are recognizable. The more prominent system, which contains the larger number of shears and faults, strikes northwest and parallels in a general way the strike of the Landlock overthrust fault; the other system generally strikes east or almost normal to the strike of the Landlock overthrust. The dips of both systems are steep, generally 55° to 90°.

All mineral deposits of Landlocked Bay are connected closely with faults or fissures; they are most abundant near the Landlock-overthrust fault where the shattering has been most intense.

The copper deposits at Landlocked Bay were formed by replacements of the crushed rock in shear zones and by the filling of fractures. The ore minerals are predominantly chalcopyrite, pyrrhotite, and pyrite. Associated with the ore minerals are minor amounts of sphalerite, galena, arsenopyrite, chalmersite, silver, and gold. Pyrite, where present, invariably was the first mineral to be deposited, but deposition of the other ore minerals followed soon thereafter. Sphalerite was the last to be deposited.8/ Masses of nearly solid sulfides, lenticular both in plan and section, are distributed irregularly within the sheared material. The thickness of known ore lenses ranged from mere films to several feet but seldom were more than 5 feet; the maximum recorded width was 9-1/2 feet.

The intense recent glacial scouring of this area afforded little opportunity for surface alteration or for secondary enrichment of the ore deposits. Secondary copper minerals are of little importance; they consist, chiefly, of malachite or azurite stain and of small flakes of native copper.

WORK PERFORMED BY BUREAU OF MINES

Field Investigations

Eight of the principal mines and prospects adjacent to Landlocked Bay were examined by the Bureau of Mines. Fieldwork included clearing brush from access trails, reopening caved portals, surveying, sampling, and mapping. Over a mile of new trail was cleared of dense brush. The No. 4 level of the Threeman mine, which was caved for 25 feet from the portal, was reopened and retimbered; debris was removed from the portals of most of the other mines and prospects examined. Each mine working was located by triangulation from stations established by the United States Coast and Geodetic Survey, and all of the important underground workings were surveyed by transit and tape. Thirty-eight channel samples were obtained from the various deposits and were analyzed for copper, zinc, lead, sulfur, gold, and silver. Sample locations and analyses are shown on figures 2 through 10; mines and prospects examined are described below.

7/ Work cited in footnote 5 (p. 6), p. 273.
8/ Work cited in footnote 6 (p. 6), p. 298.

SAMPLE NO.	WIDTH FEET	Cu %	Zn %	Ag Oz./Ton	Au Oz./Ton
1	1.0	8.60	0.10	"	"
2	4.0	1.10	.05	"	"
3	5.0	.25	.05	"	"
4	1.5	3.40	.05	0.01	0.07
5	1.0	3.90	.05	.08	.02
6	2.0	.60	.05	"	.01
7	2.0	.70	.05	.01	.02
8	2.7	1.70	.05	"	"
9	4.9	1.20	.05	"	"
10	5.0	3.10	.05	"	"
11	2.1	2.08	.32	"	"
12	3.5	3.86	.17	"	"
13	3.3	.29	.26	"	"
14	3.0	2.97	.21	"	"
15	2.0	4.36	.25	.32	"
16	.7	4.22	.64	.78	"

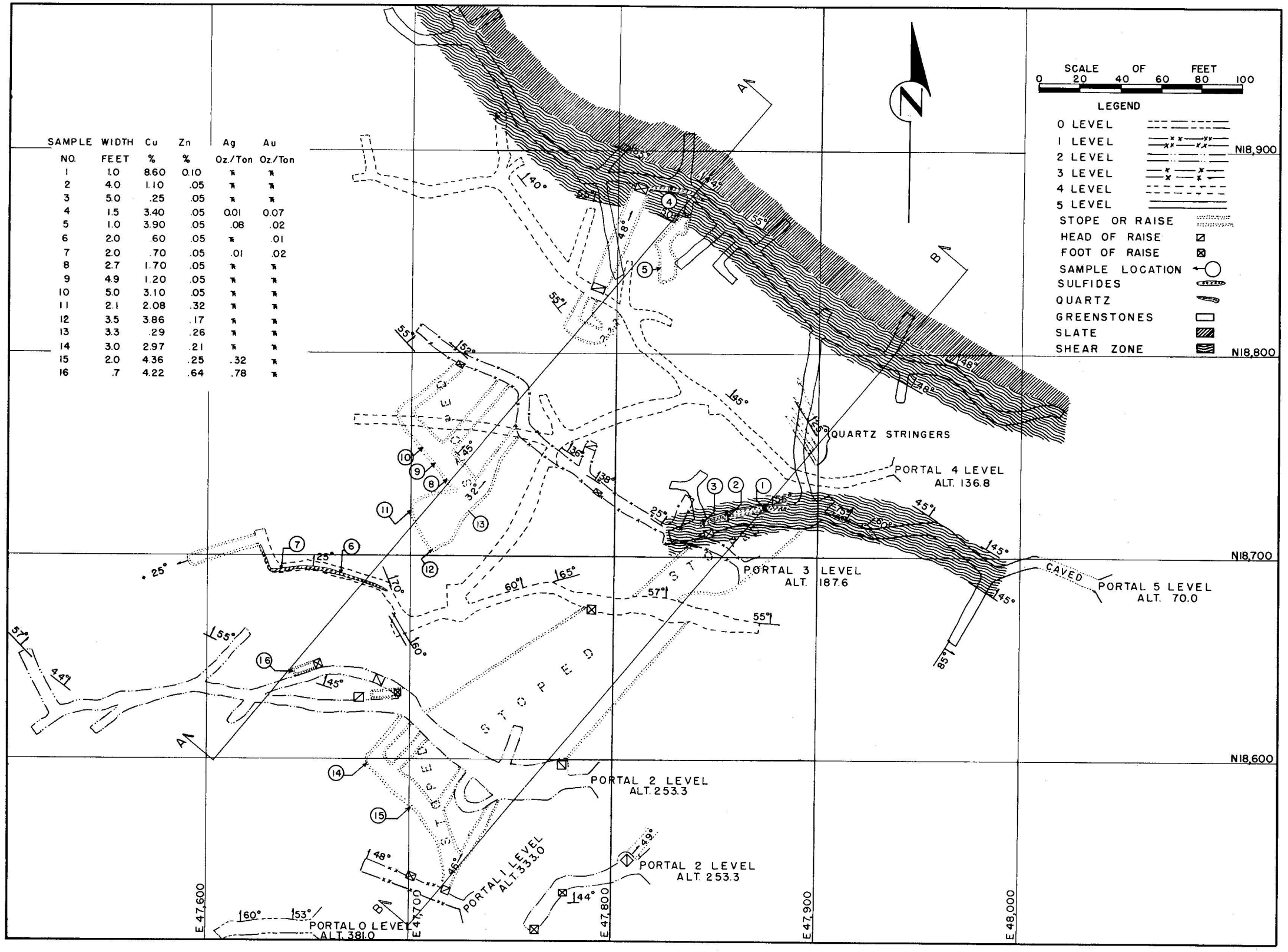


Figure 3. - Plan of Threeman mine, Landlocked Bay, Alaska.

