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MINERALOGRAPHY REPORT ON ENGINEER MINE

A report submitted in partial fulfillment of the
course in Geology 409 of Fourth Year Applied Science at
the University of British Columbia

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April 15 1951

Acknowledgments

This report is based on laboratory work done on specimens collected by Mr. R. L. Christie.

The writer wishes to convey his thanks to Dr. R. M. Thompson and to Mr. J. Gower who photographed and X-rayed specimens and offered helpful advice; and to Mr. J. Donnan who helped in the preparation of the polished sections.

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General Mineralization

The ores at Engineer Mine occur in veins that range from simple veins a few inches in thickness to compound ones over 200 feet in thickness. The veins consist of quartz, calcite, and intercalated and brecciated wall rock. Vugs lined with calcite or quartz are very common, measuring often as much as one by two feet in cross-section. Banding and comb structure are also common, both around the fragments of wall rock and along the walls of the veins. The included fragments are more highly concentrated along the foot-wall than along the hanging-walls of the veins.

According to H. T. James¹, resident mining engineer for the Atlin district, bands of light green material were plentiful on the lower levels and consisted of a fine-grained aggregate of quartz and a micaceous material. Metallic min-

1. James, H. T., Report of the Minister of Mines, B.C., 1927, p. C113.

erals were very scarce except for the pyrite which occurred throughout the brecciated material and as crystals lining the quartz vugs. Some chalcopyrite was found in vugs and large reniform masses of allemontite were commonly found in the upper levels. The economically important metal was gold which occurred as a light-coloured material (identified microscopically as electrum) and which was almost invariably associated with a dark-green mica.

Microscopic examination and X-ray analysis have shown that the metallic minerals present are arsenic, antimony, allemontite, dyscrasite, miargyrite, pyrargyrite, electrum, pyrrhotite, and arsenopyrite. The non-metallic minerals are quartz, calcite, and fuchsite.

Since arsenic, antimony, and allemontite constituted most of the sections examined in the laboratory and since little is known of these minerals, the mineralogy report is concerned mostly with them.

Allemontite, Arsenic, and Antimony

Introduction

The existence and composition of allemontite has long been a question for debate.

W. E. Ford², in "Dana's Textbook of Mineralogy", has ascribed to it the formula $SbAs_3$ and called it arsenical antimony.

Walker³, after studying allemontite from Atlin,

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2. Ford, W. E., Dana's Textbook of Mineralogy, 4th ed., p.400.
 3. Walker, T. L., "Allemontite from Atlin, B.C.", Am. Mineralogist, 1921.

B.C. in 1921, came to the conclusion that allemontite is really an intergrowth of antimony and arsenic and not a definite compound or an isomorphous mixture. He suggested that the word "allemontite" be dropped from the literature.

In 1936, Ralph J. Holmes⁴ made an X-ray study of allemontite. He concluded that allemontite consists of an intergrowth of two components. Component "A" is arsenic bearing antimony in such small amounts that there is no change in the X-ray pattern from that of pure arsenic. Component "B" is an antimony-arsenic mixture which might be a compound or a solid solution. The variable composition, which lead Walker to discredit the existence of allemontite, is due to variations in relative portions of the two components. Holmes suggested that under the original conditions of formation, arsenic and antimony formed a solid solution series and under later changed conditions only component "B" was stable and any arsenic present in excess of that necessary to form "B" was released as free arsenic. He thinks that the name "allemontite" should be restricted to component "B" and not to the intergrowths of components "A" and "B" as proposed by Vander Veen.

Investigations by A. B. Edwards⁵ have shown that under natural conditions the single solid solution phase of arsenic and antimony has undergone unmixing as shown by the qualitative equilibrium diagram of Fig. 1.

4. Holmes, R. J., "An X-ray Study of Allemontite", Am. Mineralogist, 1936.

5. Edwards, A. B., "Texture of the Ore Minerals", 1947, p. 41.

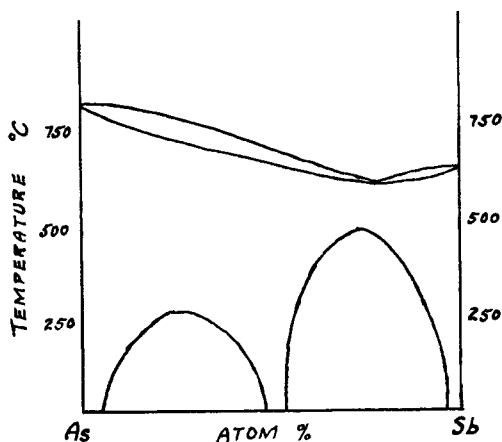


Fig. 1. Equilibrium Diagram of the Arsenic-Antimony System.

Edwards states that in natural intergrowths, three homogeneous alloy phases have been established. These are (1) an arsenic-rich phase containing up to five atomic percent antimony, (2) an antimony-rich phase, containing up to five atomic percent arsenic, and (3) an intermediate arsenic-antimony phase containing about 50 atomic percent of each. For this third solid solution, he proposes the name "stibarsenic". The natural intergrowths consist of either a mixture of the antimony-phase and the arsenic-antimony phase (allemontite I), or a mixture of the arsenic-phase and the arsenic-antimony phase (allemontite III). Less commonly, the homogeneous arsenic-antimony phase occurs alone (allemontite II). X-ray examination shows that, although the arsenic-antimony phase (stibarsenic) has a distinctive X-ray pattern, it is an alloy and not a compound, and owes its persistent homogeneity to the fact that its composition is intermediate between the two immiscibility gaps of Fig. 1.

