A STUDY OF TETRAPHILETITE IN SOME
BRITISH COLUMBIA ORES

by

Clifford S. Lord

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INTRODUCTION
IMPORTANCE OF TETRAHEDRITE

The importance of silver production from the pyrite-chalcopyrite-sphalerite-galena type of ore is well recognized. About two-thirds of the entire production is obtained from argentiferous galena. Guild appears to have shown that silver, above 0.10 percent, exists in galena as unreplaced spots of silver minerals, such as tetrahedrite.

He says:

"Indeed, much of the galena in the silver deposits has replaced tetrahedrite and its silver content is thus due to residual spots of silver-bearing tetrahedrite as well as argentite."

Tetrahedrite, then, is of fundamental importance in primary silver-lead ores.

It is of no less importance as the ultimate source of the silver in secondary silver deposits. In Guild's words,

"The ruby silvers rank amongst the most important silver minerals in many of the rich deposits of the United States and elsewhere. As already pointed out the early minerals of silver are confined mainly if not entirely to tetrahedrite and argentiferous galena. They are therefore held to be the source of the later enriched products. Tetrahedrite is probably the most prolific source as shown by the microscopic investigations, and the fact that the late silver minerals are most often arsenic or antimony compounds."

The above statements should leave no doubt as to the ultimate economic importance of tetrahedrite. Any data on such a mineral are likely to prove to be of eventual, if not immediate, value. These considerations clearly justify the proposed investigation - a study of the tetrahedrite in a suite of British Columbia ores.

OBJECT AND AIMS OF PAPER

Referring to the composition of tetrahedrite,

Winchell says,


"Most of the standard text books of mineralogy now give the formula of tetrahedrite as Cug Sb2 S7 with the comment that Ag, Zn, Fe, may "replace" part of the Cu under valence control. That is, Ag5 Sb2 S7, Zn4 Sb2 S7, and Fe4 Sb2 S7 are supposed to be possible constituents of tetrahedrite crystals to some extent. It is too early as yet to claim that the constitution of tetrahedrite can be expressed in any form that is correct beyond question but it is at least possible to show conclusively that the current formula is incorrect, if the best analyses now available can be trusted."

and further, that,

"It is unfortunately true that practically all analyses now available were made on samples whose purity was not tested by microscopic methods --- "

Therefore, analyses of microscopically selected material should constitute a definite contribution towards the solution of this problem.
III

The silver content is of prime economic importance. It is hoped that it may show some definite relation to -

1. Geographic distribution of deposits
2. Mineral association
3. Type of deposit
4. Relative age of galena and tetrahedrite
5. Physical properties

Lastly, it may be found possible to correlate the results with those of other workers in this field.

GENERAL SUMMARY

A suite of British Columbia tetrahedrite ores has been collected. Ores from ten localities were found suitable for the present investigation. From these, pure tetrahedrite has been selected, checked with the metallographic microscope, and analysed. An attempt has been made to develop a satisfactory formula, and other studies undertaken, as suggested above.
Before proceeding, the writer wishes to acknowledge his indebtedness to all those who have in any way assisted him in the preparation of this paper. To members of the Geological Staff of the U. B. C., the author wishes to express his sincerest thanks. Special thanks are due Dr. H.V. Warren, of the U. B. C., under whose supervision this work was carried out. To Mr. J.D. Galloway, Provincial Mineralogist, and Mr. F. Woodside, B. C. Chamber of Mines, the writer is indebted for comprehensive suites of tetrahedrite-bearing ores of British Columbia. All analytical work was carried out under the close supervision of Mr. H.N. Thomson, Department of Mining and Metallurgy, U. B. C., without whose guidance and sustained interest the work could not have been carried on. Mr. W.B. Bishop very kindly undertook to do the required fire-assaying. Lastly, but none the less sincerely, the author wishes to thank his colleagues, who have in many small ways collaborated with him during the preparation of this paper. Deserving special mention are Messrs. J. Currie and A. Smith.
CHAPTER I

METHODS EMPLOYED
Outline Map
of
BRITISH COLUMBIA

SPECIMENS OF TETRAHEDRITE
which are studied in this paper
are from the deposits
SHOWN IN RED

one specimen, not shown,
came from Keno Hill, Y. T.
PREPARATION FOR ASSAY

Methods employed in the collection, selection and assay of the material will be briefly described here.

Through the kindness of Mr. J.D. Galloway, Department of Mines, Victoria, and Mr. F. Woodside, B.C. Chamber of Mines, Vancouver, a suite of tetrahedrite-bearing B.C. ores was made available for study.

Of these, only a few proved suitable. Since it was necessary to separate very pure tetrahedrite from the ores only comparatively coarse grained material could be used, as selection from a fine grained intergrown ore would have been impracticable.

From each of these apparently suitable specimens, chips of tetrahedrite were taken, mounted in dammar gum, and polished, preparatory to microscopic examination. Examination showed some of the tetrahedrite to be so intimately intergrown with other minerals as to preclude any possibility of a satisfactory separation, or of a satisfactory, corrected, analysis.

Specimens which proved, in polished section, to contain pure or nearly pure tetrahedrite, were either,

1. in the case of the less complex ores, broken down with a light hammer, the pure tetrahedrite being continuously selected,

or,

2. crushed to -10 mesh.
Where crushing was adopted, all ore was passed through a 10 mesh screen and caught on 14 and 20 mesh screens. It was not found necessary or practicable to deal with material of -20 mesh.

It was found most convenient to roughly select the mineral by eye, and to check the selection with a 10 X binocular microscope.

Pyrite and chalcopyrite were common impurities. The latter was commonly finely disseminated throughout much of the tetrahedrite. Here, it was decided to select a few hundred milligrams free from the impurity and to assay this for iron. This, subtracted from the percentage of iron in the main sample, would indicate the amount of iron to be removed as pyrite or chalcopyrite impurity. The small percentage of iron in the purer sample would be taken as entering into the composition of tetrahedrite.

This method was not found practicable for two reasons -

1. the near impossibility of selecting mineral entirely free from the finely disseminated impurities, especially chalcopyrite.
2. the relatively broad accuracy limits of the iron assays when dealing with such low percentages.

Eventually it was decided to remove all iron as pyrite or chalcopyrite according to the impurities found. Where no iron impurities were found, iron was assumed to occur
Selecting and checking pure tetrahedrite.

The crushed and sized ore can be seen, spread out on sheets of paper, on either side of the microscope.

The grains are picked out with tweezers, examined under the binocular, and placed in suitably labelled phials, shown near the microscope.
as pyrite. Alternatively, iron might have been taken in as an impurity.

The zinc content was more troublesome. In only three cases was it known to be present as an impurity - as sphalerite. In other cases it was not noted in the selected mineral and yet occurred, in quantities up to several percent, in one case about 6 percent.

The possibilities are partly in solid solution, partly as inclusions. A small percentage of impurity would escape detection. It is unlikely, however, that several percent of sphalerite would pass unnoticed.

To check the selected mineral, a few grains (usually between 6 and 12) were embedded in Canada balsam, polished and examined under the metallographic microscope both by reflected and oblique illumination. The grains were selected at random from each sample and were of such a size as to give an area of
as pyrite. Alternatively, iron might have been taken to enter the formula, with zinc.

The zinc content was more troublesome. In only three specimens was it known to be present as an impurity - as sphalerite. In other cases it was not noted in the selected mineral and yet occurred, in quantities up to several percent, in one case about 6 percent.

The possibilities are

1. that it is present as sphalerite and escaped detection under the microscope.

2. that zinc enters into the composition of tetrahedrite.

3. that it occurs partly as an impurity and partly as a mineral entering into the composition of tetrahedrite.

The possibility that zinc might be present in solid solution has not been considered.

Considering the method of checking the purity of the selected tetrahedrite it is quite possible that a small percentage of impurity would escape detection. It is unlikely, however, that several percent of sphalerite would pass unnoticed.

To check the selected mineral, a few grains (usually between 6 and 12) were embedded in dammar gum, polished and examined under the metallographic microscope both by reflected and oblique illumination. The grains were selected at random from each sample and were of such a size as to give an area of
polished surface about equivalent to a 1/8 inch disc.

The pure mineral was then ground, thoroughly mixed, and was ready for assay.

ASSAY METHODS AND RESULTS

Standard commercial assay methods were employed throughout. Results were recorded to tenths only. Further figures would have been meaningless.

In all cases the percentage content of the following elements was determined — Copper, Silver, Lead, Zinc, Insoluble, Iron, Antimony, Arsenic and Sulphur. In one sample a mercury determination was made and checked.

The general methods followed will be outlined here. No attempt will be made to give the detailed procedures.

Copper (all samples).

Copper was determined by the Fluoride-Iodide method.

Thomson, H.N.: Copper Determination by the Fluoride-Iodide Method.

The procedure, as outlined by Thomson, was followed closely excepting that .5 to 1 gram of ferrous ammonium sulphate was added to the sample in each case. This was done so as to have the assay made in the presence of iron, a condition essential to accuracy. The iron hydroxide precipitate is also used as an indicator of neutrality.

Precautions taken, when using this method for the determination of copper in the presence of mercury, are
described in Chapter III under "Analysis and Formula".

All copper determinations were entirely satisfactory.

Single determinations were made on each, using 250 milligrams of mineral. All titration end points were reasonably permanent, indicating satisfactory conditions throughout. Samples number 2, 3, 4 and 6 were re-assayed and checked closely.

Silver (all samples).

Mr. W.B. Bishop kindly offered to run all samples for silver. One-half to 1 gram charges were used with standard fire assay methods. A correction for absorption of silver by the cupel was made where necessary, as in the case of the high-silver samples.

No check assays were made.

Lead, Zinc, Insoluble and Iron (Samples 1, 2, 3, 5 & 6).

Assays for this group of elements were run on 500 milligrams, of samples 1, 2, 3, 5 and 6.

Standard methods were used, excepting insofar as they were modified, to permit determinations of the four elements to be made on the one weight of mineral.

The mineral was brought into solution with hydrochloric acid and nitric chlorate mixture and then fumed with sulphuric acid.

Lead was removed at this point as insoluble lead sulphate, together with "Insoluble". It was then dissolved in
ammonium acetate, separated from undissolved material including "Insoluble", and titrated with ammonium molybdate. As no lead molybdate precipitates formed, lead was taken as nil in all cases.

**Insoluble** - The above residue containing the "Insoluble" was boiled with hydrochloric acid, filtered, ignited and weighed.

**Iron and Zinc** - Iron and zinc were contained in the filtrate from the lead sulphate.

Iron was separated from zinc as the hydroxide in alkaline solution. It was filtered out, dissolved, and titrated with potassium dichromate in acid solution.

Zinc determinations were made, on the filtrate from the iron hydroxide, by the Ferricyanide Method. This proved to be quite unsatisfactory on such low percentages of zinc with 500 milligrams of sample.

The iron determinations were later checked. Any great accuracy is not to be expected by volumetric methods, on such low percentages, where the amount of the sample taken must be kept below 500 milligrams.

The results of the check assays are tabulated below. They give some idea of the order of accuracy obtainable under these conditions.
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<td>trace</td>
</tr>
<tr>
<td>2</td>
<td>.5 - 1.0</td>
<td>trace</td>
</tr>
<tr>
<td>3</td>
<td>1.2</td>
<td>trace - .4</td>
</tr>
<tr>
<td>5</td>
<td>3.8</td>
<td>4.8</td>
</tr>
<tr>
<td>6</td>
<td>.5 - 1.0</td>
<td>1.4</td>
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Lead and Zinc (Samples 4, 12, 17, 18 and 20).

Here, lead and zinc were run on the same sample (500 milligrams), the "Insoluble" and iron being determined later, with the sulphur.

Ferrous ammonium sulphate was added to each, to bring down antimony and arsenic with iron hydroxide in alkaline solution. Lead was to have been separated as insoluble lead sulphate. Lead results were again nil in every case.

Zinc determinations were made by the Ferricyanide Method but proved to be unsatisfactory, as before.

Zinc (in all samples).

It was necessary, then, to make zinc assays on all samples by the "Phosphate Zinc" Method. Essentially, by this

method, the zinc is separated as zinc sulphide in weak acid solution and precipitated as zinc ammonium phosphate in a neutral solution. The weight of the phosphate multiplied by \(0.3664\) gives the weight of zinc in the assay.

There is good reason to believe that these results are accurate.

Only in one case was an assay duplicated. This checked.

250 milligrams were used for all assays.

Sulphur, Insoluble and Iron (on all samples).

250 milligrams and, where possible, 500 milligrams were taken of all samples and these assayed for the above three elements. "Insoluble" and iron determinations served as a check on those already obtained for samples 1, 2, 3, 5 and 6.

The general procedure is to convert the sulphides to sulphates and to precipitate the sulphate as barium sulphate, to be weighed and calculated to sulphur.

The sulphur was brought into solution and filtered from the "Insoluble". This was boiled with hydrochloric acid and weighed.

The sulphur, in hydrochloric acid solution, was precipitated as barium sulphate by the addition of barium chloride. This was filtered out and weighed.

Iron was precipitated from the filtrate with ammonium hydroxide, re-dissolved in acid, and determined as before.
Antimony.

In every case, the antimony determination was made on 250 milligrams of mineral.

The weighed mineral was brought into solution with nitric chlorate, the solution evaporated to dryness twice with hydrochloric acid, and the residue taken into solution with hydrochloric acid and tartaric acid. Sodium sulphite was added as a reducing agent. Hydrogen sulphide gas was bubbled in, precipitating arsenic, antimony and copper. Arsenic and antimony were dissolved from this precipitate with sodium sulphide and sodium hydroxide, then precipitated with sulphuric acid. The antimony of the precipitate was taken up with hydrochloric and tartaric acid. Antimony was titrated, in the presence of sodium bicarbonate, with iodine solution, free iodine at the end point being detected with starch solution.

