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THE GEOLOGY AND MINERALOGY
OF
THE LITTLE BILLY MINE
TEXADA ISLAND, B.C.

by

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A thesis submitted to the Department of Geology and Geography of the University of British Columbia, as partial fulfillment of the requirements for the Degree of Master of Applied Science.

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CONTENTS

CONTENTS (cont'ed)

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Chapter I.

INTRODUCTION

The object of this thesis is to summarize the published information on the geology of the Little Billy mine, and to augment this data by a further study of the gangue and the ore minerals and to describe the types of ore. In answering the above problem, frequent use has been made of the ore of the nearby Marble Bay mine. This ore is massive and the minerals are readily visible for determination, whereas the ore of the Little Billy is disseminated, a fact which made the determination of minerals and paragenesis difficult and uncertain.

The research involved in this thesis was intended to answer the following questions:

1. The mode of occurrence of the gold and silver in the ore of the Little Billy mine.
2. The nature of the volatiles or mineralizers associated with the contact-metasomatism of the Little Billy mine.
3. The size of screened product which will give the best separation of gold, silver and copper.

The Little Billy mine is located about a quarter of a mile west of Vananda on Texada Island, which is about seventy miles north-west of Vancouver and about two miles from the mainland (fig.1).

PREVIOUS WORK, AND SOURCES OF INFORMATION

The first report on Texada Island was given by Mr.J.Richardson of the Geological Survey in the Annual Report of 1873-84, after he made a brief examination of the iron range on the west coast of the Island. Two years later G.M.Dawson examined the entire coast line. His work was published in the Annual Report, Vol. II, 1887.

Reference to the mining progress on Texada Island was given in the Reports of the Minister of Mines, British Columbia, and the Summary reports of the Department of Mines, Ottawa. Detailed accounts of the mining progress and general geology was published by W.M.Brewer of Victoria in the Engineering and Mining Journals from 1900 to 1906.

The first general survey of the Island was made by O.E. Le Roi of the Geological Survey in 1906. This report was published in 1908 as "A preliminary Report on a Portion of the Main Coast of British Columbia and Adjacent Islands". In the same year an accurate geological survey of the Island

was made by the late R.C.McConnell. His work was published in Memoir 58, 1914, as "Texada Island, B.C."- Mr.McConnell's Memoir was the first publication to give a detailed report on the geology and the mines of Texada Island.

The first detailed study of the "Marble Bay Mine" was published in 1921 by Dr.V.Dolmage in "Economic Geology". A careful study of the genesis of the Magnetite deposits of Texada Island was made by Dr. C.O.Swanson in 1923. His report "The Genesis of the Texada Island Magnetite Deposits" was published in the Summary Report of the Geological Survey, 1924.

The publications mentioned above, and others in the "Selected Bibliography", have been consulted frequently during the research for this report, and free use has been made of McConnell's descriptions of topography, relief, and general geology.

HISTORY OF MINING ON TEXADA ISLAND.

The first discovery of bornite on Texada Island was made in the early nineties, but attracted very little attention because the ore was disseminated in limestone and was of a low grade.

The ore body of the Marble Bay Mine was discovered in 1897, during the ownership of Palmer & Cristie of Toronto.

After preliminary surface work the shaft was sunk to 500 feet and proved the presence of a large quantity of bornite ore. By 1901 the Marble Bay Mine had become the largest mine on Texada Island, and it was worked continuously until 1924. By this time the available ore was mined, and exploration failed to show any new ore. Approximately twenty-five million dollars in copper, gold, and silver ore had been extracted from the Marble Bay Mine. The ore yielded approximately 5% copper, .3 ozs. gold and 4 ozs. of silver, with no decrease of the gold or silver values with depth.

At the same time as development was started on the Marble Bay Mine, work was started on the Copper Queen, Cornell, and Little Billy mines by the Vananda Copper and Gold Companies Limited. These mines are located within a mile and a half of Vananda. Although they contained the same minerals, and were a similar type of deposit, they did not have the same quantity or quality of ore as the Marble Bay. To utilize this low-grade ore, the Vananda Copper Company built a 50-ton copper smelter. These mines were worked until 1903 and then were leased and worked intermittently until they were abandoned in 1920.

In 1943 the abovementioned mines were purchased by the Industrial Metal Mining Company, and the first to be reconditioned was the Little Billy, (Fig.2). Extensive

diamond drilling from the old workings and from the surface located the "Prosser Ore Body". (Map in folder). Encouraged by finding the new ore body, the Industrial Metal Company started to recondition the Copper Queen Mine, half a mile south of the Little Billy.

In December 1944, the Little Billy, the Copper Queen and the Cornell Mines were leased by Pioneer Gold Mines Ltd. of Vancouver, B.C. In January 1945 the Industrial Metal Mining Co. started to de-water the Marble Bay Mine, and by March 1945 the first three levels were de-watered and reconditioned. An extensive diamond drilling and development programme is planned for the future.

Since the purchase of the Little Billy mine the Pioneer Gold Mining Company has deepened the shaft 200 feet and has started the development of the 480 level.

MINERAL DEPOSITS OF TEXADA ISLAND

"The mineral deposits consist of replacement deposits of the contact metamorphic type, and a few gold-quartz veins. The former are the more important and may be subdivided into deposits worked principally for their copper content, and those worked for iron. These groups are not sharply divided since magnetite ore invariably contains chalcopyrite and bornite, and chalcopyrite-bornite

ore contains minor amounts of magnetite." (28)

In addition to the copper and iron deposits, the limestones, marbles, clays and sands are important. The limestone of the Marble Bay formation, which contains over 95 percent calcium carbonate, is widely used on the Pacific coast as a source of lime.

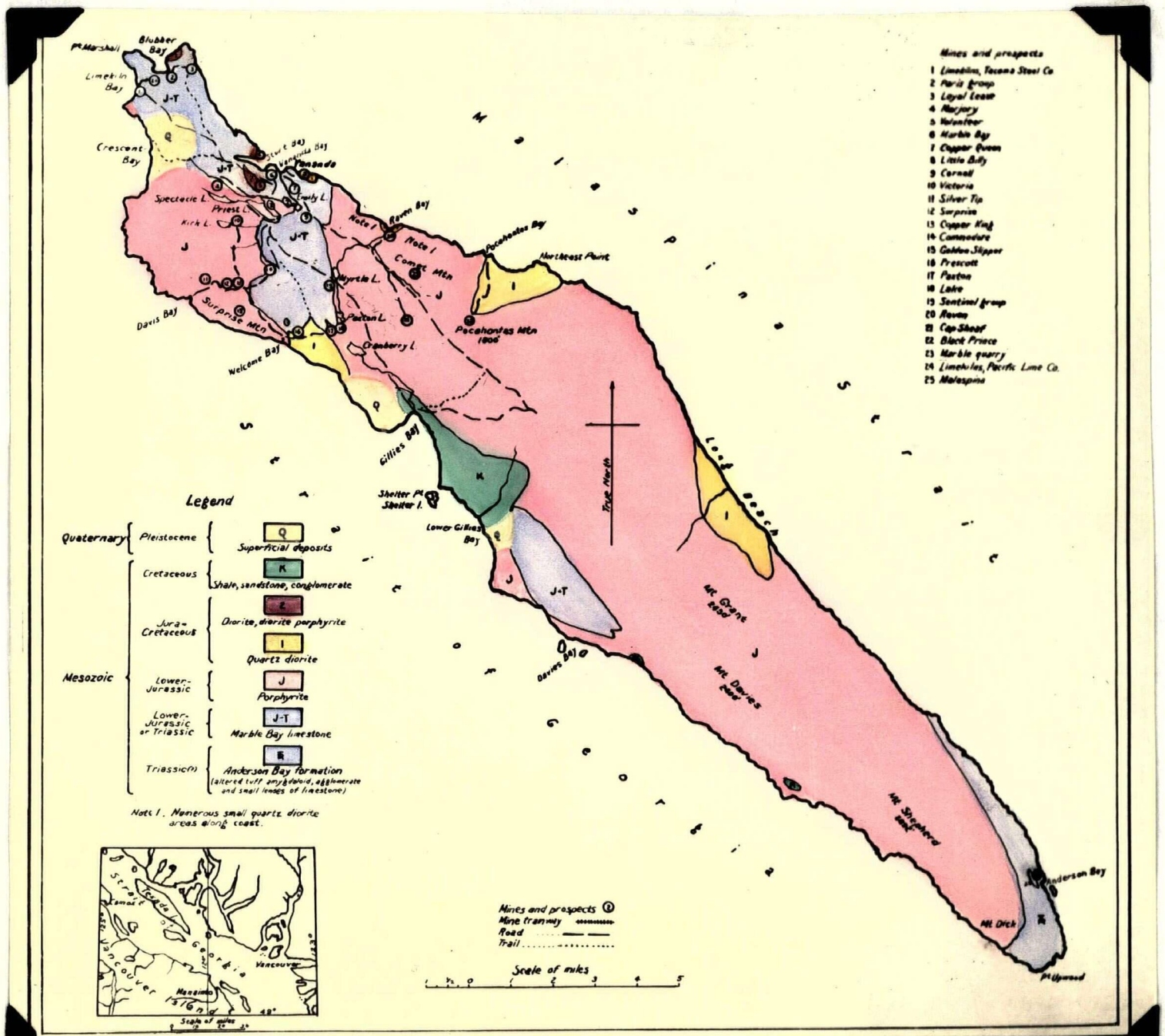


Diagram showing the geology of Texada Island, British Columbia.

...ical Survey, Canada.

Chapter II.

TOPOGRAPHY and GEOLOGY of TEXADA ISLAND.

TOPOGRAPHY.[28]

Texada Island is a partially submerged ridge paralleling the mainland at a distance of two to four miles. It has a length of thirty miles, a maximum width of five miles, and an average width of three miles. The shore line is indented by few deep bays, except at Long Beach on the east coast and Lower Gillies Bay on the west coast. The coast consists mostly of low rock cliffs worn and broken by the incessant action of the ocean.

RELIEF.[28]

Except for limited movements of elevation and depression, Texada Island has not been noticeably disturbed since Cretaceous times. The present topographic forms are the results of long continued erosion. The softer rocks, represented by Cretaceous sandstones and shales, and limestones of lower Mesozoic age, have been worn down into basins and rough seaward-sloping plains. The more resistant rocks, such as porphyrites, project as hills and ridges.

The vertical relief in the southern portion of the island, where the rocks consist largely of porphyrites, is in strong contrast to that in the northern portion, where

the rocks are largely limestone, sandstone, and shale. The southern portion of the island is a single steep-sided, rock-crested ridge rising from the waters edge on both shores and culminating in Mt.Shepherd, 2892 feet above sea level. In the central part of the island, the highland which continues northward from Mt.Shepherd, broadens out, becomes more irregular, and is interrupted on both sides by wide depressions. The prominent elevations here are Mt.Davies, 2484 feet, Mt. Grant, 2450 feet, and Pocahontas Mountain, 1800 feet.

North and west of Pocahontas Mountain the general elevation sinks abruptly several hundred feet, and from this point to the northern end of the island the relief is comparatively low. The high rugged peaks and ridges which characterize the southern portion of the island are replaced by round-topped hills and ridges not exceeding a thousand feet in height. Surprise Mountain, a long ridge rising from the west coast to a height of nearly a thousand feet, is the most conspicuous elevation in the northern portion of the Island. Comet Mountain, just south and east of the Little Billy Mine, attains a height of 750 feet.

With the exception of a few small drift-covered areas, the surface of Texada is everywhere rough and broken. The low-lying portions are incised by shallow rock canyons, and worn hummocks and ridges project above the thinly dis-

tributed boulder clays.

The general deepening of the valleys near the coast is a post-glacial feature, and is attributed to an uplift of the island which occurred at the close of the glacial period. Beaches with marine shells are found at a number of points, at elevations 428 feet above the present sea level.

GEOLOGY OF TEXADA ISLAND.

The Anderson Bay formation is the oldest on Texada Island. This formation, a volcanic series, was placed by McConnell[28] in the Triassic. The youngest Mesozoic rocks are a group of upper Cretaceous rocks composed of soft sandstones, sands, clays and shales.

Glacial and recent deposits are represented by boulder clays, sands, silts, and creek gravels.

The Formations of Texada Island[28].

Quaternary	Recent - Creek gravels, peat, etc.	
	Glacial - Boulder clays, sands, silts, etc.	
Mesozoic	Upper Cretaceous -	Soft sandstone, sands, clays and shales.
	Lower Cretaceous or Upper Jurassic -	Diorites and diorite-porphyrites in small stocks and dykes.

Upper Jurassic (?)	-	Quartz-diorites (Coast Range batholith ?)
Lower Jurassic (?)	-	Texada group, porphyrites, Texada Group of Le Roi[25] (in Part)
Triassic or Jurassic	-	Marble Bay formation (Limestone).
Triassic	-	Anderson Bay formation: schists, tuffs, agglomerates, amygdaloids, and marbles. (Texada group of Le Roi in part).

ANDERSON BAY FORMATION.[28]

The rocks of the Anderson Bay formation are exposed only on the south-eastern edge of the island (fig.1). The formation is made up of an alternating series of slates, quartzites, conglomerates, marbles, tuffs, agglomerates, amygdaloids, and lead-green schists. These beds resemble lithologically the Sicker series of the Vancouver group which have been placed by Clapp[13] in the Triassic or Lower Jurassic.

MARBLE BAY FORMATION.[28]

The limestones of the Marble Bay formation occur in two belts; one belt just south of Lower Gillies Bay, and the other across the northern portion of the island (fig.1).

In addition to these areas, McConnell[28] reports numerous limestone inclusions in the porphyrites of the Texada formation. These inclusions vary in size and shape, ranging from angular shreds a few yards in length to rounded or lenticular areas a quarter of a mile or more in length.

The bedding planes of the Marble Bay limestone, except in a few unaltered places, are usually obscured. The principal partings consist of strong vertical jointage planes. In the less altered areas the beds undulate in low folds with an occasional sharp upturn near dykes and other igneous bodies.