In this report, the term "allemontite" will be used

to refer to the arsenic-antimony phase. The arsenic-rich phase will be called arsenic because it has the same X-ray pattern as pure arsenic and because most native arsenic also has some antimony in solid solution. Similarly, the antimony-rich phase will be called antimony. It is thought that the terms Allemontite I, Allemontite II, and Allemontite III are little known and that confusion may result in using them. As indicated by the phase diagram of Fig. 1 and by laboratory observations, any intergrowths of arsenic and antimony are usually allemontite plus either antimony or arsenic.

Laboratory Procedure

Arsenic, antimony, allemontite, and dyscrasite, in polished section, are various shades of creamy white and greyish white. Because of this similarity in appearance and because of the close association of these minerals, they will be considered under one group when discussing laboratory procedure.

All the etch reagents listed in Short's "Microscopic Determination of the Ore Minerals" were tried and the polarization colors were noted. These four minerals vary from isotropic to strongly anisotropic with polarization colors usually of yellowish-brown and dark bluish- or brownish-grey. Similarly, the etch reagents listed in Short are of little use because, as shown in the table on page 4, none of these minerals has definite distinguishing reagents.

Use of $KMnO_4$

Some distinction could be made with a solution of $KMnO_4$. Both acidic and basic solutions were tried, but the

basic solution, although not as strong as the slightly acidic solution, gives a more uniform etch. A solution of 1 gram of KMnO_4 per 100 c.c. of water was used and it was found that the solution must be made every laboratory period because it seems to become weaker with standing and its etching powers change. The following results were obtained after applying KMnO_4 for one minute:

Arsenic: The reagent almost immediately tarnishes the mineral yellowish-brown. If the solution is left for one minute and then the KMnO_4 is washed off and the tarnish rubbed off with wet tissue before it has time to dry, the arsenic will still have a slightly darkened grey colour which can only be removed by buffing. Repeated treatments like this will darken the arsenic thus increasing the contrast between it and the allemontite. If instead of wiping off the reagent after one minute has elapsed, the KMnO_4 is just washed off with water, the brown tarnish upon drying, will turn dark brown with patches of blue iridescent tarnish.

Antimony: The result is usually negative, but a very slight brownish-yellow tarnish may appear if the mineral is allowed to dry after the KMnO_4 is washed off. Any tarnish which may result can be easily removed with wet tissue.

Allemontite: If the mineral is allowed to dry, after the KMnO_4 has been washed off, a yellowish-brown tarnish will usually result. This can usually be removed by rubbing with wet tissue.

Dyscrasite: The mineral is almost immediately tarn-

ished and if, after one minute, the solution is washed off, a dull irridescent tarnish will usually result. If, while washing off the $KMnO_4$, the dyscrasite is rubbed lightly with wet tissue, the tarnish becomes very bright. This bright tarnish is usually blue on lathed crystals and is of several colors on the round blebs, being usually red in the middle and green on the outside. If rubbed fairly hard while still wet, the tarnish is completely removed.

In the foregoing descriptions the expression "allow the mineral to/dry" means---wait till the thin film of water, which remains after the washing, has evaporated. If the tarnishes are allowed to dry completely, they can only be removed by buffing.

With a little practice, the above procedure can be used to distinguish dyscrasite and to tell arsenic from antimony or allemontite. The following color relations can be used to tell antimony and allemontite apart after they have been distinguished from arsenic and dyscrasite.

Relative Colors

The relative colors of these four associated minerals are fairly consistent and can usually be used to identify some of the minerals in a section after one of the minerals has been identified by other means. The following results were obtained:

- Arsenic (light grey) - against Allemontite (creamy-white)
- Arsenic (light grey) - against Dyscrasite (creamy- to yellowish-white)
- Antimony (white) - against Allemontite (greyish-white)

- Antimony (white) - - against Dyscrasite (creamy- to yellowish-white)
- Allemontite (white) - against Dyscrasite (creamy- to yellowish-white).

With different optical orientation, most of the above minerals, upon close examination, exhibit slightly different shades of white. Consequently, two adjacent areas of the same mineral with different optical orientation might be interpreted as two different minerals by using the above color criteria. After some practice this error can usually be avoided. This difference in relief in two adjacent areas shows up in places in the antimony of Specimen 6.

Macroscopic Examination

The arsenic-rich and the antimony-rich specimens from the Engineer Mines are markedly different macroscopically.

The arsenic-allemontite specimens exhibit coarse colloform banding with the free surfaces sometimes displaying botryoidal structure. The alternating bands of arsenic and allemontite range in thickness from microscopic to about one inch. In the specimens from Engineer Mine, arsenic bands are much thicker than are allemontite bands and can be distinguished on the surface of the polished section by the black tarnish which arsenic acquires on exposure to the air. Tension fractures, caused by changes in volume on cooling, occur parallel to the banding. The botryoidal structure is not very common in the arsenic-allemontite ores, but in one specimen where it occurs, the individual lobes are about one-half inch in diameter and are covered with a finer botryoidal structure in which the individual lobes are about 1/32 inch in diameter.