All end points seemed satisfactory. However, such a procedure gives scope for appreciable manipulation errors.

Arsenic.

In most cases, 500 milligrams of mineral was assayed for arsenic. In a few cases, only 250 milligrams was available.

The Hydrozine Sulphate Distillation Method was employed, as outlined by Keffer.

Essentially, the arsenic is brought into solution under oxidizing conditions and then distilled off in the presence of hydrozine sulphate, hydrochloric acid and sodium.
bromide. The arsenious chloride is condensed, dissolved in water, and titrated against an iodine solution in the presence of sodium bicarbonate.

These determinations appeared to be perfectly satisfactory.

It is worth noting here that, should tin have been present in the sample, it would have been distilled over and titrated with the Arsenic. The results have been recorded as percent arsenic. Actually they may be percent arsenic plus tin.

Incidentally, the determination of tin by distillation appears to be a new method. In view of the fact that present methods do not appear to be wholly satisfactory, it would appear to be well worth further investigation.

General.

Assays could not be run in duplicate due to insufficient material. For the same reason, weights of mineral were sometimes used which gave titrations of only a few cubic centimeters. Great accuracy is not to be expected from such titrations.

**COMMENTS ON GENERAL ACCURACY**

As will be noted in the next chapter, the totals in all assays fall below 100 percent, ranging from 93.2 to 98.5. Lacking the time and material required for a check of
all assays, the following comments are in order.

All assay work was carried out with care, as it was realized from the first that check assays could not be run. Further, all work was carried out under the close supervision of Mr. H.N. Thomson, Professor of Metallurgy, University of British Columbia.

A few check assays have been run, as mentioned above. These checked to within the limits of error of the methods employed and it is thought that no major errors occur in the figures given. Errors in the order of fractions of a percent are to be expected, from the methods employed, but it is clearly not in these discrepancies that we may look for the missing percentages.

Several other points tend to support the belief in the general accuracy of the figures given, as:

1. The uniformly low results.

The maximum divergence of totals is 5.2 percent, and the average variation much less. The fact that these are uniformly low suggests one of two alternatives. Either the methods employed give consistently low results or impurities, not assayed for, are present throughout. A combination of these two possible causes is also to be considered.

As more or less standard assay methods have been used throughout, the second alternative appears to be the more probable.

Had the totals been erratic - some below and others above 100 percent - the fault would obviously have been with
the assaying.

2. A tendency towards constancy in the summation of the atomic proportions of copper and silver. This will be seen from the table on Page 7.

Excluding Samples 1 and 5 (by reason of their peculiar composition) the remainder fall into three groups. These are: Samples 2, 6; Samples 3, 17, 20; Samples 4(?), 12, 18.

3. A parallel tendency in the case of arsenic and antimony. Here we have exactly the same groups as before: Samples 2 and 6; 3, 17 and 20; and 4, 12 and 18.

Such close, parallel grouping must be more than a coincidence.

EXPLANATION OF LOW TOTALS

The following considerations account, in part at least, for the low totals.

1. The probable presence of some soluble or partially soluble gangue, giving a low result for "Insoluble", which is assumed to include all gangue, as quartz.

2. The presence of minor amounts of copper carbonates and silicate (crysocolla) in the selected material.

3. The probable presence of other elements not assayed for.

4. The persistent presence of a dull brownish black to black coating on the selected grains.

5. The persistent presence of this same non-metallic material in prominent parts throughout many of the
sections examined.

Other elements not assayed for and likely to occur are, as suggested by Dana, nickel, cobalt, mercury, manganese, bismuth and tin. The tin content, if any, has probably been included in the arsenic results, as explained above.

Various elements might be present in a soluble gangue, such as lime and magnesia, barium, sulphate, alumina, etc.
CHAPTER II

THE ORES - MINERALOGY AND PARAGENESIS.
SUMMARY OF CHAPTER

The mercurial ore, from the Windermere, has been adequately treated in Chapter III.

The ores from the other nine localities will be dealt with here.

Each deposit will be discussed briefly, insofar as published data are available. In some cases a perusal of the literature has revealed no references to the deposits. In such cases, a general district description is all that has been possible.

The specimens from the deposits will then be dealt with, each in turn, first macroscopically and then microscopically, giving the mineralogy and paragenesis as determined under the metallographic microscope.

Studies of mineralogy and paragenesis were undertaken for several reasons.

1. An accurate idea of the mineral association is essential in view of the impracticability of selecting absolutely pure tetrahedrite for assay.

2. In determining the order of deposition of the minerals, special attention was given to galena-tetrahedrite relations. As suggested by Warren, the order of deposition of these minerals may bear some relation to the distribution of silver between tetrahedrite and galena in the same ore. Early galena might be shown to be the silver bearing mineral or, should tetrahedrite be the earlier of the two, it may be the
silver carrier. This possibility will be discussed later, insofar as possible without assays of the galena.

3. Further work will be necessary, involving assays of the accompanying galena, to complete this phase of the investigation. The paragenetic determinations, already made, will be essential.

4. It may be possible to show some relation between analyses and mineral association. This would be especially useful in the case of the silver content.

THE ORES: THEIR MINERALOGY AND PARAGENESIS

Azurite, malachite and crysocolla have been recognized in many specimens and probably occur to some extent in all.

In the description of mineralogy and paragenesis, but little attention has been paid to these supergene minerals. At the time, it was not thought that they would be of any particular importance in this study.

Azurite, as suggested by Dolmage, may be the more common carbonate with tetrahedrite, at least under conditions of alteration as found in British Columbia.

Specimen No. 1.

This has been adequately treated in Chapter III.

Specimen No. 2.

Black Bear Group, Cuesnel Mining Division.
Location - The claims are situated about 30 miles south-east of Quesnel, near the northeast bank of Quesnel river. They are reached by a road and trail from the town.

The deposit - This group is described in the 1921 report to the British Columbia Minister of Mines as the Copper Queen Group.

The 1928 description is found under the heading of Black Bear Group.

Mineralization accompanies a quartz vein occurring in a shear zone in what has been classified as an augite porphyrite by the Provincial Mineralogist. The vein is 2 to 2½ feet, and the shear zone about 15 feet, in width. Tetrahedrite, azurite and a little chalcopyrite are noted. The vein trends north and south and dips 27° east. The schist enclosing the quartz vein is reported to be barren.

Macrosopic description - In the material investigated, tetrahedrite was scattered as highly irregular and interconnected masses through a medium-grained, granular, milk-white quartz gangue. A little limonite and azurite are present. The tetrahedrite is finely granular and so shows a much-interrupted fracture. In detail, as under a hand lens, individual grains of tetrahedrite seem to have the characteristic conchoidal fracture and lustre.

Paragenesis - Tetrahedrite, quartz and a single grain of a greenish carbonate gangue were the only minerals recognized.
Specimen No. 3.

Jo-Jo Group. Three Forks, Slocan Mining Division.

Location - The claims are situated about 7 miles from the town of Three Forks (on the C.R.R.).

The Deposit - In the 1904 Annual Report of the B. C. Minister of Mines this group is stated to be of "about the same character" as the McAllister group, which it nearly adjoins.

B.C. Minister of Mines; Ann. Rept., 1904, p.182.

On this property, a mineralized quartz vein, lying between schist and argillite, trends northeast-southwest, and dips 50° southeast. The vein is 3 to 4 feet wide and is reported to carry "galena, gray copper, and silver sulphides, the ore as shipped, running over 250 oz. to the ton."

Macroscopic description - Tetrahedrite occurs in bunches and irregular stringers between well rounded areas of bluish white milky quartz. Minor amounts of the mineral have good conchoidal fracture and brilliant lustre. Most of the mineral has a less regular fracture and somewhat lower lustre.

Mineralogy and Paragenesis - In polished section, tetrahedrite, galena and sphalerite (?) were recognized. The gangue is quartz.

Tetrahedrite constitutes the main bulk of the metallics. Galena occurs in minor quantities. Sphalerite (?) is rare.

The order of mineral deposition has been determined satisfactorily; at least for the sections examined.

The sphalerite was not identified with certainty. By
SPECIMEN 3

Tetrahedrite and sphalerite. Tetrahedrite, here, is unquestionably the younger mineral. It embays, veins, and includes, the sphalerite.

Camera lucida drawing X 275
SPECIMEN 3

A veinlet of tetrahedrite and galena in quartz.

Tetrahedrite first veined the quartz. Galena has now largely replaced this vein, leaving a few unreplaced "islands" and specks of tetrahedrite.

Galena etched with nitric acid
Panchromatic plate
1/50 second exposure X 85
SPECIMEN 3

Etched galena replacing tetrahedrite and quartz. The well rounded outlines of unreplaced "islands" of tetrahedrite and quartz show clearly. There would seem to be little doubt as to the late age of the galena.

Panchromatic plate

1/50 second exposure    X 85
SPECIMEN 3

Galena, quartz and tetrahedrite. The galena veins the tetrahedrite. Contradicting this evidence we have the tetrahedrite embaying, and including "islands" of the galena. Direct evidence, then, is inconclusive. Indirect evidence, as the occurrence of chalcopyrite typically within tetrahedrite rather than within galena, suggests that tetrahedrite was introduced before the galena.

Camera-lucida drawing X 85
sunlight the powder was a light yellow - somewhat lighter than is typical for blende. Colour, etch tests, and hardness check with those given for blende.

Sphalerite is replaced by tetrahedrite as illustrated in the accompanying camera-lucida drawing. The veining of the sphalerite is obvious. Unreplaced "islands" of sphalerite are surrounded by the tetrahedrite of the replacing veinlet. The sphalerite boundaries tend to be concave towards the replacing tetrahedrite.

Galena clearly replaces tetrahedrite as shown in the accompanying photomicrograph (Plate V). In the photograph, the galena has been etched with nitric acid to give contrast. The well rounded unreplaced areas of tetrahedrite completely surrounded by the galena are excellent evidence of replacement. It is noteworthy that no specks of tetrahedrite, or other unetched mineral, were observed within the etched galena areas.

Replacement by galena shows a tendency to commence along the sphalerite-tetrahedrite contacts.

The sequence of deposition, as established above, is:

<table>
<thead>
<tr>
<th>youngest</th>
<th>galena</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tetrahedrite</td>
</tr>
<tr>
<td>oldest</td>
<td>sphalerite</td>
</tr>
</tbody>
</table>

This is the normal sequence for these minerals.

Specimen No. 4.

Langley Collection, Ainsworth Mining Division.

Location. - This ore was supplied by the B. C. Chamber of Mines from the Langley Collection from the Ainsworth Mining Division. The precise locality from which it was taken is not known.

The Deposits. - Most of the Ainsworth lead-silver deposits occur associated with the limestone bands of the Slocan and Ainsworth series, although some are in quartzites. Deposits are of both the true fissure and replacement types, and these are probably contemporaneous. The main fissure veins may follow master joint planes.

Galena and sphalerite occur in a gangue of calcite, siderite, quartz and fluorite. The galena is silver bearing, usually carrying about 20 ounces per ton. Native silver, where it occurs, is always secondary. Silver, where it occurs in the primary mineralization, is intimately mixed with the galena and invisible. No mention of tetrahedrite (or freibergite) was found.

It is interesting to note that "The replacement veins, in contrast to the fissure veins, carry low values in silver and lead and high values in zinc."


Macroscopic description. - Masses of tetrahedrite and a little galena occur in a gangue of coarse milky white quartz. The tetrahedrite varies from that with a high lustre and smoothly curving uninterrupted fracture to that with an
irregular fracture and steely lustre.

**Mineralogy and Paragenesis** - The following metallic minerals were recognized: tetrahedrite, galena, a supergene (?) mineral and chalcopyrite. They occur quantitatively in about the order mentioned, tetrahedrite being the most abundant. The others are relatively unimportant.

The gangue is quartz.

The order of deposition of the ore minerals could not be determined with any degree of certainty. Minerals, other than tetrahedrite, occur in such small quantities that but few contact areas could be found in polished sections.

The inter-relations of the supergene (?) mineral, the galena and the tetrahedrite are shown in the accompanying photomicrograph (Plate VII).

The supergene mineral veins, and is clearly younger than, the tetrahedrite.

It surrounds, and makes a feathery contact with, the galena. It is probably younger than the galena.

Near the centre of the photomicrograph is an area of tetrahedrite which has apparently been veined and nearly surrounded by galena. The supergene mineral has selectively replaced the galena so that now the galena veinlet is somewhat broken. Former continuity of the veinlet is further suggested by the parallel orientation of the cleavage pits in the galena at either end of the replaced veinlet.

The evidence for this process of the selective replacement of the galena is confirmed on other contacts in the
same section. The contact between the supergene mineral is usually a series of smooth curves. But the same supergene mineral has replaced the galena in such a way as to leave a highly irregular contact. This seems to the writer to suggest a more rapid replacement of the galena. It might, however, be explained by some reference to the properties which result in cleavage and lack of cleavage in galena and tetrahedrite respectively.

Chalcopyrite occurs in entirely insignificant quantities.

The mineral above described as supergene was not identified. The following properties were determined:

- slightly harder than tetrahedrite
- powder white
- very brittle
- colour darker and grayer than tetrahedrite or galena
- non-metallic
- stains dark brown with nitric acid
- the veinlets are banded parallel to the walls.