The Marble Bay formation contains the important contact metamorphic copper deposits of the Marble Bay, Cornell, Copper Queen and Little Billy Mines. As well as these copper deposits, the Marble Bay formation contains the important magnetite deposits of the Lake, Paxton and Preston Mines.[28,32]

The Marble Bay formation was placed by McConnell[28] in the Lower Jurassic or Triassic. This would correspond to the Sutton limestone of the Vancouver group.[13,14] On Quadra Island, forty miles north of Texada Island, is a massive limestone which is similar, and hence has been called the Marble Bay formation.[25]

TEXADA FORMATION.[28]

The Texada formation, which covers the greater part of Texada Island, consists mostly of basic, massive igneous rocks of varying composition and texture, but classified generally as porphyrite.[28] The formation, which is several thousand feet thick, comprises a series of volcanic rocks including much andesite and andesite porphyry. In addition to the andesite there are diabase and augite-porphyrite, hornblende-porphyrite and some basalt. The rocks are seldom fresh, and usually contain large amounts of secondary chlorite and epidote, which gives them a greenish colour. The rocks of the Texada formation are a group of superimposed flows, folded steeply in the southern part of the island along an axis having a northwest trend,[18] and are probably of the same period of volcanism as the Vancouver Volcanics.[13]

INTRUSIVE ROCKS.

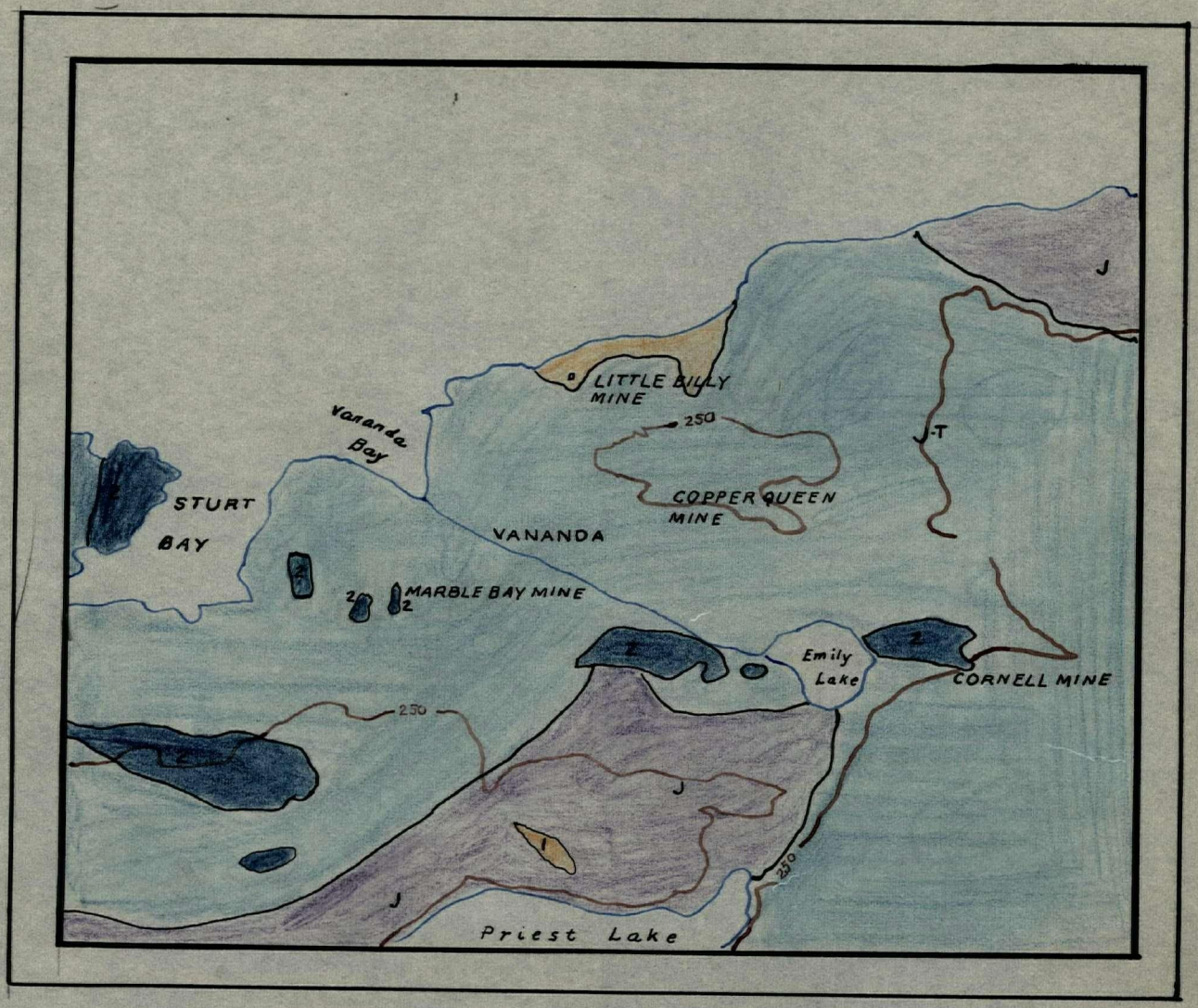
(a) Stocks.

The quartz-diorite occurs in small stocks and dykes, intruding both the Marble Bay and Texada formations[28]. There are four areas of quartz-diorite exposed, one being at the Little Billy Mine. In papers by Dr. Dolmage[18] and Dr. Swanson[32] these intrusions have been further described. Dr. Swanson called the more acidic phase of the quartz-diorite

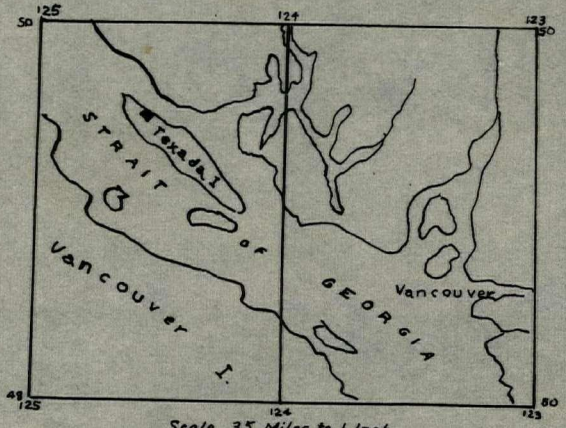
the "Gillies intrusive", which is a tonalite in composition.

(b) Dykes.

Several types of dykes occur, such as syenite-porphyrite, augite-syenite, diorites, and diorite-porphyrites.[28] The diorite-porphyrite dykes are of interest: Some of the ore bodies of Copper Queen and Marble Bay Mines were cut by these dykes[28,6] which are generally later than the quartz-diorite intrusive.



2000 FEET TO 1 INCH



Scale 35 Miles to 1 Inch

JURA-CRETACEOUS	2	Diorite, diorite porphyrite
	I	Quartz diorite
LOWER JURASSIC(?)	J	Porphyrite
LOWER JURASSIC OR TRIASSIC	J-T	Marble Bay limestone

Fig 2

Chapter III.

THE GEOLOGY OF THE LITTLE BILLY MINE

The two main formations at the Little Billy mine are the Marble Bay limestone and the quartz-diorite.(fig.2) The ore bodies, which have been formed at the contact of these formations, are of contact-metamorphic origin.

MARBLE BAY LIMESTONE.

The Marble Bay limestone is the oldest formation at the mine and is cut by the quartz-diorite intrusive, alaskite and some andesite dykes. The andesite dykes are suggested by their alteration to be pre-quartz-diorite.

The hand specimens of unaltered limestone are composed of coarse grey crystals of calcite up to 10 centimeters in length, but specimens of limestone from the contact-metamorphic areas are usually white or light grey in colour and occur as subhedral crystals not more than a centimeter in length. In thin section, the limestone of the contact areas is composed of 80 percent clear cloudy anhedral crystals of calcite and 20 percent of irregularly shaped areas of serpentine, containing interstitial carbonaceous material.

QUARTZ - DIORITE

The quartz-diorite crops out in the Little Billy mine area as a stock of roughly rectangular outline, half a mile long by a quarter of a mile wide, intruding the Marble Bay limestone. The quartz-diorite is also cut by numerous andesite dykes.

Lithology. In hand specimen, the quartz-diorite is, in general, a light grey holocrystalline rock composed of quartz, feldspar, and minor amounts of biotite and hornblende. The feldspars are generally subhedral crystals, while the quartz is interstitial. Irregular masses of pyrite, chalcopyrite, and molybdenite are scattered throughout the specimen. In thin section the quartz-diorite is composed of 55 percent plagioclase feldspar ($Ab_{60}An_{40}$), 17 percent hornblende, 15 percent quartz, 10 percent orthoclase, 2 percent biotite, and subordinate amounts of magnetite, apatite and augite. Feldspars occur as subhedral crystals up to 1 millimeter in length, with an abundance of equi-dimensional zoned feldspars. Quartz is largely interstitial in interlocking grains up to .7 millimeters in diameter. Biotite and hornblende occur as subhedral grains, with some of the former chloritized. Magnetite is concentrated in and around the other mafic minerals. The early crystallization and

consequent settling of the crystals would explain the concentration of the magnetite with the mafic minerals.

Sections of quartz-diorite taken from the contact zones show that the hornblende and biotite have been altered to chlorite. The feldspars show alterations to sericite.

In the quartz-diorite are rounded dioritic inclusions up to 12 inches in diameter, which are similar to inclusions noted by Dr. Swanson[33] in the Gillies Intrusive. Concerning these inclusions, he suggested that they "probably represent some of the earliest products of the crystallization of the dioritic magma".

1. ALASKITE DYKES.

Lithology. Hand specimens from both dykes were very similar. The specimens were white with a watery appearance, composed of feldspar, interstitial quartz and a few scattered grains of biotite and hornblende.

In thin section the alaskite is composed approximately as follows: 40 percent quartz, 35 percent plagioclase ($Ab_{90}An_{10}$), 25 percent orthoclase and a few crystals of biotite and hornblende. The quartz occurs as anhedral crystals and the feldspars as subhedral crystals up to 1 millimeter in length. There is an abundance of equi-dimensional zoned plagioclase, the centres of which are altered to

sericite and have a cloudy appearance. The slide contains no metallic minerals.

2. ANDESITE DYKES. (Diorite-porphyrite of McConnell[28]).

Lithology: Hand specimens of these dykes are medium to dark green in colour and aphanitic. Some specimens have a few scattered crystals of plagioclase about 2 millimeters in length. The metallic minerals seen in the hand specimens are pyrite, molybdenite and magnetite.

In thin section, these dykes are composed approximately as follows: 53 percent plagioclase ($Ab_{60}AN_{40}$), 17 percent hornblende, 12 percent orthoclase, 10 percent quartz, 5 percent biotite, and subordinate amounts of sericite, magnetite, pyrite, apatite and calcite. The plagioclase occurs as subhedral crystals about 1 millimeter in length, which have been partially altered to sericite. The hornblende occurs as lath-shaped crystals, both singly and in clusters. Biotite, quartz, apatite, orthoclase and calcite occur as subhedral crystals less than .2 millimeters in diameter. The metallic minerals are interstitial and are irregularly scattered throughout the slide.

The pre-quartz-diorite dykes have been altered by the development of grossularite. A section across an altered zone shows that hornblende and biotite have been

altered to chlorite. There is a vein of grossularite about 4 millimeters wide and adjacent to it there is a notable increase in calcite and magnetite. Flakes of molybdenite appear in the vein with the grossularite. In the chloritized areas are two small veins of axinite.

Dykes of similar composition were found in the Copper Queen[6] and Marble Bay mines.[18] According to the investigators, these andesite dykes had no control over the deposition. Similarly, in the Little Billy mine these dykes appear to have no control over the deposition of the ore.

Chapter IV.

KINDS OF ORE.

The intrusion of the quartz-diorite into the limestone has formed areas of skarn up to 100 feet in width, which contain the ore bodies of the Little Billy mine. These ore bodies can be classified as follows:

1. A bornite-magnetite ore in a skarn gangue, which occurs as a lenticular body about fifteen feet in width and roughly parallel to the quartz-diorite intrusive at the east end of the 180 level. Mine assays of this ore are as follows:

Copper	±	1.5 percent
Gold	±	0.05 oz/Ton
Silver	±	1.5 oz/Ton

2. A disseminated bornite-chalcopyrite ore in a fibrous wollastonite gangue, the "Prosser ore body" and the ore in the old stopes on the west end of the 180 level are of this type, assaying as follows:

Copper	±	2 percent
Gold	±	0.2 oz/Ton
Silver	±	0.6 oz/Ton

Hand specimens show bornite and chalcopyrite in long narrow bands one or two millimeters in width in the wollastonite.

THE "PROSSER ORE BODY".

The "Prosser ore body was located by a vertical diamond drill hole drilled from the surface some three hundred feet south and west of the collar of the shaft. This hole was known as the Prosser hole and showed 60 feet of ore 273 feet below the surface. Average values for this core are:

Silver ———	.2 oz/Ton
Gold ———	.5 oz/Ton
Copper ———	2 percent

Further information was obtained by diamond drilling from the east end of 280 level. The copper, gold and silver values were slightly lower than the above assays.

Two thin sections from the Prosser hole show that the copper minerals are bornite and chalcopyrite; the gangue minerals are wollastonite, serpentine and quartz. The thin sections have a banded appearance (fig.9). The bornite and chalcopyrite appear to be interstitial and have partially replaced the wollastonite crystals, (fig.8).

Thin sections of ore from margins of old stopes on the 180 level and from the Prosser ore show that the ore bodies are similar.

LOCATION OF THE LITTLE BILLY ORE

The ore of the Little Billy occurs in the limestone and at the margins of the quartz-diorite, and is of contact metamorphic origin. The bornite-magnetite ore occurs as a lenticular body parallel to the quartz-diorite intrusive, and the bornite-wollastonite, which comprises the bulk of ore, occurs in an embayment in the quartz-diorite. (See map in folder).

Related Deposits.

In the Marble Bay mine, the ore bodies were in limestone and when mined to a depth of 1700 feet, the ore was bottomed at the contact of a granodiorite intrusion (18). At the Prescot and Paxton mines (28), four miles south of Vananda, are copper magnetite deposits similar to that in the east end of the 180 level of the Little Billy. These deposits were also formed at the contact of the Marble Bay limestone and the quartz-diorite.

Summary.

The copper and iron deposits of Texada Island occur at or near the contact of the dioritic intrusions of the Coast Range batholith and the Marble Bay limestone. A close genetic relation is suggested by the proximity of each deposit to a dioritic intrusion.

Chapter V.

MINERALOGY.

Contact Metasomatic Minerals.

In the areas adjacent to the quartz-diorite intrusion are developed the following contact metasomatic minerals:

Calcite. The calcite, associated with both types of ore, is usually anhedral and white to grey in colour.

