Excellent job - I have not seen the carbonate but it is not out of place.
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A MINERALOGRAPHIC STUDY OF SUNLOCH COPPER ORE

by

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A REPORT SUBMITTED IN

PARTIAL FULFILLMENT OF THE REQUIREMENTS

OF THE GEOLOGY 409 COURSE

IN THE

DEPARTMENT OF GEOLOGY

THE UNIVERSITY OF BRITISH COLUMBIA

APRIL, 1951.

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CONTENTS

ABSTRACT

There are three principal sulphides in the Sunloch copper ore: chalcopyrite is the most abundant and is the source of copper; pyrrhotite, which is found in its greatest quantity in a low grade copper zone, is nickeliferous; pyrite has a general, but smaller, distribution than pyrrhotite and contains inclusions of arsenopyrite in minor amount. The nature of the nickel mineralization is not evident but there are indications that nickel occurs in solid solution in pyrrhotite.

INTRODUCTION

The Sunloch mine is situated on the west coast of Vancouver Island near the mouth of Jordan River. The location and geological setting are shown in Figure 1. Jordan River flows in a deep channel through the Sunloch property and adjoining property of the Gabbro Mines Ltd., which lies to the west of Sunloch claims. The main workings of the Sunloch mine are about two miles upstream from tidewater. The Jordan River townsite, 45 miles by road from Victoria, is the site of the B. C. Electric power plant which supplies electricity to Victoria, and also the headquarters for a truck-logging operation of the Alaska Pine Company. Geographically, the Jordan River locality is an ideal site for a mining operation.

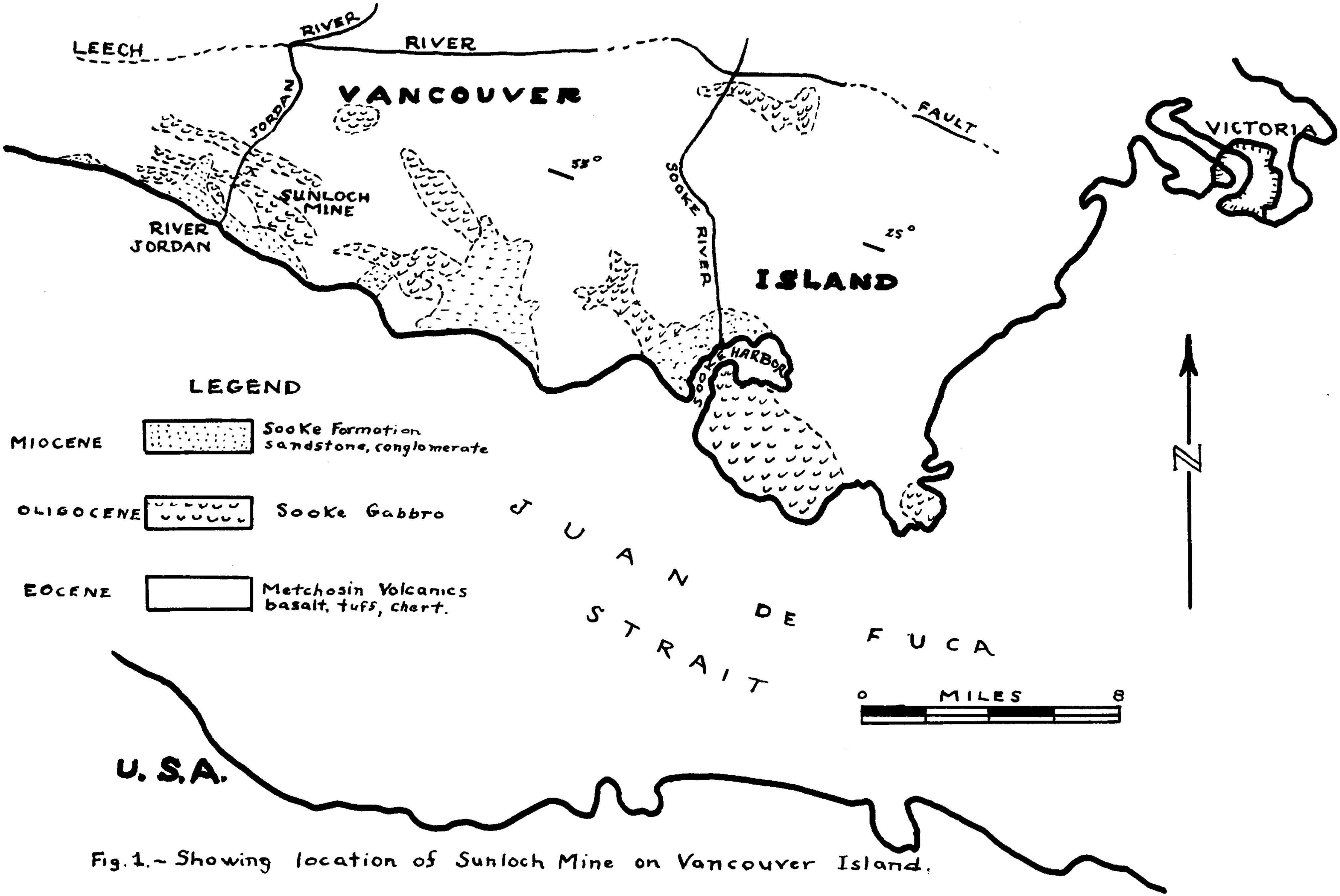


Fig. 1.- Showing location of Sunloch Mine on Vancouver Island.