Paragenetic evidence brought out here is inconclusive. The following tentative sequence is suggested.

youngest | unidentified supergene mineral
----------|------------------------
         | galena
oldest   | tetrahedrite
SPECIMEN 4

Indicating replacement of galena and tetrahedrite. The replacing mineral ("Sup") has not been identified. It is probably supergene. "Island" and "delta" structure of the replaced minerals, especially the tetrahedrite, show clearly. The feathery borders of the galena contrast with the comparatively regular tetrahedrite boundaries. This is taken to indicate preferential replacement of the galena.

Panchromatic plate
1/50 second exposure
natural colors X 85
Location - Knox Hill lies about 40 miles northeast of the town of Rayo, Yukon Territory.

The deposit - In reviewing the mining industry in the Yukon for 1920, it was stated that these mines were the largest and most valuable of the time.

This property was leased from the Government in 1916, and the vein has been worked for a length of 4 to 8 feet and a maximum width of 0.5 to 1 foot. The ore does not extend deep and seems to be confined to the upper part of the vein.

Another general feature of the deposit is the existence of a number of northeast trending faults while the general trend of the mineralized veins is to the northwest. Ore shoots generally occur at or near the intersection of the two types of structures. This suggests that either:

1. fissure intersections have localized the mineralization, or
2. mineralization has localized the younger, northwest trending faults.
Specimen No. 5.

Sadie Claim, Keno Hill, Yukon.

Location - Keno Hill lies about 40 miles northeast of the town of Mayo, Yukon Territory.

The Deposit - In reviewing the mining industry in the Yukon for 1930, Cockfield states "The Sadie ore shoot proved to be the largest found to date and furnished 100,000 tons of ore."


This property was worked by Treadwell-Yukon Co., Ltd., under lease from Keno Hill, Ltd., during 1929, and was exhausted early in 1930.

This deposit lies at the southeast end of a faulted vein in greenstone - the Sadie-Treadwell vein. The vein has been traced for nearly 3000 feet with an average width of 7 to 8 feet and a maximum width of 70 feet. On the Sadie, the ore did not extend below the 400 foot level. This shallow depth seems to be characteristic of the ore shoots of the camp.

Another general feature of the camp is the existence of a number of northeast trending faults while the general trend of the mineralized veins is to the northeast. Ore shoots generally occur at or near the intersection of the two types of fissures. This suggests that either:

1. fissure intersections have localized the mineralization, or
2. mineralization has localized the younger, northwest trending faults.
In his 1930 report, Cockfield leaves this problem unsettled.


The vein is one of the main longitudinal fractures of the area, and is cut by a fault along its length. It is offset by numerous cross-fractures, and one large cross-fault on the Sadie property.

Galena, freibergite and sphalerite have been noted as the important ore minerals, with a siderite gangue. Native silver, pyrargyrite, quartz, arsenopyrite, pyrite and chalcopyrite occur.


Macrosopic description - Irregular masses of tetrahedrite occur in a light brownish siderite gangue. The few specks of galena are usually separated by gangue from the tetrahedrite. The siderite is coarse grained and shows the characteristic curving cleavage faces.

Mineralogy and Paragenesis - In polished section, tetrahedrite, chalcopyrite, and specks of a silvery mineral were recognized. The gangue is siderite. There is very little quartz.

It was not possible to cut a section showing tetrahedrite and galena in contact, as these two minerals were everywhere separated by gangue.

Tetrahedrite and galena are the only metallics present in appreciable quantities.

Chalcopyrite cuts the tetrahedrite in fine veinlets and is clearly the younger.
SPECIMEN 5

Tetrahedrite and siderite. Tetrahedrite veins siderite along the cleavage. One edge of the veinlet of tetrahedrite (dark) follows cleavage in the siderite throughout its length. Irregular replacement is more common on the other boundary. Such a veinlet would seem to have resulted primarily from fissure filling, and to a less extent from subsequent replacement of the host.

Panchromatic Plate

1/50 second exposure

X 85
Galena veins altersite, gained by cleavage directions as shown in the accompanying photomicrograph (Plate VIII).

An uncalcified silver mineral occurs in very small quantities as blebs with rounded to sub-angular outlines in the tetrahedrite. Its color is a lighter shade of silver gray than the tetrahedrite. Absence of relief would indicate that its hardness is not as high as might be expected, and it is not native silver and lead sulfide.

The texture of the tetrahedrite is as would be a well developed grainy texture. It was collected by Mr. A. Hatchinson, of Quenline, Cariboo Mining Union. Specimen No. 10 is from the Shuswap Group, Prince George, Cariboo, of which Mr. Hatchinson is part owner.
Galena veins siderite, guided by cleavage directions, as shown in the accompanying photomicrograph (Plate VIII).

An unidentified silver mineral occurs in very small quantities as blebs with rounded to sub-angular outlines in the tetrahedrite. Its colour is a lighter shade of silver gray than the tetrahedrite. Absence of relief would indicate that its hardness is about that of tetrahedrite. Hardness and etch tests could not be made on such small specks of material. It is not native silver and seems to be too hard for the usual silver and lead sulpharsenides and sulphantimonides.

The order of deposition is probably as follows:


This replacement of tetrahedrite by chalcopyrite is as would be expected.


The tetrahedrite in this ore assayed 25.2 percent silver, thus placing it in the class of Freibergite.

Specimen No. 6.

It is not known from what property this ore was taken.

It was collected by Mr. A. Hutchinson, of Quesnel, Cariboo Mining Division. Specimen No. 18 is from the Snowshoe Group, Prince George, Cariboo, of which Mr. Hutchinson is part
It seems probable that Specimens 6 and 18 are from the same property, especially as the ores themselves are macroscopically identical.

**Mineralogy and Paragenesis** - This ore was of exceptional purity. Only tetrahedrite and quartz were found in the polished sections.

The surface of the tetrahedrite was somewhat more pitted than is usual for this mineral.

Specimen No. 12.

**Location** - The location of the deposit from which this sample was taken is not known. The locality was given as "Illecillewat" which would place the deposit somewhere in the Revelstoke-Glacier district.

**The Deposits** - Gunning, in his report on the Big Bend map area, divides the mineral deposits into four classes, namely

2. Copper deposits.
3. Lead Zinc deposits.
4. Quartz-Tetrahedrite veins.


This specimen clearly belongs to the fourth class.

The only quartz-tetrahedrite veins described in the Illecillewat district are those of the Old George group.

**Gunning, H.C.; op. cit., p.191.**

These veins are staked on a series of small irregular,
lenticular, quartz veins in crystalline limestone. Ore minerals are pyrite, sphalerite, galena, boulangerite and probably tetrahedrite. Values are principally in silver. The gangue is quartz with some calcite.

Other similar occurrences in the Big Bend area carry tetrahedrite, bouronite and boulangerite (?).

Mineralogy and Paragenesis - Polished surfaces showed only very pure tetrahedrite and quartz.

Examination, under binoculars, of the crushed ore showed a very few grains of pyrite, chalcopyrite (?), galena and sphalerite (?).

These could not be found in the polished sections and no depositional sequence was worked out.

Specimen No. 17.

Submarine Group, Lytton, Ashcroft Mining Division.

Location - No reference to this property was found in the B.C. Minister of Mines or Geological Survey of Canada reports.

The Deposits - Lode deposits in the Ashcroft District have been summarized as follows:

B.C. Minister of Mines; Annual Report, 1925, p.79.

"Lode mining in this division has been identified chiefly with low grade copper impregnations of zones of shearing and fracturing in a complex series of rocks of plutonic, volcanic and sedimentary origin. This mineralization is of a possibly more recent origin than is the case with the ore bodies in closer relationship to the seat of the main western
batholithic intrusion."

Ore minerals are bornite and chalcopyrite, usually carrying values in gold and silver. No mention of the occurrence of tetrahedrite was found.

Mineralogy and Paragenesis - Tetrahedrite, galena and pyrite are recognized. The gangue is quartz. An unidentified, greenish, supergene mineral veins the tetrahedrite.

Galena and pyrite represent only a small percentage of the metallics. Pyrite appears as a few small rounded blebs.

The paragenesis, in this case, could not be determined very satisfactorily.

Pyrite, in deposits of this type, is usually an early-formed mineral. Its occurrence here, as isolated rounded grains, suggests early deposition.

Galena doubtfully veins tetrahedrite. Pyrite, taken to be the first-formed mineral, was noted in tetrahedrite only. This is confirmatory evidence of the late age of the galena, as, if galena had replaced pyrite prior to the introduction of tetrahedrite, it might now be expected to include some pyrite. However, due to the relatively greater abundance of tetrahedrite, the value of this indirect evidence is questionable.

Contradicting the above evidence as to the late age of the galena we have the fact that the tetrahedrite shows a tendency to embay the galena. However, this fact, in itself, has little diagnostic value.

The order of deposition, then, is doubtfully
SPECIMEN 17

An enlarged photograph of fragments of crystals of tetrahedrite from Ore Specimen 17. The general tetrahedral form shows clearly, with "o", "n" and "d" faces as marked.

x 8
The deposit—According to the 1923 report, mineralization accompanies a diorite dyke, up to 300 feet in width, cutting slate. The very slight mineralization of pyrite, pyromellite, and malachite is found in the diorite and along the diorite-slate contact zone. It is further stated that "assayed show that the mineralized rock does not carry appreciable values in gold and silver, and that the average samples have too low a copper content to be of exceptional importance."

In the 1923 report, according to information supplied, the mineralized zone is located about 15 miles north of a certain town.
determined as follows:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>youngest</td>
<td>galena</td>
</tr>
<tr>
<td>oldest</td>
<td>pyrite</td>
</tr>
<tr>
<td></td>
<td>tetrahedrite</td>
</tr>
</tbody>
</table>

This is the normal sequence.

The difficulty experienced in accurately determining this sequence was due to the impossibility of obtaining more than a very few galena-tetrahedrite contacts.

Specimen No. 18.

Snowshoe Group, Prince George, Cariboo.

Location - This property is mentioned in the 1918 Annual Report of the B.C. Minister of Mines. It is situated 15 miles northeast of Prince George.

The Deposit - According to the 1922 report, mineralization accompanies a diorite dyke, up to 300 feet in width, cutting shale. The very slight mineralization of pyrite, pyrrhotite, and chalcopyrite is found in the diorite and along the diorite-slate contact zone. It is further stated that "assays show that the mineralized rock does not carry appreciable values in gold and silver, and that the average samples have too low a copper content to be of commercial importance."

In the 1923 report, according to information supplied
by one of the shareholders, "We went down on this (shaft) 17 feet, to a depth of 27 feet, and ore taken out at this depth assayed $23 in gold, silver and copper, and had widened out from a stringer to 3 feet wide, with evidence of still further widening..." Unfortunately, the assay results for the three metals are grouped together. It should be emphasized that this information is supplied by one of the owners.

Mineralogy - Only tetrahedrite and quartz were noted in the polished sections.

Specimen No. 20.
Silver Star, Similkameen.

Location - This is one of the claims of the Sparkler Group, situated on Cambie Creek, a tributary of Similkameen river within about 6 miles of the headwaters.

The Deposit - Tetrahedrite is not mentioned in the descriptions of this group in the Annual Reports of the B.C. Minister of Mines. It is stated that "The copper contents were not assayed."


The pyrite-arsenopyrite-sphalerite-chalcopyrite mineralization seems to be genetically related to an intrusion of gabbro into the sedimentaries. The ore occurs in a series of veins and lens-shaped bodies, localized by joint planes and other fractures in the rock.

Mineralogy and Paragenesis - The minerals occurring are: arsenopyrite, sphalerite (?), galena, tetrahedrite, chalco-
pyrite, hypogene (?) veinlets and quartz.

The order of abundance of the ore minerals is about as follows, beginning with the most plentiful: tetrahedrite, chalcopyrite, galena, (sphalerite (?) and arsenopyrite).

Large areas of tetrahedrite are relatively pure except for irregularly distributed blebs of chalcopyrite. These vary from the merest specks to fair sized masses, although it is rarely so plentiful as to be visible without the microscope. These seem to be residual areas in the replacing tetrahedrite. The chalcopyrite boundaries are usually concave towards the tetrahedrite. Occasionally we have the relations as shown in Plate XI, where chalcopyrite seems to vein the tetrahedrite. Age relations are indeterminate. That tetrahedrite has replaced the chalcopyrite seems the more likely interpretation.

The relative ages of galena and tetrahedrite could not be proved conclusively. No evidence other than the character of the contacts could be found.

Plate X is taken to indicate that the tetrahedrite has replaced the galena for the following reasons:

1. smoothly curved contacts are convex towards tetrahedrite.
2. residual "outliers" of galena occur in the tetrahedrite.

Certain relations, seen in other sections, can equally well be interpreted as galena veining tetrahedrite or as galena partially replaced by tetrahedrite. Chalcopyrite, however, is rarely surrounded by galena while its occurrence
as blebs within tetrahedrite is characteristic. This suggests that galena has replaced both tetrahedrite and chalcopyrite.

The above evidence is admittedly inconclusive.

A tentative sequence is:

<table>
<thead>
<tr>
<th>youngest</th>
<th>galena</th>
</tr>
</thead>
<tbody>
<tr>
<td>---------</td>
<td>tetrahedrite</td>
</tr>
<tr>
<td>---------</td>
<td>chalcopyrite</td>
</tr>
<tr>
<td>oldest</td>
<td>arsenopyrite</td>
</tr>
</tbody>
</table>

The ores having been described, the analyses will next be considered.
SPECIMEN 20

Galena, tetrahedrite, chalcopyrite and quartz.
Tetrahedrite appears to "bite into" galena, and therefore doubtfully replaces it.