Reagent	Arsenic	Antimony	Allemontite	Dyscrasite
HgCl ₂	weak ¹ greyish-brown tarnish	weak light-brown tarnish	very weak yellowish-brown tarnish	immediate yellowish-brown tarnish
KOH	negative	negative	negative	negative
KCN	negative	usually negative	strong, very light-brown tarnish	weak light-brown or strong ² dark-brown, tarnish
HCl	negative	usually negative	1 minute- negative 2 minutes - very strong blueish-grey tarnish in patches, and near contact with surrounding arsenic	α -dyscrasite -light brown β -dyscrasite -negative
FeCl ₃	grey with black dots (very strong)	1 minute - strong light brown tarnish 1½ minute- strong blueish-grey tarnish	immediate irridescent tarnish	immediately irridescent, then brown
HNO ₃	-quickly irridescent -delayed slow effervescence (sometimes) -finally very dark grey fumes tarnish light brown	quickly irridescent, then dark brownish-grey	irridescent, then dark brownish-grey	immediately irridescent; sometimes followed by vigorous effervescence and finally turning grey; fumes tarnish yellowish-brown
Aqua-regia	delayed effervescence which becomes more vigorous with time; etches differentially grey and black	delayed action, then turns through light brown to dark brown while effervescing	delayed effervescence and dark brown to black tarnish; fumes tarnish brown	not tried; probably positive

Observed Etch Results

1. "weak" tarnish means the tarnish can be easily rubbed off with wet tissue.
2. "strong" tarnish means the tarnish cannot be removed with wet tissue.

The antimony-allemontite specimens do not have coarse banding but have a fine botryoidal or pimply structure. Individual pimples range in size from microscopic to about one-quarter inch in diameter; those of the nearly pure allemontite being more rounded than those of the antimony specimens. Spaces between individual lobes or groups of lobes of the botryoidal minerals are filled with calcite (Fig. 2B).

Microscopic Examination

Arsenic-Allemontite

Most of the specimens of this type exhibit alternating, sharply-defined bands of allemontite with darker bands of arsenic containing allemontite. In one specimen, however, the contact between these two types of bands was very irregular (Fig. 9 and Fig. 10). If the sharply-defined bands are examined under a magnification of 625, it is seen that the light bands are usually allemontite, often with a few barely visible beads of arsenic dispersed throughout. The dark bands are usually arsenic with minute rods and beads of allemontite dispersed throughout, or a eutectoidal intergrowth of arsenic and allemontite. Some of the arsenic bands contain up to 50 percent of allemontite in minute rods and irregular patches while other arsenic bands contain a dendritic network of allemontite ^{with additional beads of allemontite} between the meshes of this network (see Specimens 1, 3, and 5). Although many of the adjacent bands of arsenic have only slight differences in composition, the contact between any two bands is very sharp as can be seen under a magnification of 625. The banding shows that the mineralizing solutions were alternating in composition from those

containing 50 atomic percent antimony to those containing less than 50 atomic percent antimony. The bands having equal amounts of antimony and arsenic formed pure allemontite without releasing excess arsenic and the bands containing under 50 atomic percent antimony were deposited as a homogeneous solid solution which, on cooling, released the excess antimony as allemontite. The phase diagram of Fig. 1 shows that very small changes in composition can greatly alter the ratio of arsenic to allemontite.

Many of the bands exhibit cusps and curves (Fig. 10) which are probably the internal expression of what would be botryoidal structure if a free surface were present.

Examination under crossed-micros reveals a mosaic of irregular, slightly elongated grains up to one-half millimeter in length. The boundaries of these grains are not dependent upon the boundaries of the bands. The optical orientation of the dispersed allemontite could not be definitely determined because of the small size of the rods and beads. In some specimens, however, all the dispersed allemontite in one band extinguishes at the same time, regardless of the grain boundaries.

Tension fractures were formed in the arsenic-allemontite specimens on cooling. These fractures are parallel to the banding between the arsenic and allemontite but they are usually not along the contacts of these two minerals. The fractures cut across individual grains and so must have formed after solidification.

Some of the arsenic grains of Specimen 4 have twinning in which the individual twins have a slight curvature resulting from deformation of the specimen. According to M. J. Buerger⁶, if KMnO_4 acidified with H_2SO_4 is applied to a twinned grain, the twinning, if rotational, will become accentuated; but if it is translational it will remain unaltered. The result obtained when this procedure was applied to the arsenic grain proved the twinning was rotational.

Antimony-Allemonite

No banding is seen in these specimens. However, two types of the antimony-allemonite combinations occur,--- specimens composed mostly of antimony and specimens composed mostly of allemonite.

In the antimony specimen, the antimony occurs as small rounded areas, separated by calcite. These areas range in length from 1/16 inch to one inch and consist of either antimony or antimony plus allemonite. The allemonite occurs as an irregular area along the boundaries of the antimony and calcite and has been released from the antimony on cooling.

