

409

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600335

The Oregon Property, Hedley.

General introduction

The Oregon Property lies five miles east of Hedley B.C. (on the east side of Cahill creek) It has been mined under the name "French Mine" from 1950 to 1961. The average daily output has amounted between 30 and 40 tons of ore. Only in 1958, 59 and 60 it reached up to 50 tons. The gold (percentage) recovered per ton ^{amount} dropped continuously from 0.8 ounces in the beginning to 0.4 ounces at the close of the mine. In all the Oregon Property produced 61,485 ounces of gold. Other values of the mine have been Bismuth and Tellurium and to a very small extent silver.

Geologic setting.

The mine is located in a salient of triassic and later rocks. These consist in the mine area of a cherty tuff layer at the base, 15 to 20 (locally up to 60) feet of limy strata and on top again a tuff, fine grained and dark colored. The limestone thickening is caused by structural deformation and has been interpreted as "nap type folding". The salient of limestone and tuffs is about half

April, 1, 1964

a mile wide and extends a mile southwestward. There it has been cut by intrusive granodiorite. In the ore zone the tuffs and parts of the limestone show strong brecciation. Brecciation has taken place before vapors and fluids associated with the granodiorite altered the limestone to skarn and emplaced the Co-Ni-Bi-Te-Au suite of minerals.

Post ore disturbance has displaced the ore zone by NNE striking faults. The average displacement at each fault is said to be fifteen feet.

April, 1, 1964

Megascopic description

The handspecimens reveal a remarkable uniformity in their composition of non-opaque minerals. The texture however is very variable. The main components are garnet and diopside. In addition several specimens contain calcite and Heclenbergite. Quartz is rather scarcely distributed and wollastonite was only found in one specimen.

With the exception of the three massive Chalcopryrite - Bornite handpieces the ore minerals are very sporadic distributed through the gangue. With the help of micro chemistry the following minerals could megascopically be determined:

two different Co - As - minerals, Niccolite, Threopryrite, Bornite, Chalcopryrite, Molybdenite, Bi-Telluride and Gold.

Its alteration products or coatings, limonite chlorite and malachite were recognized.

Pyrrhotite, said to be one of the most abundant minerals, and native Bi, reported from all authors who wrote about Nickel Plate Mountain could not be found.

April, 1, 1964

The Minerals

Garnet: Grossularite $\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3$

Grossularite was ascertained by x-ray check. It occurs from wine yellow to dark reddish brown and has a resinous lustre. The distribution is massy and the fracture conchoidal. Some subhedral faces can be observed. Ore minerals are pepperlike in garnet dispersed. The thin section shows that the ore migrated along minute cracks. Large cracks are healed with calcite and/or ore minerals, sometimes also quartz.

Diopside: $\text{CaMg}(\text{Si}_2\text{O}_6)$ incl.

Hardness is about 6. The color is green in variable shades. The rectangular cleavage is diagnostic for the Pyroxene family. The cleavage is well developed, large parting planes parallel to (100) or (001) are common. In one specimen they are plated with Bi-Telluride. Besides the well formed large crystals Diopside occurs also massy, revealing the same aspect as garnet only distinct by color and vitreous lustre. In the thin section this variety ~~occurs~~ appears very fine granular. Ore minerals are interstitial.

Hedenbergite $\text{CaFe}(\text{Si}_2\text{O}_6)$ incl.

Its appearance is rather few. It occurs in the same way as diopside. The darker green color and a distinct Fe-test are diagnostic.

Calcite CaCO_3 trig.

It occurs in some specimens as perfect crystals. Its light color, Hardness 3, and perfect cleavage are diagnostic. These idiomorphic crystals reach considerable size and include arsenopyrite and hedyrite also well developed and of considerable size. In the thin-section calcite has been found filling cracks associated with sulfides.

Wollastonite CaSiO_3 trcl.

It reveals the typical fibrous structure which gives it a silky luster. The color is grey-white, the hardness about 5. The perfect (001) and (100) cleavage causes the fibrous appearance.

From the ore minerals only Bi-telluride and Arsenopyrite will be mentioned here because of their unusual size and perfectness of appearance. All ore minerals together will be discussed under the heading, microscopic description.

Arsenopyrite FeAsS mcl.

April, 1, 1964

some well developed aggregates occur in the above mentioned calcite crystals. They show perfect prismatic outlines and a vertical striation of the prism zone. The silver white color and the strong Fe, As test confirm the arsenopyrite. Fractures are uneven, the hardness around 6.

Bi-telluride hex.

