THE MINERALOGY OF THE ORES OF THE DUTHIE MINE, SMITHERS, B.C.

By

A. Kenneth Roberts.

4th year Geological Engineering,
University of British Columbia.

Dept. of Geology
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ABSTRACT

Perhaps the most convenient and practical method of making a detailed study of ores is by the technique of polished sections. Apart from the establishment of the identity of the minerals, the following characteristics of the minerals may, as a rule, be satisfactorily determined: (1) grain or crystal size, (2) shape, (3) degree of crystallization, (4) mutual relationships between the grains, (5) structural features, and (6) paragenesis or sequence of crystallization.

Use of this technique in the examination of the ore from the Duthie mine at Smithers, B.C., showed that the ore minerals were medium grained and bore relatively simple relationships with one another. The various minerals identified, and their sequence of crystallization, beginning with the oldest, appeared to be as follows: arsenopyrite, pyrite, galena, sphalerite, chalcopyrite, bornite, pyargyrite, tetrahedrite, and gold.

The Mineralogy of the Duthie Mine, B. C.

I. Introduction

A. Location

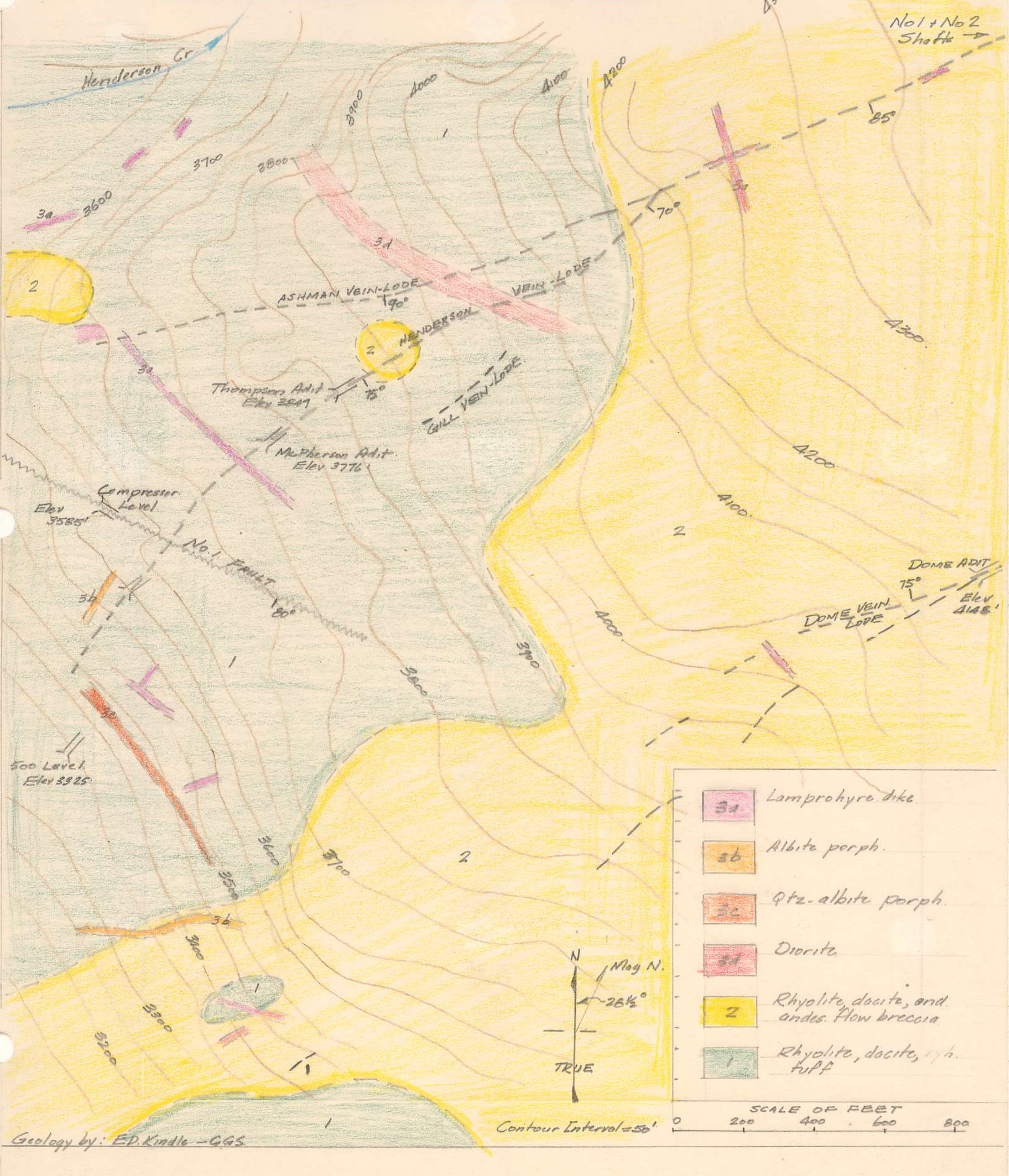
The Duthie mine, in the Omineca Mining District, is on the western slope of Hudson Bay Mountain, 7½ miles west of Smithers. A good motor road about 15 miles long connects the mine with Smithers, and the Prince George - Prince Rupert branch of the Canadian National Railways, as well as the highway, pass through the town.