HISTORY OF MINING ACTIVITY

Mining exploration in the Jordan River area commenced in 1915. During the period 1916-1920, 3776 feet of tunnel were driven and 3500 feet of diamond drilling were done in the River, Center and Cave zones of the Sunloch property. Development work stopped in 1920 after about 150,000 tons of ore averaging 3½% copper had been indicated.

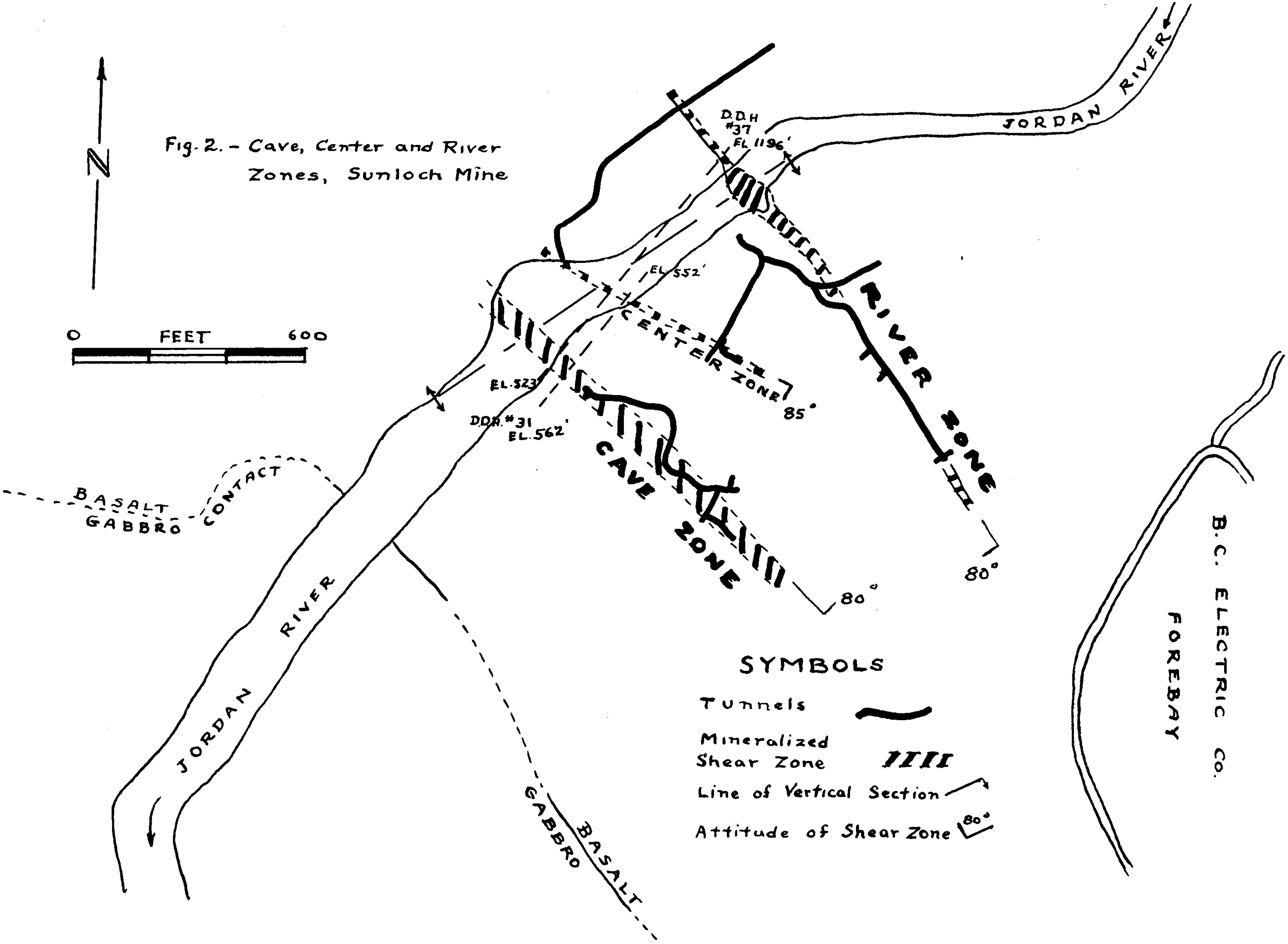
The Sunloch group of claims had originally been developed by the Sunloch Mining Company who sold their interests in 1919 to the Consolidated Mining and Smelting Company. In 1949, Hedley Mascot Gold Mines Ltd. took an option on these claims from C. M. and S. Co. and at the same time acquired rights on the Gabbro group from Gabbro Copper Mines Ltd. These properties, which had been idle since 1920, have been extensively explored by Hedley Mascot during the past two years and favorable results have been reported.