Camera-lucida drawing X 275
SPECIMEN 20

Chalcopyrite, tetrahedrite and quartz.
The chalcopyrite, in this section at least, is unquestionably the younger. It also occurs as irregular rounded blebs throughout the tetrahedrite. Such an occurrence, in itself, is non-diagnostic.

Camera lucida drawing  X 85
CHAPTER III

MERCURIAL TETRAHEDRITE FROM NORTH KOOTENAY MINES, LTD.,
WINDERMORE MINING DIVISION, B.C.
INTRODUCTION

While making preliminary blowpipe determinations on a suite of tetrahedrite ores of B.C., a mercurial variety was noted. Later work showed the selected mineral to be carrying about 6% mercury.

As schwatzite (mercurial tetrahedrite) was previously unknown in B.C., and is of rare occurrence throughout the world, a separate chapter has been devoted to this occurrence.

Six occurrences of schwatzite are listed by Dana

with analyses. The mercury content varies from 2.70 to 17.32. Mercury content of the original occurrence at Schwaz, in the Tyrol, is given as 15.5%.

In North America, mercurial tetrahedrite occurs near Sumpter, Oregon. No other occurrence of the mineral on this continent is known to the writer.

Proposed Outline.

Occurrences of mercurial tetrahedrite, as described in the literature, will be briefly discussed. Special attention will be given to an occurrence in Oregon, the nearest known deposit to that of the Windermere District. The Economic Geology of the Windermere will be briefly described, and published data on the occurrence to be studied will be summarized. The results of a detailed study of the ore will be given and discussed.
Generally speaking, mercury occurs in two types of deposits. By far the most important are those in which the metal occurs in the form of cinnabar. In other deposits it occurs as an essential constituent in tetrahedrite, as first described from Schwaz, Tyrol.


Cinnabar sometimes occurs in the oxidation zone through the decomposition of tetrahedrite. Cinnabar mineralization at the surface may persist to depth or its place, in depth, may be taken by mercury-bearing tetrahedrite. The occurrence or non-occurrence of other heavy metal compounds with the cinnabar of surface showings may give a clue as to its primary or secondary nature - a point of economic importance.

Other quicksilver minerals are of secondary importance.

Mercurial tetrahedrite might be said to form a connecting link between typical mercury deposits (cinnabar) on the one hand and silver-lead-zinc deposits (galena, sphalerite and tetrahedrite) on the other. This will be further discussed under "Mineralogy and Paragenesis."

Known Deposits.

The accompanying table of antimonial quicksilver deposits is taken from Becker. The data from deposits in deposits in

<table>
<thead>
<tr>
<th>Locality</th>
<th>Geological Formation</th>
<th>Antimony Ore</th>
<th>Barite</th>
<th>Galena &amp; Sphalerite</th>
<th>Calcite</th>
<th>Pyrite</th>
<th>Carbon &amp; Bitumen</th>
<th>Quartz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borneo</td>
<td>Palaeozoic</td>
<td>dominating</td>
<td>frequent</td>
<td>—</td>
<td>dominating</td>
<td>frequent</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Bosnia</td>
<td>Triassic</td>
<td>dominating</td>
<td>—</td>
<td>frequent</td>
<td>dominating</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Russia (Nikitovka)</td>
<td>Carboniferous</td>
<td>dominating</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>frequent</td>
<td>—</td>
</tr>
<tr>
<td>Servia (Avala)</td>
<td>Serpentine</td>
<td>frequent</td>
<td>seldom</td>
<td>seldom</td>
<td>frequent</td>
<td>frequent</td>
<td>—</td>
<td>dominating</td>
</tr>
<tr>
<td>Sumpter, Oregon</td>
<td>Carboniferous</td>
<td>antimonite &amp; schwatzite</td>
<td>—</td>
<td>rare</td>
<td>a little with arsenopyrite</td>
<td>—</td>
<td>—</td>
<td>dominating</td>
</tr>
<tr>
<td>Windermere, Brit. Col.</td>
<td>late Pre Cambrian</td>
<td>dominating</td>
<td>frequent</td>
<td>common in Windermere. Not noted in ore.</td>
<td>—</td>
<td>frequent</td>
<td>—</td>
<td>present</td>
</tr>
</tbody>
</table>
Oregon and British Columbia are added.

With the exception of the Bosnia occurrence, all are pre Mesozoic. Quartz, pyrite and calcite are usually present. Galena and sphalerite and barite may occur.

Becker, summarizing his monograph on the mercury deposits of the Pacific slope, says: "The minerals which occur in considerable quantities with quicksilver ores are few in number. Pyrite or marcasite is nearly always present, arsenic or antimony is found at many localities and copper ores sometimes accompany cinnabar. Other metalliferous minerals are comparatively rare. The principal gangue seems to be invariably either silica, sometimes hydrous, or carbonates, chiefly calcite."

As to the temperature of formation of mercury deposits, Lindgren states:

"The occurrence of quicksilver minerals is by no means confined to any certain kind of deposits or to any given age or epoch of metallization. However such minerals are not known to occur in deposits of distinctly igneous origin nor in pegmatite dikes, nor in veins of the deepest zone. High temperature is evidently unfavorable for their development."

As the mineral association of Epithermal mercury deposits, he gives

- cinnabar, pyrite, marcasite, stibnite (common)
- chalcopyrite and millerite (rare)
opal, chalcedony, quartz, calcite, dolomite common gangue
barite and alunite rare gangue

As a Mesothermal association he gives
Lindgren, W.; op. cit., p. 629.
pyrite, arsenopyrite, chalcopyrite, galena, blende, with
tetrahedrite and cinnabar less conspicuous.
gangue of quartz and calcite.

Arsenopyrite here indicates deposition under condi­
tions of temperature and pressure at least above those usually
responsible for Epithermal deposition.

This mineral is apparently absent from the Windermere
and is not mentioned in Becker's table.

All these deposits, with the exception of that in
Oregon, seem to be of rather low temperature deposition, agree­
ing more nearly with Epithermal than with Mesothermal mineral
associations.

The mercurial varieties of tetrahedrite given in
Dana show a higher average specific gravity than the normal
variety. Variation in the specific gravity does not correspond
with the variations in mercury content.

The appearance of arsenopyrite in the Sumpter,
Oregon, deposit makes the mineral assemblage of this gold
deposit agree more closely with that cited from Lindgren as a
Mesothermal occurrence.
Deposit of Schwatzite near Sumpter, Oregon.

This being the nearest known occurrence of mercurial tetrahedrite, it seems worthy of a short description. Lindgren, W.; U.S.G.S. 22nd Ann. Rept., Pt. 2, 1901, p. 664.

The deposit was worked by the Columbia Gold Mining Co., as a gold deposit. Mineralization is found along a fracture zone in brittle, black siliceous argillites, rarely showing stratification or schistosity. The zone trends northeast and dips 60° southwest. This fracture zone, about 40 feet wide, consists of abundant black argillite fragments and blocks in a matrix of white quartz. The quartz sometimes shows drusy comb structure. Pyrite, sericite, and sometimes calcite have resulted from the alteration of the wall rock.

Metallic minerals are chiefly pyrite and arsenopyrite. Other minerals found are native copper, gold, sphalerite, pyrargyrite, cinnabar, antimonite, chalcopyrite, stibnite, a telluride and schwatzite. The gangue is chiefly quartz. Other gangue minerals are sericite, fuchsite, and calcite.

The pay occurs in streaks, following either wall, or crossing from one wall to another.

GENERAL ECONOMIC GEOLOGY OF WINDERMERE DISTRICT

A general outline of the Economic Geology of this district will be given here. The relation of the mercurial occurrence to type occurrences of the district can then be
discussed below. It will be seen that the mineral association of the mercurial deposit is exceptional for the Windermere.

The General and Economic Geology of the area has been covered by Walker in his report on the "Geology and Mineral Deposits of Windermere Map Area, B.C.


The North Kootenay Mines deposit lies well within this map area, and on the eastern slope of the Purcell range.

The exposures are of Devonian and older sediments intruded by Jurassic granite stocks.

The Pre-Cambrian Purcell and Windermere Series are cut by greenstone dykes and sills. Unconformably overlying these are sedimentary formations ranging from Upper Cambrian to Upper Devonian in age. These are all intruded by Mesozoic (probably Jurassic) granite stocks and apophyses. This is unconformably overlain, within the map area, by unconsolidated Pleistocene and Recent deposits.

Lead-silver and lead-silver-zinc are the economically important metallic deposits of the area. No copper or gold deposits of value have been found. Nor are the barite and gypsum deposits of any importance at present.

Lead-silver and lead-silver-zinc deposits occur as fissure and bed veins, associated with minor anticlinal folds on the limbs of the larger folds. The veins tend to strike with the folding - about north 30 degrees west. They are commonly the rocks of the Purcell series.
Metallic minerals noted are:

- galena
- sphalerite
- pyrite
- chalcopyrite
- freibergite
- some covellite

Oxidized minerals are:

- chiefly cerussite

Gangue minerals are:

- quartz (two generations)
- calcite (white to pale cream)
- barite (dense and massive to crystalline and white to pale green)
- siderite (alteration of pyrite)

The order of deposition is given as

- youngest: galena, tetrahedrite, sphalerite, pyrite
- oldest: gangue

As quartz is the chief gangue mineral, the position of barite and calcite in the sequence has probably not been determined accurately. Siderite gangue is younger than the pyrite, from which, according to Walker, it has been formed.

---

If he intends to imply that the barite is one of the
first formed minerals, this conclusion does not check with that arrived at by the present writer.

He mentions several notable features. With reference to tetrahedrite he says:

op. cit., p. 44.

"Freibergite or argentiferous tetrahedrite is the principal silver-bearing mineral. It shows marked variations in its microchemical reactions apparently due to the varying silver content."

This statement may be found to be significant in view of the possible mercury content of other tetrahedrite ores of Windermere.

Further, in accordance with general observations in the Cordillera, he finds that

op. cit., p. 45.

"the properties situated at the higher elevations are on the whole essentially lead-silver bearing and practically free from zinc, whereas the properties located at lower altitudes carry considerably more zinc, and it is in these properties that the replacement of zinc blende by galena is noticeable."

The property of the North Kootenay Mines Ltd., at an elevation of 9250 feet, judging by the ore examined, carries no zinc and so fits into this general rule.

Further, there are no contact metamorphic deposits, nor are contact phenomena well developed. To quote Walker,
WINDERMERE MAP AREA
showing location of
PRETTY GIRL CLAIM,
NORTH KOOTENAY MINES, LTD.
"There is no evidence of mineralization being concentrated in the neighborhood of granite bodies."

He believes that the deposits are connected with the period of Jurassic mountain building and igneous intrusion.

THE DEPOSIT
Pretty Girl Claim, North Kootenay Mines, Ltd.

This deposit is first mentioned, in the 1898 Annual Report of the B.C. Minister of Mines, as one of six locations, viz., the Venus, New Chum, Pretty Girl, Minniehaha, Old Chum, and Beauty, held by the New Golden B. C. Company, of London, England, represented by W.G. Mitchell-Innes, of Golden. Of the group, only the Pretty Girl has been worked.

The claim is situated about 18 miles west of the town of Windermere. It lies on the summit of the divide between the headwaters of Boulder and Law's Creek, at an elevation of 9250 feet, on the east slope of the Purcell Range.

Walker, in his section on Economic Geology, makes no mention of the Pretty Girl claim and has not visited that ridge.

Personal communication.

For data on this property, reference must be made to reports of the B.C. Minister of Mines.

steeply dipping soft shales trending N 25° W. The gray copper ore, with accompanying carbonates, lies between the layers of the shales or slates. The statement is made that

"There seems to be no vein in the usual acceptance of the term, but a zone in the bedding of the shales---" A representative sample is stated to contain 26.68% copper and 55.5 oz. of silver per ton.

In the 1915 report mention is made of a vein "which varies from a seam up to 10 inches in width, consisting of quartz somewhat stained with malachite (copper carbonate)."


Assays of grab samples gave 20.8% copper and 38 ounces of silver per ton.

In the 1928 report the property is again referred to as follows:


"The Pretty Girl, situated on the summit of the ridge between Slade and Law Creeks, was operated by the North Kootenay Mines, Ltd., of which J.A. Lundy is president."

No further information is given in these reports.

MINERALOGY AND PARAGENESIS

Macroscopic Description of Specimen

In all, several pounds of ore from the North Kootenay Mines was obtained through the courtesy of the B.C. Chamber of Mines, Vancouver.
It showed but little variation and might well all have come from the same lump of ore.

In all probability it is not representative material, but, in the absence of a more complete suite, will be described.

One piece of ore carries a piece of the vein wall. It is a greyish green indurated shale in part altered to a somewhat scaly talcose or chloritic material at the ore contact. It is in contact with massive mercurial tetrahedrite. Insufficient material was at hand to permit of the study of the significance, if any, of the association of the more massive ore with the vein wall.

Malachite and azurite with a little iron oxide are the conspicuous alteration products.

The ore tends to occur in bands - a band of massive and comparatively pure tetrahedrite against a band of sparser mineralization in a finely crystalline white baritic gangue. The chalcopyrite, pyrite and resultant iron oxide are seen in this baritic ore. In the absence of a systematic suite of specimens, no observations can be made on the relation of banding to vein walls.

Mineralogy and Paragenesis

The following minerals have been recognized: tetrahedrite (mercurial), pyrite, chalcopyrite, bornite, chalcocite, azurite, malachite, barite and quartz.