The Duthie property includes the following mining claims; Henderson, Raven, Hummingbird, Canary, Galena, Queen, Dome, White Swan, Pacific, and Vancouver Crown.

B. History and Development

The Henderson vein-lode was discovered in 1921 and the property was optioned by J. F. Duthie of Seattle, Washington. Underground operations began in 1922, and development was carried on till 1924. Small shipments of high-grade, hand-sorted ore were made in 1924, 1925, and 1926. In 1927 a modern 50-ton flotation mill was installed and 5500 tons of ore were treated that year. Production and development advanced rapidly during the next two years, and in 1929, 10,000 tons of ore were milled. In 1930 mining operations were suspended. Since this time the mine has been operated by various companies and leasers up to the present.

MAP OF THE DUTHIE MINE, SMITHERS, B. C.



II. General Geology[1]

The principal vein-lodes occur in rhyolite, dacite and andesite flows, flow breccias, and rhyolite tuffs, of middle or upper Jurassic age. (See map of Duthie Mine Property- page 2). The most common rock in the vicinity of the mine is the light-colored, fine-grained rhyolite.

Numerous lamprophyre, quartz-albite porphyry, and albite porphyry dikes of upper Cretaceous age intrude the volcanic rocks in the mine area. A gray diorite dike 50 feet wide intersects the McPherson and the 500 level in the mine. The vein-lodes are chiefly formed by replacement along four mine fault zones which are known as the Ashman, Henderson, Fault Plane and Dome. Generally, these mineralized fault zones strike northeasterly and dip 70° southeast to vertical. They vary from a few inches to 8 feet wide and from 700 to 3500 feet long.

Assay of 100 lb. test lots in 1942 were as follows:[2]

	Au.	Ag.	Cu.	Pb.	Zn.	As.	Sb.	Fe.	S.	SiO_2
	oz/ton	oz/ton	%	%	%	%	%	%	%	%
633T	0.20	250.5	0.7	34.6	13.4	1.6	1.5	8.6	16.8	9.5
634T	0.18	316.5	0.9	40.5	11.8	0.8	1.2	10.0	16.2	11.8

(1) Kindle, E. D. Mineral Resources, Hazelton and Smithers Areas, Cassiar and Coast Districts, British Columbia. G.S.C., Mem. 223.

(2) Annual Report of B.C. Minister of Mines, 1942, pp. A26 and A31.

III. Mineralogy

The information recorded in the main part of this report has been obtained from the microscopic examination of 12 polished sections of Duthie mine samples. The sections were cut by Mr. J. Donnan of the Department of Geology, University of British Columbia, then mounted and polished by the writer.