Grossularite. Grossularite occurs as large masses and individual cinnamon-coloured garnets. The specific gravity varied from 3.64 to 3.75. Although grossularite is associated with both types of ore, it is much more abundant with the bornite-wollastonite than with the bornite-magnetite ore. Associated with the grossularite are dark green acicular crystals of epidote. Some of these garnets show double refraction.

Diopside. Diopside is a common gangue mineral and occurs as well-formed crystals with garnets, being contemporary with them. In some thin sections the diopside forms about 30 percent of the gangue and shows replacement by chalcopyrite

and bornite.

Wollastonite. Wollastonite forms about 60 percent of the gangue of the Prosser ore body, and occurs as fine acicular intergrown crystals less than three millimeters in length. Large white crystals of wollastonite, with no bornite or chalcopyrite replacement, were found on the margins of old stopes. However, in the Marble Bay mine, three quarters of a mile west of Little Billy, bornite and chalcopyrite replace a similar type of coarse wollastonite.

The wollastonite crystals have formed normal to the sides of the grossularite, diopside and andradite, suggesting that the wollastonite is of a later period of deposition.

Andradite. Andradite occurs as small green crystals (sp.g. 3.85) at the edges of old stopes. Although the andradite is associated with both types of ore, it is more abundant with the bornite-magnetite than with the bornite-wollastonite. The andradite was developed at the same time as the grossularite.

Epidote. Epidote formed in small bunches of acicular crystals. It is associated with the grossularite, andradite and white calcite, and formed about the same time.

Quartz. Quartz occurs as small subhedral to anhedral

crystals interstitial with the other gangue minerals. In polished sections the edges and centres of several quartz crystals have been replaced by bornite or chalcopyrite. There are repeated instances of quartz crystals being replaced by irregular masses of quartz, suggesting more than one generation of quartz.

Serpentine. Serpentine (var.antigorite) appears in thin sections of the wollastonite-bornite ore as short fibrous flakes, light green to colorless. The serpentine appears to be one of the latest minerals to form.

Axinite. H (fe, Mn) Ca_2Al_2B (si O_4) 4. - Small veins of axinite were identified in the thin section taken from the altered zone of an andesite dyke and from some thin sections of calcite. The axinite appears to have formed at the time of the recrystallization of the limestone.

THE ORE MINERALS.

The study of the mineralogy of the Little Billy mine was made from ore specimens collected by the writer. Polished sections were made of ore typical of the "Prosser Ore Body", magnetite-bornite ore and some ore composed entirely of chalcopyrite. Polished sections were also made from

Dr.Gunning's Marble Bay suite of specimens.

In the preliminary examination of the sections, the following minerals were noted: pyrite, chalcopyrite, bornite, pyrrhotite, magnetite, tetrahedrite, molybdenite, sphalerite, galena, chalcolite, covellite, silver and gold. As well as the forementioned minerals, there were disseminated throughout the chalcopyrite and bornite small anhedral to subhedral masses of silver-white and galena-grey coloured minerals. These two minerals occurred in masses never larger than 40 microns in diameter. The silver-white mineral was wehrlite ($Bi_3 Te_2$) and the galena-grey mineral was hessite ($Ag_2 Te$).

Method of Determining Wehrlite and Hessite.

The size of the minerals prevented the writer from obtaining definite etch reactions and microchemical tests. Furthermore, these minerals appeared to be isotropic under crossed nicols. A study was therefore made of some twenty sections of the Marble Bay ore, which is chiefly massive bornite or chalcopyrite. The massive bornite sections contained the same silver-white and grey metallic lustered minerals in masses up to 40 microns in diameter, and the massive chalcopyrite contained the same minerals in masses up to 300 microns in diameter. (fig.17, 18). The hessite occurred

always intergrown with wehrlite, while the wehrlite often occurred alone. (fig.21).

Etch reactions on the minerals were as follows:

	HNO_3	HCL	KCN	$FECL_3$	KO H	$HGCL_2$
Silver-white (Wehrlite)	+	–	–	+	–	–
Galena-grey (Hessite)	+	–	+in one min.or longer	+	–	–

From the following chart, the writer assumed that the silver-white mineral was tetradymite. However, microchemical and spectroscopic analysis of a clean fragment always gave a good test for silver. Spectroscopic analysis showed that silver was always present in an amount greater than one percent. As no etch reactions are given for wehrlite in the literature, the writer assumed the mineral to be an argentiferous variety of tetradymite.

Spectroscopic analysis, etch reactions and anomalous anisotropism of the galena-grey mineral readily suggested that the mineral was hessite.

Two fragments of the forementioned minerals were sent to Mr.Robert Thompson of the Department of Geology at the University of Toronto for x-ray analysis. He confirmed the writer's determination of hessite and pointed out that the silver-white mineral was wehrlite. The etch reactions for wehrlite have been included on the accompanying chart.

Mineral	Ref.	System	Hard.	Colour	Anisotropism	HNO_3	HCL	KCN	$FECL_3$	KOH	$HGCL_2$	$FeCl_3$ 1:1	$KMNO_4$ 1:1 H_2SO_4	
Richardite (Cu_3Te_2)	29	?	B	purple-red similar to bornite	strong - + Ext. in 360° - fiery orange	black	Grey to brown	grey slowly	grey to brown	irred-black	purple.			always associated distinguished by colour
Weissite (Cu_2Te)	29	?	B	Light grey colour like chalcocite	Weak - colours similar to chalcocite	brown	brown	brown	brown	slowly brown	Light brown			
Altaite (PbTe)	29	I	B	Galena white	—	dark grey	irred to neg	—	irred	—	—			cubic cl. - No H_2S fumes - Like galena
Melonite ($NiTe_2$)	29, 32	?	B	pale yellow - creamy pink	strong browns	black	brown?	—	brown	—	—			rare - gives microchem for Ni readily
Tellurium (Te)	29	H	B	silver - white	Strong colour of Grey	black	tarnish to neg	—	brown to neg	—	—			perf. prismatic cl.
Joseite (Bi_4TeS_2)	36	H	B	steel grey	medium colours of grey	black	black	—	blue	—	—	blue	blue	
Wehrlite Bi_3Te_2		H	B	silver white	medium to strong - shows xtal intergrowth	black	black	—	black	—	—	black	blue	Contains 2 percent Ag - good microchem for Ag
Tellurbismuth (Bi_2Te_3)	36	H	B	galena - grey	Weak - greys	black	—	—	blue	—	—	blue	blue	may exhibit triang. set of striations at 60° on cl. surf.
Tetradymite (Bi_2Te_2S)	29	H	B	silver - white	weak	black	— positive in short (29)	—	blue	—	—	neg	blue.	sometimes shows graphic intergrowth
Hedleyite (Bi_7Te_2)	35	H	B	silver-white	Slight	black	—	—	blue	—	—	blue	fine brown	platy cleavage prominent
Caluverite (Au, $AgTe_2$)	29, 32	M	C	Light yellow to creamy white	Strong grey - brown - shows twinning	black	—	—	brown to neg	—	—			
Krennerite (Au $AgTe_2$)	29, 32	O	C	creamy-white.	" " " " "	black	—	—	yellow	—	—			only positive determination by X-ray
Sylvanite (Au $AgTe_4$)	29, 32	M	C	creamy-white to grey	" " " " "	irred. to black	—	—	yellow to neg	—	—			
Hessite (AgTe)	29	I	A	grey	May show anomalous anisotropism	black	black slowly	Black longer than 1 min	irred	—	Light brown?			resembles argentite when scratched
Colusite ($(Cu,Fe,Mn,Sn)_4(S,As,Te)_{3-4}$)	29	I	C	bronzy grey	—	brown	brown	tarnish	—	—	—			Assoc. with copper ores at Butte.
Petzite $(AgAu)_2Te$	29, 32	I	A	galena white	—	irred	irred to neg	—	irred	—	—			cubic cl. less perf than galena.
Coloradoite (HgTe)	29	I	C	pinkish grey	—	brown to neg	grey to black	—	—	—	—			Rare - Etch with $FeCl_3$ and clean with HCL shows strong Anisotropism
Goldfieldite ($6Cu_2S,Sb_2)(S,Te)_3$	29	I	B	grey	—	brown	brown to neg	brown?	—	—	—			assoc. with tetrahedrite
Nagyagite (Pb, Au_3TeS)?	29, 32	O	B	bluish white	Light to dark grey	irred to neg	—	—	—	—	—			platy habit like molybdenite

Note on Wehrlite.[38]

Wehrlite is a member of the tetradymite group. The mineral was first found by Wehrle in the Deutsch-Pilsen, Hungary, in 1831, and was the only known authentic occurrence. In 1944, Dr. H.V. Warren, of the Department of Geology at the University of British Columbia, noted a second occurrence of wehrlite in the ore of the White Elephant mine, near Vernon, B.C. The wehrlite of the Little Billy and Marble Bay mines of Texada Island is the third authentic occurrence.

Wehrlite[38] contains the following :

Bismuth	59.47	-	70.02	percent
Tellurium	28.52	-	35.47	percent
S	0	-	2.33	percent
Ag	0.48	-	2.07	percent

Wehrlite is a medium temperature mineral and is not common in contact metamorphic deposits.[27]

Note on Hessite.

Hessite[38] is associated with other tellurides, gold, silver and native tellurium. It has a rather widespread occurrence and is found in Liberia, Roumania, Western Australia, Mexico, the United States and Canada. In British Columbia it has been found at North Star Mine, near Rossland, the Conwest claims, Taseko Lake and the Little

Billy and

Marble Bay mines, Texada Island.

Hessite contains the following :

Ag	59.4 - 62.8 percent
Te	35.9 - 37.7 percent

Hessite, like wehrlite, is a medium temperature mineral and is not common in contact metamorphic deposits.

Minerals of the Polished Section.

The polished sections of the Little Billy ore contain the following : pyrite, molybdenite, magnetite, bornite, chalcopyrite, chalcocite, wehrlite, hessite, sphalerite, pyrrhotite, galena, tetrahedrite, covellite, gold and silver. The minrgeals are described in the probable order of their age.

Pyrite. ($Fe\ S_2$) - Pyrite occurs as cubes up to two centimeters in width in hand specimens taken from the margins of old ore bodies. In polished section of both types of ore, it occurs as crystals and irregularly-shaped masses scattered unevenly throughout. Two generations are suggested by cubes of pyrite being replaced by irregular masses of pyrite. In almost every specimen, quartz accompanies and occurs as hexagons or irregularly-shaped masses within the pyrite. Pyrite is the earliest of the metallic

lustered minerals of the Little Billy ore. The deposition of pyrite ceased before the other sulphides were deposited. The bornite and chalcopyrite tend to surround and replace pyrite.

Molybdenite ($Mo\ S_2$). No definite age relationship of the molybdenite could be deduced from the polished sections, as the molybdenite was not in contact with any of the other minerals. Flakes of molybdenite were noted in hand specimens and thin sections of grossularite formed in the andesite dykes. Molybdenite appears in the skarn, quartz-diorite, and limestone of the upper level. The association of the molybdenite with the grossularite would suggest that it is earlier than the chalcopyrite and bornite and about the same age as the pyrite.

Magnetite (Fe_3O_4). In polished sections the magnetite appears to be about the same general age as the bornite and chalcopyrite. However, the association of the magnetite with the pyrite and molybdenite in the skarn would suggest that it is earlier than the chalcopyrite and bornite. Magnetite composes about one percent of the bornite-wollastonite ore, and about forty percent of the bornite-magnetite ore.

Bornite ($Cu_5\ Fe\ S_4$). Bornite is the most important copper

mineral of the Little Billy ore. In thin and polished sections the bornite has replaced the gangue minerals wollastonite, diopside, etc. (Fig.20). Intergrowths between the bornite and chalcopyrite indicate essential contemporaneity (Fig.15). All gangue minerals are earlier than the bornite, except the serpentine and the late calcite.

Chalcopyrite ($Cu\ Fe\ S_2$). Chalcopyrite is the second in importance of copper minerals in the ore of the Little Billy. Although the chalcopyrite appears to be contemporaneous with the bornite in most of the sections, there are a few which show chalcopyrite in long narrow veins in the bornite. The chalcopyrite appears in irregular masses replacing the wollastonite and diopside.

Chalcocite (Cu_2S). Chalcocite is not an abundant mineral in the ore. It is usually intimately associated with the bornite and occurs as irregular boundaries and veins replacing the bornite. The writer did not see any graphic intergrowth or "grating" suggested by Bastin[42] as common to hypogene deposits of bornite and chalcocite. However, chalcocite was found in increased quantities in the lower levels of the Marble Bay mine. The depth below the sea level and consequent lack of ground water circulation, the undiminished quantity of chalcocite with depth, and the

association of chalcocite with bornite were criteria used by Dr. Dolmage[18] to prove chalcocite to be hypogene.

Wehrlite (Bi_3Te_2). Wehrlite occurs as anhedral to subhedral masses in the chalcopyrite and bornite, usually larger than 70 microns in diameter. It is often associated with blebs of hessite, suggesting a simultaneous crystallization. A few crystals of wehrlite and hessite, associated with gold, were noted in the gangue.(fig.20,21). Wehrlite is the most abundant of the silver minerals in the Little Billy ore.

Hessite (Ag_2Te). In the material used for the positive determination of the tellurides, hessite always appeared in contact with wehrlite (fig.17). However, one specimen from the 180 level of the Little Billy shows hessite as irregular masses within the gangue (fig.20) about 90 microns in diameter.

Sphalerite (Zn S). A minor amount of sphalerite (less than one percent) occurs in the polished sections as irregular masses within and bordering the chalcopyrite. Blebs of sphalerite, spotted with specks of chalcopyrite formed by "ex solution" often occur in the chalcopyrite, suggesting that the sphalerite is about the same general age as the chalcopyrite.

Pyrrhotite (Fe S). Pyrrhotite occurs as small irregular

masses about 100 microns or less within the chalcopyrite and bornite, and appears to be the same general age as the bornite and chalcopyrite.

Galena (Pb S). Galena was not seen in the polished sections. However it was noticeable in the super-panner tips of both types of ore.

Tetrahedrite 5 (Cu_2S). 2 (Cu Fe). 2 (Sb_2S_3).

Tetrahedrite occurs as scattered irregular blebs less than 70 microns in diameter. It appears to be more abundant in the bornite-magnetite ore than in the bornite-wollastonite. No definite age relation can be determined for tetrahedrite.