This appears to be an unusual association for the
SPECIMEN 1

Barite, tetrahedrite, pyrite and chalcopyrite. Taken to show the typical mode of occurrence of chalcopyrite within tetrahedrite — as irregular veinlets and isolated blebs throughout. The dark border around the gangue is merely a depression. The dark areas within the tetrahedrite are pits, originally containing earthy black non-metallic material.

Panchromatic plate
Kodak Color filter (X 3)
1/25 second exposure

X 85
SPECIMEN 1

Tetrahedrite, chalcopyrite and pyrite. The chalcopyrite occurs as veinlets and as areas bordering pyrite residuals. This close association of pyrite and chalcopyrite is typical in this ore. The black areas are pits, containing soft non metallic material. This is believed to account, in part, for the low assay totals.

Panchromatic plate
Kodak Color filter (X 3)
1/10 second exposure X 275
SPECIMEN 1

Tetrahedrite and chalcopyrite replacing pyrite. The pyrite shows as well rounded grains of high relief. Tetrahedrite and chalcopyrite are not differentiated in the photograph. Many of the smaller veinlets are of chalcopyrite. Tetrahedrite, intimately associated (as usual) with chalcopyrite, and replacing pyrite in this way, is undoubtedly primary.

Panchromatic Plate
Kodak Color filter (X 3)
1/25 second exposure  X 85
Specimen 1

Chalcopyrite, pyrite and tetrahedrite. The veinlet is a supergene mineral.

This association of pyrite and chalcopyrite is typical. Pyrite occurs as isolated rounded grains arranged in lines, forming "veinlets". Chalcopyrite occupies these same lines, surrounding or bordering the pyrite. Such pyrite "veinlets" may or may not be accompanied by chalcopyrite but pyrite seems to be essential to chalcopyrite areas.

Camera-lucida drawing X 85
SPECIMEN 1

Chalcopyrite, pyrite, tetrahedrite and barite. Chalcopyrite shown replacing pyrite. Tetrahedrite-chalcopyrite relations indeterminate.

Camera-lucida drawing X 85
Windermere District.

In the ore examined, the association of tetrahedrite, pyrite and chalcopyrite in a gangue of quartz and barite is by far the most common. The age relations for this group of minerals have been fairly satisfactorily determined and will be discussed first. This is the mineral association found in the massive ore.

A somewhat different and less satisfactorily determined association is found in the disseminated mineralization in the gangue areas. The minerals here are too fine-grained and too intimately intergrown to permit of satisfactory determination. Further, they occur in such small quantities as to be of minor importance only. The discussion of the paragenesis of this group, and of its relation to the first group, will be left until later.

Malachite, azurite and limonitic iron oxide occur as alteration products.

1. The quartz, pyrite, chalcopyrite, tetrahedrite, barite mineralization.

These minerals were deposited in the order mentioned. Overlapping and contemporaneous deposition occurred in the case of chalcopyrite and tetrahedrite.

The relations will be discussed, as far as possible, in the order of deposition.

Quartz occurs as a few isolated rounded grains in the barite and is probably one of the first formed minerals.

Pyrite is undoubtedly an early mineral occurring
characteristically as groups and masses of well rounded grains included in, and veined by, tetrahedrite and chalcopyrite. This is clearly shown in Plate XV.

Chalcopyrite veins tetrahedrite and, in other places, is included and embayed by it. Therefore it must have been deposited before, after, and contemporaneously with, tetrahedrite. Plates XIV and XVI, taken together, illustrate this overlap.

Chalcopyrite is usually seen as patches and blebs in tetrahedrite, and accompanying pyrite. Good examples of its veining tetrahedrite are not very common. It sometimes occurs as isolated blebs and specks in tetrahedrite, but for the most part is found as illustrated in Plates XVI and XIV - closely associated with pyrite. The presence of pyrite would appear to have been especially favorable to the deposition of chalcopyrite. Pyrite occurs as lines or "veinlets" of isolated grains and it is along these same lines that we find chalcopyrite concentrated. Tetrahedrite areas on either side are likely to be comparatively pure.

It is probable that most of the chalcopyrite and tetrahedrite are contemporaneous.

The barite gangue was determined by a flame test for barium and a sodium bicarbonate fusion test for sulphate. The gangue is unaffected by acid, colorless, and harder than calcite. It clearly replaces all other hypogene metallics and quartz. Plate XIX shows replacement remnants of pyrite, chalcopyrite and tetrahedrite in barite.
SPECIMEN 1

Bornite in dark barite gangue. Accurate determinations were impracticable under this magnification. The dark gangue distinctly embays, and is therefore younger than, the metallics. The main bornite mass contains laths and veinlets of chalcopyrite, best seen at the top of the section. The patchy areas within the bornite may indicate replacement by chalcocite or covellite and limonite.

Panchromatic plate
Kodak Color filter (X 3)
1/10 second exposure  X 275
SPECIMEN 1

Pyrite and tetrahedrite in barite gangue. Relations here are taken to indicate replacement of the sulphides by the gangue. They appear as embayed, and incompletely replaced, remnants scattered through the replacing gangue.

Panchromatic plate
no filter X 85
CHART showing RELATIVE AGES OF MINERALS in ore from PRETTY GIRL CLAIM WINDERMERE M.D.
2. The chalcopryite, bornite, chalcocite, barite mineralization.

The small amounts in which this disseminated mineralization occurs precludes the possibility of positive identification.

Chalcopryite was satisfactorily identified. A pinkish brown mineral may be bornite although the colour is a little too decided. The possibility of its being bornite is supported by the occurrence, within it, of laths or needles of chalcopryite, oriented in three groups. It may be that these are following octahedral cleavage.

A bluish mineral has about the colour of covellite. Irregular feathery-edged areas of a slightly darker, brownish mineral are developed in the covellite (?). By oblique illumination it seems to show a faint brownish red internal reflection. Its colour, by reflected light, however, does not seem to quite check with that of limonite.

No particular mineral of this group shows any marked relief so all must be of the same order of hardness.

These minerals are shown on Plate XVIII.

Bornite (?) was the first to be deposited. This is cut by distinct veinlets of chalcopryite. Chalcopryite also occurs as laths or needles within the bornite (?). This mode of occurrence may indicate, according to Lindgren, either replacement or unmixing.

Lindgren, Mineral Deposits, 1928, p.213.

In the present case, then, chalcopryite is in part younger than the bornite (?) and in part either younger or
contemporaneous.

The covellite replaces bornite (?) about the periphery of the grains. Replacement veinlets from the covellite border may isolate areas of bornite and finally leave a few irregularly rounded remnants of bornite in covellite.

Chalcopyrite needles rarely cut the covellite. A few project into it from the bornite but this relation is probably due to delayed replacement of chalcopyrite by covellite. The bornite has been preferentially replaced.

Areas of a somewhat darker grayish-brown mineral replace the covellite with a feathery embaying border.

All are replaced by barite gangue except the supergene covellite (?) and its replacing mineral.

Chalcopyrite is common to the above two types of mineralization. In the absence of evidence to the contrary it must be assumed that we have but one generation of chalcopyrite. Correlating, we see that bornite (?) was deposited after (probably) pyrite and before barite. If the remaining minerals (covellite (?) and limonite (?)) are supergene, and have metasomatically replaced the bornite, they are probably younger than the barite.

The time relations of these minerals are shown graphically in Plate XX.

Etch Reactions

Etch tests were made on grains of pure selected mineral and are compared with etch tests given for tetrahedrite
in standard works on the subject.

The material used showed no metallic minerals other than the Schwatzite. Irregular cracks and pits were common on the polished surfaces. As the reagents were applied only to the mineral under examination, results were not influenced by galvanic action.

Consistent technique was employed throughout. The specimen was polished on the rouge block immediately before applying the reagent. The reagent was left in contact with the mineral for one minute, then washed off with a stream of water from the tap. Surplus water was blown away and the surface allowed to dry. The effect of the reaction was then observed.

The specimen was then repolished on the rouge block preparatory to the next test.

All reactions were checked by repetition, using other grains.

The following tests, then, were obtained for schwatzite. They check very closely with those published for tetrahedrite, and, in themselves will not determine this variety of tetrahedrite.
As determined for schwatzite as given for Tetraahedrite, in

<table>
<thead>
<tr>
<th>HNO₃ conc.</th>
<th>Farnham</th>
<th>Davy &amp; Farnham</th>
<th>Short</th>
<th>Kraus &amp; Hunt</th>
</tr>
</thead>
<tbody>
<tr>
<td>irridescence to brown stain fumes tarnish</td>
<td>slowly stains brown</td>
<td>neg. fumes tarnish</td>
<td>fumes tarnish</td>
<td></td>
</tr>
<tr>
<td>HNO₃ 1:1</td>
<td>very slight brown stain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCl 1:1</td>
<td>neg.</td>
<td>neg.</td>
<td>neg.</td>
<td>neg.</td>
</tr>
<tr>
<td>KCN 20%</td>
<td>neg. to very slight brown stain</td>
<td>sometimes stains faint</td>
<td>neg.</td>
<td>—</td>
</tr>
<tr>
<td>FeCl₃ 20%</td>
<td>neg.</td>
<td>neg.</td>
<td>neg.</td>
<td>—</td>
</tr>
<tr>
<td>KOH sat.?</td>
<td>neg.</td>
<td>neg.</td>
<td>neg.</td>
<td>—</td>
</tr>
<tr>
<td>HgCl₂ sat.?</td>
<td>neg.</td>
<td>neg.</td>
<td>neg.</td>
<td>—</td>
</tr>
<tr>
<td>Aqua Regia</td>
<td>neg. fumes may tarnish slightly</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mercurial mineral appears to show a more definite reaction to nitric acid than the ordinary varieties.

**Physical Properties**

The physical properties of this tetrahedrite show a distinct variation from those of the normal mineral -
presumably due to the mercury content.

Typical tetrahedrite shows a smooth conchoidal fracture and a high, almost splendent, lustre. In other varieties the fracture is somewhat uneven - almost hackly and the very high lustre not apparent. On examining the mercurial mineral it is at once apparent that it has not the appearance of the normal material. It has a silvery white colour and a distinctly uneven fracture. Under the hand lens there is seen to be a decided tendency towards conchoidal fracture in individual grains.

In the accompanying table, the physical properties of this mineral are tabulated against those given in Dana.

Dana, E.S.: A System of Mineralogy, 1896, p.137.

Dana lists an analysis of schwatzite carrying 5.57 percent mercury with a specific gravity of 4.733. In the present material we have 6.1 percent mercury and a specific gravity of 4.83.
## Comparison of Physical Properties of Tetrahedrite and Schwatzite

<table>
<thead>
<tr>
<th>As in Dana</th>
<th>Schwatzite Windermere, B.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>isometric tetrahedral</td>
<td></td>
</tr>
<tr>
<td>also massive; granular, coarse or fine; compact.</td>
<td>massive granular</td>
</tr>
<tr>
<td>cleavage none</td>
<td>cleavage none</td>
</tr>
<tr>
<td>fracture subconchoidal to uneven</td>
<td>uneven, subconchoidal in detail</td>
</tr>
<tr>
<td>rather brittle</td>
<td>less brittle than material with smooth fracture.</td>
</tr>
<tr>
<td>lustre metallic, often splendent. colour flint gray to iron black.</td>
<td>metallic, not splendent</td>
</tr>
<tr>
<td>streak like colour, sometimes inclining to brown and cherry-red</td>
<td>powder dark reddish brown</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
H & = 3.4 \\
G & = 4.4-5.1 \\
\text{Schwatzite } G & = 4.733-5.356 \\
\text{ (average 5.081)} & = 4.83
\end{align*}
\]
ANALYSIS AND FORMULA

Analyses, of course, had to be made in presence of mercury.

To check the effect of mercury on copper assays by the Fluoride-Iodide method, a series of synthetic samples were made up with known amounts of copper, and assayed. Pure copper foil in the presence of ferrous ammonium sulphate was used to standardize the standard solution of thiosulphate. Synthetic samples of ore were made up with copper and antimony present in the proportions found in the preliminary assays. To one set mercury was added. In another it was added in the proportion found in the natural ore and in other assays it was added in two, three and four times the natural percentage.

The results of assays on these show a progressive small interference of mercury on the copper determinations. The effect, however, of 6 percent mercury is but slight. In this case the value of the thiosulphate solution in terms of copper was obtained by titration of the synthetic sample containing 6 percent Hg, and the effect of the interference thus compensated for.

The Analysis gave -

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>33.8</td>
</tr>
<tr>
<td>Silver</td>
<td>0.2</td>
</tr>
<tr>
<td>Lead</td>
<td>---</td>
</tr>
<tr>
<td>Zinc</td>
<td>4.0</td>
</tr>
<tr>
<td>Insol.</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Iron  1.0
Antimony  23.4
Arsenic  1.4
Sulphur  22.1
Mercury  6.1

Taking out the insoluble and correcting to 100 percent, we have -

Copper  36.8
Silver  .2
Zinc  4.3
Iron  1.2
Antimony  25.4
Arsenic  1.5
Sulphur  24.0
Mercury  6.6

100.0

Insufficient material was available for check analyses.

The low total is probable to be accounted for as follows -

1. The presence of copper carbonates, conspicuous in the ore.
2. Barite gangue entering into the assayed material. The gangue is dominantly barite. Neither Ba nor SO₄ were assayed for.
3. The probable presence of other elements, not
assayed for, in this somewhat unusual ore.