It occurs in coarse plates up to 8 mm² size. Its color is tin white. The larger plates are coated with a brown to black tarnish. The perfect basal cleavage is responsible for the ~~development~~ occurrence of the large plates. The mineral is soft and sectile. Very thin platings on diopside partings are common in one specimen.

April, 1, 1964

Microscopic Description

By microscopic study and x-ray analysis in addition to the above mentioned minerals the following ones were found. Cu_2S , CuS , the two Co-As minerals turned out to be three: Cobaltite, Skutterudite, and Safflorite.

99% of the Bi-Telluride is Hedleyite. # Joseite B was found in the 7th x-ray check together with Hedleyite.

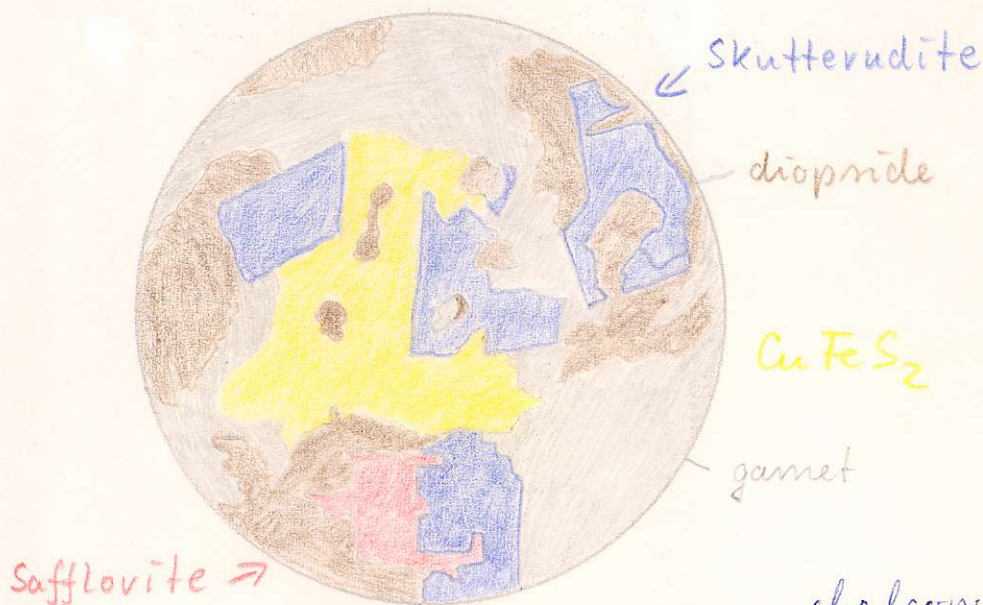
Skutterudite $CoAs_3$

cube. H: F. refl: 56% color: white, fine polish, isotropic. Cleavage could not be observed. Idiomorphic X-outlines are often to recognize. The mineral is distinctly lighter than Cobaltite and has a better polished surface. x-ray analysis indicated the straight end-member of the Skutterudite series.

HNO_3 turns skutterudite faint grey and produces scratches. Bonite, $CuFeS_2$, Safflorite and Hedleyite are observed to replace skutterudite.

The following picture shows some typical forms of the observed skutterudite and its relation to Safflorite and Chalcopyrite.

April, 1, 1964



medium power.