Covellite (CuS) ~~(Cu)~~. Covellite is sparsely scattered throughout the bornite as small veins or rosettes of small plates, along seams or gangue boundaries. Covellite, like chalcocite, in the Marble Bay mine[18] was found to be more abundant in the lower levels. Hence the same reasoning can be used to prove that covellite is of hypogene origin.

Gold (Au). No definite age can be given for the gold. It was found only in one section. In this section it was found in the gangue alone, (fig.23) with wehrlite and hessite. (fig.21 & 22)

Silver (Ag). Silver occurs as veinlets (fig.13) and blebs

(fig.16) in the chalcopyrite and bornite and appears to be deposited a little later than the sulphides (fig.13).

Summary.

Definite age relations of the sulphides were not readily visible in the polished sections. The sulphides appear to be of the same general age with the pyrite being a little earlier. Silver was the only mineral that veined the bornite. Gold was found in a small irregular mass in a gangue-filled fracture in some pyrite, suggesting that it was probably of a later period of deposition.

The gold of the Little Billy occurs as native gold and the silver occurs as native silver and silver tellurides.

Chapter VI.

PARAGENESIS.

The paragenesis of the silicate and the sulphide minerals will be discussed under the following headings: the bornite-wollastonite ore, the bornite-magnetite ore, source of solutions, and the mode of transfer.

The Bornite-Wollastonite Ore.

The largest ore body is composed of bornite and chalcopyrite replacing fibrous wollastonite (fig.7). The formation of this ore suggests the following sequence of events:

1. The formation of the skarn minerals at the contact of the quartz-diorite and the limestone. The skarn being composed of diopside, epidote and quartz deposited first, grossularite, andradite and white calcite developed later, and final deposition of pyrite, magnetite and molybdenite.
2. The partial replacement of the epidote, diopside and grossularite by wollastonite. A small amount of calcite and quartz was deposited with the wollastonite.
3. A general replacement of the wollastonite, diopside and garnet by the bornite, chalcopyrite and the tellurides.

A small amount of quartz appears to have been deposited with the sulphide minerals[x]. The gold and silver appear to be deposited a little later than the sulphides.

4. A general fracturing and crushing of the silicate and sulphide minerals. In the openings caused by the movement, there was deposited quartz, calcite and serpentine.

The Bornite-Magnetite Ore.

The occurrence of this small lense-like deposit of bornite-magnetite is very similar to those on the west coast of the Paxton, Lake, and Prescott mines. The same conditions and formations are present in the Little Billy as in these mines: that is, the proximity of the bornite-magnetite to the quartz-diorite intrusion, the late alaskite dykes, and the replacement of the skarn rocks by magnetite with lesser amounts of bornite and chalcopyrite. Dr.Swanson[32] concluded that the magnetite deposits of the west coast "were formed by magmatic solutions in which the materials were concentrated by the crystallization of the intrusive.....

(x) In the contact metamorphic deposits of the Dolores mine in Mexico, Fenner (41) found that quartz was one of the most important minerals with regard to ore deposition. The repeated instances of intimate association of the quartz with the sulphides suggested a close genetic relation.

The release of solutions from the intrusive was effected by fracturing caused by cooling of the mass, and, as a consequence, the distribution of the deposits is mainly controlled by structural conditions at the time of replacement which favored the movements of solutions along the general contact zone".

Source of Solutions.

The ore-forming solutions probably originated as the end products of the differentiating dioritic magma. The following evidence supports this statement:

1. The occurrence of the ore body in an embayment in the quartz-diorite. (See plan of 280 level in folder).

2. The presence of disseminated masses of pyrite, molybdenite and chalcopyrite in the quartz-diorite.

3. The fact that the ore bodies of the Marble Bay mine when followed down through the limestone, lead directly to a stock of granodiorite, which is itself considerably mineralized[18].

4. The occurrence of contact metamorphic deposits on Vancouver Island[13], deposits which are formed at the contact of the coast range intrusive and the limestone of the Vancouver Group.

MODE OF TRANSFER.

The alteration of the Marble Bay limestone, at the contact of the quartz-diorite by the development of the contact metasomatic minerals discussed in Chapter V, has involved the transfer of carbon dioxide, and the addition of iron, aluminium and silica. Mineralizers or volatiles which aid in this transfer have been suggested by Lindgren[27] to be sulphur, chlorine, boron, fluorine and arsenic.

In the contact metamorphic deposits at Hedley, B.C., Dolmage and Brown[20] found scapolite developed in large quantities at the marble line - the edge of the altered zone. From this they concluded that the chlorine of the scapolite was one of the volatiles. The scapolite formed at the marble line when the available silica had been used in the formation of the skarn. With the above idea in mind, the writer made a close examination of the thin sections of the Little Billy ore for minerals containing chlorine, fluorine or boron, e.g. scapolite, chondrite, or axinite, and only two small veins and a few scattered crystals of axinite were found. However, spectroscopic analysis of 19 samples of calcite from the skarn and adjacent areas showed that the calcite contained varying amounts of boron, all less than one percent. The largest concentrations of boron were found in the calcite

from areas close to the quartz-diorite intrusive. Calcite or marble from the adjacent areas, contained only traces of boron. (See map in folder). Hence it appears that one of the volatiles associated with the contact metasomatism of the Little Billy mine was boron.

CONCLUSION.

The sequence of events that led to the formation of the Little Billy ore bodies can be summarized as follows:

1. The gentle folding of the area in a north-westerly direction.
2. The intrusion of the quartz-diorite into Marble Bay limestone.
3. The differentiation of the dioritic magma to a siliceous magma and the consequent formation of alaskite dykes.
4. The expulsion of the volatiles (contact metasomatism) and the solutions of iron, aluminium, silica and boron, with the formation of the skarn minerals.
5. The replacement of the skarn minerals by bornite, chalcopyrite, and the gold and silver minerals.
6. The final fracturing and crushing, and the filling of these fractures by quartz and calcite.

Chapter VII.

EXAMINATION OF THE LITTLE BILLY ORE BY HAULTAIN SUPER-PANNER.

The object of this examination is to determine which particle size will give the best gravity separation.

The Haultain super-panner was used for this gravity separation and was chosen in preference to a Wilfey table, the alternative machine, because the feed can be worked until a good separation is obtained. The super-panner separates the feed into three products; a tip, a middlings product and a slime, and is designed to handle low-grade ores or mill tailings. The Little Billy ore is a higher grade than normally used on a super-panner; consequently large amounts of copper, gold and silver were held in the middlings product.

Examination of the table of results will show a series of discrepancies between the amount of gold or silver in the feed and the sum of the values in the tip, middlings product and slime in each group. The presence of free gold and silver, combined with the smallness of the assay samples, has caused this erratic distribution of values.

Two large samples were picked; one sample of bornite-wollastonite ore from the west end; the other sample a bornite-magnetite ore from the east end of the 180 level. These were crushed and screened.

Four size groups were obtained as follows:

- 100 + 150 mesh
- 150 + 200 mesh
- 200 + 325 mesh
- 325 mesh

After weighing, these products were separated on the super-panner. Each size of the bornite-wollastonite ore gave three products; a bornite tip, a middlings product and a tailings or slime. The same procedure was used for the bornite-magnetite ore, and a fourth product - magnetite - was separated from the ore by moving a magnet in a beaker over the super-panner. The products were dried, weighed, examined under the ultra-pak and assayed.

Ore used for these tests was originally picked for the making of polished sections and consequently gold, silver and copper values are higher than the mine ore would average, as shown in the following

	Sample	Au. oz/Ton	Ag. oz/Ton	Cu. percent
Bornite-wollastonite ore:	mine average	0.3	0.9	2%
	Super-panner	0.7	1.9	9.16%

	Sample	Au. oz/Ton	Ag. oz/Ton	Cu. percent
Bornite-magnetite ore:	Mine ore	0.04	1.4	2%
	Super-panner	0.07	4.72	5.2%
		0.08	2.52	5.2%

Examination of the bornite tips under the "ultra-pak" indicated the following approximate percentages by area of constituents:

The bornite-wollastonite ore (tips)

95%	Bornite
2%	Chalcopyrite
1%	Pyrite
(	Chalcocite
(	Covellite
(	Galena
(	Sphalerite
2% (	Magnetite
(	Gold
(	Silver
(	Wehrlite
(	Hessite

The bornite-magnetite ore (tips-magnetite removed)

85%	Bornite
10%	Chalcopyrite
2%	Pyrite
(	Galena
(	Sphalerite
(	Tetrahedrite
3% (	Barite ?
(	Gold
(	Silver
(	Tellurides

The galena and tellurides were distinguished by formation of

a tellurium pool upon heating the tips on a pyrex slide. (fig.17).

In the following tables and corresponding graphs, which were computed from the results of ore separation on the super-panner, the bornite-wollastonite ore has been called the disseminated bornite ore.

TABLE 1.

GOLD IN DISSEMINATED BORNITE ORE

Product	Corrected Weight in Grams	Oz/Ton.	Total (Mg)	Distribution in -100 feed. In Each Size Wt.%	In Each Size Au.%	In Total -100 Feed Wt.%	In Total -100 Feed Au. %
-100 + 150	124.3	0.7	2.98			18.8	38.7
Bornite Tip	11.8	3.04	1.230	9.5	66.5	1.8	20.6
Middling	109.4	0.16	0.600	87.9	32.4	16.5	7.2
Slime	3.1	0.20	0.021	2.6	1.1	0.5	0.4
			1.851	100.0	100.0		28.2
-150 + 200	86.7	0.56	1.675			13.2	19.1
Bornite Tip	88.3	3.2	0.910	9.6	68.3	1.3	15.3
Middling	70.7	0.14	0.339	81.5	25.4	10.7	5.7
Slime	7.7	0.30	0.084	8.9	6.3	1.2	1.4
			1.333	100.0	100.0		22.4
- 200 + 325	125.3	0.24	1.030			18.8	11.7
Bornite Tip	2.1	6.6	0.450	1.8	46.8	0.3	7.6
Middling	85.2	0.14	0.408	67.8	42.4	12.8	6.8
Slime	38.0	0.08	0.104	30.4	10.8	5.7	1.8
			0.962	100.0	100.0		16.2
- 325	326.8	0.24	2.680			49.2	
Bornite Tip	6.0	3.20	0.655	1.9	33.2	0.9	11.0
Middling	110.8	0.12	0.455	33.8	23.1	16.7	7.7
Slime	210.0	0.12	0.863	64.3	43.7	31.6	14.5
			1.973	100.0	100.0		33.2
Total	663.1		6.119			100.0	100.0

Fig. 4

Graph Showing Distribution of Gold in Disseminated Bornite Ore

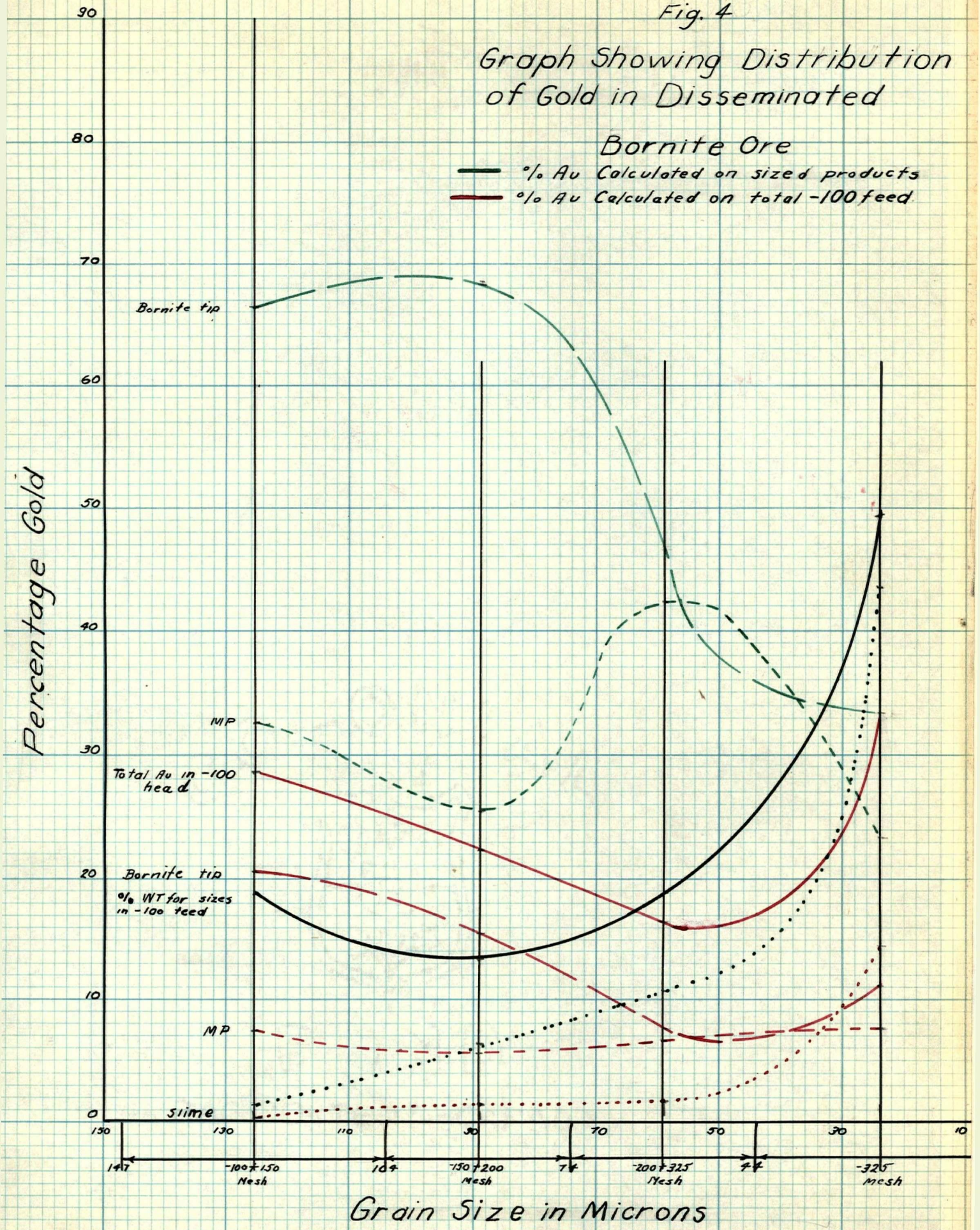


TABLE 2.