A. General

The metallic ore minerals, in order of abundance, are: arsenopyrite, galena, sphalerite, pyrite, chalcopyrite, bornite, tetrahedrite, and ruby silver (pyrargyrite). The ore also contains gold, but no free gold was visible.

The general mineralogical name ruby silver has been employed, rather than pyrargyrite, because microchemical tests indicated the presence of arsenic, in addition to the antimony. This is explained further in the report.

The non-metallic minerals associated with the sulphides are vein quartz, calcite, and possibly some siderite and rhodochrosite. The gangue minerals were relatively scanty in the samples examined.

B. Detailed

(1) Galena (PbS)

Galena is found in substantial amounts in all the vein-lodes throughout the mine. This mineral occurs as euhedral crystals with a medium to coarse texture (up to 1 c.m. in size). Some specimens exhibit high percentages of galena intimately mixed with sphalerite, chalcopyrite, arsenopyrite, and pyrite.

It was suspected that the galena carried substantial amounts of silver, since this is often the case in lead-zinc-silver deposits. A microchemical test was carried out using a particle of uncontaminated galena, but the test gave a negative result. However, since the lead was greatly in excess of the silver, it was thought to have interfered with the formation of the carmine-red crystals of silver bichromate.[3] A more accurate test would involve the precipitation and the removal of the lead first. Alternatively, a fire assay could be carried out on a galena sample not containing foreign matter.

Samples selected along the Henderson vein (3,800 foot level) assayed:

Gold	0.03 -	.145	oz/ton
Silver	0.50 -	1.00	oz/ton
Lead	10	-30	%
Zinc	5	-10	%

The values of the above metals vary widely from place to place in along the same vein. The average tenor of the ore mined since 1934 is close to: gold, .024 oz/ton; silver, 37 oz/ton; lead, 5%; and zinc, 5%.

The galena crystals join those of sphalerite, chalcopyrite, bornite and calcite along curved or sinuous boundaries, while the contacts with arsenopyrite, pyrite and quartz

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(3) Short, M.N. Microscopic Determination of the Ore Minerals, U.S.G.S. Bull. 914.

are straight or irregular. The straight contact results when euhedral crystals of arsenopyrite, and quartz are present.

A very important tendency of this ore, from an economical viewpoint, is the increase in silver values with an increase in the lead content.[4]

(2) Sphalerite (ZnS)

The sphalerite is not as plentiful in the samples examined as the galena, although this does not necessarily imply the same conditions at the mine. Other physical properties were: a fine-grained texture, a dark brown-black color, and the characteristic adamantine luster. The color indicates a high iron content. (i.e. approaching the marmatite variety of sphalerite).

A notable feature observed in these polished sections is the frequent inclusions, often microscopic, of chalcopyrite and some bornite in the sphalerite. The inclusions have curved or rounded contacts, and their distribution is uneven. In some places they tend to form along the cleavage directions of the sphalerite. It is generally believed that these inclusions result from (a) the "unmixing" or "exsolution" of a solid solution, or (b) replacement.[5] The former theory has the greater support.

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(4) Howard, H.M., Professor of Mineral Dressing, University of British Columbia, Personal Communication.

(5) Bastin, E.S. et al. Criteria of Age Relations of Minerals, Economic Geology, Sept.-Oct.,1931, pp. 561-610.

(3) Chalcopyrite ($CuFeS_2$)

As stated above, the chalcopyrite is found chiefly in the sphalerite. Although not abundant it occurs in blebs here and there throughout the ore. The evidence on hand shows that the sphalerite, chalcopyrite, and bornite were contemporaneous.

(4) Ruby Silver (Pyrargyrite, $3Ag_2S.Sb_2S_3$)

This mineral was observed as microscopic grains associated with quartz and galena in only 2 of the 12 polished sections. This was rather surprising since the ore has moderate silver values (10-40 oz/ton), and much of this amount would, in all probability, be furnished by the ruby silver. This scarcity of ruby silver could be attributed to two causes: (1) the samples came from points where the ruby silver content was low, or (2) the ruby silver occurs as lenses or stringers.