Dividing by atomic weights, we get the atomic proportions -

<table>
<thead>
<tr>
<th>Element</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>.575</td>
</tr>
<tr>
<td>Silver</td>
<td>.002</td>
</tr>
<tr>
<td>Zinc</td>
<td>.066</td>
</tr>
<tr>
<td>Iron</td>
<td>.021</td>
</tr>
<tr>
<td>Antimony</td>
<td>.211</td>
</tr>
<tr>
<td>Arsenic</td>
<td>.020</td>
</tr>
<tr>
<td>Sulphur</td>
<td>.750</td>
</tr>
<tr>
<td>Mercury</td>
<td>.030</td>
</tr>
</tbody>
</table>

Iron was deducted as chalcopyrite impurity. Elements of corresponding valence were grouped. We have -

<table>
<thead>
<tr>
<th>Element</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>.56</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>.10</td>
</tr>
<tr>
<td>Mercury</td>
<td>.10</td>
</tr>
<tr>
<td>Antimony</td>
<td>.23</td>
</tr>
<tr>
<td>Arsenic</td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td>.71</td>
</tr>
</tbody>
</table>

These proportions correspond to the formula,

3 \((Cu,Ag)\_2S\_3\), \((Hg,Zn)S\) \((As,Sb)\_2S\_3\)

This is the usual formula for the other samples of tetrahedrite studied. Here, however, mercury replaces zinc in indefinite proportions.
COMPARISON WITH OTHER DEPOSITS OF WINDERMERE DISTRICT

Mercury in tetrahedrite has not previously been recognized in this district although tetrahedrite is a characteristic mineral. When the presence of mercury was detected in the mineral it was hoped that it might prove to be general in the gray copper ores of the district.

Specimens from several prospects in the district were made available through the kindness of Dr. J.F. Walker, Geological Survey Canada.

It was hoped mercury would be identified in some of these prospects, giving a district of mercurial tetrahedrite.

Several methods suggested themselves for the detection of mercury.

The most obvious method was to use the ordinary commercial assay methods on selected tetrahedrite. Specimens of ore from two prospects were large enough to permit of the use of this method. Assays on tetrahedrite from the Hot Punch group, and from the Silver Spray property, gave mercury nil. These properties are located about 5 and 11 miles, respectively, to the south of the Pretty Girl claim.


Specimens from other properties consisted only of polished sections so that assay and blowpipe methods were excluded.

It was hoped that the presence of mercury would give the mineral some characteristic etch test. A careful series of etch tests, run on the known mercurial tetrahedrite, gave the
results tabulated on page 48. These proved to be non-diagnostic. Etch tests, then, could not be used to detect mercury in the other specimens.

Microchemical tests were not used.

Galena, sphalerite, pyrite, a little chalcopyrite, and tetrahedrite, in a quartz gangue is the characteristic mineral assemblage of the district. In the deposit under discussion we have mercurial tetrahedrite, pyrite, and a little chalcopyrite, in a barite gangue. Neither galena nor sphalerite was noted.

A comparison of the mineral association shows the mercurial deposit to be unusual in the district and so decreases the likelihood of mercury being found in the tetrahedrite of the other deposits - deposits of a different type.

This brings us to the question of genesis.

GENESIS

But little can be said here, due to the lack of detailed published information on the property.

Mineralization occurs as a zone, between the bedding of the shales, trending N 25° W. This corresponds with the general trend of Lead-Silver-Zinc deposits as already described.

Walker, J.F.; op. cit., p.43.

The deposit is referred to as a "zone", following the bedding of the shales. This would suggest replacement, either selective
replacement of favourable beds or replacement by solutions outwards from some permeable channel. Lacking detailed information, it is useless to speculate on the origin of this bedding channel.

A small piece of the vein wall on one of the specimens was suggestive of filling, with possible subordinate replacement.

The deposit will be compared with Lindgren's Meso-thermal and Epithermal deposits. It will be seen to occupy an intermediate position.

Of Epithermal deposits Lindgren says:


"Arsenic and antimony, bismuth -- are common --;--- the typical quicksilver deposits belong to this class.

"--- complex silver sulphantimonides and sulpharsenides are also characteristic;----. Among them are proustite, pyrargyrite, mniargyrite, stephanite, polybasite, tetrahedrite and more rarely enargite.

"Of the gangue minerals quartz is the most abundant, ---- Calcite, dolomite, barite, and fluorite are locally the dominant gangue minerals."

Of Mesothermal deposits, he says:

Lindgren, W.: op. cit., p.599.

"The principal metals contained are gold, silver, copper, lead and zinc.--- The ore minerals are sulphides, arsenides, sulphantimonides and sulpharsenides. Pyrite, chalcopyrite, arsenopyrite, galena, zinc blende, tetrahedrite,
tennantite and native gold are the most common. The predominating gangue mineral is quartz, but carbonates are also common, such as calcite, dolomite and ankerite; fluorite and barite are occasionally of importance.

In this case we have prominent barite, the presence of mercury and the absence of galena and sphalerite; all against including the deposit in the typical Mesothermal class. The mercury and barite would suggest a somewhat lower temperature of deposition. Pyrite, chalcopyrite and tetrahedrite are not very diagnostic.

The ore has not typical Epithermal structure. It should probably be classed as a low temperature Mesothermal deposit.

Deposits of this type might be considered as forming a connecting link between normal Epithermal mercury deposits with cinnabar and the typical silver-lead-zinc Mesothermal deposits. In this connection Beyschlag, Vogt, and Krusch say: Beyschlag, Vogt & Krusch: Ore Deposits, 1916, p.657.

"Such occurrences (mercurial tetrahedrite) in general, however, are rare and of little importance, so that it may be said that a sharp line exists between the lead-silver-zinc lodes and the quicksilver lodes proper."

SUMMARY AND CONCLUSIONS

A deposit of mercurial tetrahedrite occurs about 18 miles west of the town of Windermere, B.C.
The mercurial content of the ore has not previously been recognized.


Mercurial tetrahedrite is the dominant metallic. Pyrite and chalcopyrite are the other important sulphides. The gangue is barite.

This mineral association is unusual in the Windermere district.

It probably indicates deposition at a temperature below that of the normal silver-lead-zinc deposits of the district.

The selected mineral was analysed and the following formula suggested.

$$3 \left[ (\text{Cu,Ag})_2 S, (\text{Hg,Zn})S \right] \cdot (\text{As,Sb})_2 S_3$$

The physical properties differ somewhat from those of typical tetrahedrite, notably those of fracture, brittleness, colour, lustre and streak.

The etch reactions do not differ materially from those of the normal tetrahedrite.

The economic importance of the discovery of mercury in this deposit cannot be estimated from the meagre information at hand. Accessibility, tonnage, average mercury content, and treatment, are factors to be considered.
CHAPTER IV

ANALYSES & FORMULAE.
DATA

Assays were made of pure tetrahedrite from each specimen, as described above.

The uncorrected assay results are shown below.

<table>
<thead>
<tr>
<th>Number</th>
<th>Cu</th>
<th>Ag</th>
<th>Pb</th>
<th>Zn</th>
<th>Insol.</th>
<th>Fe</th>
<th>Sb</th>
<th>As</th>
<th>S</th>
<th>Hg</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.8</td>
<td>.2</td>
<td></td>
<td>4.0</td>
<td>4.9</td>
<td>1.0</td>
<td></td>
<td>23.4</td>
<td>1.4</td>
<td>22.1</td>
<td>6.1</td>
</tr>
<tr>
<td>2</td>
<td>35.7</td>
<td>.5</td>
<td></td>
<td>5.4</td>
<td>5.3</td>
<td>.6</td>
<td></td>
<td>21.0</td>
<td>3.7</td>
<td>23.6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>22.5</td>
<td>11.0</td>
<td></td>
<td>4.8</td>
<td>12.5</td>
<td>.4</td>
<td></td>
<td>20.4</td>
<td>1.3</td>
<td>20.6</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>32.8</td>
<td>4.8</td>
<td></td>
<td>4.3</td>
<td>2.4</td>
<td>2.1</td>
<td></td>
<td>24.2</td>
<td>2.0</td>
<td>22.5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>19.2</td>
<td>25.2</td>
<td></td>
<td>4.3</td>
<td>1.3</td>
<td>.2</td>
<td></td>
<td>19.8</td>
<td>.2</td>
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</tr>
<tr>
<td>6</td>
<td>36.5</td>
<td>.5</td>
<td></td>
<td>5.7</td>
<td>3.4</td>
<td>1.4</td>
<td></td>
<td>22.5</td>
<td>3.6</td>
<td>24.9</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>35.7</td>
<td>2.9</td>
<td></td>
<td>4.8</td>
<td>1.2</td>
<td>2.2</td>
<td></td>
<td>18.6</td>
<td>6.0</td>
<td>24.9</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>29.8</td>
<td>7.8</td>
<td></td>
<td>4.8</td>
<td>2.8</td>
<td>3.7</td>
<td></td>
<td>18.5</td>
<td>4.6</td>
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</tr>
<tr>
<td>18</td>
<td>37.4</td>
<td>.4</td>
<td></td>
<td>5.4</td>
<td>1.6</td>
<td>1.2</td>
<td></td>
<td>23.3</td>
<td>3.8</td>
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</tr>
<tr>
<td>20</td>
<td>31.2</td>
<td>6.3</td>
<td></td>
<td>6.3</td>
<td>12.8</td>
<td>1.0</td>
<td></td>
<td>23.9</td>
<td>1.4</td>
<td>23.7</td>
<td></td>
</tr>
</tbody>
</table>

These analyses show an appreciable "Insoluble" content. Further, the totals fall short of 100 percent.

For the purposes of calculations, the "Insoluble" was removed and the percentages adjusted to give a total of 100 percent, as shown below.
<table>
<thead>
<tr>
<th>Number</th>
<th>Cu</th>
<th>Ag</th>
<th>Zn</th>
<th>Hg</th>
<th>Fe</th>
<th>Sb</th>
<th>As</th>
<th>S</th>
<th>Uncorrected total less Insol.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36.8</td>
<td>.2</td>
<td>4.3</td>
<td>6.6</td>
<td>1.2</td>
<td>25.4</td>
<td>1.5</td>
<td>24.0</td>
<td>92.0</td>
<td>100.0</td>
</tr>
<tr>
<td>2</td>
<td>39.5</td>
<td>.6</td>
<td>6.0</td>
<td>.6</td>
<td>23.2</td>
<td>4.1</td>
<td>26.0</td>
<td>90.5</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>27.8</td>
<td>13.6</td>
<td>5.9</td>
<td>.5</td>
<td>25.2</td>
<td>1.6</td>
<td>25.4</td>
<td>81.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>35.4</td>
<td>5.2</td>
<td>4.6</td>
<td>.2</td>
<td>26.1</td>
<td>2.1</td>
<td>24.3</td>
<td>92.7</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>20.6</td>
<td>27.1</td>
<td>1.5</td>
<td>5.1</td>
<td>21.3</td>
<td>.2</td>
<td>24.2</td>
<td>93.0</td>
<td>100.0</td>
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</tr>
<tr>
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<td>38.4</td>
<td>.5</td>
<td>6.0</td>
<td>1.5</td>
<td>23.7</td>
<td>3.7</td>
<td>26.2</td>
<td>95.1</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>37.5</td>
<td>3.0</td>
<td>5.1</td>
<td>2.3</td>
<td>19.6</td>
<td>6.3</td>
<td>26.2</td>
<td>95.1</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>32.2</td>
<td>8.4</td>
<td>5.2</td>
<td>3.9</td>
<td>20.0</td>
<td>5.0</td>
<td>25.3</td>
<td>92.7</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>38.9</td>
<td>.5</td>
<td>5.6</td>
<td>1.2</td>
<td>24.3</td>
<td>4.0</td>
<td>25.5</td>
<td>96.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>33.3</td>
<td>6.7</td>
<td>6.7</td>
<td>1.0</td>
<td>25.5</td>
<td>1.5</td>
<td>25.5</td>
<td>93.8</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Atomic proportions were calculated in each case, by dividing by the atomic weights. Atomic weights used were:

- Copper: 64
- Silver: 108
- Zinc: 65.4
- Mercury: 201
- Iron: 56
- Antimony: 126
- Arsenic: 75
- Sulphur: 32

All calculations have been made on a ten inch slide rule, greater accuracy being meaningless.

The atomic proportions are shown below, together
with the iron minerals known to be present as impurities.

<table>
<thead>
<tr>
<th>Number</th>
<th>Cu</th>
<th>Ag</th>
<th>Zn</th>
<th>Hg</th>
<th>Fe</th>
<th>Sb</th>
<th>As</th>
<th>S</th>
<th>Iron Impurities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.575</td>
<td>0.002</td>
<td>0.066</td>
<td>0.030</td>
<td>0.021</td>
<td>0.211</td>
<td>0.020</td>
<td>0.750</td>
<td>Chalcopyrite</td>
</tr>
<tr>
<td>2</td>
<td>0.617</td>
<td>0.006</td>
<td>0.092</td>
<td>0.011</td>
<td>0.193</td>
<td>0.054</td>
<td>0.021</td>
<td>0.812</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.434</td>
<td>0.126</td>
<td>0.090</td>
<td>0.009</td>
<td>0.210</td>
<td>0.021</td>
<td>0.793</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.553</td>
<td>0.048</td>
<td>0.070</td>
<td>0.041</td>
<td>0.217</td>
<td>0.028</td>
<td>0.759</td>
<td>Chalcopyrite</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.322</td>
<td>0.251</td>
<td>0.023</td>
<td>0.091</td>
<td>0.177</td>
<td>0.003</td>
<td>0.755</td>
<td>Chalcopyrite</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.600</td>
<td>0.005</td>
<td>0.092</td>
<td>0.027</td>
<td>0.197</td>
<td>0.049</td>
<td>0.818</td>
<td></td>
<td>Pyrite &amp;</td>
</tr>
<tr>
<td>12</td>
<td>0.586</td>
<td>0.028</td>
<td>0.078</td>
<td>0.041</td>
<td>0.163</td>
<td>0.084</td>
<td>0.818</td>
<td>Chalcopyrite</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>0.503</td>
<td>0.084</td>
<td>0.079</td>
<td>0.070</td>
<td>0.167</td>
<td>0.067</td>
<td>0.791</td>
<td>Pyrite</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>0.608</td>
<td>0.005</td>
<td>0.086</td>
<td>0.021</td>
<td>0.202</td>
<td>0.053</td>
<td>0.797</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.521</td>
<td>0.062</td>
<td>0.102</td>
<td>0.018</td>
<td>0.213</td>
<td>0.020</td>
<td>0.791</td>
<td>Chalcopyrite</td>
<td></td>
</tr>
</tbody>
</table>

Iron was taken to be present only as an impurity.
Where iron minerals were not noted in the polished sections, the iron was assumed to be present as pyrite.