SILVER IN DISSEMINATED BORNITE ORE

Product	Corrected Weight in Grams.	Oz/Ton	Total Mg.	Distribution in -100 feed. In Each Size % Wt.	Ag.%	Total -100 Feed % Wt.	Ag. %.
-100 + 150	124.3	2.32	9.950			18.8	19.5
Bornite Tip	11.8	25.00	10.100	9.6	59.0	1.8	13.7
Middling	109.4	1.84	6.900	87.9	40.3	16.5	9.3
Slime	3.1	1.00	0.106	2.5	0.7	0.5	0.1
			17.106	100.0	100.0		23.1
-150 + 200	86.7	2.52	7.500			13.2	14.7
Bornite Tip	8.3	37.80	10.750	9.6	63.0	1.3	14.5
Middling	70.7	1.86	4.500	81.5	26.4	10.7	6.1
Slime	7.7	6.88	1.810	8.9	10.6	1.2	2.5
			17.060	100.0	100.0		23.1
-200 + 325	125.3	2.16	9.270			18.8	18.2
Bornite Tip	2.1	25.40	1.745	1.8	17.1	0.3	2.4
Middling	85.2	2.26	6.600	67.8	64.6	12.8	8.4
Slime	38.0	1.44	1.870	30.4	18.3	5.7	2.5
			10.215	100.0	100.0		13.3
-325	326.8	2.16	24.20			49.2	47.5
Bornite Tip	6.0	26.80	5.500	1.8	18.4	0.9	7.5
Middling	110.0	2.88	10.901	33.8	36.4	16.7	14.8
Slime	210.0	1.88	13.500	64.4	45.2	31.6	18.2
			29.901	100.0	100.0		40.5
Totals	663.1		73.382			100.0	100.0

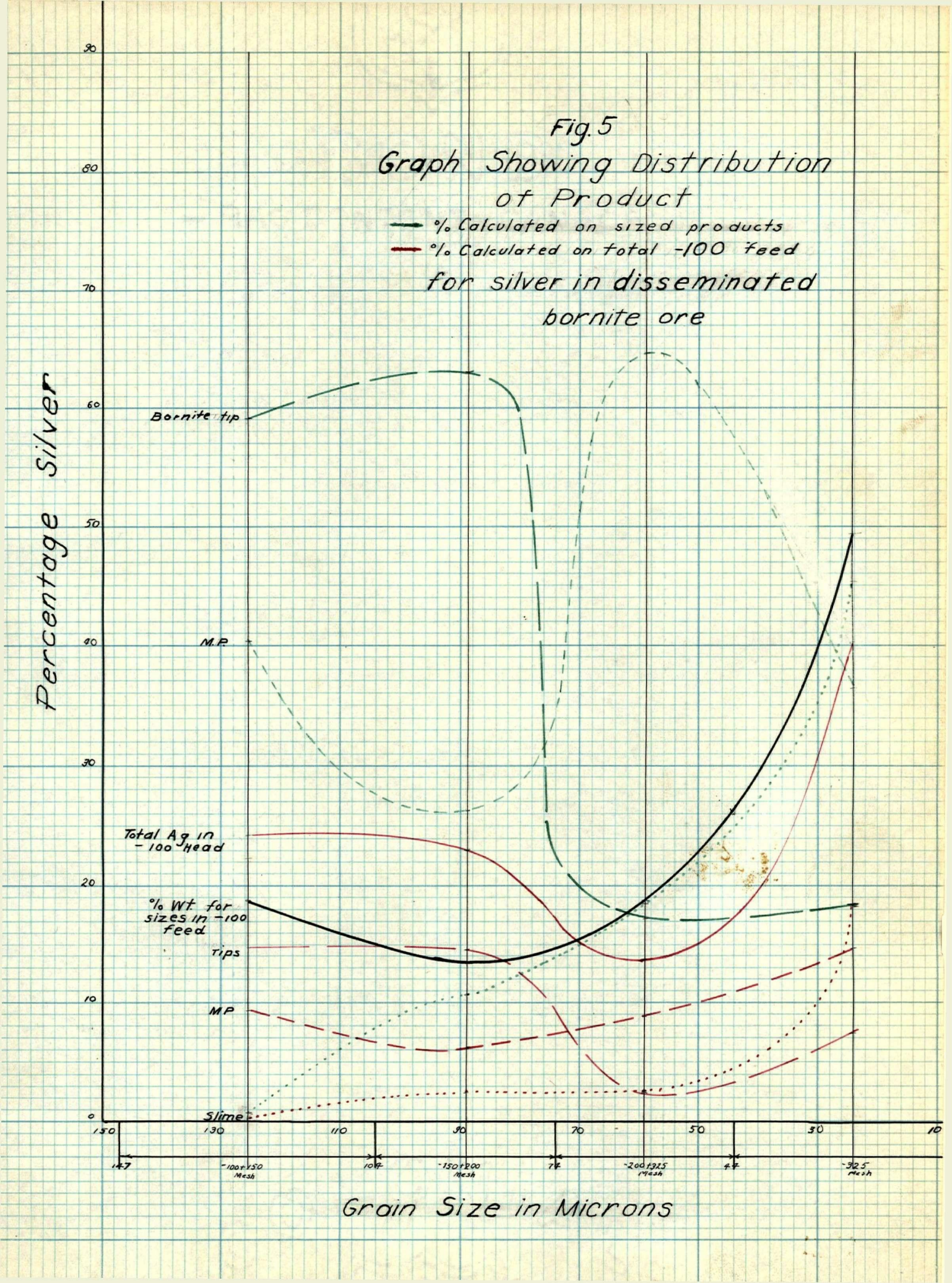


Fig. 5
Graph Showing Distribution of Product
% Calculated on sized products
% Calculated on total -100 feed
for silver in disseminated bornite ore
Percentage Silver
Bornite tip
M.P.
Total Ag in -100 Head
% Wt for sizes in -100 feed
Tips
M.P.
Slime
90
80
70
60
50
40
30
20
10
0
150
130
110
90
70
50
30
10
14.7
-100+150 Mesh
10.4
-150+200 Mesh
7.4
-200+325 Mesh
4.7
-325 Mesh
Grain Size in Microns

TABLE 3.

COMPARISON OF GOLD AND SILVER IN SIZED PRODUCTS TO TOTAL -100 FEED

1 DISSEMINATED BORNITE ORE

Product	Oz/Ton Au.	Oz/Ton Ag.	Total (Mg.) Au.	Total (Mg.) Ag.	Distribution in -100 % Wt.	% Au.	% Ag.
Sample	0.40	2.60	9.05	58.00	100	100	100
-100 + 150	0.80	2.32	3.40	9.95	18.8	38.7	19.5
-150 + 200	0.52	2.52	1.68	7.50	13.2	19.0	14.8
-200 + 325	0.24	2.16	1.03	9.27	18.8	11.7	18.2
- 325	0.24	2.16	2.68	24.20	49.2	30.6	47.5
			8.79	50.92	100.0	100.0	100.0

2 MAGNETITE-BORNITE ORE

(following 2 Pages.)

Product	Oz/Ton Au.	Oz/Ton Ag.	Total (Mg.) Au.	Total (Mg.) Ag.	Distribution in -100 % Wt.	% Au.	% Ag.
Sample	0.08	3.9	3.3	160.5	100	100	100
-100 +150	0.10	4.16	1.79	74.90	43.9	50.2	41.2
150 + 200	0.08	4.56	0.76	43.71	23.1	21.3	24.2
-200 + 325	0.06	4.64	0.61	35.79	18.6	17.1	19.8
-325	0.07	4.46	0.41	26.80	14.4	11.4	14.8
			3.57	181.20	100.0	100.0	100.0

TABLE 4.

GOLD IN BORNITE-MAGNETITE ORE

Product	Corrected Weight in Grams.	Oz/Ton	Total Mg.	Distribution of -100 In Each Size % Wt.	Au. %	Total -100 Feed %Wt.	Au.%
-100 + 150	524.3	0.10	1.790			43.9	50.2
Bornite Tip	8.0	2.10	0.575	1.6	40.4	0.6	15.3
Middling (NP)	280.7	0.04	0.386	53.4	27.1	23.8	10.3
Magnetite	202.0	0.06	0.415	38.6	29.2	16.7	11.1
Slime	33.6	0.04	0.046	6.4	3.3	2.8	1.2
			1.422	100.0	100.0	43.9	37.9
-150 + 200	280.3	0.08	0.766			23.1	21.3
Bornite Tip	9.1	2.6	0.800	3.2	61.4	0.8	21.3
Middling	188.8	0.06	0.389	67.3	29.8	15.6	10.4
Magnetite	51.2	0.04	0.070	18.1	5.5	4.2	1.9
Slime	31.2	0.04	0.043	11.4	3.3	2.5	1.1
			1.302	100.0	100.0	23.1	34.7
-200 + 325	225.8	0.08	0.617			18.6	17.1
Bornite Tip	1.5	3.4	0.175	0.6	29.3	0.1	4.7
Middling	75.3	0.08	0.201	33.4	33.6	6.2	5.4
Magnetite	52.4	0.05	0.089	23.2	14.9	4.3	2.4
Slime	96.6	0.04	0.132	42.8	22.2	8.0	3.5
			0.597	100.0	100.0	18.6	16.0
-325	175.4	0.07	0.415			14.4	11.5
Bornite Tip	1.2	3.0	0.123	0.8	28.7	0.1	3.3
Middling	58.4	0.06	0.120	33.2	28.0	4.8	3.2
Magnetite	38.5	0.06	0.079	21.9	18.5	3.1	2.1
Slime	77.3	0.04	0.106	44.1	24.8	6.4	2.8
			0.428	100.0	100.0	14.4	11.4
TOTAL	1205.2		3.750			100	100

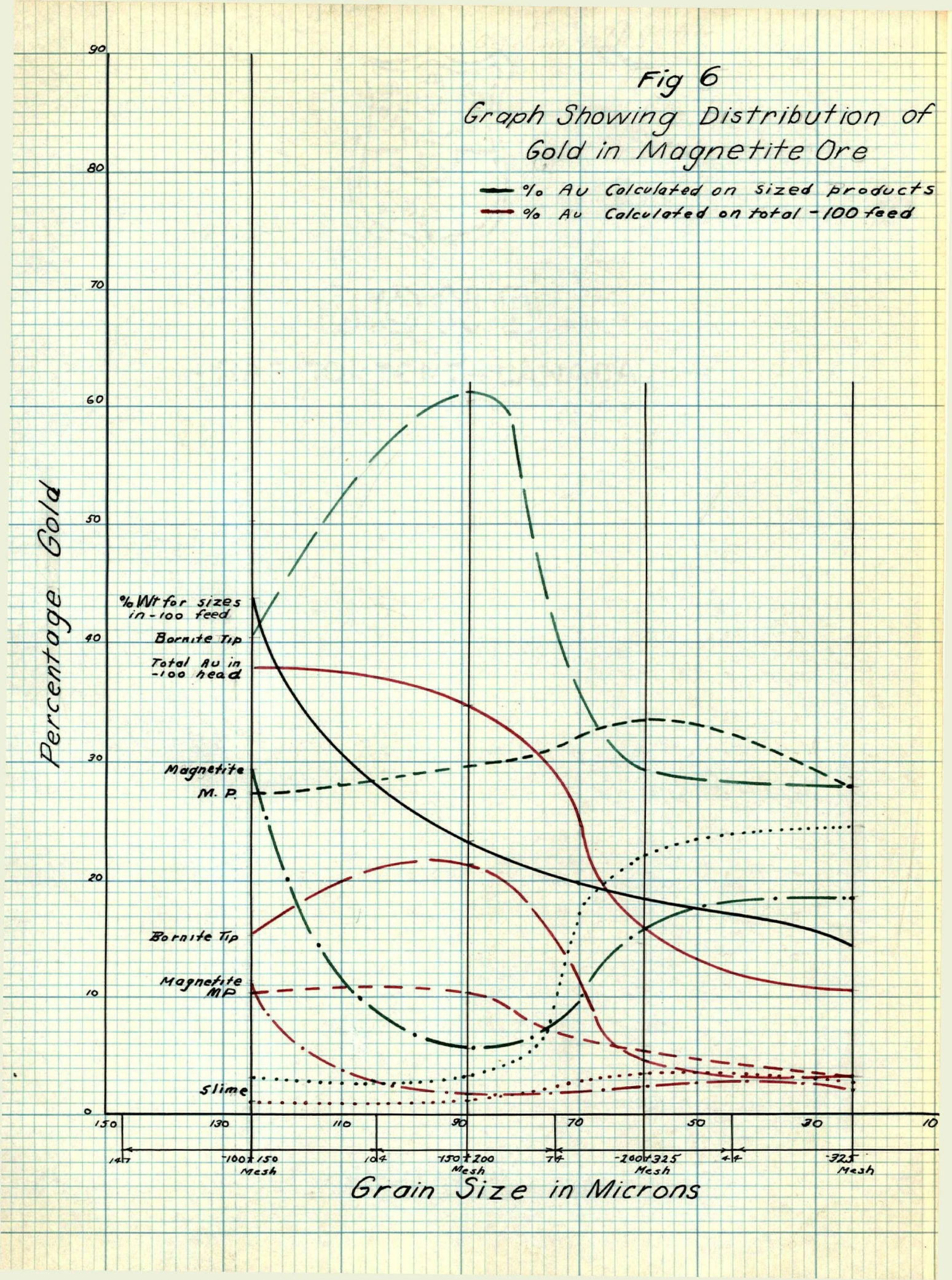


Fig 6
Graph Showing Distribution of Gold in Magnetite Ore
% Au Calculated on sized products
% Au Calculated on total -100 feed
Percentage Gold
90
80
70
60
50
40
30
20
10
0
% Wt for sizes in -100 feed
Bornite Tip
Total Au in -100 head
Magnetite M. P.
Bornite Tip
Magnetite MP
Slime
150
130
110
90
70
50
30
10
147
-100+150 Mesh
104
-150+200 Mesh
74
-200+325 Mesh
44
-325 Mesh
Grain Size in Microns

TABLE 5.