Microchemical tests gave positive tests for silver, antimony and arsenic. This was not unexpected, since the particles of ruby silver were very minute, and closely associated with galena and arsenopyrite.

(5) Arsenopyrite (FeAsS)

Arsenopyrite is the commonest mineral observed. Much of it occurs as euhedral crystals and appears to have been one of the earliest sulphides. The crystals average about .2 m.m. in size. Euhedral crystals are found included in quartz, and most of the other sulphides. Several good examples of arsenopyrite replacing the quartz were noted with diamond or square outlines. Areas on the polished sections clearly show the arsenopyrite replaced by the galena, sphalerite and chalcopyrite.

(6) Pyrite (FeS_2)

Pyrite was present as irregular masses in small amounts. The grain size varied from .05 to 2 mm. and averaging about 1 mm. The pyrite occurs most often with sphalerite and chalcopyrite. In some places galena, sphalerite and chalcopyrite appear to be replacing the pyrite. While the evidence is suggestive, it is not conclusive.

(7) Non-metallic Minerals

The non-metallic gangue minerals are quartz, calcite, and possibly rhodochrosite. The majority of the quartz was deposited early, but some evidence points to deposition during the main period of mineralization. Deposition of the calcite in the form of veinlets, in part preceded and in part followed the period of metallic mineralization. There is every indication that the early calcite and quartz have been replaced to some extent by the subsequent sulphides.

Tetrahedrite ($5Cu_2S.2\ (Cu,Fe)S.2Sb_2S_3$)

Although the samples and the polished sections were examined with great care, no tetrahedrite could be found. However, tetrahedrite does occur in the ore, and has been reported by Kindle. Whether the tetrahedrite is essentially the copper-antimony sulphide or silver bearing was not recorded.

The scarcity of the pyrargyrite and tetrahedrite made it impossible to determine satisfactorily the relationships of these minerals with the other minerals.

IV. Paragenesis

The age relationships of some of the minerals have been outlined. However, the sequence of events in chronological order is as follows:

(1) Quartz was the first mineral to fill the fault fissures, possibly in conjunction with calcite.

(2) Sulphide solutions of deep-seated origin began to deposit arsenopyrite and pyrite simultaneously. (This may or may not have been followed by some fracturing).

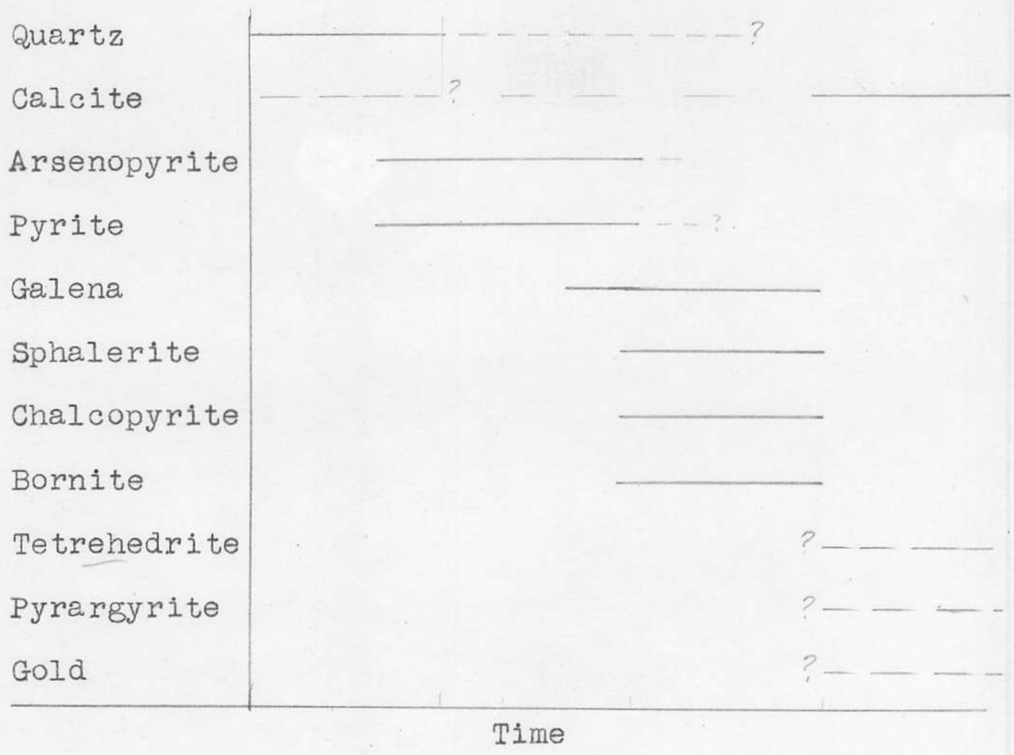
(3) The deposition of galena, sphalerite, and chalcopyrite- either contemporaneously or with an overlapping age relationship.