The allemonite-rich material also occurs as rounded irregular areas separated by calcite (see Fig. 2B). The allemonite forms the bulk of these areas and under crossed-nicols and a magnification of 625 exhibits a very fine irregular mosaic pattern. The antimony occurs as a very narrow exsolution rim along the areas of allemonite and also as a reef-like ridge separated from the main areas of allemonite by a thin

6. Buerger, M. J., "The Plastic Deformation of Ore Minerals", Am. Mineralogist, 1928, pp. 1-7.

band of calcite (see Fig. 3). The following explanation is offered for this structure: A vein of quartz exhibiting comb structure was badly fractured and the spaces were filled with allemontite which solidified. Particles of the fractured quartz then settled against the allemontite. On further cooling, antimony was released from the allemontite and formed a rim along the outside of the allemontite and also around the quartz particles. Yet further cooling caused contraction and tension fractures along the line of quartz particles. The calcite was then introduced, filling the empty spaces and the tension cracks. From observations of other areas of the same specimen, it was proved that the order of deposition was quartz first, allemontite second, and calcite third.

Oxides on the Arsenic and Antimony Minerals

Only two kinds of oxides were found on the specimens from Engineer Mine.

A white to creamish-colored powder identified by X-ray analysis to be ξ enarmonite (Sb_2O_3) covers much of the pimply antimony and also coats cavities in the quartz of the antimony specimens. This oxide also coats the allemontite bands of the arsenic-allemontite specimens where a cross-section of the banding is exposed.

Purplish- to reddish-brown oxide, identified by X-ray analysis to be hematite, coats the arsenic bands of the arsenic-allemontite specimens. The hematite also coats cavities in the quartz of the antimony-allemontite specimens.

Dyscrasite (Ag₃Sb)

Dyscrasite occurs as exsolution in laths up to two millimeters and in rounded and irregular patches (see Fig. 5). It is associated with arsenic, antimony, and allemontite. In some cases, the dyscrasite occurs as a few laths or blebs scattered at random throughout the whole specimen. In one case (Specimen MgA-1), the dyscrasite is concentrated in two definite bands in the arsenic. The dyscrasite in the one band occurs in arsenic which contains about 10 percent dispersed allemontite. It is in the form of large laths and irregular patches. In some places the laths seem to radiate out from the patches. (see Fig. 5). In the second band of this specimen, the dyscrasite also occurs in the arsenic, but each individual lath is surrounded by a small area of allemontite (see Fig. 7 and Fig. 8). The arsenic in this area contains about 50 percent dispersed allemontite. The following explanation is offered for the differences in these two bands: The silver at temperatures just below those of solidification of the dyscrasite forms a compound or solid solution with the antimony and this compound or solution has a higher ratio of antimony to silver than does the compound dyscrasite. Upon cooling, this compound or solution releases the excess antimony and forms dyscrasite. The antimony forms allemontite with the surrounding arsenic and in the case where the arsenic contained less than 10 percent dispersed allemontite it absorbed the extra allemontite formed. In the case where the surrounding arsenic contained about 50 percent dispersed allemontite, the extra allemontite could not all be

absorbed by the arsenic and so remained around the dyscrasite laths.

not mentioned in latest Dana.

Short⁷, in his "Microscopic Determination of Ore Minerals", has listed two kinds of dyscrasite---an α -dyscrasite and a β -dyscrasite; the former is more silvery in color and more chemically reactive than the latter. In the laboratory work, two kinds of dyscrasite were noticed. Out of three specimens tested with HCl, two were negative to the etch reagent and one attained a brown tarnish. It was also noticed that if the specimens were left exposed to the air, some laths of the dyscrasite would tarnish a blue or dark grey color while other laths of the dyscrasite would remain unchanged. Other differences in chemical reactions were noticed when KCN and HNO₃ were applied. Some blebs or laths effervesce with the HNO₃ and others just etch. In one case, the bleb which effervesced with HNO₃ was also one of those which tarnished in air.

could be diff. due to orientation

The dyscrasite is isotropic to anisotropic and its polarization colors are yellowish-brown to dull bluish-grey. The specimens examined had no natural twinning, but in some cases the dyscrasite will twin under the pressure of a needle.

Ruby Silvers

Ruby silvers were found in an antimony-rich specimen and in an arsenic-rich specimen.

Miargyrite (Ag₂S.Sb₂S₃), identified by its strong anisotropism and red internal reflection, occurs in the arsenic of Specimen MgA-1. It occurs in irregular patches beside the

7. Short, M. N., "Microscopic Determination of Ore Minerals", U. A. Geological Survey Bull. 914, p. 126a.

dyscrasite laths (see Fig. 6) or completely surrounded by dyscrasite (see Fig. 5). It seems to have been formed by exsolution.

Not checked
Miargyrite and pyrargyrite ($3\text{Ag}_2\text{S}\cdot\text{Sb}_2\text{S}_3$) occur together in the antimony of Specimen 6 and seem to be replacing the calcite along the contacts of the calcite and antimony. The miargyrite was identified by X-ray analysis and the pyrargyrite was identified by its weak anisotropism and its deep red internal reflection. Where the pyrargyrite is in contact with the calcite, it has a reddish-brown internal reflection.