PURPOSE AND METHODS OF CURRENT STUDY

The object of this mineralographic study, which was undertaken as part of the Geology 409 course at the University of British Columbia during the 1950-1951 term, was to work out the identities and paragenesis of the metallic minerals of the Sunloch ore with particular attention to the nature of the nickel mineralization.

The suite of specimens available for examination consisted of ten core samples taken from two diamond drill holes which were drilled in 1950 to intersect the Cave, Center and River zones of the Sunloch

Fig. 2. - Cave, Center and River Zones, Sunloch Mine



mine. Figures 2 and 3 show the position of these drill holes--D. D. H. #37 and D. D. H. #31. Seven of the specimens were selected from core recovered from the Cave zone because the Hedley Mascot Company has found a higher percentage of pyrrhotite and obtained corresponding higher values in nickel, but lower values in copper, from that zone than from other main zones. Assays of samples used in this study ranged from 0.09 % to 0.38 % nickel, with an average of 0.25 % nickel.

The ore minerals were examined in polished section under the reflecting microscope at magnifications ranging from X 50 to X 350.

In addition to the mineralographic work done on the core samples, use was made of the superpanner to separate the various metallics for individual X-ray and assay analyses for nickel. For this procedure, ore was ground to minus 200 mesh. Samples which had been taken from the Cave zone in 1950 by the Hedley Mascot geologist were used for these tests. The main object of the superpanner work, which was done on small samples, was to see if a nickel tip could be obtained for analysis.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the valuable advice and kind assistance of Dr. H. V. Warren and Dr. R. M. Thompson of the Department of Geology of the University of B. C. He is also indebted to J. W. Young, geologist of Hedley Mascot Company, for supplying samples of ore and for generously furnishing geological information and maps of the Sunloch ore deposit. The Skeleton Diagram by Mr. Young, which is attached to the back cover of this report, has been included to show the form and size of