SILVER IN BORNITE-MAGNETITE ORE

Distribution in - 100Feed

Product	Weight in Grams	Oz/Ton	Total (Mg.)	In Each Size. % Wt.	In Each Size. % Ag.	Total -100 Feed % Wt.	Total -100 Feed Ag. %
100 + 150	524.3	4.16	74.90			43.9	41.3
Bornite Tip	8.0	16.90	4.63	1.6	7.4	0.6	3.1
Middling	280.7	3.96	38.20	53.4	61.2	23.8	25.7
Magnetite	202.0	2.14	14.80	38.6	23.7	16.7	10.0
Slime	33.6	4.16	4.78	6.4	7.7	2.8	3.2
			62.41	100.0	100.0	43.9	42.0
-150 + 200	280.3	4.56	43.70			23.1	24.2
Bornite Tip	9.1	25.84	7.95	3.2	25.2	0.8	5.4
Middling	188.8	2.54	16.40	67.3	52.0	15.1	11.2
Magnetite	51.2	1.46	2.55	18.1	8.1	4.2	1.7
Slime	31.2	4.36	4.66	11.4	14.7	2.5	3.2
			31.56	100.0	100.0	23.1	21.5
-200 + 325	225.8	4.64	35.80			18.6	19.8
Bornite Tip	1.5	27.60	1.42	0.6	5.2	0.1	1.0
Middling	75.3	4.40	11.01	33.4	39.3	6.2	7.5
Magnetite	52.4	1.39	2.49	23.2	8.9	4.3	1.8
Slime	96.6	3.96	13.10	42.8	46.6	8.0	8.9
			28.02	100.0	100.0	18.6	19.2
-325	175.4	4.46	26.8			14.4	14.8
Bornite Tip	1.2	47.00	1.93	0.8	7.8	0.1	1.4
Middling	58.4	3.82	7.62	33.2	30.1	4.8	5.1
Magnetite	38.5	1.94	2.56	21.9	10.1	3.1	1.8
Slime	77.3	4.96	13.10	44.1	52.0	6.4	8.9
			25.21	100.0	100.0	14.4	17.3
Totals	1205.8		149.2			100	1000

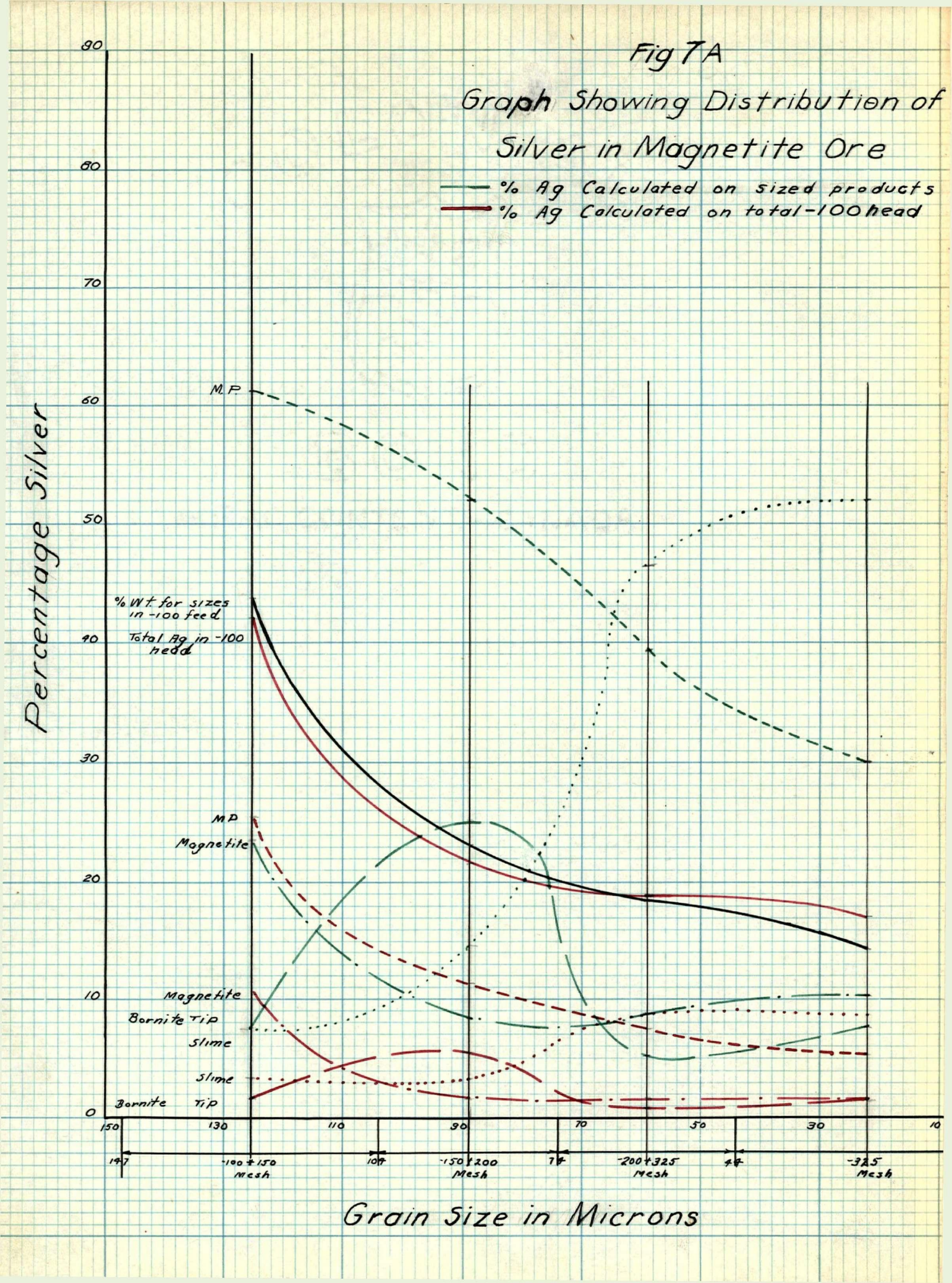


Fig 7A
Graph Showing Distribution of Silver in Magnetite Ore
% Ag Calculated on sized products
% Ag Calculated on total -100 head
Percentage Silver
90
80
70
60
50
40
30
20
10
0
M.P.
% Wt. for sizes in -100 feed
Total Ag in -100 head
MP
Magnetite
Magnetite
Bornite Tip
Slime
Slime
Bornite Tip
150
130
110
90
70
50
30
10
14#
-100+150 Mesh
10#
-150+200 Mesh
7#
-200+325 Mesh
4#
-325 Mesh
Grain Size in Microns

TABLE 6.

COPPER IN DISSEMINATED BORNITE ORE (TIPS ONLY)

Sample	%Cu.	Wt. of Tip	Gms Cu. in Tip	% Cu. Feed	Gms. in Feed	Gms. Cu. Feed	% Cu. Conc. in Tip.
Total -100 Sample				3.5	663.1	23.9	
-100 + 150	50.86	11.8	6.00	4.08	124.3	5.08	118%.
-150 + 200	45.16	8.3	3.74	4.05	86.7	3.51	106%
-200 + 325	47.80	2.1	1.10	3.06	125.3	3.84	28%
-325	41.44	6.0	2.48	2.95	326.8	9.65	25%
						22.08	

COPPER IN MAGNETITE-BORNITE ORE (TIPS ONLY.)

Sample	% Cu.	Wt. of Tip	Gms Cu. in Tip	% Cu. Feed	Gms. in feed	Gms. Cu. in Feed	%Cu. Recovered for Each Size.
Sample				6.7	1205.2	74.2	
-100 + 150	38.08	8.0	3.05	5.96	524.3	31.2	9.7
-150 + 200	42.86	9.1	3.89	6.65	280.3	18.9	20.6
-200 + 325	38.12	1.5	0.57	6.80	225.8	15.3	3.7
-325	41.88	1.2	0.50	7.50	175.4	13.2	2.5
			8.01			78.6	

OBSERVATIONS OF THE SUPER-PANNER RESULTS.

1. The best separation or freeing is indicated by the highest ratio by percent of gold or silver to the total weight, by percent of the material, or on the graph by the maximum difference of ordinate.

2 (a). In the disseminated bornite or the bornite-wollastonite ore, the best separation of the gold was at 110 microns. The maximum amount of gold was in the - 150 + 200 mesh. The gold still contained minor amounts of gangue at 100 microns. (fig.16).

(b). The best separation of silver was at 90 microns. The greatest percentage of silver was in the - 150 + 200 mesh product.

3 (a). In the magnetite-bornite ore the best separation of gold was at 90 microns. This is shown clearly by the sudden rise of the graph of the percentage of gold (in each sized product).

(b). The best separation of silver was at 22 microns. However a good separation of silver was obtained at 90 microns.

4. The slime or tailing in the + 150 mesh is due to dry screening. Some of the "fines" have coated the larger particles and have been separated by the washing water.

5. The copper assays of the bornite tip (table 6)

show that the best concentration of copper, in the bornite-wollastonite ore was in the - 100 + 150 mesh, or at an average grain size, at about 90 microns. This result would be in agreement with the average size of the bornite masses seen in Fig. 8.

6. For the bornite-magnetite ore, the best concentration was in the - 150 + 200 mesh. However this recovery was only 20.6%. A large percentage of bornite was noted in middlings product.

7. The graph of the silver in the bornite-wollastonite ore rises suddenly for the - 325 mesh size. This is due to the presence of brittle silver tellurides - wehrlite and hessite - The graph of the silver falls rapidly in the - 325 mesh size of the bornite-magnetite ore, because the silver occurs chiefly as native silver rather than as a silver telluride.

8. The silver-gold ratio was not included in the tables as the results were erratic owing to the presence of free gold and silver.

CONCLUSION.

The following conclusions have been reached:

1. The gold of the Little Billy ore occurs chiefly as native gold, the silver occurs as the silver tellurides, hessite and wherlite, and as native silver.

2. One of the volatiles or mineralizers associated with the contact metasomatism of the Little Billy ore was boron.

3 (a). In the bornite-wollastonite ore, the best separation of gold was at 110 microns or the - 150 + 200 mesh size. The best separation of silver was at 90 microns. The best concentration of copper was in the - 100 + 150 mesh size.

(b) In the bornite-magnetite ore, the best separation of gold was at 90 microns, while the best separation of silver was at 22 microns. However, a good separation of silver was also obtained at 90 microns. Hence the best separation of gold and silver was in the - 100 + 150 mesh size. The best separation of copper was in the - 150 + 200 mesh size.

APPENDIX A

PHOTOMICROGRAPHS

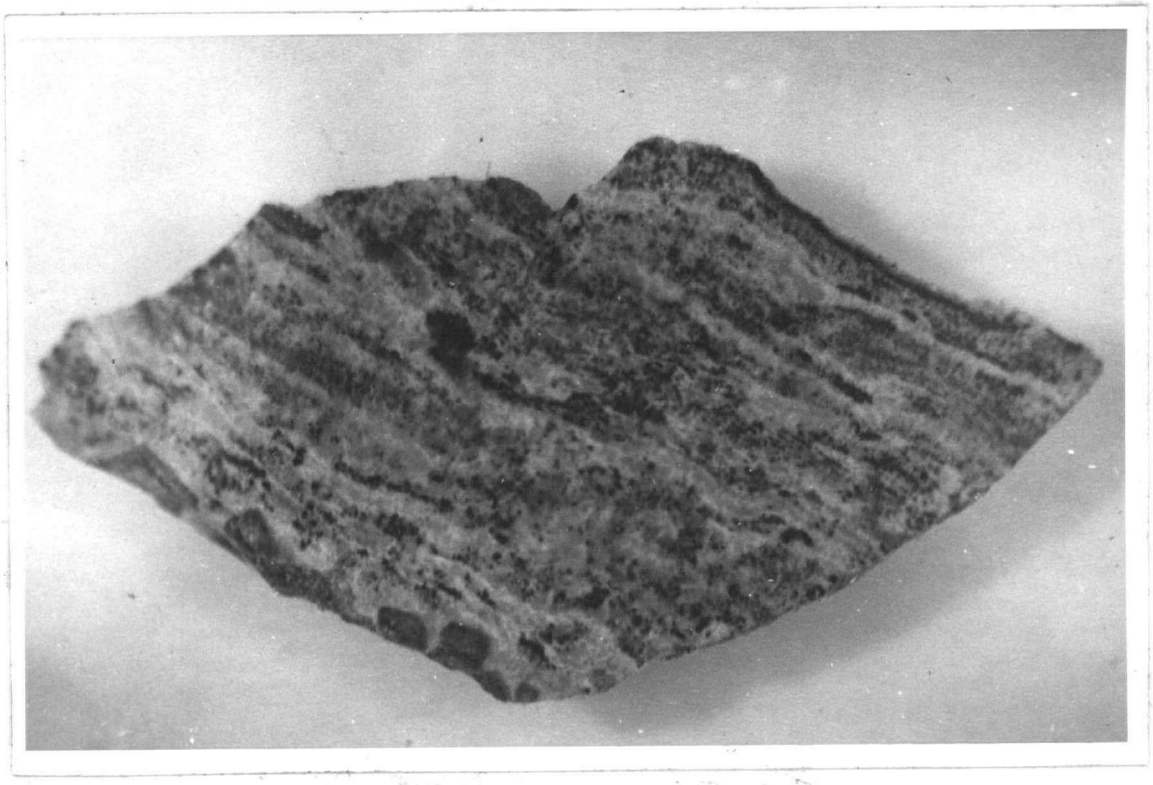


FIGURE 7

Typical ore from the Little Billy mine, showing disseminated bornite and chalcopyrite in a garnet-wollastonite gangue.

X I

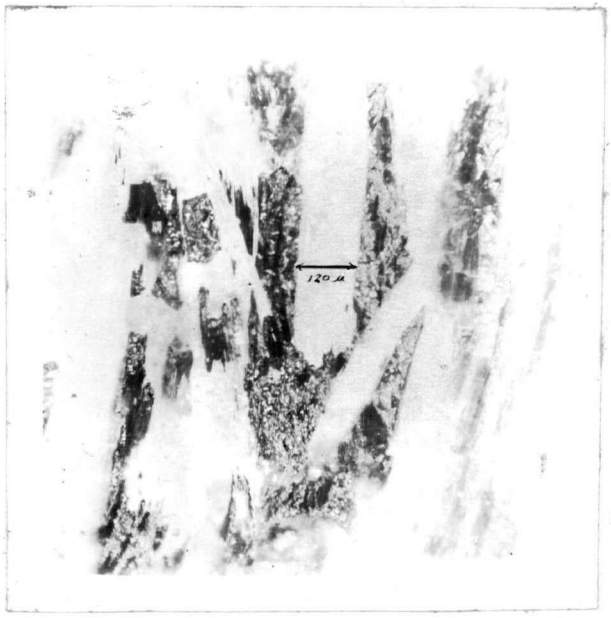


FIGURE 8

Bornite replacing wollastonite.
Thin section from the Prosser ore body, 468 feet from the surface.