Electrum and Fuchsite

The electrum (Ag,Au) occurs in arborescent forms in a dark green mica. Numerous small veins which have an average width of 200 microns, and which are composed of patches of quartz and electrum, cut the mica. The quartz and electrum in these veins were probably deposited contemporaneously.

The refractive index of the green mica, taken by comparison with oils, is between 1.5866 and 1.5993. This range of indices is lower than that of the vanadium mica, roscoelite⁸, but is approximately equal to that of the chromium mica, fuchsite. The mica is very finely crystalline with some of the needle-like crystals forming spherulites.

Arsenopyrite and Pyrrhotite

Arsenopyrite was seen in two polished sections, Specimens 8 and 9. In both of these sections it is in irreg-

8. Winchell, A. N., "Elements of Optical Mineralogy", 4th ed., 1951, p.369.

ular patches and in rhomb-shaped crystals surrounded by latter quartz (see Fig. 4).

Arsenopyrite also occurs on the surface of casts in some quartz. It occurs as minute, prismatic, yellowish-brown tarnish^{ed} crystals which are up to 1/10 millimeter in length. These crystals appear to coat the quartz, but, when examined with binoculars, are seen to occupy minute hollows in the quartz. Since some of the casts in the quartz have rhomb-shaped cross-sections, they were probably formerly occupied by crystals of calcite. The arsenopyrite crystals may have been on the outside of the calcite before the quartz was deposited. Such an order of deposition would account for the arsenopyrite crystals occupying hollows in the quartz.

The pyrrhotite only occurs in Specimen 8 where it occupies spaces along the cleavage planes of calcite (see Fig.4). Such an occurrence indicates that the pyrrhotite was deposited after the calcite and at a lower temperature than that of the melting point of calcite.

Quartz and Calcite

Very fine-grained quartz encloses or partly encloses most of the specimens examined (Fig. 2). Much of this quartz seems to contain numerous small fragments of calcite which, when beneath the polished surface of colorless quartz, show as white spots. These calcite fragments have been leached out of the quartz along the vein contacts thus leaving the surface of the quartz full of small irregular holes. In other specimens (see Specimen 12), crystals of calcite up to two

inches across have been leached out of the quartz, leaving it full of casts. Quartz also occurs as crystals lining many of the vugs and as fragments in the interstices of the antimony-allemontite specimens.

Calcite occurs mainly as a filling in the interstices of the antimony-allemontite specimens. In such cases, its deposition follows one period of quartz deposition and precedes another.

Paragenesis

At Engineer Mine, there were several periods of mineralization separated by periods of fracturing. The specimens can be grouped into different types, each type probably coming from a different part of the mine and each type having its own characteristic paragenesis.

Dyscrasite shows exsolution characteristics and has been deposited simultaneously with the surrounding minerals which may be either arsenic, antimony, or allemontite. Also any association of either arsenic and allemontite or antimony and allemontite is ^{as} an exsolution pair.

The deposition of the arsenic-allemontite (Specimens 1, 3, 4, and 5) was followed by brecciation and then by deposition of quartz around the fragments (Fig. 2A). Such an origin would account for the banding in the arsenic abutting against the quartz banding at right angles and for the banding in the quartz completely encircling the fragment of arsenic.

Specimen 6 is composed mostly of antimony in which

calcite largely fills the spaces between the lobes of antimony. Ruby silvers have partly replaced the calcite along its rims. A one half-inch vein of quartz passes through the centre of the antimony specimen and, as in the arsenic specimens, was probably injected after fracturing of the antimony.

The relative age of the quartz and allementite (Specimens 2 and 7) is difficult to determine. Upon a macroscopic inspection, the allementite looks as though it is filling the centre of a quartz vein. A microscopic examination reveals that the enclosing quartz completely surrounds areas of allementite indicating that it was deposited after the allementite. However, the quartz in the interstices of the allementite has good crystal outlines and was deposited before the calcite and probably before the allementite. The quartz lining the specimen also contains one rhomb of arsenopyrite, indicating that this quartz was second to the arsenopyrite. Probably the best way to explain the above structures is to allow two periods of quartz mineralization,---one before and one after the deposition of the allementite and calcite.

Specimen 8 shows clearly the relations between arsenopyrite, quartz, calcite, and pyrrhotite (see Fig. 4). Because arsenopyrite occurs in rhomb-shaped crystals in the quartz, it was deposited before the quartz. The well defined crystals of quartz which occur in the calcite and the quartz which exhibits comb structure projecting into the calcite, indicate that the calcite was deposited after the quartz. The occurrence of pyrrhotite along the cleavage planes of the calcite proves that the pyrrhotite was deposited after the calcite

and at a temperature below that of the melting point of calcite.

The electrum, as stated previously, always occurs with quartz in veins that cut the fuchsite. Fuchsite⁹ has a wide distribution throughout the gold-bearing districts of the Canadian Shield. It is associated with faults and is probably hydrothermally altered wall rock. At Engineer Mine, the fuchsite and the associated electrum always occur as tabular fragments enclosed in quartz.