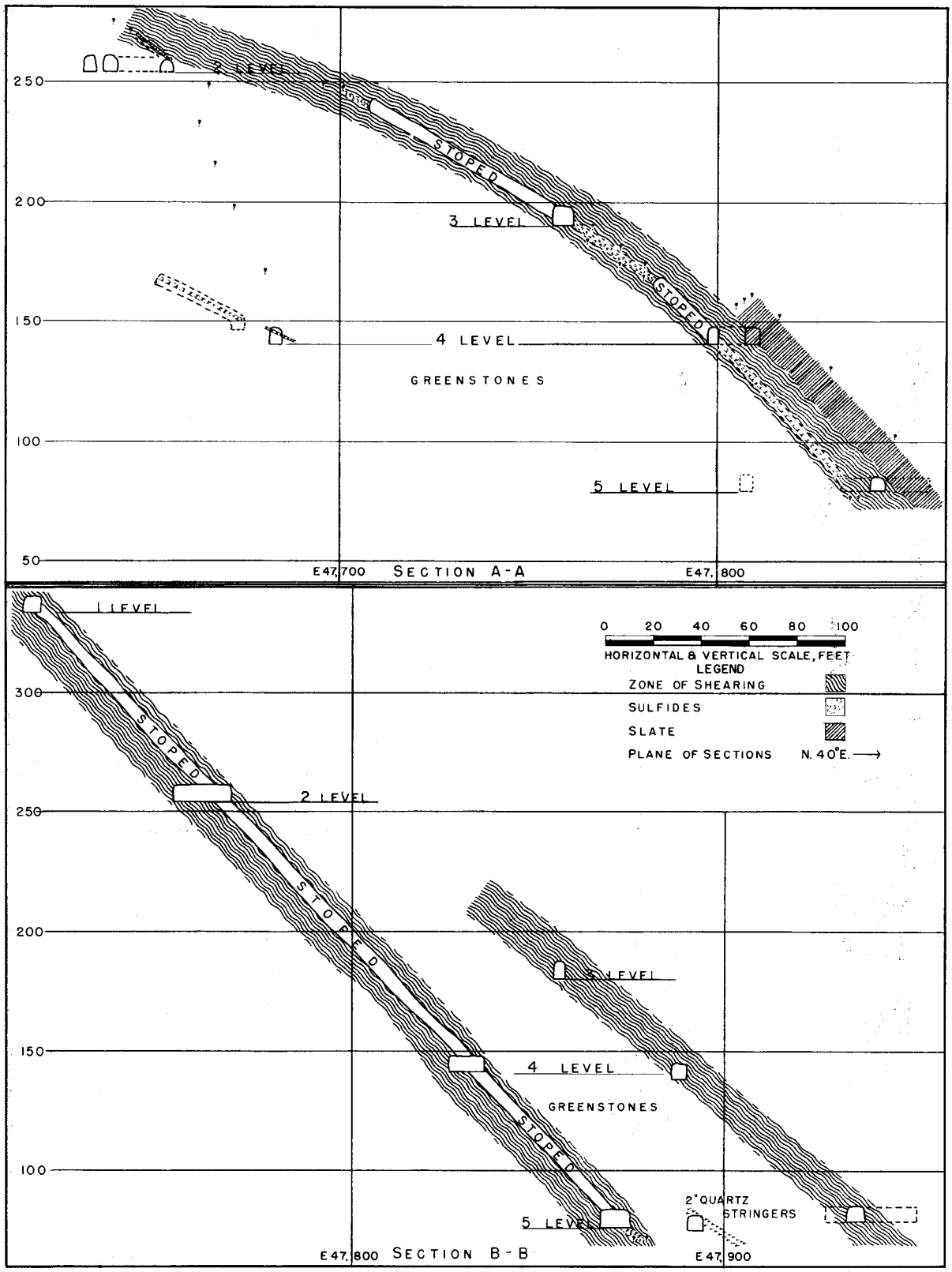


Figure 4. - Sections A-A and B-B, Threeman mine.