X 67

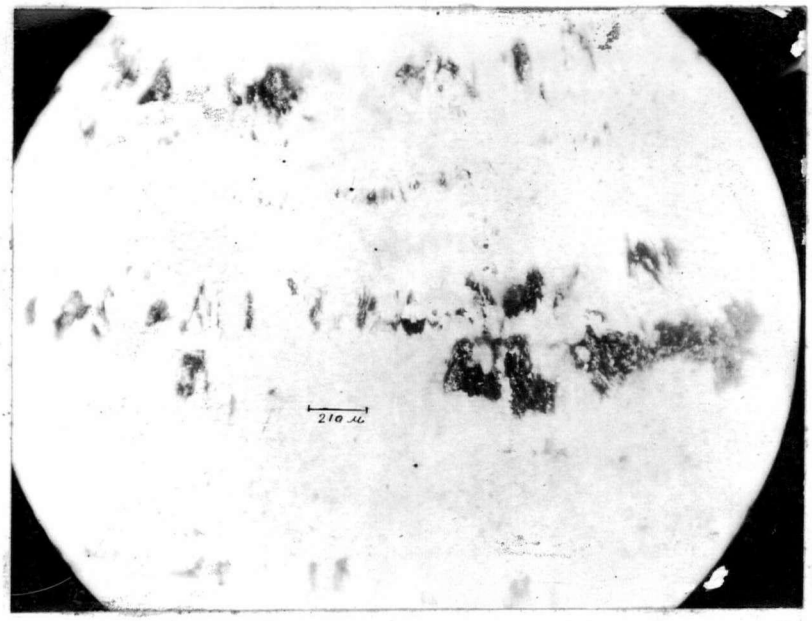


FIGURE 9

Bornite replacing wollastonite, showing the banded appearance of the ore. Thin section of the Prosser ore body 443 feet from the surface.

X 37

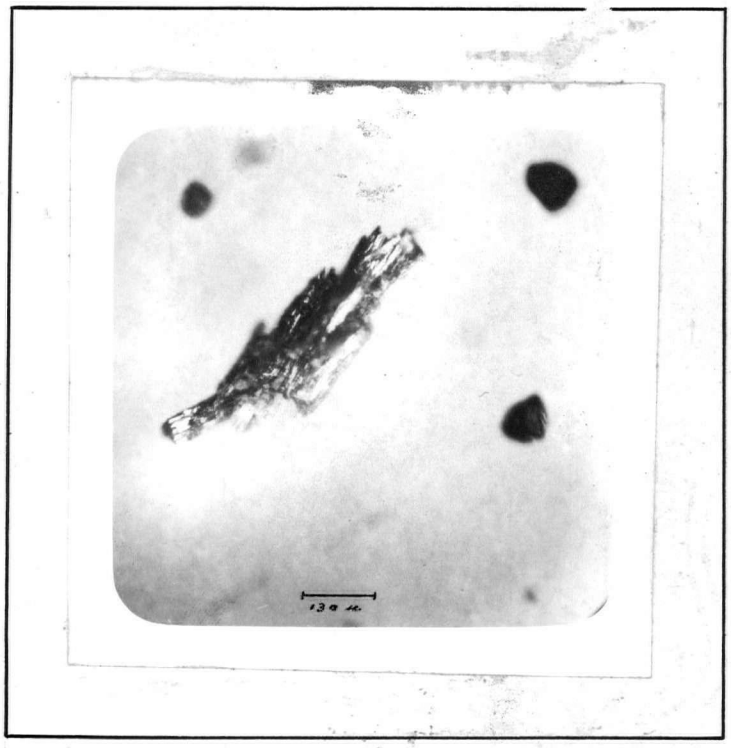


FIGURE 10

Crystal of wehrlite in -150+ 200 mesh product of the bornite wollastonite ore.

X 77

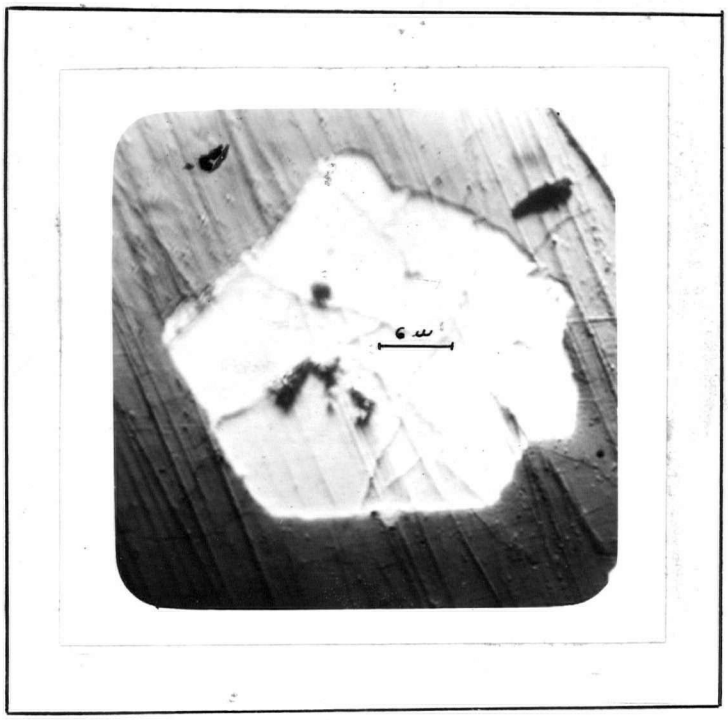


FIGURE 11

Wehrlite in bornite

X 1500

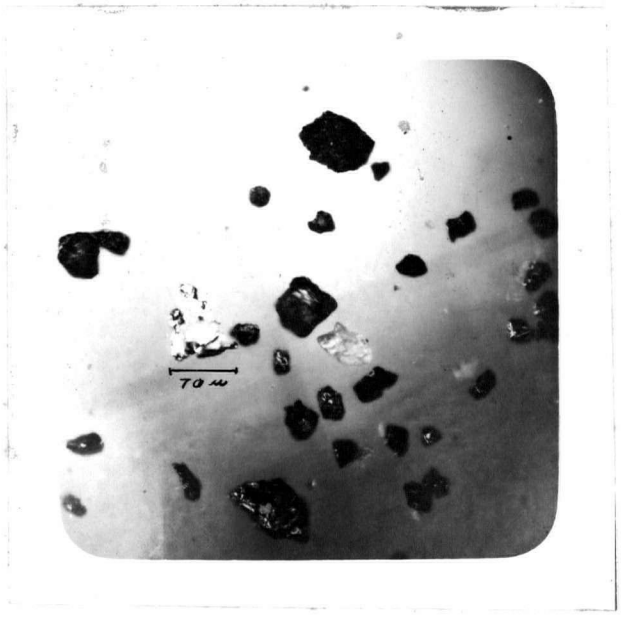


FIGURE 12

Gold with quartz in bornite tip from - 150 + 200 mesh of bornite-wollastonite ore.

X 100

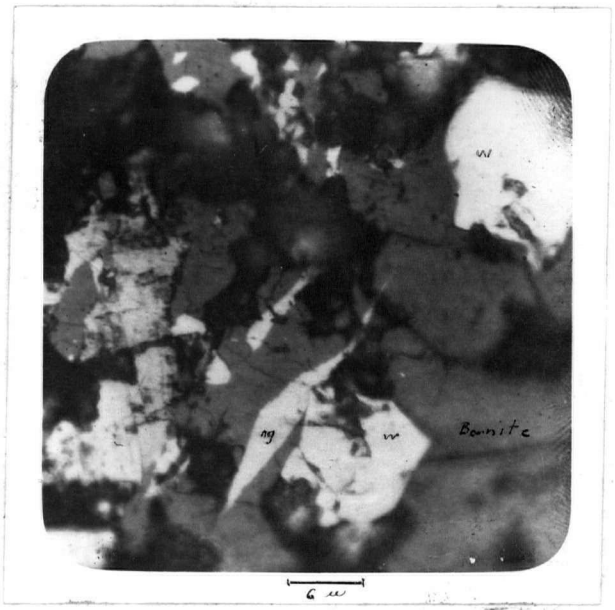


FIGURE 13

Silver (Ag) and wehrlite (w) in Bornite.

X 1500

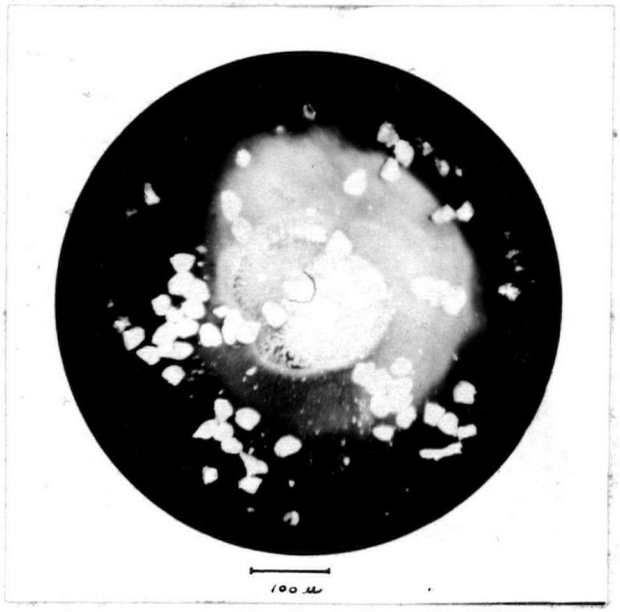


FIGURE 14

"Tellurium Pool"

from hessite heated on pyrex slide.

-100 150 mesh tip.

X 100

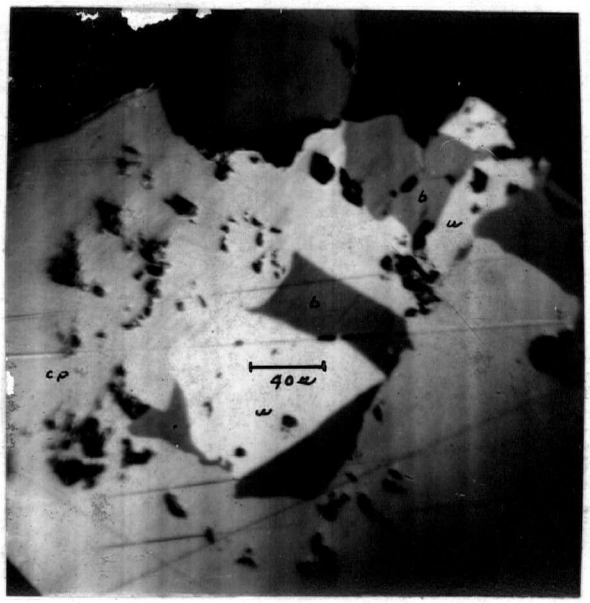


FIGURE 15

Wehrlite and bornite in

Chalcopyrite.

X 370

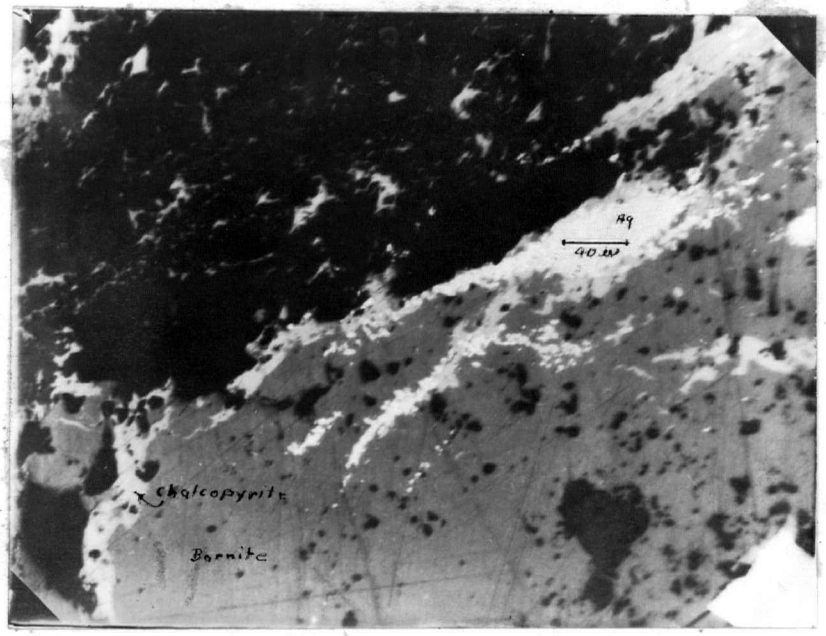


FIGURE 16.

Silver replacing bornite
and chalcopyrite.

X 250

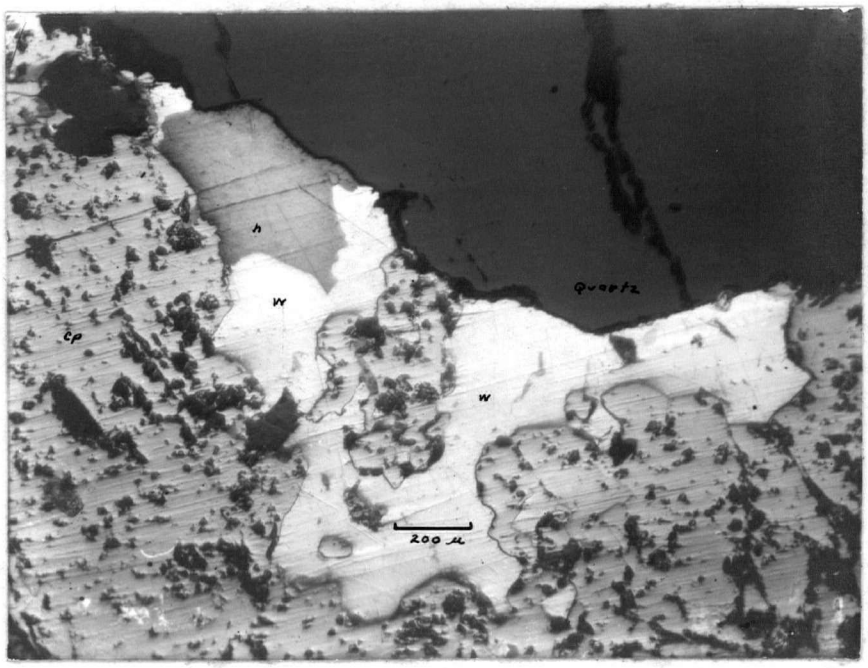


FIGURE 17

Wehrlite and hessite in chalcopyrite

Marble Bay Mine.