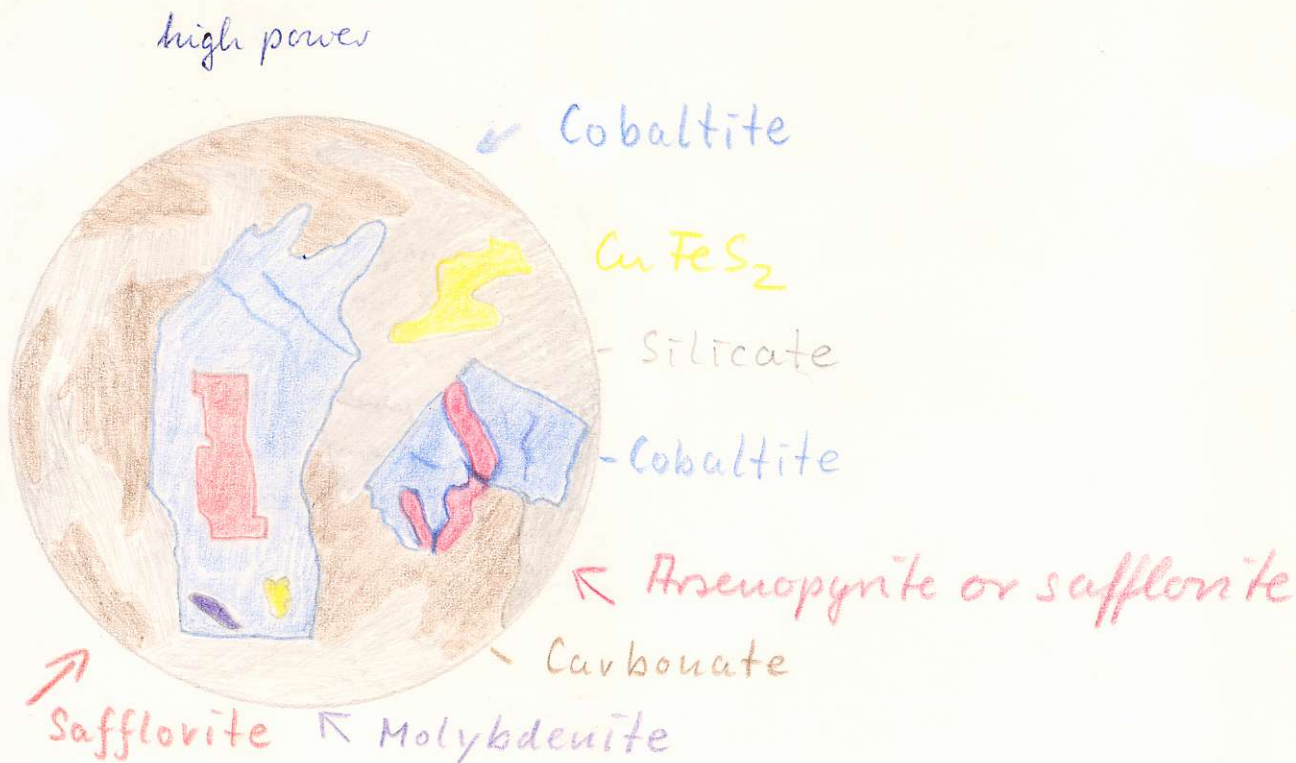
chalcopyrite and safflorite replacing skutterudite.

Safflorite II $CoAs_2$ mel.

the hardness of the mineral is anomalous soft about D
 Color: white with a bluish tint. Refl. 55, very fine
 polish. Refl. pleochr. very weak. A. l. strong, blue
 orange yellow. No characteristic star shaped twinning
 could be observed. Skelletal and euhedral crystal out-
 lines. By skell~~etal~~ aggregates distinction between $FeAsS$
 was only possible by microchemical test. x-ray ana-
 lysis gave the Safflorite II species. Safflorite IV ~~is~~ has
 been described from Hedley.

HNO_3 etches deeply and reveals a kind of etch cleavage.
 With the exception of $FeAsS$ and Covellite safflorite

has been observed in contact with all other minerals.
 There are some idiomorphic inclusions of safflorite in
 Cobaltite which may be interpreted as pre-cobaltite
 On the other hand cracks in cobaltite are filled with
 either $FeAsS$ or $CoAs_2$ (too small for distinguishing)
 If the latter is the case the cobaltite formation falls completely
 within the range of the safflorite deposition.



Cobaltite grown around a safflorite grain. Chalcopyrite,
 Molybdenite and $FeAsS$ or $CoAs$ fill cracks and
 holes.