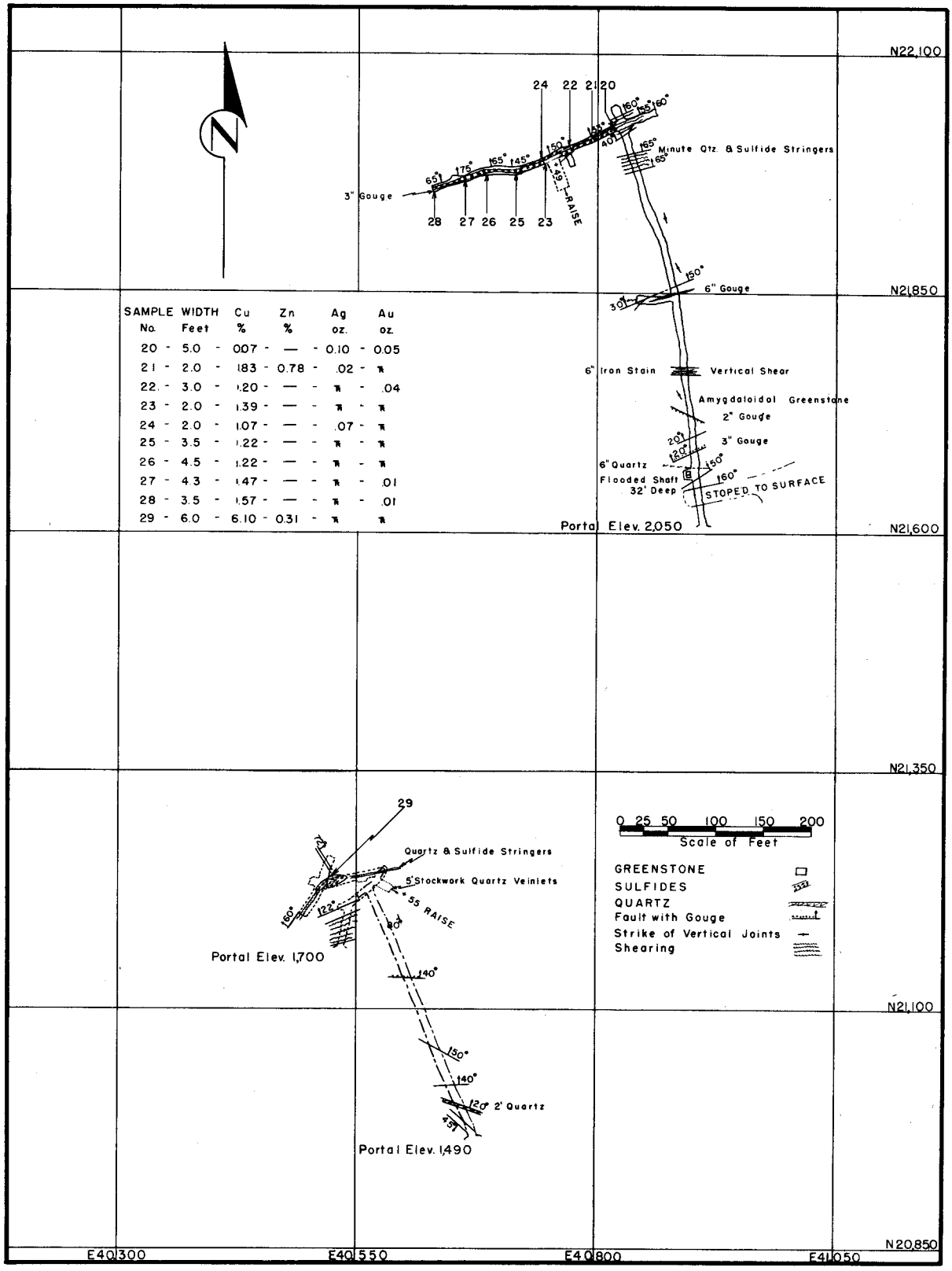


Figure 5. - Standard mine, Landlocked Bay, Alaska.

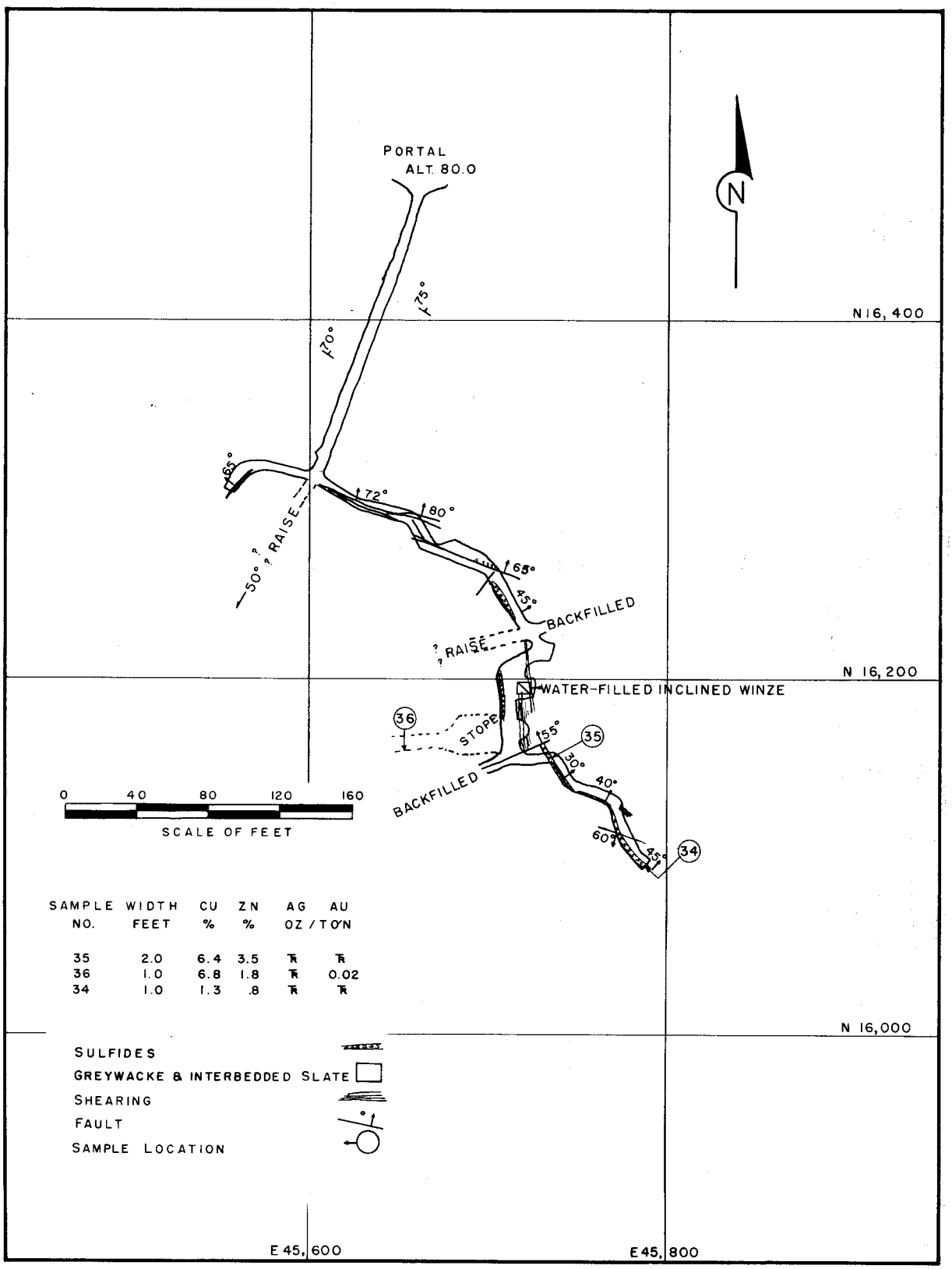


Figure 6. - Landlocked Bay Copper Mining Co.