(material used for positive identification of wehrlite and hessite).

X 120

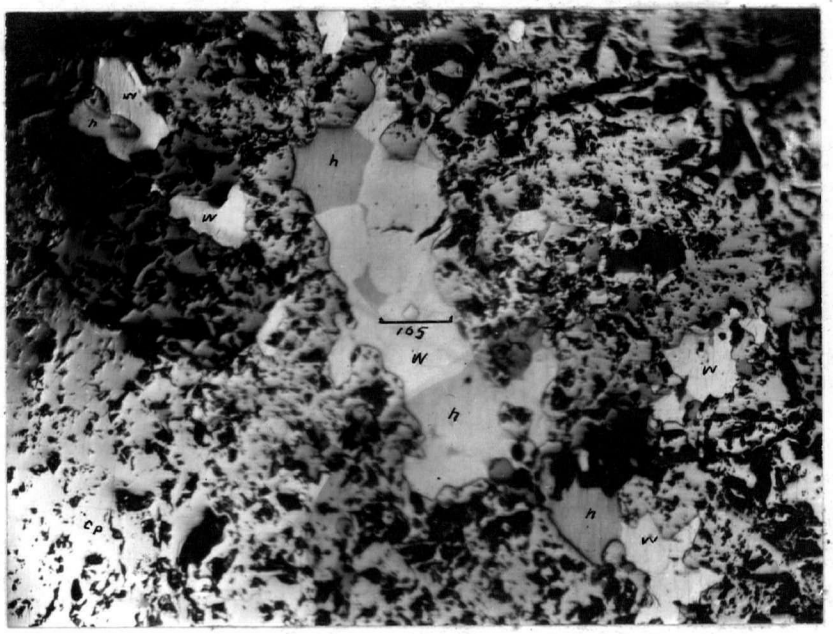


FIGURE 18

Wehrlite and hessite in chalcopyrite

Marble Bay Mine.

(material used for positive identification of wehrlite and hessite).

X 120

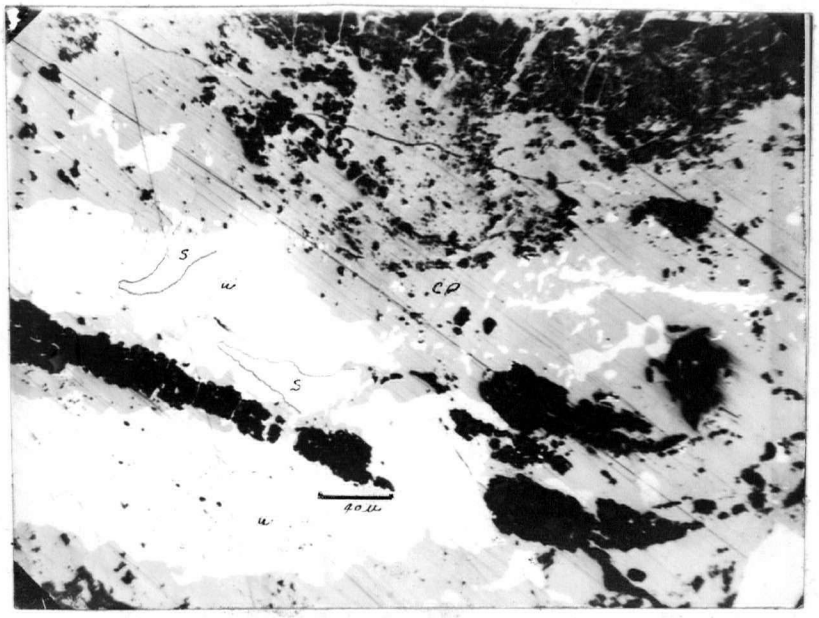


FIGURE 19

Silver in wehrlite
and chalcopyrite.

X 350

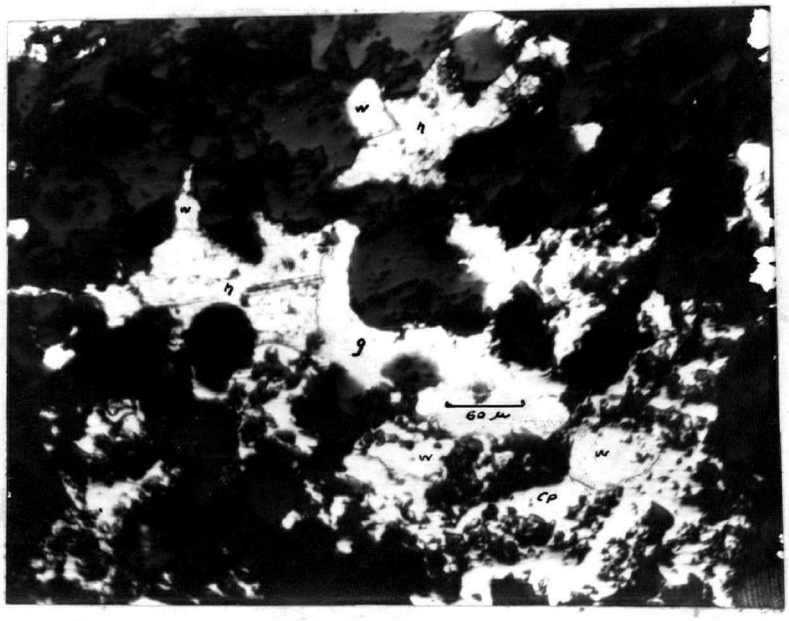


FIGURE 20

Gold, wehrlite, hessite
and chalcopyrite in quartz.

X 165

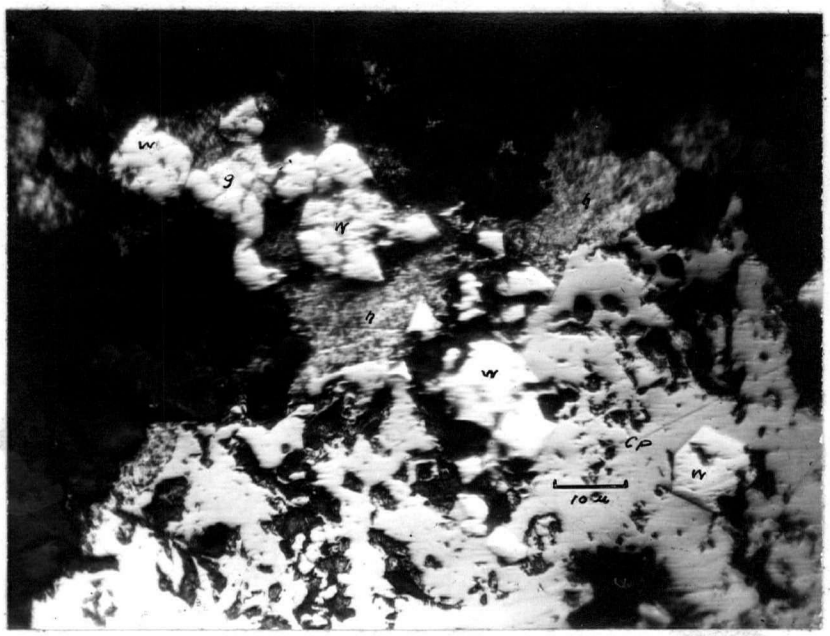


FIGURE 21.

Gold, wehrlite and hessite
in chalcopyrite and quartz.

X 405

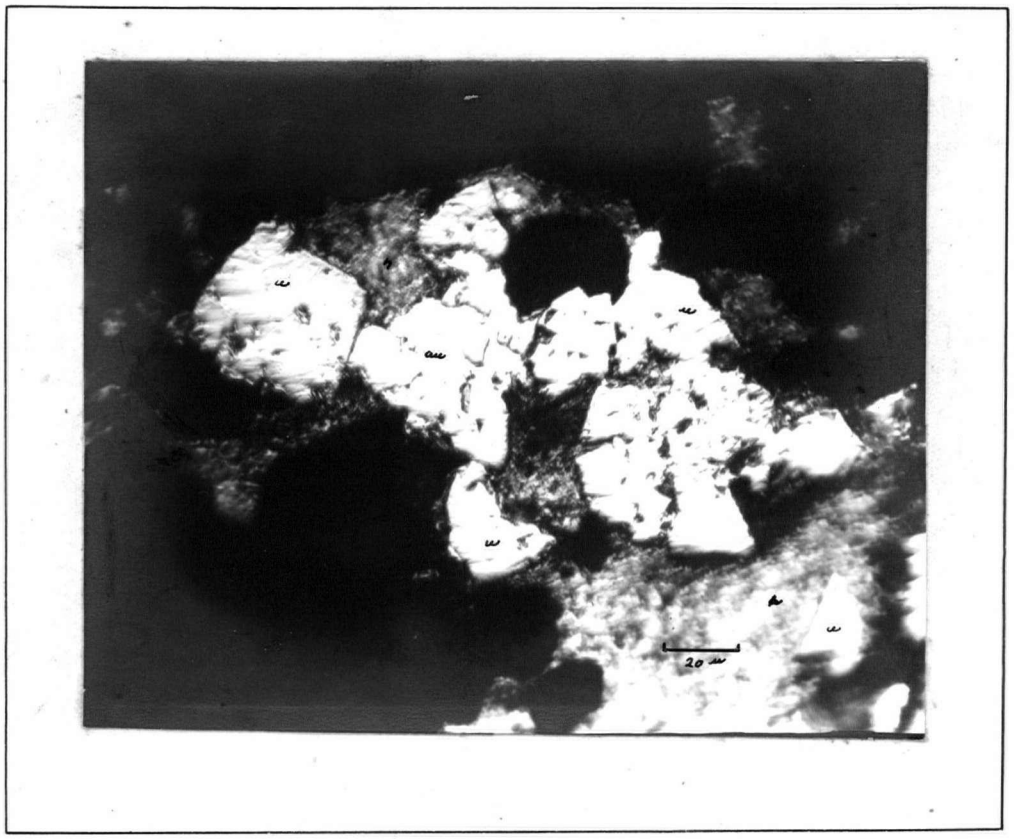


FIGURE 22

Gold, wehrlite and hessite in quartz.

X 810

FIGURE 23

Gold in a quartz vein
cutting pyrite.

X 470

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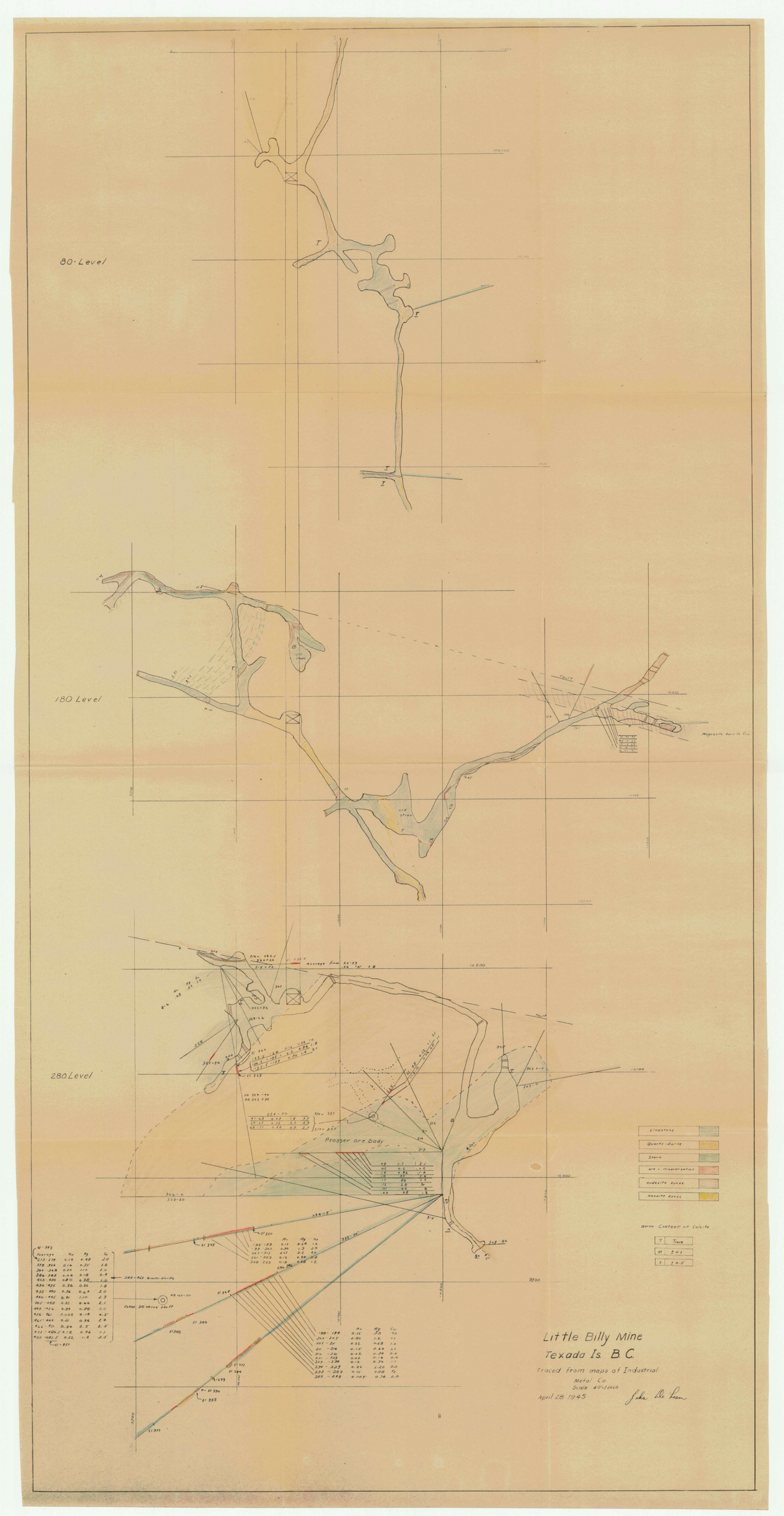
80-Level
180 Level
280 Level
Prosser ore body
Limestone
Quartz-diorite
Sharm
ore - mineralization
Andesite dykes
Rhyolite dykes
Barren Content of Calcite
T Trace
M ± 0.1
S ± 0.5
Little Billy Mine
Texada Is. B.C.
Traced from maps of Industrial
Metal Co.
Scale 40'=1 inch
April 28 1945