(4) The deposition of tetrehedrite, pyrargyrite, and gold were probably deposited after the sphalerite and chalcopyrite.

(5) The calcite filling the small fractures and openings concluded the deposition.

These latter stresses and resulting fractures are shown by calcite filled fissure veinlets in the sphalerite, and by the bent cleavage planes in the galena.

The evidence upon which the above sequence of events are based, is on the criteria of the age relations of minerals as summarized by E. S. Bastin[6] et al. In some instances the age relations have been assumed perhaps without sufficient supporting criteria. Furthermore, the writer feels that paragenesis as determined from the study of the polished sections should be supplemented and confirmed by a detailed field study of the mine property, the general geology of the mining area, the vein system, and structural controls,(if any are present).



V. <u>Genesis and Age of Deposit</u>

The mineralization was probably accomplished by ascending hot metal-bearing solutions in the fault and fissure systems. These solutions were a product of differentiation

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(6) Bastin, E.S. et al. <u>Criteria of Age Relations of Minerals,</u> Economic Geology, Sept.-Oct., 1931, pp.561-610.

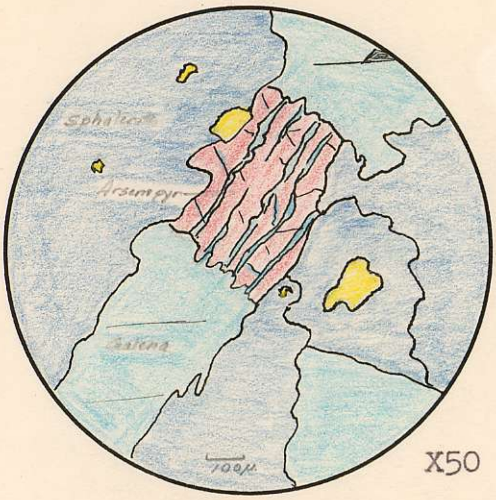


Fig. 1

Section VIII

Arsenopyrite in a matrix of galena and sphalerite. The fragments of arsenopyrite were probably a single grain, which was fractured and then replaced by the galena.

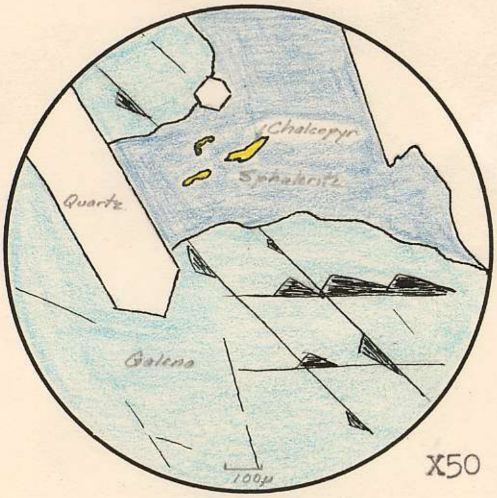


Fig. 2

Section XII

Typical galena, sphalerite, chalcopyrite and quartz associations. The sphalerite separating two areas of galena with similar orientation suggests replacement of the galena by the sphalerite. Euhedral crystals of quartz indicate it is early.