Although it is likely that any order of deposition determined from the available information will be partly incorrect, the following probable paragenesis is given:

1. formation of tension fractures
2. formation of fuchsite by wall rock alteration
3. deposition of arsenopyrite
4. deposition of quartz and electrum
5. deposition of arsenic, antimony, and allemontite
6. deposition of calcite
7. deposition of ruby silvers
8. deposition of pyrrhotite
9. fracturing of veins
10. deposition of most of quartz.

Conclusions

Cairnes in his report on the Taku Arm belt, proposed two probable methods of formation of the quartz veins. He favors the theory which states that the quartz-carrying

9. Whitmore, D. R. E., Berry, L. G., and Hawley, J. E., "Chromium Micas", Am. Mineralogist, Jan.-Feb., 1946, Vol. 31.

solutions were forced into a weak part of the strata. The quartz, after being deposited, enlarged the fractures by forcing out the walls with its pressure of crystallization. The writer thinks that, if such were the case, there would be no crystal-lined spaces in the centres of the quartz veins as are present at Engineer Mine. It is thought that the quartz crystals would have to completely fill the fissures before they could start to force the walls apart on crystallization. The open spaces probably indicate that the fissures were in existence before deposition of the quartz and were formed by tensional stresses.

The mineralization at Engineer Mine suggests that it is a mesothermal deposit. Fuchsite, according to a report¹⁰ in the "American Mineralogist", is usually associated with minerals that suggest deposition at medium to high temperatures and pressures. Pyrrhotite, although sometimes found in low-temperature deposits, is usually found with medium to high temperature minerals. Arsenic and antimony, as shown by the phase diagram of Fig. 1, form an exsolution eutectoid at temperatures usually between 200°C and 400°C. The presence of ruby silvers also points to deposition at medium temperatures. The presence of open crystal-lined vugs probably indicates that the temperatures and pressures of deposition were not extremely high.

10. Whitmore, D. R. E., Berry, L. C., and Hawley, J. E., "Chromium Micas", Am. Mineralogist, Jan.-Feb., 1946, Vol. 31.

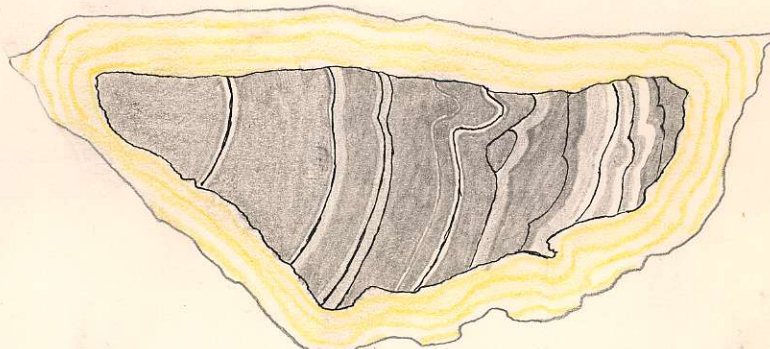


Fig. 2A

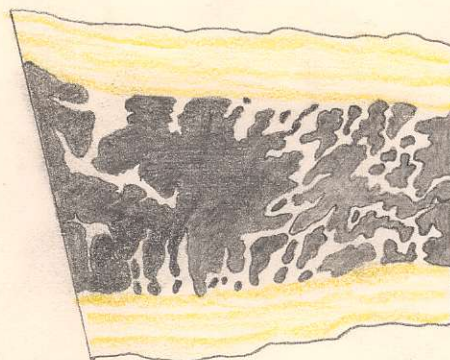


Fig. 2B.

Figure 2:

- A. Fragment of arsenic (grey) and allemontite (white) surrounded by quartz (yellow) and containing tension cracks---Specimen 5.
- B. Cross section of vein---Specimen 2.
quartz---yellow
allemontite---grey
calcite---white.

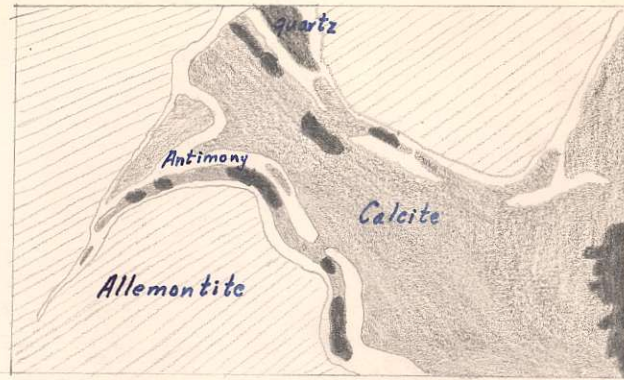


Fig. 3. Sketch from Specimen 2, Mag. X200.