This assumption was necessary for specimens 2, 3, 6 and 18, assaying (uncorrected) 0.6, 0.4, 1.4 and 1.2 percent iron respectively. The assumption is justifiable, in view of the low percentages.

The atomic proportions were then corrected, iron being taken out as pyrite or chalcopyrite impurities, together with the combined copper and sulphur. The figures, corrected for the impurities, are given below.
<table>
<thead>
<tr>
<th>Number</th>
<th>Cu</th>
<th>Ag</th>
<th>Zn</th>
<th>Hg</th>
<th>Fe</th>
<th>Sb</th>
<th>As</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.554</td>
<td>0.002</td>
<td>0.066</td>
<td>0.030</td>
<td></td>
<td>0.211</td>
<td>0.020</td>
<td>0.708</td>
</tr>
<tr>
<td>2</td>
<td>0.617</td>
<td>0.006</td>
<td>0.092</td>
<td></td>
<td></td>
<td>0.193</td>
<td>0.054</td>
<td>0.790</td>
</tr>
<tr>
<td>3</td>
<td>0.434</td>
<td>0.126</td>
<td>0.090</td>
<td></td>
<td></td>
<td>0.210</td>
<td>0.021</td>
<td>0.775</td>
</tr>
<tr>
<td>4</td>
<td>0.512</td>
<td>0.048</td>
<td>0.070</td>
<td></td>
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<td>0.217</td>
<td>0.028</td>
<td>0.677</td>
</tr>
<tr>
<td>5</td>
<td>0.231</td>
<td>0.251</td>
<td>0.023</td>
<td></td>
<td></td>
<td>0.177</td>
<td>0.003</td>
<td>0.573</td>
</tr>
<tr>
<td>6</td>
<td>0.600</td>
<td>0.005</td>
<td>0.092</td>
<td></td>
<td></td>
<td>0.197</td>
<td>0.049</td>
<td>0.764</td>
</tr>
<tr>
<td>12</td>
<td>0.566</td>
<td>0.028</td>
<td>0.078</td>
<td></td>
<td></td>
<td>0.163</td>
<td>0.084</td>
<td>0.736</td>
</tr>
<tr>
<td>17</td>
<td>0.503</td>
<td>0.084</td>
<td>0.079</td>
<td></td>
<td></td>
<td>0.167</td>
<td>0.067</td>
<td>0.651</td>
</tr>
<tr>
<td>18</td>
<td>0.608</td>
<td>0.005</td>
<td>0.086</td>
<td></td>
<td></td>
<td>0.202</td>
<td>0.053</td>
<td>0.755</td>
</tr>
<tr>
<td>20</td>
<td>0.503</td>
<td>0.062</td>
<td>0.102</td>
<td></td>
<td></td>
<td>0.213</td>
<td>0.020</td>
<td>0.755</td>
</tr>
</tbody>
</table>

**FORMULAE**

Formulae, fitted to these atomic proportions fall into three groups. Silver, mercury and zinc are assumed to "replace" copper under valence control. Arsenic is taken as replacing antimony.


Below are shown the atomic proportions, corrected for impurities, grouped, and given to two figures, and the corresponding approximate formulae.
<table>
<thead>
<tr>
<th>Number</th>
<th>Cu + Ag</th>
<th>Zn</th>
<th>Hg</th>
<th>Sb + As</th>
<th>S</th>
<th>Formulae</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.55</td>
<td>0.07</td>
<td>0.03</td>
<td>0.23</td>
<td>0.71</td>
<td>3[(Cu,Ag)₂S₃,(Hg,Zn)S] ⋅ (As,Sb)₂S₃</td>
</tr>
<tr>
<td>2</td>
<td>0.62</td>
<td>0.09</td>
<td></td>
<td>0.25</td>
<td>0.79</td>
<td>10[(Cu,Ag)₂S₃,ZnS] ⋅ 3(As,Sb)₂S₃</td>
</tr>
<tr>
<td>3</td>
<td>0.56</td>
<td>0.09</td>
<td></td>
<td>0.23</td>
<td>0.77</td>
<td>10[(Cu,Ag)₂S₃,ZnS] ⋅ 3(As,Sb)₂S₃ approx.</td>
</tr>
<tr>
<td>4</td>
<td>0.56</td>
<td>0.07</td>
<td></td>
<td>0.22</td>
<td>0.76</td>
<td>8[(Cu,Ag)₂S₃,ZnS] ⋅ 3(As,Sb)₂S₃ approx.</td>
</tr>
<tr>
<td>5</td>
<td>0.48</td>
<td>0.02</td>
<td></td>
<td>0.18</td>
<td>0.57</td>
<td>10[(Cu,Ag)₂S₃,ZnS] ⋅ 3(As,Sb)₂S₃ approx.</td>
</tr>
<tr>
<td>6</td>
<td>0.61</td>
<td>0.09</td>
<td></td>
<td>0.25</td>
<td>0.76</td>
<td>3[(Cu,Ag)₂S₃,ZnS] ⋅ (As,Sb)₂S₃</td>
</tr>
<tr>
<td>12</td>
<td>0.59</td>
<td>0.08</td>
<td></td>
<td>0.25</td>
<td>0.74</td>
<td>3[(Cu,Ag)₂S₃,ZnS] ⋅ (As,Sb)₂S₃</td>
</tr>
<tr>
<td>17</td>
<td>0.59</td>
<td>0.08</td>
<td></td>
<td>0.23</td>
<td>0.65</td>
<td>3[(Cu,Ag)₂S₃,ZnS] ⋅ (As,Sb)₂S₃ very approx.</td>
</tr>
<tr>
<td>18</td>
<td>0.61</td>
<td>0.09</td>
<td></td>
<td>0.25</td>
<td>0.75</td>
<td>3[(Cu,Ag)₂S₃,ZnS] ⋅ (As,Sb)₂S₃</td>
</tr>
<tr>
<td>20</td>
<td>0.56</td>
<td>0.10</td>
<td></td>
<td>0.23</td>
<td>0.75</td>
<td>10[(Cu,Ag)₂S₃,ZnS] ⋅ 3(As,Sb)₂S₃</td>
</tr>
</tbody>
</table>

All analyses, with the exception of numbers 4 and 17, fit fairly closely one or the other of the two formulae:

1) \(10[(Cu,Ag)₂S₃,ZnS] \cdot 3(As,Sb)₂S₃\)

2) \(9[(Cu,Ag)₂S₃,ZnS] \cdot 3(As,Sb)₂S₃\)

or

\(3[(Cu,Ag)₂S₃,ZnS] \cdot (As,Sb)₂S₃\)

From these analyses, tetrahedrite would appear to...
form an isomorphous series.

The analysis of sample 4 fits approximately the formula \( 8[(Cu,Ag)\_2S,ZnS] \cdot 3(As,Sb)\_2S_3 \) which again fits into the isomorphous series.

Copper and silver replace one another in all proportions from 37.4 percent copper and .4 percent silver to 19.2 percent copper and 25.2 percent silver.

Zinc, as zinc sulphide, replaces the \((Cu,Ag)\_2S\) molecule in variable proportions, the zinc forming up to 6.3 percent of the mineral, by weight.

In all analyses, except one, zinc was present as 4 percent or over. As no zinc was found in the polished sections of the material studied under the microscope, it is logical to assume that it should be included in the formula.

In the mercurial tetrahedrite (Specimen No. 1) mercury and zinc, having the same valence, have been written as replacing each other in indefinite proportions. This \((Hg,Zn)S\) molecule in turn replaces, again in indefinite proportions, the \((Cu,Ag)\_2S\) molecule.

Specimen 5 is remarkable for its high silver content of 25.2 percent. It fits, quite closely, one of the same two general formulae.

Formulae and Silver Content

If we study these formulae in relation to silver content, and omit those of Numbers 4 and 17, both of which are approximations, we see that the following relation holds:
low-silver tetrahedrite, formula:

\[ 3 \left[ (\text{Cu}, \text{Ag})_2 \text{S}, \text{ZnS} \right] \cdot (\text{As}, \text{Sb})_2 \text{S}_3 \]

high-silver tetrahedrite, formula:

\[ 10 \left[ (\text{Cu}, \text{Ag})_2 \text{S}, \text{ZnS} \right] \cdot 3(\text{As}, \text{Sb})_2 \text{S}_3 \]

Number 2 appears to be an exception to this generalization.
CHAPTER V

THE SILVER CONTENT.
The silver content of tetrahedrite is clearly of major importance. In this Chapter it will be considered in connection with:

1. geographical location of deposits studied.
2. the mineral association of these deposits.
3. the type of deposit, i.e. true fissure or replacement.
4. the age of the associated minerals, particularly the galena.
5. physical properties.
6. etch tests.

LOCALITY

Specimens 2, 6 and 18 are from adjacent areas in Cariboo and Quesnel Mining Divisions (Plate ).

It is possible that Specimens 6 and 18 are from the same deposit.

Uncorrected assays of the tetrahedrite from these deposits give a silver content of .55, .5 and .45 percent, respectively.

These deposits will be considered further, under the heading of "Mineral Association".

MINERAL ASSOCIATION

The above three specimens (2, 6 and 18) with very low
silver are of simple mineral association - quartz and tetrahedrite only. The next lowest silver assay was from Specimen No. 12 - also a simple ore of quartz and tetrahedrite. Here, however, very minor quantities of other minerals, including galena, appeared.

With the exception of Specimen No. 1, all other ores carry at least 4.8 percent silver, and with this marked increase in silver content, we have a parallel marked increase in the proportion of associated minerals. The only other metallic mineral common to all these is galena.

Therefore, it might be concluded that these quartz-tetrahedrite ores, when free from galena, are very poor in silver and, further, that the appearance of galena accounts for, or is in some way connected with, the silver content of the tetrahedrite.

Further work, on the silver content of the galena of these ores, would be of interest.

Assays on other ores, along similar lines, will be needed to establish this relation. Should it be established, it would be of the utmost practical importance.

The possibility of establishing some such relationship for the gold content at once suggests itself. Gold determinations were not made in the course of this work.

However, in connection with Specimen No. 18, it has been stated that "the assays show that the mineralized rock does not carry appreciable values in gold and silver." This

suggests that these simple tetrahedrite-quartz veins are poor in both gold and silver. If this is true, they can be of little economic importance.

TYPE OF DEPOSIT

Generally, tetrahedrite of fissure veins carries a higher percentage of silver than that of replacement deposits. Warren, H.V.; personal communication.

All deposits considered here probably belong to the true fissure type.

The generalization does not hold in this case. Four of the ten samples assayed carried .55 percent silver or less.

One of these, the mercurial mineral discussed in Chapter III, is unusual and its failure to fit the generalization is not surprising.

The others, Specimens 2, 6 and 18, are the simple tetrahedrite-quartz ores mentioned under MINERAL ASSOCIATION. They are low in silver and yet are undoubtedly from fissure veins.

RELATIVE AGE OF GALENA AND TETRAHEDRITE

Here, again, further work must be done on the silver content of the associated galena. It might then be possible to show some relation between the relative ages of these minerals and the distribution of the silver.

The galena-tetrahedrite ores in this group are those
of Numbers 3, 4, 5, 17 and 20. The age of the galena in No. 5 could not be determined. In the remaining four, galena was, as nearly as could be determined, later than the tetrahedrite. In all these we have 4.8 percent silver, or over.

As pointed out above, it appears, from a general survey of the analyses, that there is some close connection between the presence of galena and the silver content of the tetrahedrite. And yet galena seems to have formed later than the tetrahedrite. This point requires further investigation.

Lacking galena assays, further speculation here is meaningless.

PHYSICAL PROPERTIES

The physical properties to be considered in relation to silver content are:

1) streak
2) specific gravity
3) fracture and lustre.

Streak.

All specimens gave a black or very dark brown streak on the streak plate.

It is only under special conditions that the brownish and reddish shades can be observed to advantage.

Two methods were used in comparing the streaks and in each case the samples were arranged in order, according to the streak, from reddish brown to dull black, and numbered
consecutively. Thus the powder at the reddish end of the scale was given the number 1, and that at the black end, the number 10.

The first method consisted in comparing the shade of the very fine powder which adhered to the glass walls of the vials in which the pure, powdered mineral was kept prior to assay. The second method was to spread a uniformly thin layer of each powdered specimen on a sheet of white paper. In each case they were arranged in order according to shade, and numbered 1 to 10.