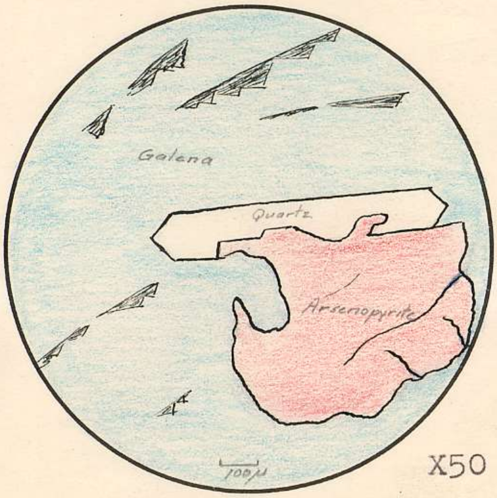
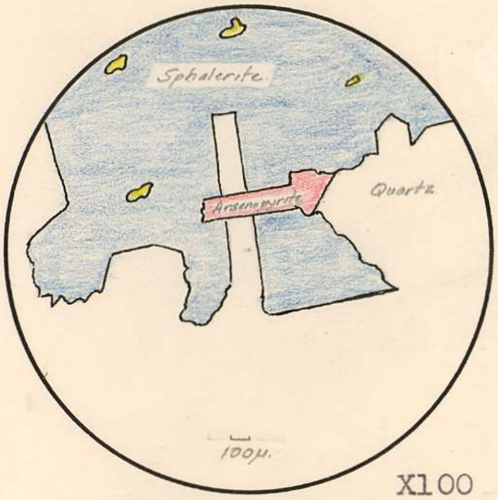


Fig. 3

Section VI

Relationships between galena, arsenopyrite and quartz. The arsenopyrite has replaced the earlier quartz crystals and in turn the galena has begun to replace the arsenopyrite to a limited extent. The bent cleavage of the galena has been caused by stress.

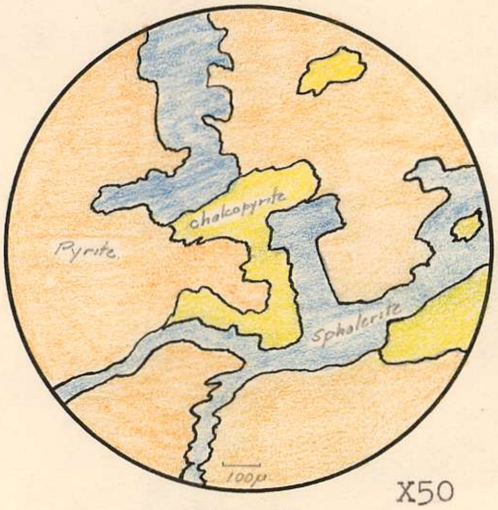


X100

Fig. 4

Section XII

Arsenopyrite and quartz. This camera lucida drawing indicates the possibility of the arsenopyrite deposited later than the quartz.

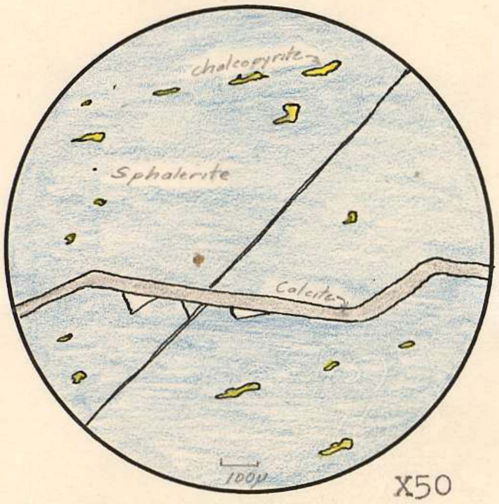


X50

Fig. 5

Section I

Sphalerite, chalcopyrite and pyrite. The sphalerite and chalcopyrite vein and replace the chalcopyrite.