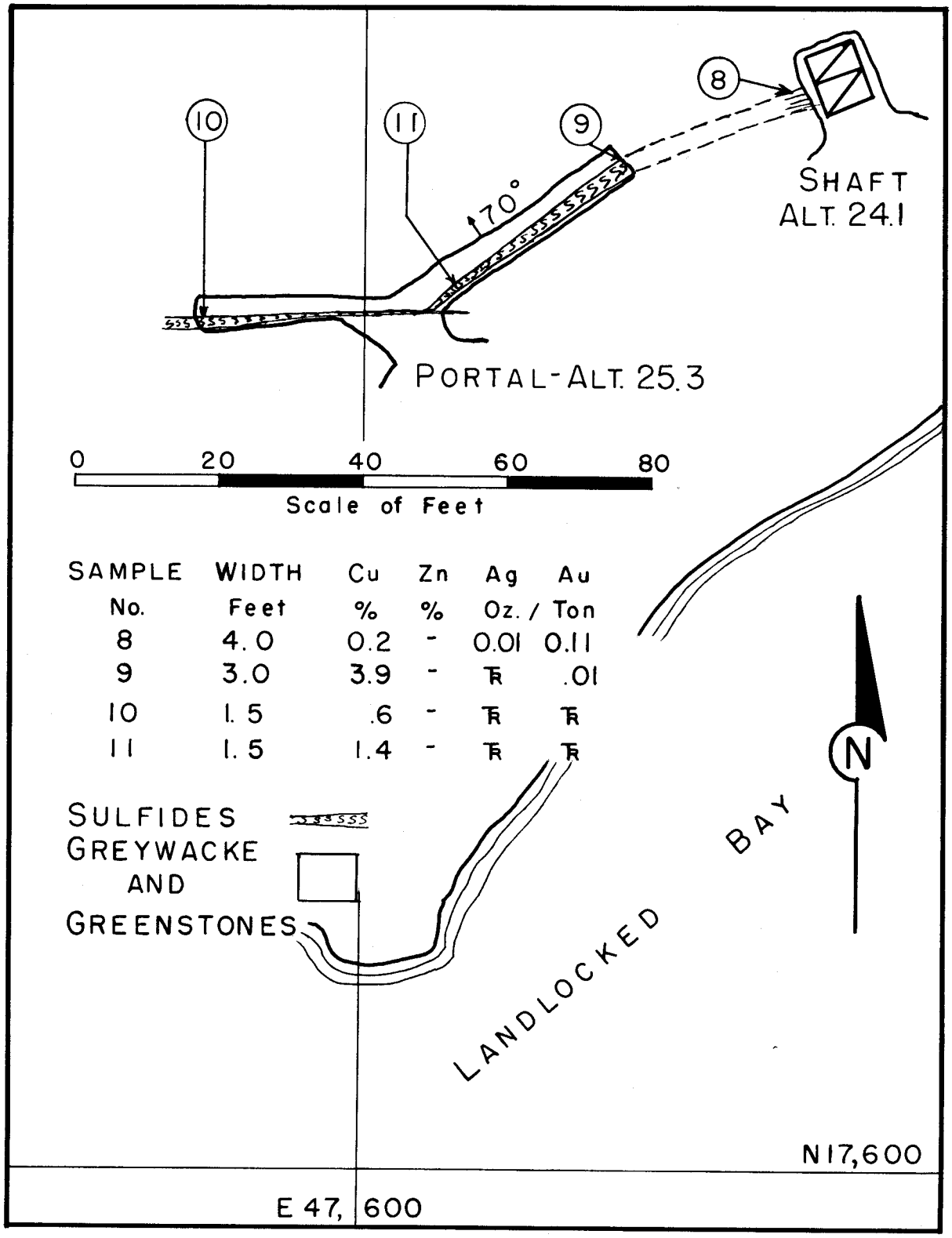
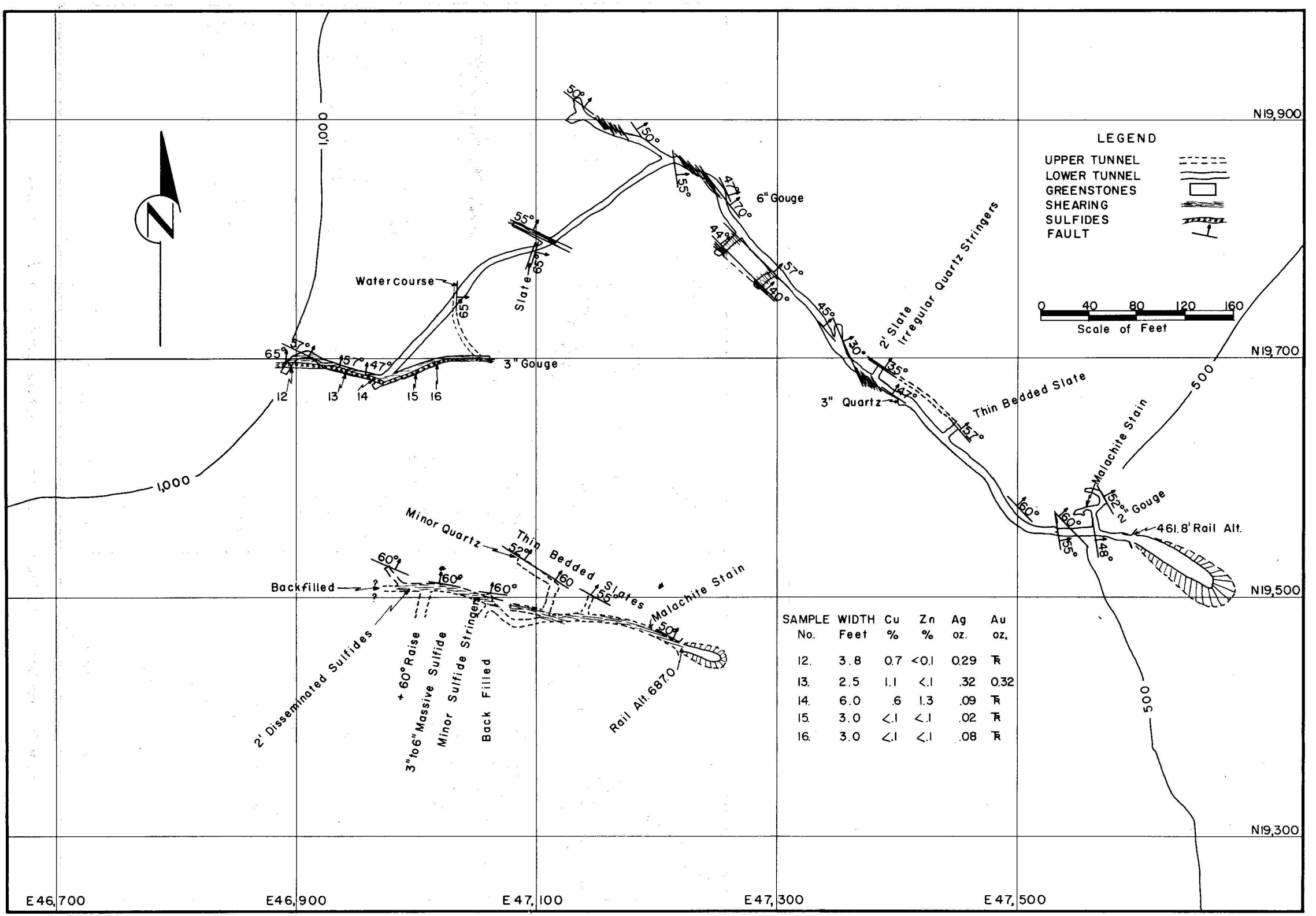
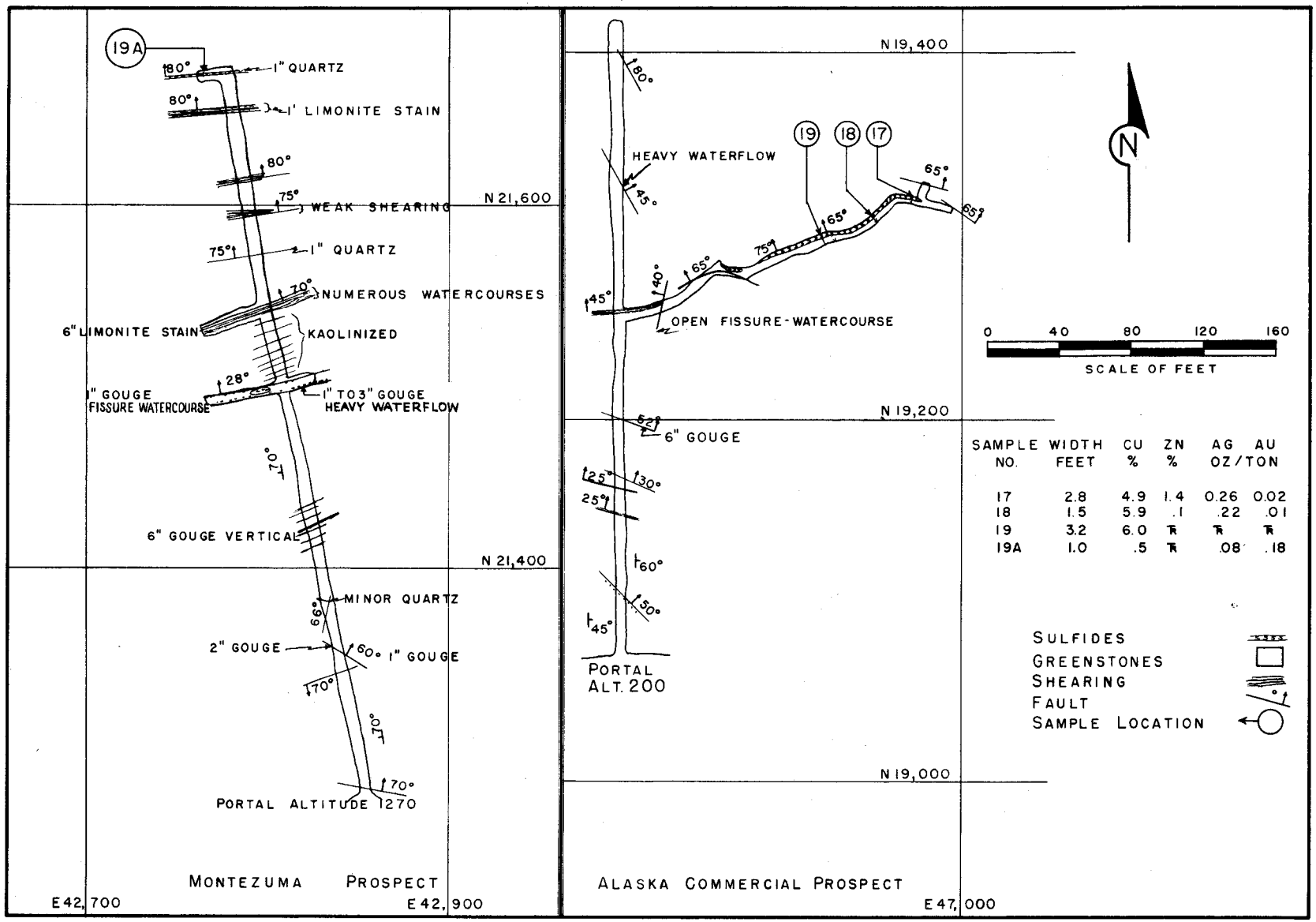