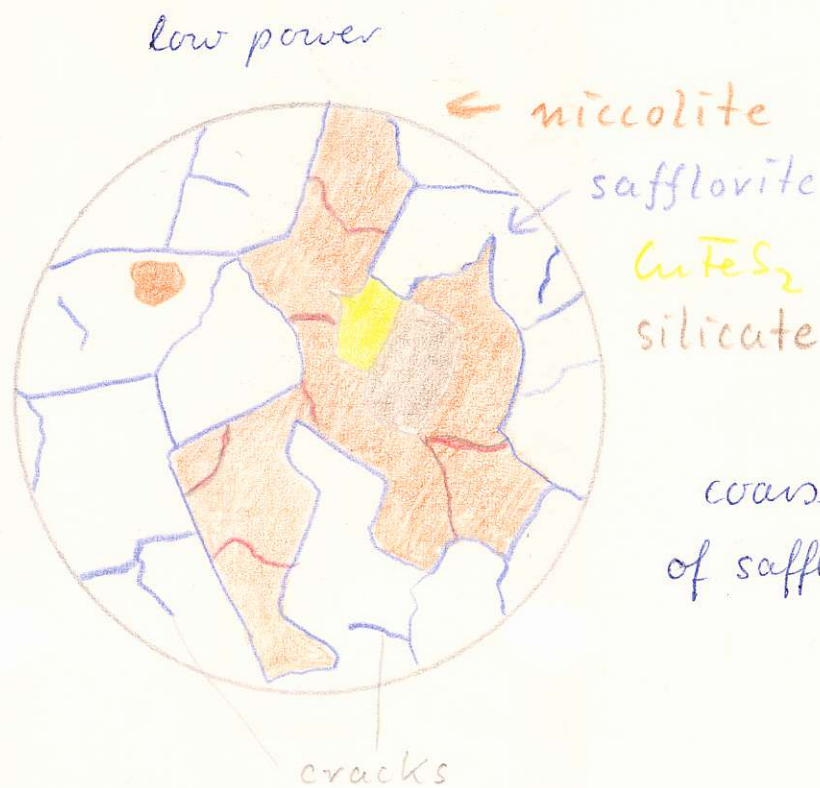
April, 1, 1964

Nicolite NiAs here.

Hardness like safflorite anomalous soft, about D. color, saturated pink. Refl. 51% Refl. pleo. strong; Δ . l. very strong: yellow-violet-blue. straight but not complete extinction. Mineral confirmed by microchemical test and x-ray analysis.

HNO_3 effervesces strongly.

Nicolite has been found in contact only with safflorite and $CuFeS_2$. Nicolite and safflorite are more or less contemporaneous, $CuFeS_2$ is later.



coarse grained intergrowth of safflorite and niccolite.

April, 1, 1964

Cobaltite $CoAsS$ cub.

H: G, color: white with a pink cast, isotropic to weak $\mathcal{A}.l.$: close colors - purple - bluish. has a very bad pitted polish, which lowers the reflectivity 51% and make cobaltite pale in comparison to skutterudite. cobaltite occurs in single subhedral grains and in massive aggregates. Here the weak $\mathcal{A}.l.$ may reveal the grain size. Actually Cobaltite is very rare. It has been confirmed by x-ray analysis.

all etch tests were negative.

Cobaltite is only in contact with safflorite and ? $FeAsS$, $CuFeS_2$ and molybdenite. $CuFeS_2$ and molybdenite are definitely younger than the cobaltite. The attitude of safflorite / arsenopyrite has been discussed under safflorite.

Arsenopyrite $FeAsS$ mcl.

H: F color: white, Refl. 53%, polish good. Refl. pleo. weak; $\mathcal{A}.l.$: strong blue - reddish - brown yellow. Observed in skeletal growth and also forming the characteristic rhombohedrons. Skeletal aggregates ^{can} only ^{be} distinguished by means of microchemistry from $CoAs_2$ (~~to~~ distinguished)

HNO_3 etches deeply and may in contrast to safflorite

give a brown tarnish.

FeAsS has been replaced by bornite, $CuFeS_2$, and molybdenite. Gold has been found in cracks of FeAsS.

low power



Arsenopyrite revealing typical ends as they will never occur with saffronite.

Molybdenite
silicate

molybdenite replacing FeAsS

medium power



Arsenopyrite in skeletal growth being replaced by bornite and chalcocopyrite.

Bornite Cu_5FeS_4 cub.

H: B in a fresh polish the color is pinkish brown. It takes very soon a purple tarnish. Refl. 19%. The polish is smooth and fine. An anomalous ~~anisotropism~~ ^{isotropism} has been observed. It reveals the grain size which is irregular and coarse. Several grains show twin lamellae.