The results are given below:

<table>
<thead>
<tr>
<th>Specimen number</th>
<th>Streak number (on glass)</th>
<th>Streak number (on paper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>1 (dark chocolate brown)</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>10 (dull black)</td>
<td>10 (dull brownish black)</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>1 (reddish brown)</td>
<td>3</td>
</tr>
</tbody>
</table>

As comparison was made by eye only, these results probably would not be duplicated in another trial.
The above table will be rearranged to permit a more ready comparison of silver content and streak number. The silver content will be included in the table and specimens arranged in order of silver content, beginning with the lowest.

<table>
<thead>
<tr>
<th>Specimen number</th>
<th>Silver content</th>
<th>Streak number (on glass)</th>
<th>Streak number (on paper)</th>
<th>Average streak number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2</td>
<td>6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>18</td>
<td>0.45</td>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>0.5</td>
<td>4</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>0.55</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>2.9</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4.8</td>
<td>9</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>20</td>
<td>6.35</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>7.8</td>
<td>7</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>11.0</td>
<td>8</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>25.2</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

It is to be observed that:

1. The five specimens showing a silver content of 2.9 percent or under have, with one exception, an average streak number of 3.

2. The four specimens showing a silver content of from 4.8 to 11.0 percent have, with one exception, an average streak number of 7 or 8.

3. The remaining specimen, with a silver content of 25.2 percent, has an average streak number of 10.
Therefore, we may conclude, that, the darker the streak the greater the silver content. This conclusion is in direct contradiction to Dana, who, under "Freibergite" states "streak often reddish".


This conclusion is probably of little practical importance as the differences in the streak are much too slight to permit of more than a doubtful comparison with specimens of known silver content. Still, at times, in field work, such a method of estimating the silver content might be useful.

Specific Gravity.

Specific gravity determinations were made for six specimens. They were corrected for "Insoluble" content, taken as silica.

The corrected results, arranged in order of their silver content, are given below:

<table>
<thead>
<tr>
<th>Specimen number</th>
<th>percent silver</th>
<th>specific gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.2 (6.1 mercury)</td>
<td>4.83</td>
</tr>
<tr>
<td>6</td>
<td>.5</td>
<td>4.45</td>
</tr>
<tr>
<td>4</td>
<td>4.8</td>
<td>4.57</td>
</tr>
<tr>
<td>20</td>
<td>6.3</td>
<td>4.67</td>
</tr>
<tr>
<td>5</td>
<td>25.2</td>
<td>4.71</td>
</tr>
</tbody>
</table>

For numbers 6, 4, 20 and 5 the specific gravity
varies directly as the silver content. The mercury content of number 1 accounts for its high specific gravity.

Fracture and Lustre.

Specimens were arranged side by side, in order of their silver content. There was no clear relation between variations in fracture and lustre, and silver content.

**ETCH TESTS**

A systematic series of etch tests were made on pure tetrahedrite from each specimen. As the silver content varied up to 25.2 percent it was hoped that the silver content would in some way be reflected in the etch reactions.

A standardized technique was employed throughout these tests. The same grain of pure tetrahedrite was used for the series of reagents. It was polished on rouged chamois between each test. Reagents were allowed to remain on the specimen for one minute and then washed with a gentle stream of water. Surplus water was blown away, and the specimen dried and examined. For faint reactions, etched and unetched portions in contact were examined.

Results were checked and tabulated. No significant variations in the etch tests, from those given in standard works, were noted. Concentrated nitric acid normally left a light brown stain. Reactions to other reagents were practically negative.
CHAPTER VI

SUMMARY AND CONCLUSIONS
The results of this paper are summarized below.

ANALYSES.

All analyses fall appreciably below 100 percent.

ACCURACY.

The percentages given are probably correct. The low totals are satisfactorily explained. Sufficient checking has been done to justify confidence in the results.

MERCURIAL TETRAHEDRITE.

Tetrahedrite from North Kootenay Mines, Ltd., Windermere, assayed 6.1 percent mercury. Mercurial tetrahedrite, or schwatzite, has not previously been recognized in British Columbia. Etch reactions are not diagnostic. The fracture and the lustre are not those of normal tetrahedrite.

The formula may be written

\[ 3[(Cu,Ag)_{2}S, (Hg,Zn)S](As,Sb)_{2}S_{3} \]

ARGENTIFEROUS TETRAHEDRITE OR FREIBERGITE.

Tetrahedrite from Keno Hill, Yukon, assayed 25.2 percent silver. This is remarkably high, as Dana (unabridged) lists only two examples of freibergite carrying over 25 percent silver.

Etch reactions are not diagnostic. Nor can fracture or lustre be correlated with the high silver content.

The formula may be written
10\([(\text{Cu,Ag})_2 \text{S}_2 \text{ZnS}] \cdot 3(\text{As,Sb})_2 \text{S}_3\]

An analysis of the associated galena would be interesting.

**TETRAHEDRITE LOW IN SILVER.**

Where tetrahedrite is low in silver it is unassociated with other minerals and we find a simple tetrahedrite-quartz ore. Three such samples came from the Cariboo and one from the Illecillewat.

**TETRAHEDRITE HIGH IN SILVER.**

As the silver content of the tetrahedrite increases, the ores become more complex. The increase is closely related to the galena content.

**GALENA-SILVER RELATIONS.**

Further work is required to show whether or not there is any parallel relation in the silver content of the galena, or orderly distribution of the silver between galena and tetrahedrite.

**TYPE OF DEPOSIT.**

All ores examined are from fissure veins, as contrasted to true replacement deposits. The silver content of the tetrahedrite of these vein deposits varies widely, up to 25 percent. The association of tetrahedrite with galena, and other minerals, in quartz veins, favours the formation of
highly argentiferous tetrahedrite.

STREAK AND SILVER CONTENT.

The streaks vary from dark reddish brown to dull black. Low silver content gives a reddish streak; high silver content results in a dull black streak.

SPECIFIC GRAVITY AND SILVER CONTENT.

The specific gravity of tetrahedrite tends to increase as the silver content. The presence of mercury is also indicated by an increased specific gravity.

FRACTURE AND LUSTRE.

Fracture and lustre vary with the source of the tetrahedrite. No relation between the variation of these physical properties and the silver content was noted.

FORMULAE

Tetrahedrite, as studied, appears to vary in composition, forming an isomorphous series.

The formulae are:

\[ 10\left[\text{(Cu,Ag)}_2 \text{S, ZnS}\right]_3 \]
\[ 9\left[\text{(Cu,Ag)}_2 \text{S, ZnS}\right]_3 \]
\[ 8\left[\text{(Cu,Ag)}_2 \text{S, ZnS}\right]_3 \]

The composition of the highly argentiferous varieties corresponds to that of the first formula.
PHOTOMICROGRAPHIC SET UP
A few details of technique are appended. This is justified only insofar as details of method differ from those of standard practice.

Available apparatus, not always the most suitable, has had to be used. The actual technique evolved for this apparatus may be of interest to those working along similar lines in the future.

Technique, justifying mention here, is that developed for:

1. Preparation of dammar gum and mounting mineral specimens therein.
2. Photomicrography.

**DAMMAR SECTIONS**

Where it was necessary to polish small pieces of ore, or where it was desirable, because of the saving of time in grinding, to prepare sections under one half inch in diameter, it was found convenient to use a gum mount of the following composition.

**Composition**

\[
\begin{align*}
\text{Dammar Gum} & \quad 3 \text{ parts} \quad 150 \text{ grams} \\
\text{Shellac (lemon)} & \quad 2 \text{ parts} \quad 100 \text{ grams} \\
\text{Turpentine(pure)} & \quad 1 \text{ part} \quad 50 \text{ grams}
\end{align*}
\]

Preparation of Stock Gum.

The gum is prepared, as described below, poured and cooled, broken to a convenient size, and kept to be remelted
and used as required. In this work, about 300 grams was prepared at a time.

The dammar gum is thoroughly melted in an aluminum or enameled saucepan. Shellac flakes are added gradually with continual stirring.

Turpentine is added as rapidly as possible. The mixture is stirred as vigorously as possible, care being necessary to prevent the turpentine taking fire. The mixture must be kept quite hot during this addition.

When all the turpentine has been stirred in, the gum is quickly poured on a well oiled sheet of tin and allowed to cool. It will be rather brittle when cold.

It is now ready to be remelted and used in the mounting of specimens as required.

Mounting the Specimen.

Brass rings, sections cut from brass tubing, were used as moulds. Dimensions of the moulds may vary from $\frac{3}{4} \times \frac{1}{2}$ inch to $1 \frac{1}{2} \times \frac{3}{4}$ inch.

In use, these are oiled with heavy machine oil, and set on an oiled tin plate. The gum is melted, and heated till quite fluid. A thin layer of gum is quickly poured into each mould, the mineral specimen or specimens quickly pressed into this, and the mould then filled with the hot gum. With rapid and accurate manipulation, six or eight sections can readily be mounted at one time.

Any melted gum, not poured, should be discarded. It cannot be remelted and used.
Where small fragments of mineral had to be mounted, these were arranged as required in the bottom of the mould, on the oiled tin, and very hot gum poured in to fill the mould. This procedure was found more satisfactory, for small grains, than that described above.

Oiled paper in the moulds was found unnecessary.

Grinding and Polishing.

The mounted specimens are removed from the brass moulds and ground and polished as usual.

The mounts, after standing several months, tend to warp and crack.

**PHOTOMICROGRAPHY**

General.

Photography of polished sections of ores through the metallographic microscope is identical in principle with the better known photographic processes.

Essentially, the required section is brought into the field of view of the microscope, a camera bellows superimposed on the eyepiece, and the resultant image sharply focussed by means of the micrometer focussing screw of the microscope. A photographic plate is substituted for the focussing screen, given a predetermined exposure, and developed and printed as usual.

Apparatus.

The photographic set-up, using equipment available at
the University of British Columbia, is shown in the accompanying illustration (Plate XXI).

The regular shutter, with lenses, is removed from the camera. The adopter, of concentric metal rings, is slipped over the eyepiece of the microscope and the camera bellows lower to fit into this adopter.

The arc lamp illustrated, with its accompanying resistance, is used as a source of illumination. It is set up so as to project a horizontal beam into the vertical illuminator of the microscope. The arc was found to be quite stable for the short exposure times required.

For accurate timing of exposures, the shutter of the copying camera, minus lenses, is fixed in the beam of the lamp as shown.

Light filters, when used, are placed over the microscope eyepiece, within the camera bellows.

Bausch and Lomb microscope 132416 was used.

Photographic Material.

Wratten and Wainwright Panchromatic plates, \(3\frac{1}{2} \times 4\frac{1}{4}\) inches, were used exclusively.

Filters, from a set of Wratten "M" filters, were used, as required, to increase the contrast between the important minerals. These filters necessitate the use of panchromatic plates, as above.

Preparation for Exposure.

In general, when a clear, sharp, image appears on
the focussing screen, the apparatus is in adjustment. It is then simply a matter of correct exposure and development.

The area to be photographed must first be located, using the microscope as usual. Some source of illumination other than the arc lamp must be used. When this has been done, and suitable magnification used, the arc lamp, shutter and camera bellows are set up as shown in Plate XXI. Adjustments are now made with the shutter mechanism in the light beam, set at "T", and shutter and diaphragm wide open.

The vertical illuminator will probably require adjustment, on both the horizontal and vertical axis, so as to give a bright, uniform field on the ground glass. The camera bellows are adjusted so as to give the required size of image. This is best made somewhat larger than required in the final print, and masked to the required size in the printing.

The image is sharply focussed, the point of perfect focus being determined with the aid of a lens.

With the microscope and objectives available, when using the higher magnifications, it is impossible to obtain sharp focus over the full field. In such cases the area of greatest importance is placed in the centre of the field (by using cross motion screws on the microscope stage) and focussed sharply. Excessive relief in the section will render sharp focus on all minerals impossible of attainment.

Care and judgment are required here, as the resultant photograph can be no more distinct than the image which appears on the screen. Contrast can be modified by the use of
filters, but definition is controlled at this point by correct illumination and focussing.

Neglecting, for the present, the use of light filters (to be discussed later), we are now ready to make the exposure.

The Exposure.

The shutter is closed, cutting off all light from the section.

A plate holder with plate is inserted in place of the ground glass, locked, and the dark slide drawn out.

One fiftieth of a second was found to be a suitable exposure for average sections. This exposure is accurately made with the shutter mechanism in the light beam.

The plate is then ready for development.

Development.

Development of the panchromatic plates must be done by the aid of a green safelight. They should not be exposed, even to this light, longer than absolutely necessary, nor should they be held close to it.

Kodak Metol Quinol developer powders were used. Completion of development was determined by inspection under the green safelight.

Development is complete when:

1) highlights of subject are just visible through the back of the plate;

2) when the image ceases to develop further;
3) when the properly exposed plate reaches the correct density.

These presuppose a fairly correctly exposed plate.

It would be more satisfactory to develop these plates by the "Time and Temperature Method". This would involve the determination of the correct time of development within a range of probable temperatures, in a developer of fixed composition and concentration. Once these factors were determined development could be done in total darkness.

Other details of development, etc., have been tabulated and filed with the Department of Geology. They refer particularly to Copying and the Preparation of Lantern Slides, but contain many points of use here.

Printing.

Satisfactory prints were obtained from Photo Arts Supply, Vancouver.

Use of Contrast Filters.

Light filters may have to be used to give the required contrast in the photomicrograph. In the selection of the best filter or filters, visual inspection is probably the best guide. Filters will require increased exposure.

Eastman Kodak Co.: "Photomicrography" and "Wratten Light Filters".

For discussion of the use of filters, the reader is referred to the above pamphlets. Both are readily obtainable, brief, and instructive, and, such being the case, no further discussion is required here.
Other general texts are listed in the Bibliography.
<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Source</th>
</tr>
</thead>
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