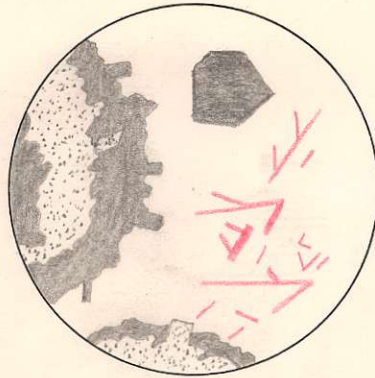






Fig. 4. Sketch from Specimen 8, Mag. X200

- | | |
|--------------|---|
| Quartz |  |
| Calcite |  |
| Arsenopyrite |  |
| Pyrrhotite |  |

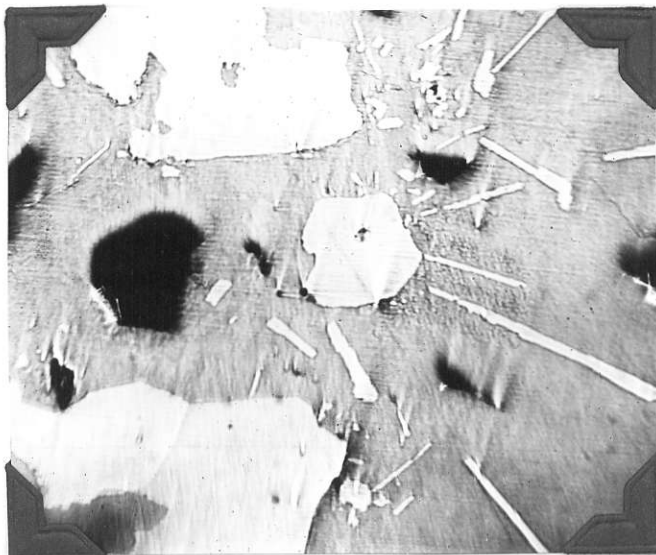


Fig. 5. From specimen MgA-1, Mag. X75
Dyscrasite - white patches and laths
Miargyrite - grey in SW corner surrounded
by dyscrasite
Arsenic - grey groundmass
Holes - black

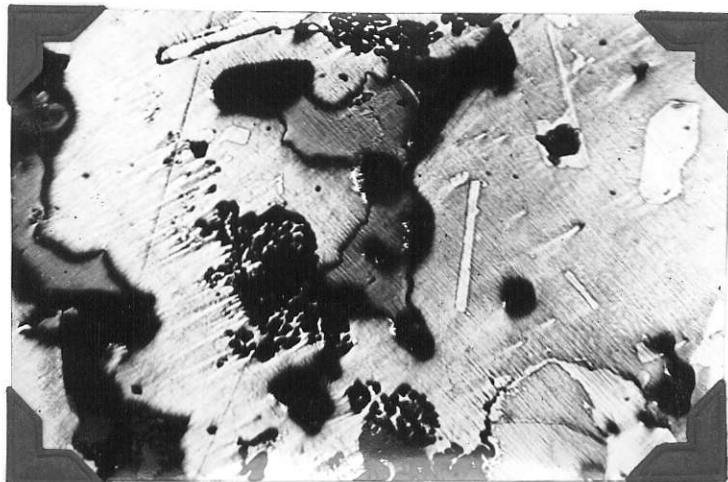


Fig. 6. From specimen MgA-1, Mag. X75
Dyscrasite - white laths and patches
Arsenic - grey groundmass
Miargyrite - two dark grey patches
Holes - black



Fig. 7. From specimen MgA-1, Mag. X75
Dyscrasite - nearly black laths (tarnished
with HNO_3 fumes)
Allemontite - grey areas surrounding dyscrasite
Arsenic - dark grey groundmass
Holes - black



Fig. 8. From same band as Fig. 7, Mag. X75
Dyscrasite - dark grey laths (tarnished
with KMnO_4)
Allemontite - white
Arsenic - grey groundmass (rough tarnish
from KMnO_4 dried on)

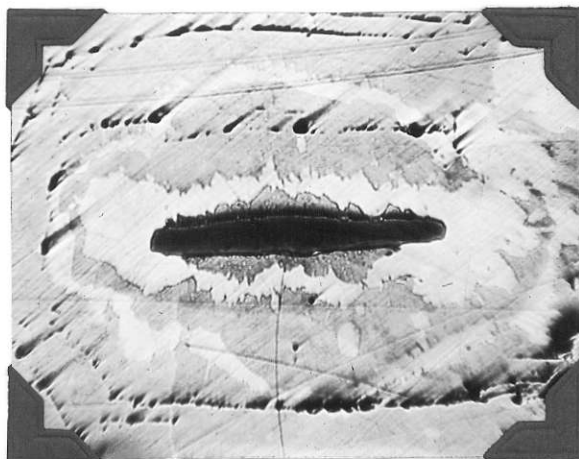


Fig. 9. From Specimen 4, Mag. X75
Dyscrasite - long black lath (tarnished blue with $KMnO_4$)
Allemontite - white bands
Arsenic - grey groundmass (darkened by applying $KMnO_4$ and rubbing off the resulting dark brown tarnish ---see laboratory procedure)
Tension fractures - black grooves