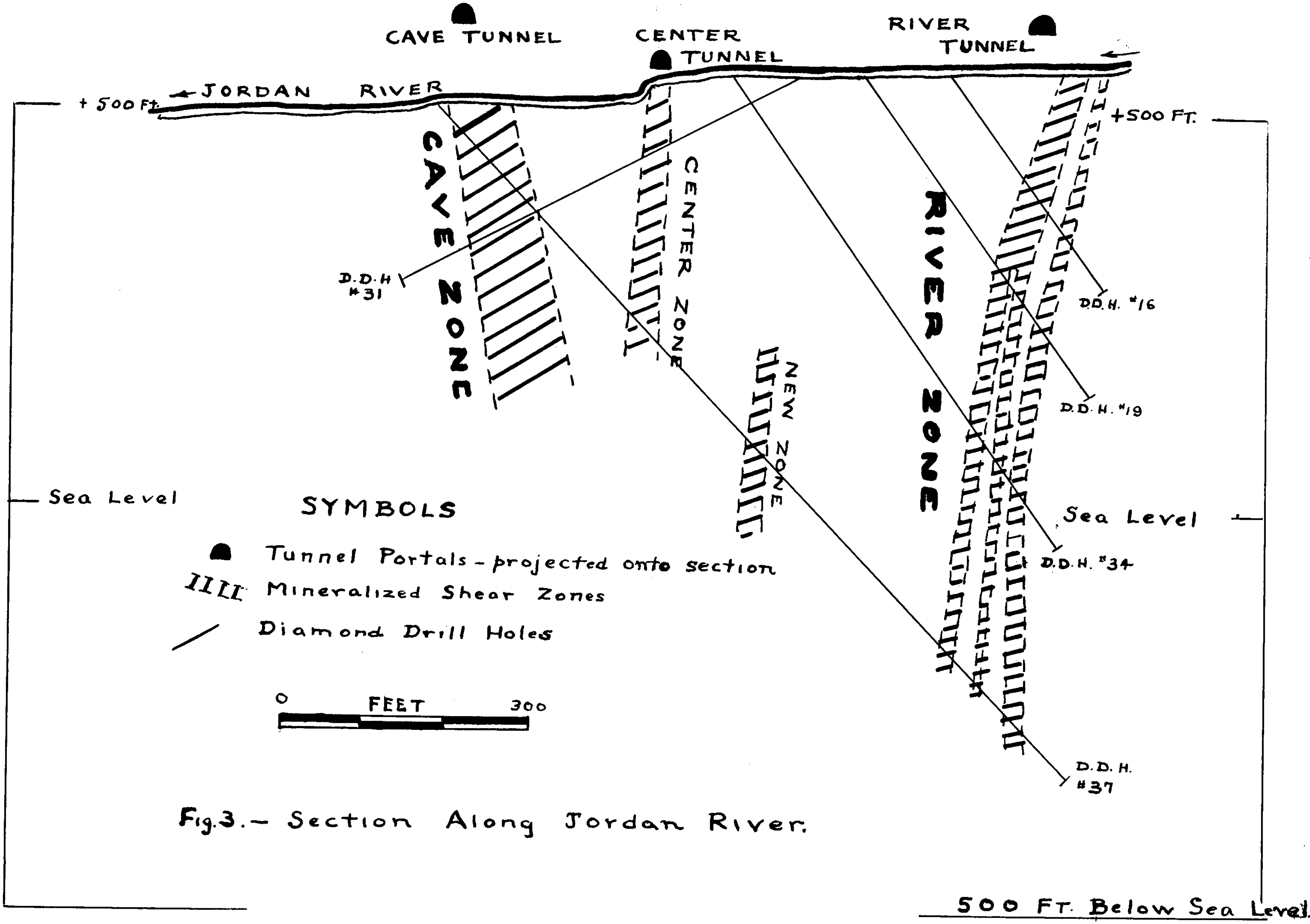


Fig.3.- Section Along Jordan River.

the ore zones of the Sunloch mine. Thanks are due also to J. A Donnan of the University geological laboratories who prepared some superpolished sections.

GENERAL GEOLOGY

As shown in Figure 1, rocks of the southwest end of Vancouver Island are Tertiary in age. The Leach River fault marks the line of contact of this Tertiary area with an area, mapped as the Leach River formation, in which the Jordan River has its source. The Leach River formation is the oldest on Vancouver Island and it occurs in a belt, five miles in width, which extends from the east coast of Vancouver Island to the fault shown in Figure 1. Rocks of lower Mesozoic age--the Vancouver group--unconformably overlie the Leach River formation in the eastern part of the Island. In the Jordan River--Victoria area, Tertiary rocks are classified as the Metchosin Volcanics, the Sooke Gabbro and the Sooke formation.

Description of Rocks.--The Metchosin Volcanics are Eocene in age. They are in the form of a thick series of basalts with minor amounts of tuffs and cherts. In zones of mineralization, basalt has been replaced by hornblende.

The Sooke Gabbro occurs as several elliptical stocks which have been intruded into the Metchosin Volcanics. In some of the stocks a marked differentiation has taken place to produce olivine gabbro, augite gabbro and anorthosite. The stocks are commonly cut by a few northeasterly trending dikes. At Jordan River, there are three parallel stock-like bodies of gabbro: the central and most important is 3000 feet at the widest exposure and has been traced for four miles; the northern and southern gabbro bodies, which are somewhat smaller, are separated from it by areas of basalt 2000 to 3000 feet in width.

The Sooke formation consists of sediments of Oligocene to Miocene age. These sediments are found on the coastal plains that extend along the west and southern coasts of Vancouver Island.

Structural Features.--The Metchosin basalt has a regional strike of about N 70° W and an average dip of 60° to the northeast. However, in the vicinity of the Sunloch mine, the strike is more northerly and the dip quite variable. The three elongated masses of Sooke Gabbro cross the Jordan River in a direction which closely parallels the strike of the Metchosin basalt.

The most important structural features in the Jordan River locality are mineralized shear zones in the Metchosin basalt which are parallel to gabbro contacts. Some of these zones have been traced for distances of more than 1000 feet. Eleven shear zones have been discovered to date; of these, the most promising occur near the northeast contact of the central gabbro mass. The River zone has been found to range from one foot to 100 feet in width; the Cave and Center zones average 130 feet and 20 feet respectively in width (Figure 2). These three zones contain the main ore bodies of the Sunloch mine.

MINERALOGY

The metallic minerals, which were identified in polished sections made from the diamond drill core samples, are chalcopyrite, pyrrhotite, pyrite, magnetite, arsenopyrite, ilmenite and cubanite. As specimens had been selected with a view to obtaining a maximum of pyrrhotite surfaces, relative percentages of the minerals were not worked out from the polished sections. However, examination of a number of hand specimens showed that the main ore minerals in order of abundance are chalcopyrite, pyrrhotite and pyrite, with chalcopyrite being the predominant mineral.

Magnetite.--This mineral can be found in small amount in all polished sections as scattered grains which have no particular spatial relationship to the sulphides. Magnetite is enclosed and veined by pyrrhotite but it occurs with the gangue silicates in greater amount. It does not appear to be a product of the solutions which deposited the sulphides. It was identified by its hardness, isotropic character, blue gray color and magnetic properties. Grain size ranges from 50 to 400 microns.

Ilmenite.--Ilmenite was noted in most polished sections as small particles which have an occurrence similar to that of magnetite. Its average grain size is 100 microns. It has a gray color, with a slight violet tinge; anisotropic effects are light gray and dark brown; its hardness is G. One particle was found that was large enough for a sample and the powder was X-rayed to establish its identity.

The X-ray diffraction apparatus photographs the raflection of monochromatic X-rays from the atomic planes of mineral powders. The pattern obtained is controlled by the size and kind of atomic lattice, and by the kind of atom in the mineral being examined. Each mineral gives a characteristic pattern which can be analyzed visually and mathematically, and the mineral identity thus worked out.