Figure 7. - Alaska Pioneer & Sourdough prospects.



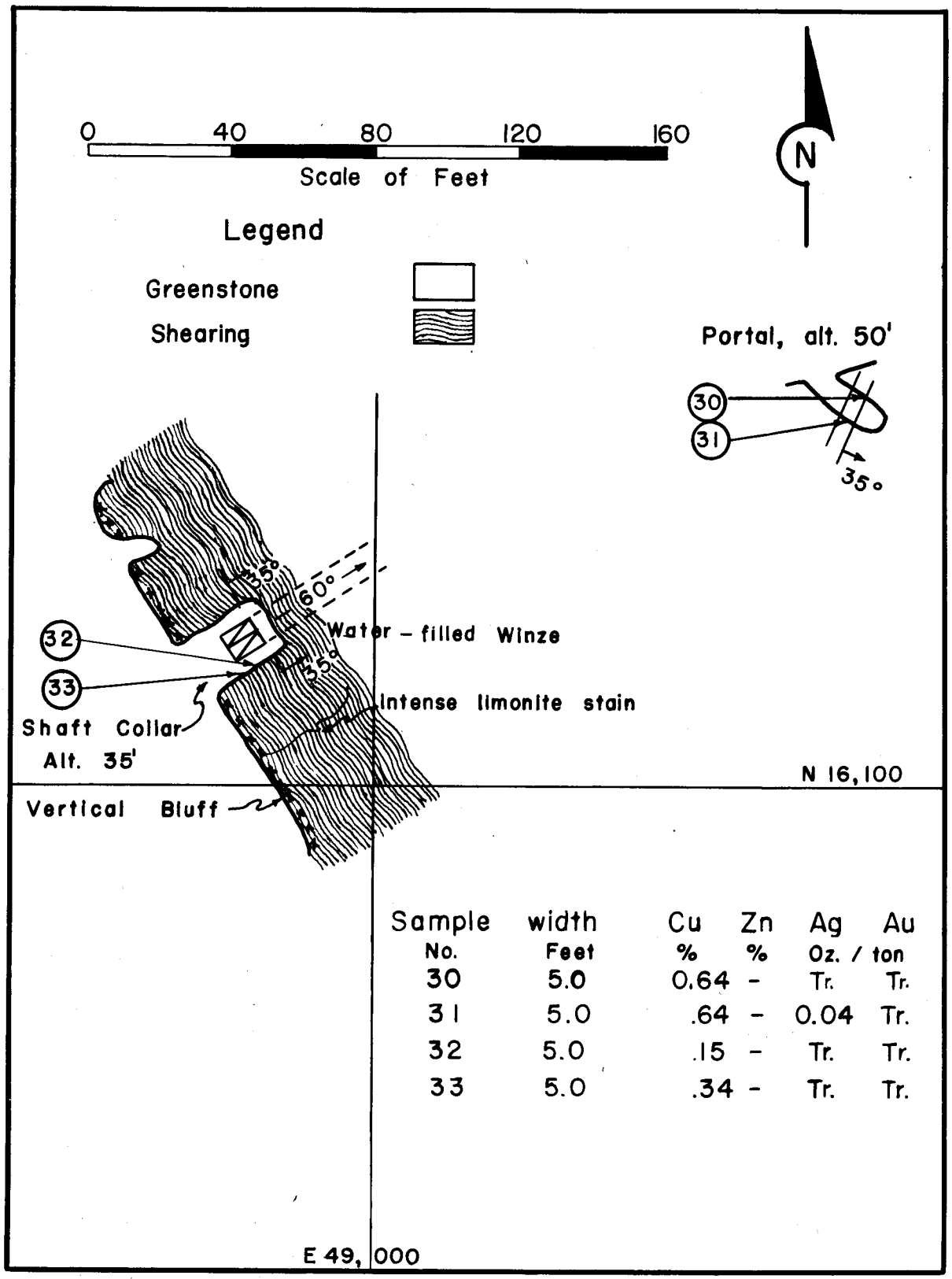
SAMPLE No.	WIDTH Feet	Cu %	Zn %	Ag oz.	Au oz.
12.	3.8	0.7	<0.1	0.29	Tr
13.	2.5	1.1	<.1	.32	0.32
14.	6.0	.6	1.3	.09	Tr
15.	3.0	<.1	<.1	.02	Tr
16.	3.0	<.1	<.1	.08	Tr