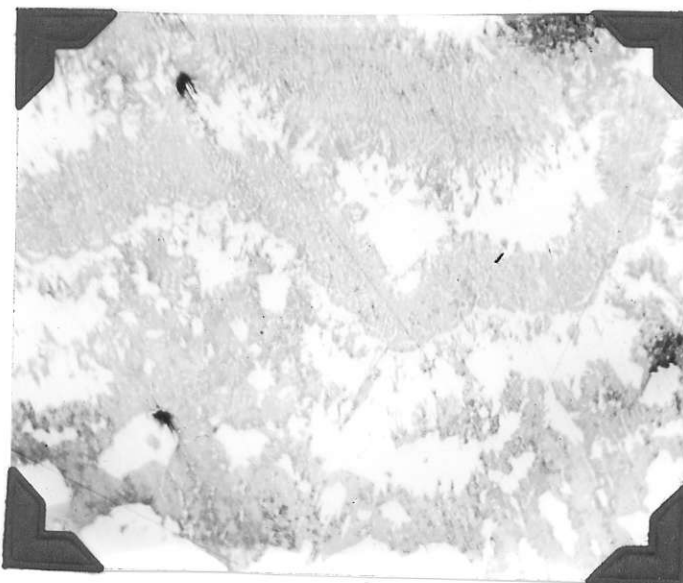


Fig. 10. From Specimen 4, Mag. X170
Allemontite - white, in bands and dispersed in arsenic
Arsenic - grey (darkened in same way as that of Fig. 9)

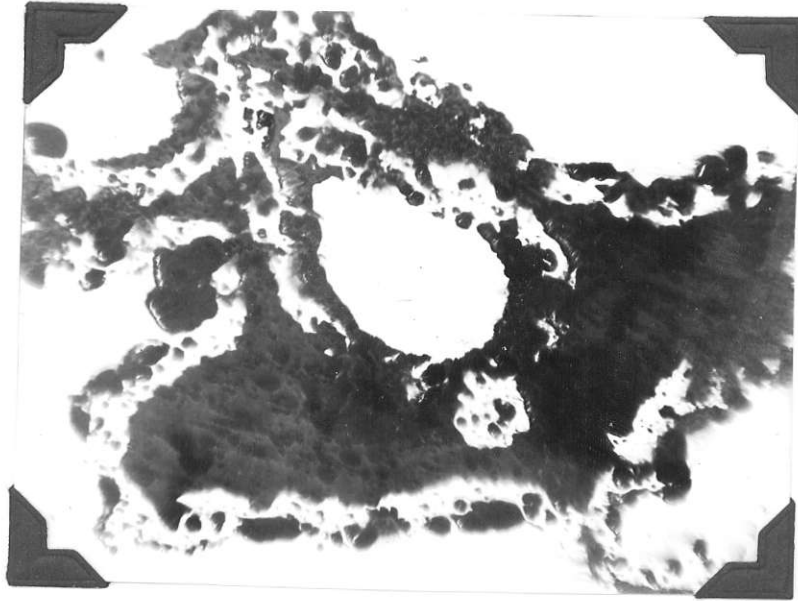


Fig. 11. From Specimen 2, Mag. X75
Allemontite - white groundmass
Antimony - white; in atol-like areas and
along edges of allemontite
Calcite and Quartz - dark gangue

Specimens and Their Minerals

The following list, showing the composition of each specimen, is for future reference. The minerals underlined are those which have been confirmed by X-ray analysis.

- | | |
|---|--|
| Woodcock, Engineer (1)
(collected by Christie) | - <u>Arsenic</u> with dispersed <u>allemontite</u> ; <u>dyscrasite</u> in rounded blebs; quartz lining. |
| Woodcock, Engineer (2)
(collected by Christie) | - <u>Allemontite</u> in rounded areas separated by calcite; antimony around edges of allemontite; quartz lining. |
| Woodcock, Engineer (3)
(collected by Christie) | - Arsenic in light gray bands; allemontite in white bands and dispersed in arsenic; quartz lining. |
| Woodcock, Engineer (4)
(collected by Christie) | - Dyscrasite in laths and blebs; <u>allemontite</u> in white bands and <u>dispersed</u> in arsenic; <u>arsenic</u> main part of specimen; quartz and calcite lining. |
| Woodcock, Engineer (5)
(collected by Christie) | - Arsenic with dispersed allemontite; allemontite in white bands; quartz lining containing fragments of argillite. |
| Woodcock, Engineer (6)
(collected by Christie) | - <u>Antimony</u> in rounded areas separated by calcite; <u>allemontite</u> along some contacts of antimony and calcite; <u>dyscrasite</u> in laths and blebs in antimony ruby-silvers replacing calcite (<u>miargyrite</u> and <u>pyrargyrite</u>). |
| Woodcock, Engineer (7)
(collected by White) | - Same as Specimen Engineer 2. |
| Woodcock, Engineer (8) | - Arsenopyrite; pyrrhotite in cleavage planes of calcite; quartz and calcite. |

Specimens and Their Minerals (continued)

- Woodcock, Engineer (9) - Electrum in fuchsite; arsenopyrite; quartz.
- Woodcock, Engineer (10) - Arsenic and allemontite; cenarmontite on the allemontite; quartz with boxwork.
- Woodcock, Engineer (11) - Antimony; hematite in cavities of quartz; cenarmontite; quartz.
- Woodcock, Engineer (12) - Arsenic; quartz with casts; arsenopyrite in minute tarnished crystals on the quartz.
- Woodcock, Engineer MgA-1 - Dyscrasite in laths and blebs; arsenic; ruby silver; allemontite around some dyscrasite laths and dispersed in arsenic.

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