Pyrrhotite.--Pyrrhotite of the Sunloch ore is massive with granular texture. Most grains are between one-tenth and two mm. in size and of an irregular shape. This mineral encloses and corrodes grains of pyrite and magnetite and has rounded inclusions of silicates. Except for these inclusions, pyrrhotite surfaces showed characteristic anisotropism between crossed nicols.

Various staining techniques were used in searching for other mineral inclusions in pyrrhotite. No distinctive reactions were obtained from the common staining reagents--nitric acid, hydrochloric acid, potassium cyanide, ferric chloride, aqua regia, potassium hydroxide and mercury chloride. Chromic acid, which will stain pentlandite blue and pyrrhotite brown, was tried in various concentrations, from weak to strong solutions, but it gave no indication of pentlandite. However chromic acid left some small needle-like patches unstained. These needles were 20 to 50 microns long with pyramid-like terminations. They were found to be somewhat anisotropic. They were noted in polished sections made from samples giving the best nickel assays but were never in great quantity, generally occurring as a group of six to eight strung out in line across pyrrhotite grains rather than in close proximity to grain boundaries.

Microchemical tests for nickel were obtained from pyrrhotite. The distribution of these positive tests was general: sample positions were not related in particular to pyrrhotite grain boundaries or to the small inclusions unstained by chromic acid, and no quantitative variations were noted in microchemical tests made in the vicinity of either of these features. The small needle-like inclusions were not large enough for individual examination by X-ray or microchemical methods and consequently identification was not possible.

A pyrrhotite sample obtained from superpanner separation assayed 0.357 % nickel. According to available information, this percentage is close to the best figures obtained for nickel assays of diamond drill core samples; it can therefore be taken as an indication that pyrrhotite is the chief nickel-bearing mineral.

Results of microscopic, microchemical and superpanner work suggest that nickel mineralization of the Sunloch copper ore is associated with pyrrhotite, and that nickel, in large part at least, is replacing iron in the pyrrhotite crystal lattice. The tiny needle-like inclusions in pyrrhotite may be nickeliferous, but, if so, their distribution and the numbers in which they were found in the polished sections examined would indicate that they represent only a small part of the total nickel content. The nickel content of the Sunloch ore is less than 1.86 %, which is the theoretical limit of solid solution of pentlandite in pyrrhotite at normal temperatures.[1]

<u>Chalcopyrite</u> <u>and</u> <u>Cubanite</u>.--Chalcopyrite occurs in massive form; staining with aqua regia showed that larger masses consist of fairly well-developed grains. At best, the mineral is weakly anisotropic. It contains corroded inclusions of magnetite and pyrrhotite and it cuts across

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1. Edwards A. B., "Textures of the ore minerals," p. 88, Melbourne, Australasian Institute of Mining and Metallurgy, 1947.

pyrrhotite grains. There are parallel lath-like intergrowths in chalcopyrite in a few places. These intergrowths are of a cream color; their size is 50 to 75 microns; polarization colors of yellow and grayish blue are discernible; they are not harder than chalcopyrite and do not stand in relief above it. These intergrowths were identified as cubanite. They occur near smoothly curving contacts of chalcopyrite and pyrrhotite.

How 1st I have heard of it

No microchemical tests for nickel were obtained from chalcopyrite.

Assay of chalcopyrite--pyrite fractions from superpanner separation gave one nickel percentage of 0.105. This result could be attributed to insufficient fineness in grinding and retention of pyrrhotite particles in the subsequent superpanner classification, but further work on a larger scale would have to be done to confirm this explanation.

Pyrite.--There are two occurrences of pyrite: the more general is as corroded grains and elongated aggregates in pyrrhotite, but there is also a definite, though minor, relationship in which pyrite veinlets cut across chalcopyrite. Grain size of the first generation pyrite is in the range of one-half to one mm. The pyrite veinlets are as much as one-tenth mm. in width and contain gangue minerals, as a wall lining, in addition to pyrite.

No evidences of nickel were obtained from microchemical examinations of pyrite, or from an X-ray analysis of pyrite powder.

Arsenopyrite.--Crystals of arsenopyrite, with characteristic triangular and diamond shaped cross sections, were noted as inclusions in some of the pyrite grains, but not in the pyrite veinlets. These crystals range in size from 50 to 150 microns, and in contrast to the isotropic pyrite, become visible between crossed nicols with greenish yellow, brown and violet polarization colors. Arsenopyrite is confined entirely to pyrite and only occurs in about 10 % of the pyrite grains.

Tests run on the superpanner gave a tip which was examined under the binoculars and found to consist of prismatic crystals of tin-white color and high luster. An X-ray of these crystals gave a typical arsenopyrite pattern with no indication of nickel content.

Gold and Silver.--Assays for gold up to 0.12 ounces and for silver up to 0.8 ounces were obtained by the Hedley Mascot Company from samples used in this study. Nothing was noted in the polished sections which would point to the nature and association of the precious metal content.

PARAGENESIS

In a determination of sequence of deposition, the following criteria were used: veining, tongues of the later mineral extending along fractures and cleavages of the earlior, interstitial habit, corrosion, inclusions, mutual boundaries and ex-solution intergrowths.