Figure 8. - Hemple Copper Co., Landlocked Bay, Alaska.



SAMPLE NO.	WIDTH FEET	CU %	ZN %	AG OZ/TON	AU
17	2.8	4.9	1.4	0.26	0.02
18	1.5	5.9	.1	.22	.01
19	3.2	6.0	Tr	Tr	Tr
19A	1.0	.5	Tr	.08	.18

Figure 9. - Montezuma and Alaska Commercial prospects, Landlocked Bay, Alaska.



Sample No.	width Feet	Cu %	Zn %	Ag Oz. / ton	Au
30	5.0	0.64	-	Tr.	Tr.
31	5.0	.64	-	0.04	Tr.
32	5.0	.15	-	Tr.	Tr.
33	5.0	.34	-	Tr.	Tr.

Figure 10. - Chisna Consolidated prospect.

Mines and Prospects

Threeman Mine

The Threeman mine is on the north shore of Landlocked Bay, approximately 1,000 feet west of the major Landlock overthrust fault (fig. 2). The deposit, on the Keystone claim, was staked in 1903. The first of several shipments of hand-sorted sulfide ore was made in 1904, and subsequent ore shipments were made at irregular intervals until 1915. The total recorded production was 5,596.5 tons of ore with an average metal content of 9.2 percent copper and minor amounts of gold and silver. Mining activity at the Threeman mine ceased in 1916. At present, only vestiges remain of the several buildings, a short aerial tram, a sorting bin, an ore bunker, and a pier that once existed on the property.

The mine was developed by 5 adits at altitudes of 70, 137, 186, 253, and 333 feet; these adits were named No. 5 to No. 1 respectively (fig. 3). Over 5,000 feet of development and exploration tunnels and crosscuts was completed in 2 rudely parallel shear zones. Except for the timbered portals of No. 4 and No. 5 levels, which were caved, all drifts and crosscuts were accessible at the time of examination. For the most part stopes are inaccessible, and where timbered and partly accessible, the timber is decayed.

The workings of the Threeman mine are in the extensively faulted and sheared greenstones, greywackes, and slates in the footwall of the Landlock-overthrust fault. Two shear zones are the most pronounced structural features and loci for ore deposition at the Threeman mine. The shear zones, which range in width from 15 to 50 feet, strike N. 60° to 70° W.; both shear zones dip to the north but diverge downward from their surface intersection above the No. 1 level (figs. 3 and 4). The ores are partly replacements of the crushed material of the shear zones and partly the filling of fractures in the shattered rocks.

The shipping-grade ore was obtained from two lenticular, almost massive bodies of chalcopyrite and pyrrhotite in the shear zones (fig. 3). The largest ore body mined was in the southernmost shear zone; its maximum stope length was about 70 feet; its width ranged from 2 to 9-1/2 feet. This ore shoot was mined from the No. 5 level to the surface, a distance of 350 feet on the dip. In the bottom of the drift on the No. 5 level the ore continues downward as a group of thin, parallel, chalcopyrite-pyrite stringers whose aggregate width averages slightly more than 3 feet throughout a strike length of about 50 feet. The other ore shoot was in the northern shear zone; it was stoped to short distances above the No. 3 and No. 4 levels. Where mined, this ore shoot was, according to the records, about 1 foot to 6 feet wide.

Petrographic studies of a composite of ore samples obtained from the Threeman mine show that the ore contains chlorite, altered ferromagnesian minerals, altered feldspar, quartz, some chalcopyrite, and small amounts of calcite, pyrite, pyrrhotite, and epidote and a very small amount of sphalerite. Channel samples that range in width from 0.7 to 5.0 feet show that the remaining ore contains 0.3 to 8.6 percent copper, up to 0.6 percent zinc, and unimportant amounts of gold and silver.

Standard Copper Mines

The underground workings of the Standard Copper mines are over 1 mile west of the Threeman mine (fig. 2). Exploration and development tunnels of the Standard Copper mines are in the precipitous south slope of Copper Mountain at altitudes

between 1,490 and 2,050 feet (fig. 5). An aerial tram once connected the tunnels to a 500-ton ore bin and wharf on the north shore of Landlocked Bay. The Standard Copper mine claims were explored and developed actively from 1906 until 1911. Shipments of 1,100 tons of hand-sorted sulfide ore, containing almost 1.5 percent copper with some gold and silver, were made in 1907 and in 1909.