X50

Fig. 6

Section I

Sphalerite, chalcopyrite, and calcite. Typical intergrowth of the sphalerite and chalcopyrite. Calcite filling a fracture developed in the sphalerite. The small blebs of chalcopyrite are probably oriented along the cleavage planes of the sphalerite.

of the magma, which formed the nearby diorite and granodiorite stocks and bosses; and the many dikes in the mine area. Some replacement of the wall rock undoubtably occurred.

The age of the diorite and granodiorite intrusive and dikes has been placed as upper Cretaceous.[7] Hence, the age of the deposit may be upper Cretaceous or possibly Tertiary.

VI. Type of Mineralization (Hypogene or Supergene)

All the metallic minerals, except pyrargyrite are generally hypogene in character. Tetrahedrite, arsenopyrite, and pyrite are invariably hypogene, while galena, sphalerite, chalcopyrite, or pyrargyrite may form under either hypogene or supergene conditions.

The lack of confirmatory evidence indicates that the problem of hypogene or supergene mineralization, and that of depth relationships, can be solved only by careful field observations including sampling, and a more extensive examination of polished sections.

VII. Milling Character of the Ore

The milling character of the ore depends on many factors, the most important are: (1) specific gravity of constituent minerals, (2) crystal structure, (3) magnetic sus-

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(7) Kindle, E.D. Mineral Resources, Hazelton and Smithers Areas, Cassiar and Coast Districts, British Columbia. G.S.C., Mem. 223, 1940, pp. 84-92

ceptibility, (4) fracture and cleavage, (5) hardness, brittleness, and friability, (6) and surface properties.

The mineralization tends to be uneven, causing a wide variation from place to place of the valuable metals present. In the polished sections the relationship between the galena and sphalerite indicates that it would be comparatively easy to effect a separation (grinding 60% to 200 mesh). Any silver values in the lead will follow the galena. Since tetrahedrite tends to "slime", precautions would be necessary to reduce or eliminate this undesirable condition.

VIII. Classification of Deposit

On the basis of the vein structure, mineralogy, mineral texture and nearness of the manifestations of igneous activity, the deposit bears the characters of a mesothermal type.

Conclusions

This study of the mineralogy of the producing veins of the Duthie mine has shown that the silver and gold values vary widely. The silver seems to occur chielfy in the galena and the pyrargyrite.

The galena, sphalerite, chalcopyrite and bornite are of contemporaneous or overlapping age.

The tetrahedrite, pyrargyrite and gold were probably deposited at the same time.

The minerals possess the characteristics of the mesothermal type of deposit.

There is not enough evidence on hand to state, with any degree of certainty, whether the mineralization is hypogene or the result of supergene or secondary enrichment.

Acknowledgements

The writer would like to extend his thanks to Drs. H.V. Warren and R.M. Thompson for this interesting assignment, and assistance on the problems arising from the examination of the sections.

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(1) Kindle, E.D. Mineral Resources, Hazelton and Smithers Areas, Cassiar and Coast Districts, British Columbia. G.S.C., Mem. 223; 1940. pp.84-92.

(2) Bastin, E.S. Graton, L.C., Lindgren, W., Newhouse, W.H., Schwartz, G.M., Short, M.N., Criteria of Age Relations of Minerals, Economic Geology, Sept.-Oct. 1931. pp.561-610.

(3) Short, M.N. Microscopic Determination of the Ore Minerals, U.S.G.S. Bull. 914

(4) Annual Report of B.C. Minister of Mines, 1942 P.A26, A31, and A54.

The following table lists (X) those ore minerals identified in each of the 12 sections.

Section No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Galena				X	X	X		X	X	X	X	
Sphalerite	X	X		X	X	X	X	X	X		X	X
Chalcopyrite	X	X		X	X	X	X	X	X		X	X
Ruby Silver											X	X
Arsenopyrite	X	X	X		X	X	X			X	X	X
Pyrite	X	X	X	X	X		X		X		X	X
Bornite	X							X				X