The veining and enclosing of magnetite and ilmenite by sulphides establishes their early formation, but the scattered distribution of these oxides and their association with silicates of the host rock suggests that they are either original rock constituents or products of metamorphic changes which preceded the sulphide deposition period.

The first sulphide in the sequence of mineral deposition was arsenopyrite which occurs as slightly corroded inclusions in pyrite (Figure 8).

The second mineral to form was pyrite. This is evident from its occurrence as corroded grains in pyrrhotite (Figure 4) and chalcopyrite (Figure 5).

The next mineral was pyrrhotite. In addition to its relationship in sequence to pyrite, there are evidences that most of it crystallized before chalcopyrite: corroded pyrrhotite grains occur in chalcopyrite and tongues of this mineral extend along grain boundaries of pyrrhotite (Figure 6).

Although chalcopyrite was for the most part later than pyrrhotite, there are some boundaries, where these two minerals are in contact, which are smooth and regularly curving. In addition, cubanite intergrowths in chalcopyrite occur near these mutual boundaries (Figure 7). The intergrowths and the smooth boundaries are suggestive of simultaneous deposition of some of the pyrrhotite and chalcopyrite.

The second generation pyrite, which is not so abundant as the first, occurs as veinlets cutting chalcopyrite and is therefore the last sulphide to crystallize (Figure 9). This later pyrite may be due to a breakdown of pyrrhotite during the final phases of hydrothermal deposition.[1]

GENESIS

The basalt in which Sunloch copper ore occurs has undergone two stages of alteration by pre-ore solutions: the first, and more complete,

1. Edwards A. B., "Textures of the ore minerals," p. 116, Melbourne, Australasian Institute of Mining and Metallurgy, 1947.

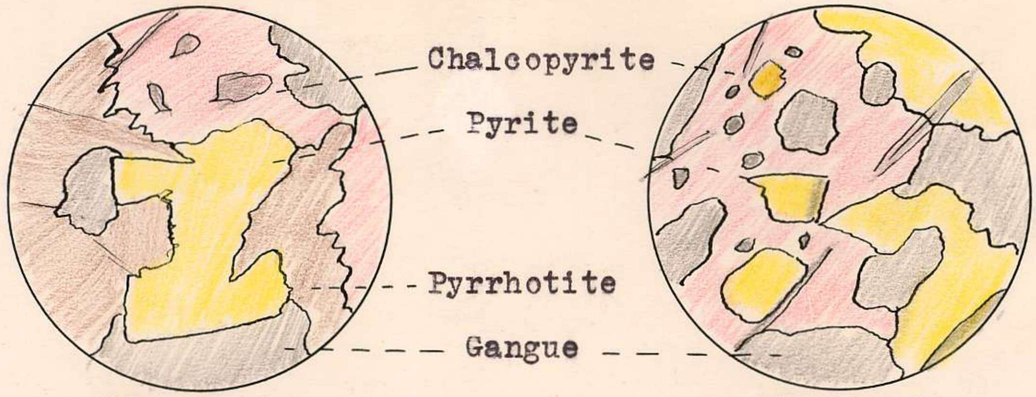

Figure 4.
Corrosion of pyrite by pyrrhotite. X 50.

Figure 5.
Corrosion of pyrite by chalcopyrite. X 50.

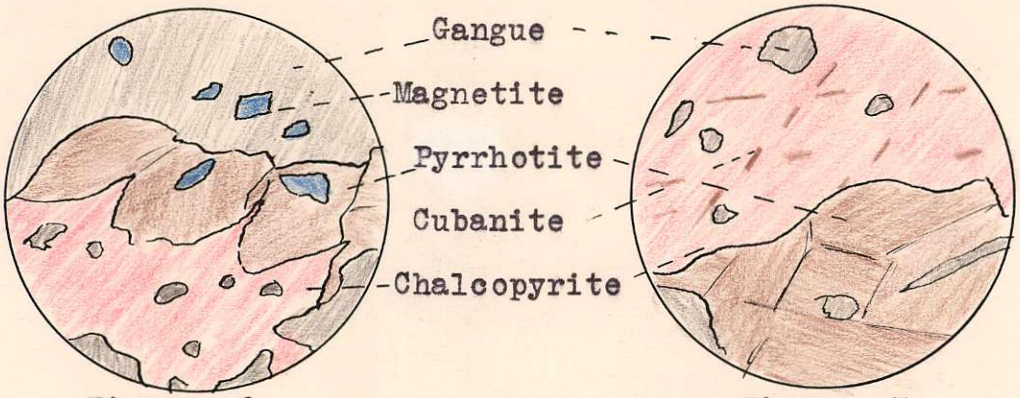

Figure 6.
Replacement of pyrrhotite by chalcopyrite. Magnetite in pyrrhotite and gangue.
X 50.

Figure 7.
Mutual boundaries of pyrrhotite and chalcopyrite with ex-solution intergrowths of cubanite.
X 50.