The ore bodies are small, lenticular masses of chalcopyrite, pyrite, and pyrrhotite at or near the intersection of shear zones or faults. The country rock is predominantly greenstone but includes some greywacke and slate. The geology is complex because of much shearing and faulting. Most of the deposits are exposed at the surface as small, rust-colored outcrops where several lines of shearing intersect. The strongest shear zones strike predominantly almost east and are indefinite in length; the rust-colored outcrops in the shear zones generally are less than 100 feet long, 1 to 20 feet wide, and mostly dip to the north at fairly steep angles.

Three adits, whose combined length is 1,250 feet, were driven at altitudes of 1,490, 1,700, and 2,050 feet to crosscut and explore the most intensely metallized shear zones (fig. 5).

The adit at the 2,050-foot altitude was driven to intersect 3 ore-bearing zones that crop out on the mountain above. The lowest of these zones, which strikes N. 80° E. and dips 60° N., was intersected 30 feet from the portal of the adit. The ore shoot on this shear zone was stoped to the surface; it produced the 1,000 tons of ore shipped in 1907. A vertical shaft 32 feet deep and 50 feet from the portal was sunk on this lead; the shaft now is filled with water. Four hundred and twenty feet from the portal of the adit a drift was driven 250 feet S. 60° W. along a metallized shear zone which contains a lens of pyrite-chalcopyrite and quartz 2 to 5 feet wide; the lens dips 45° to 75° N. Samples from this lens contained 0.07 to 0.83 percent copper, with unimportant amounts of zinc, gold, and silver.

A short adit at 1,700 feet altitude exposed a vertical, ellipsoidal, massive lens of chalcopyrite and iron sulfides whose maximum length is 32 feet and maximum width 6.0 feet. The major axis of the lens strikes N. 65° E. The massive chalcopyrite lens occurs at the intersections of several shears in greenstone. A sample across the maximum width of the lens contained 6.1 percent copper, 0.3 percent zinc, and traces of gold and silver. The adit at the 1,490-foot altitude was driven 280 feet to intersect this lens in depth but encountered no bodies of sulfides; however, it was stopped about 40 feet before reaching the vertical projection of the sulfide lens in the upper adit. A short inclined raise was driven on a stockwork of quartz veinlets found in the end of the adit at the 1,490-foot altitude (fig. 5).

Landlock Bay Copper Mining Co.

The main underground working of the Landlock Bay Copper Mining Co. is slightly more than 500 feet of tunnel on the south shore of Landlocked Bay. The portal of the tunnel, at an altitude of 80 feet, is about half a mile southwest of the Threeman mine (fig. 2). Discovery of copper ore on the property was made in 1898; underground exploration of the mine and installation of an 800-ton-capacity ore bunker near the portal of the mine were completed after 1906. Mining activity culminated in 1916 with the shipment of 928 tons of hand-sorted sulfide ores containing 4 percent copper.

The ore occurs as small lenses of chalcopyrite, pyrite, and pyrrhotite in a shear zone in greenstones or greywacke with interbedded slate (fig. 6). The shear zone is 4 to 15 feet wide; along the drift its strike changes from almost east to south and its dip flattens from 80° N. to 30° N. The localization and attitude of

the sulfide lenses in the shear zone appear to have been controlled by the intersection of the shear zone with north-dipping faults. Three lenses of chalcopyrite and pyrite are exposed in the drift. The ore lenses are 25 feet to about 100 feet long; their average width is slightly more than 1 foot. One of the lenses of sulfides was partly stoped and was explored below the drift level by a winze reported to be 25 feet deep. Samples of the ore lenses contain 1.3 percent to 6.8 percent copper, 0.8 to 3.5 percent zinc, and traces of gold and silver.

Alaska Pioneer and Sourdough Prospect

The Alaska Pioneer and Sourdough prospect, originally held by the Alaska Commercial Co., is on the north shore of Landlocked Bay 1,700 feet southwest of the Threeman mine (fig. 2). At this location 65 feet of tunnel and a shallow vertical shaft were driven to explore a shear zone that strikes N. 60° E. and dips 70° N. (fig. 7). The shear zone has a well-defined hanging wall but an indistinct foot wall. The country rock includes greenstones, slate, and greywacke. All of the workings are in greenstones.

The tunnel, at an altitude of 25 feet, exposed an almost massive lens of chalcopyrite and pyrrhotite which is 1.5 to 3.0 feet wide throughout a length of 35 feet. Samples of this lens contained 1.4 to 3.9 percent copper. A vertical shaft 25 feet deep was sunk in the shear zone 27 feet east of the tunnel face but when examined was filled with water. A sample of the shear zone above the collar of the shaft contained 0.2 percent copper.

Hemple Copper Co. Prospect

Underground exploratory tunnels of the Hemple Copper Co. are about 1,500 feet north of the Threeman mine. A tunnel, at 462 feet altitude was driven about 1,100 feet, and a tunnel at 687 feet altitude was driven 240 feet to explore a shear zone that strikes almost east and dips about 60° N. (fig. 8).

The country rock is greenstone, black slate, and greywacke. A lens chiefly composed of stringers of pyrite and pyrrhotite was exposed in the lower tunnel throughout a length of approximately 150 feet. The width of the lens ranged from 2.5 to 6.0 feet. Samples of this lens contained 0.1 to 1.1 percent copper, with unimportant amounts of other metals. The tunnel at 687 feet altitude exposed a short lens of sulfides about 6-inches wide.

Alaska Commercial Prospect

This prospect, reported to have been the first discovery of copper ore at Landlocked Bay, was located in 1897. Exploratory openings are in a nearly vertical cliff on the north shore of Landlocked Bay one-half mile west of the Threeman mine (fig. 2). A tunnel at an altitude of 200 feet was driven north into the greenstone cliff to intersect a large shear zone that outcrops above. A drift was driven 200 feet along a northeast-striking shear zone 190 feet from the portal of the tunnel (fig. 9). The drift exposed two lenses of chalcopyrite, pyrrhotite, and pyrite. The combined length of the 2 lenses exceeded 100 feet; their width ranged from 1.5 to 3.2 feet.

The strike of the largest sulfide lens is about N. 70° E.; its dip ranges from 65° to 75° N. Samples of this lens contained 4.9 to 6.0 percent copper, 0.1 to 1.4 percent zinc, and minor amounts of gold and silver.

Other exploratory openings and trenches that are said to have been driven above the tunnel are obscured by talus and brush.

Montezuma Prospect

Exploratory openings on the Montezuma claim are on the steep south side of Copper Mountain at an altitude of 1,270 feet, about 1 mile west of the Threeman mine (fig. 2). The major structure on the Montezuma claim outcrops at an altitude of 1,400 feet as a mineralized shear zone that strikes east and dips 65° N. Erosion of the outcrop of this shear zone has resulted in a well-defined, shallow trough about 50 feet wide that is traceable for over 1 mile toward the head of Landlocked Bay. Several smaller shear zones, which contain some pyrite and quartz, outcrop at altitudes of 1,500, 1,700, and 2,000 feet, respectively. These smaller shear zones generally strike N. 80° to 85° E. and dip N. at angles between 50° and vertical; their width ranges from 1 to 15 feet throughout strike lengths up to 50 feet.

The tunnel at 1,270 feet altitude was driven north 400 feet but did not intersect the major shear zone or encounter significant sulfide mineralization (fig. 9). The tunnel is driven in greenstones; it crossed several northeast-striking faults that dip 25° N. to 80° N. Most of the faults contain limonite and gouge up to 1 foot wide. A quartz-filled fracture about 1 foot wide, which strikes N. 80° E. and dips 80° N., was exposed in the end of the drift. A sample of this vein contained 0.5 percent copper, traces of zinc, 0.08 ounce of silver, and 0.18 ounce of gold per ton.

Chisna Consolidated Prospect

Exploratory workings of the Chisna Consolidated prospect are on the south shore of Landlocked Bay in the hanging wall of the Landlock overthrust fault (fig. 2). The principal underground working is an inclined shaft reported to be 40 feet deep. The collar of the shaft, a short distance from the shoreline, is at an altitude of 35 feet at the base of a rust-stained, vertical scarp or bluff slightly more than 100 feet high. The shaft was sunk to explore a zone of closely spaced fracturing or shearing about 40 feet wide which strikes N. 30° W. and dips 35° NE. Thin films of chalcopyrite, and of pyrite with gouge, fill the fractures in greenstone. A sample taken above the collar of the shaft across 10 feet of the zone contained 0.15 to 0.34 percent copper and traces of gold and silver (fig. 10). About 200 feet east of the bluff 20 feet of tunnel was driven to crosscut an outcropping fracture 5 feet wide which strikes N. 30° E. and dips 35° E. Samples of the most highly mineralized parts of the tunnel contain 0.64 percent copper and traces of gold and silver.

Laboratory Investigations

A 600-pound sample of ore for metallurgical testing was composited from 14 samples of the Threeman mine to provide a sample similar in grade and character to the ore bodies of the Threman deposit.

Character of the Ore

Detailed physical and chemical studies were made of the composite sample from the Threeman mine; the results follow:

Physical

Petrographic study showed that the composite sample essentially contains chlorite, altered ferromagnesian minerals, altered feldspar, quartz, some chalcopyrite, and small amounts of calcite, pyrite, pyrrhotite, and epidote, and a very small amount of sphalerite.

Maximum liberation occurs in the minus-65- plus-100-mesh fraction, but the bulk of the chalcopyrite is liberated in the coarser minus-48-plus-65-mesh fraction.

Chemical

Representative head samples of the composite sample were analyzed chemically and spectrographically. The results of partial chemical analyses are shown in table 2. A semiquantitative spectrographic analysis revealed the presence and approximate quantities of the following metals: Over 10 percent Al; 5 to 10 percent Ca; about 1 percent Cu; 1 to 5 percent Mg; 0.001 to 0.01 percent Ag; 0.01 to 0.1 percent Zn; 0.01 to 0.1 percent Cr; about 0.1 percent Co; over 10 percent Fe; about 0.1 percent Mn; 0.01 to 0.1 percent Ni; over 10 percent Si; about 1 percent Ti; and 0.01 to 0.1 percent V. Any other elements present are in amounts lower than the minimum detectable by the routine technique employed. A spectrographic analysis of sample 5 of the Threeman mine showed a selenium content of less than 0.01 percent.

TABLE 2. - Chemical analysis

Assay, percent						Oz. per ton	
Cu	Fe	Insol.	Zn	Ni	Co	Au	Ag
1.65	15.1	49.3	1/ 0.05	0.01	0.02	Tr	0.36

1/ Less than.

Concentration Tests

A series of flotation tests to determine the grind and reagent combination required for maximum recovery of copper from the ore was completed. Although good recoveries of copper were obtained by rougher flotation of ore ground to minus-48- or 65-mesh, it was difficult to clean the rougher concentrate. Several tests were made in which the rougher concentrate was reground before cleaning. The results shown in table 3 are typical of tests using this procedure. For this test ore was ground in a laboratory ball mill to pass a 48-mesh sieve. The pulp was conditioned with lime and collector for 5 minutes and a rougher concentrate was made. The rougher concentrate was reground 12 minutes and cleaned 3 times. Operation data of the test are shown in table 4.

By flotation 81 percent of the copper was recovered in a concentrate assaying 28.4 percent Cu, 35.3 percent Fe, and 1.9 percent acid-insoluble matter. Over 13 percent of the total copper reported in the cleaner tailings, which could be retreated to increase the recovery of copper slightly. The small amount of cobalt in the ore, which apparently is associated with pyrrhotite, was concentrated to some extent in the cleaner tailing.

Partial oxidation of the ore samples as received reduced the flotability of the copper minerals and activated the iron sulfides, making separation of copper and iron minerals more difficult.

TABLE 3. - Flotation, Threeman-mine ore

Product	Weight, percent	Assay, percent				Distribution, percent		
		Cu	Co	Fe	Insol.	Cu	Co	Fe
Concentrate	4.28	28.4	0.01	35.3	1.9	81.1	2.8	10.2
Cleaner tail, 3	1.17	6.3	.10	43.1	12.1	4.9	8.4	3.4
Cleaner tail, 2	.89	9.2	.03	26.4	24.2	5.5	2.1	1.6
Cleaner tail, 1	6.02	.8	.06	24.7	37.6	3.2	25.2	10.1
Rougher tail	87.64	.09	.01	12.6	51.7	5.3	61.5	74.7
Calculated head	100.00	1.5	.014	14.8	48.0	100.0	100.0	100.0
Combined cleaner tails..	8.08	2.5	.06	27.5	32.4	13.6	35.7	15.01

TABLE 4. - Operation data, flotation test

Circuit	pH	Reagents, pounds per ton			
		CaO	NaCN	Z-3[1/]	M.I.C.[2/]
Grinding	-	-	-	-	-
Conditioner	9.8	1.0	0.1	0.25	0.1
Rougher	9.8	-	-	-	-
Regrind	-	1.0	-	-	-
Cleaner 1	10.0	-	-	-	.05
Cleaner 2	9.5	-	-	-	-
Cleaner 3	7.5	-	-	-	-
Total		2.0	.1	.25	.15

1/ Potassium ethyl xanthate.
2/ Methyl isobutyl carbinol frother.

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