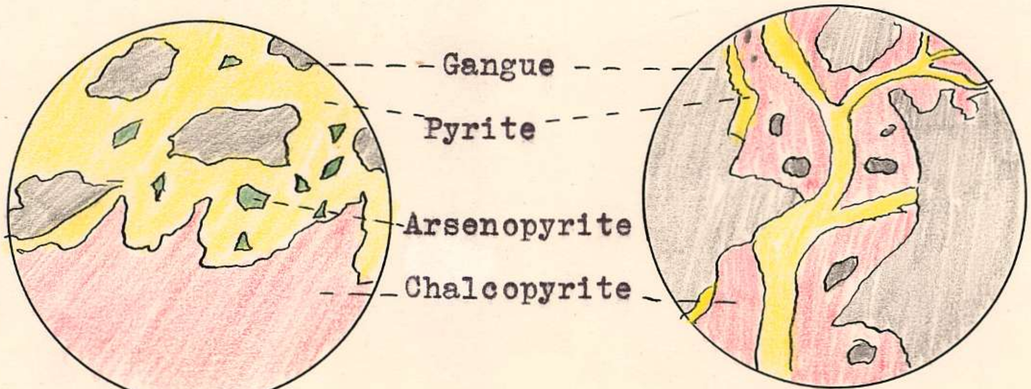

Figure 8.
Arsenopyrite inclusions in pyrite. X 50.

Figure 9.
Pyrite veining chalcopyrite.
X 50.

was the alteration of augite to hornblende; the second was the replacement of plagioclase by hornblende.[1] These changes indicate high temperature conditions which must have continued during the later hydrothermal period because a number of high temperature gangue minerals have been reported. The widespread occurrence of pyrrhotite and the presence of arsenopyrite also suggest a high temperature ore forming period.

Most of the Sunloch ore bodies are in shear zones, in basalt, which are near and parallel to gabbro-basalt contacts. There is, therefore, reason to assume that the ore is related structurally and possibly genetically to the intrusion of gabbro masses. If such be the case, the ageof the mineralization period would be post-Eocene, and the deposit can be classified as high temperature, possibly approaching pyrometasomatic in type.

Examination of hand specimens and polished sections shows that the host rock has been fractured prior to mineralization. Where mineralization is sparse, the sulphides are confined to small fractures; where it is extensive, replacement of silicates has proceeded outwards from these minor channels. The main shears, such as the Cave, River and Center zones, must have localized the mineral solutions; the small fractures increased the permeability of the basalt and thus made it a more suitable host rock for mineral deposition.

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1. Young J. W., "The Geology of the Sunloch Copper Mine, Vancouver Island." A paper presented at the Annual Western Meeting, C. I. M., Vancouver, Nov. 1950.

CONCLUSIONS

Although only a small number of polished sections were examined during this mineralographic study, certain conclusions are indicated:

1. Order of formation of the principal sulphides was pyrite, pyrrhotite and chalcopyrite. Ex-solution intergrowths of cubanite in chalcopyrite suggest a simultaneous deposition of a minor portion of chalcopyrite and pyrrhotite. Second generation pyrite is evident but not so abundant as the earlier pyrite. Arsenopyrite occurs only in minor amount and is associated with first generation pyrite.

2. Magnetite and ilmenite are either original constituents of the host rock or products of a metamorphism which preceded sulphide deposition.

3. At least some of the nickel of the Sunloch ore appears to be in solid solution in pyrrhotite. There is a possibility that tiny unidentified inclusions in pyrrhotite are nickeliferous. (are they arsenopyrite ?)

4. The exact distribution and nature of nickel, gold and silver mineralization in Sunloch ore could best be determined by chemical and microscopic examination of infrasizer fractions from a large sample. The information so obtained would assist in determining possibilities of profitable recovery of these constituents of the ore.

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EXPLANATION OF THE SKELETON DIAGRAM

by
J. W. Young

1. The outlines of a block 1100 feet long, 1000 feet wide and 1500 feet high are shown.

2. The block is cut away to show the surface of the canyon and the river bed at two edges. Between these two edges the block is cut away completely to show the tunnels and the ore zones in skeleton outline.

3. Distances in any plane parallel to the front face can be scaled off in any direction. Distances in any plane parallel to the side faces can be scaled off only in directions parallel to the edges of the side faces. Distances in any plane oblique to the faces of the block cannot be scaled off directly.

4. You are looking at the mine from the north-west side of the river. The outlines of the ore are shown by means of vertical sections, 100 feet apart, which are parallel to the front face of the block. To help in distinguishing the sections, alternate sections are shaded with horizontal striping. To further distinguish the sections and to give the correct perception of depth, each section through ore is joined by a thin guide line to its corresponding section line in the floor of the block. By following this guide line down to the section line on the floor, the observer can see how far inside the block the section lies.

5. Points in the tunnels can be similarly related in depth by referring to the little, rectangular section planes labelled X18, X22, etc.

6. The foot wall sub-zone of the River zone is colored red to distinguish it from the hanging wall sub-zone which is colored yellow. The New zone is colored brown.

7. Ore colored in solidly is of sufficiently high grade to be included in the present ore reserve estimate. Ore that is only outlined in color is below [redacted]% grade and is shown only to illustrate the continuity of the ore structure.

8. The River zone shear persists throughout the length of the River tunnel but, for simplicity, the ore above this tunnel is not shown. Similarly, the ore block in the Cave zone, lying between section 14 and the Cave tunnel portal, is not shown.

9. If the shaft method of mining should be adopted, the shaft would probably be located as shown and a main haulage crosscut driven through the zones as shown. This would be the first stage of sinking, the shaft would probably be deepened later.

10. The diagram illustrates the compactness of the mine. Little lateral development is needed owing to the generous widths of the ore zones beneath the river.

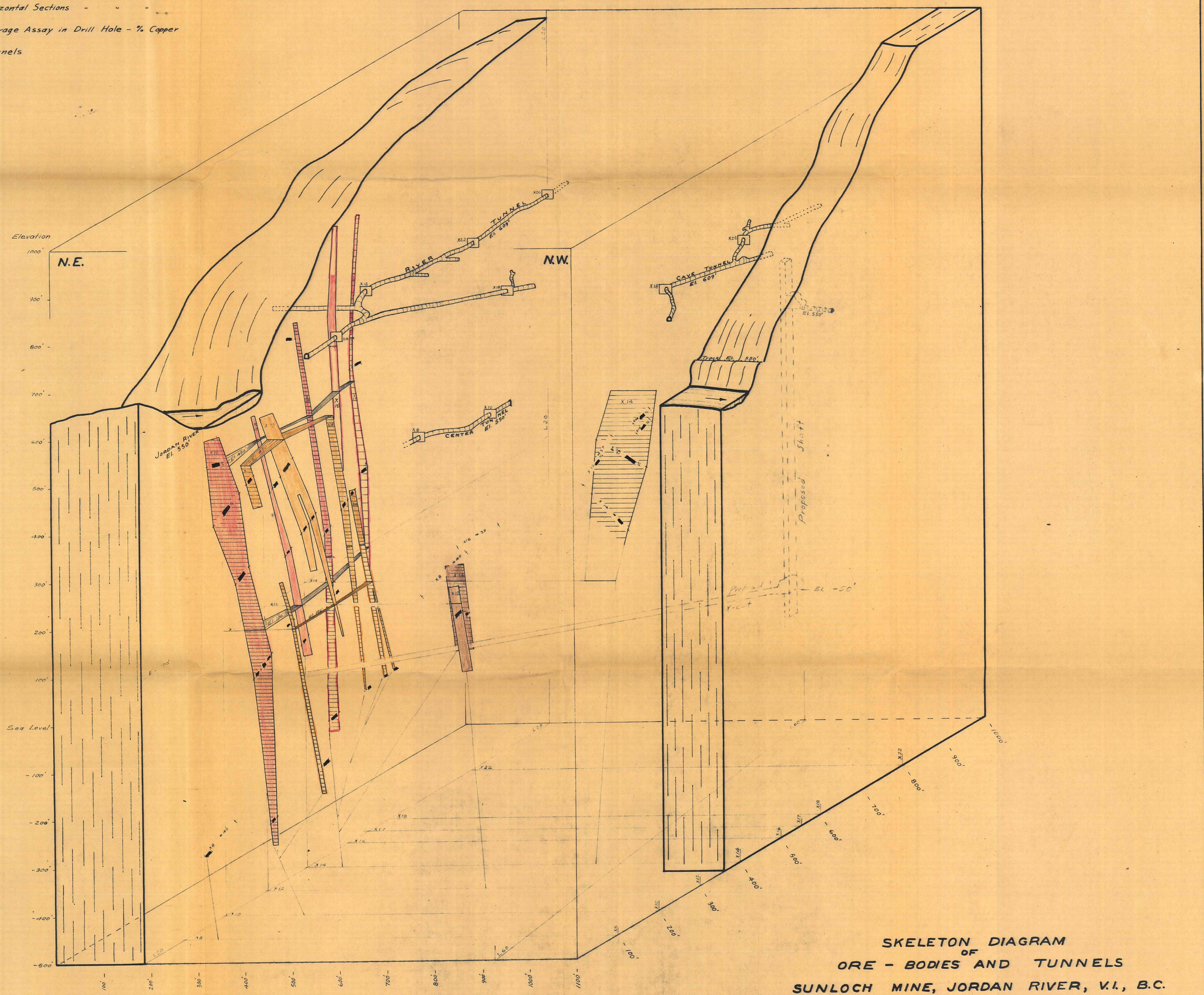
LEGEND

Vertical Sections through Ore Zones

Horizontal Sections " " "

Average Assay in Drill Hole - % Copper

Tunnels



SKELETON DIAGRAM OF ORE - BODIES AND TUNNELS

SUNLOCH MINE, JORDAN RIVER, V.I., B.C.

Scale : 1" = 100'

March, 1951

J.W. Young

HEDLEY MASCOT GOLD MINES, LTD.