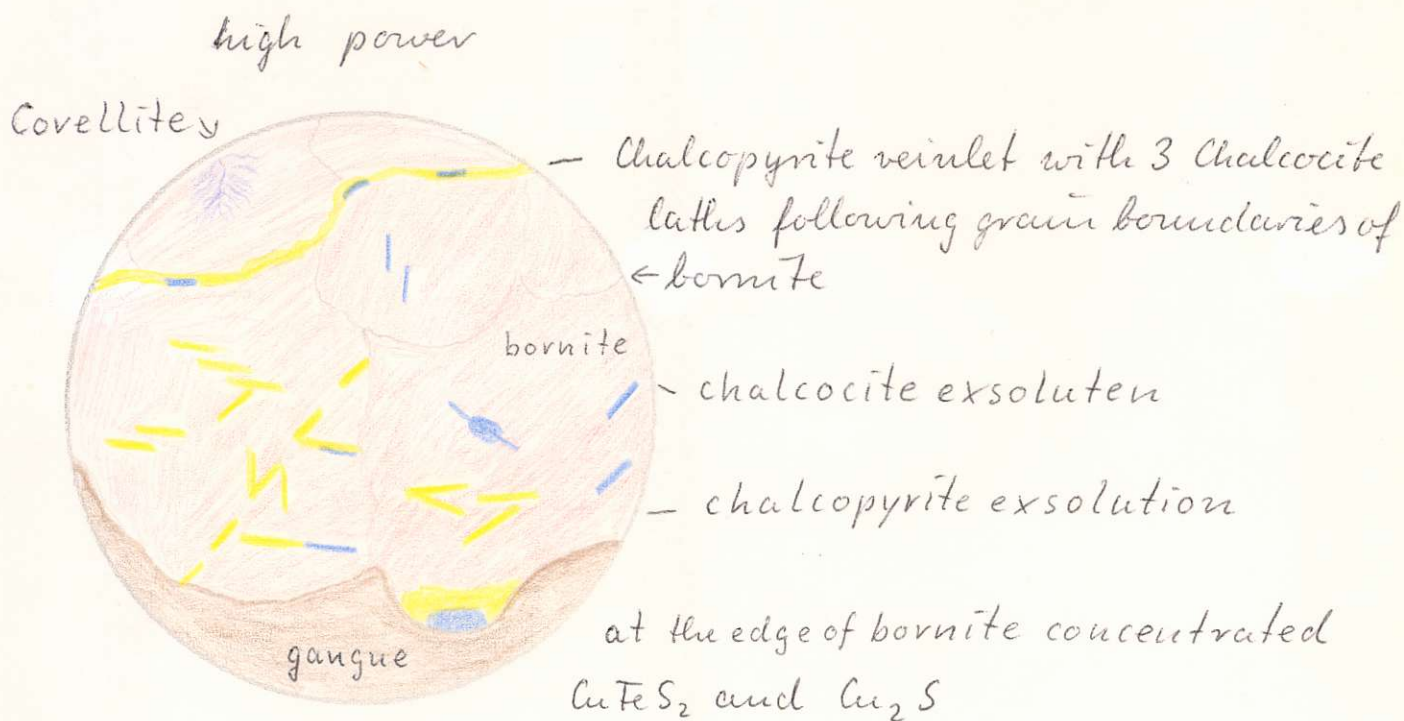
HNO_3 effervesces with bornite and stains yellow-brown. The bornite contains oriented after the (111) planes exsolution lathes of CuFeS_2 and to a small amount lathes of Chalcocite. Besides this very minute veinlets of CuFeS_2 transect the bornite following grain boundaries. Small lathes of chalcocite accompany sporadically the CuFeS_2 in this veinlets. A third occurrence of CuFeS_2 and Cu_2S is as bleb like concentrations at the edge of bornite aggregates.

The fact that CuFeS_2 has been exsolved from the bornite lattice indicates two important things:

- a) Exsolution texture is only preserved when the cooling gradient was rather high. Slow cooling ends up in a diffusion of the exsolved mineral to the grain boundary of the exsolving mineral.

April, 1, 1964

b) the exsolution takes place at $475^{\circ}C$.
A fine net of Covellite overspans the bornite. It is only visible under high power and certainly a supergene product.



Chalcocite Cu_2S here. $\xrightarrow{105^{\circ}}$ ortho.

H: B color is bluish white, Refl. 32% Anisotropism could not be observed. The reaction to etch tests is anomalous. There is no response to HNO_3 , KCN , or $FeCl_3$ as should be expected in a turn to blue. Despite that there didn't develop any etch cleavage, I think, the

April, 1, 1964

mineral is primary, contemporaneous with $CuFeS_2$.
Chalcocite is very rare, in fact, only known as exsolution product.

Covellite CuS hex.

H: B, good polish, color indigo blue. Refl. 17% yellow red A.I. colors. The mineral is only visible under high power in bornite. It overspans some areas in bornite like a "river-system". It has been formed by supergene influences.

Chalcopyrite $CuFeS_2$ tetr.

H: C; Color, yellow Refl. 43% A.I. to a peculiar green only under medium and high power recognizable. Polish is fine.

It is the most widespread mineral and in contact with all other minerals (exception covellite). Most common is a pepperlike distribution. $CuFeS_2$ as exsolution product from bornite is described above. In the paragenetic sequence $CuFeS_2$ post dates bornite and pre dates ~~Pyrite~~, molybdenite and gold. Brittleness, hardness and in cases of doubt $HgNO_3$ help to distinguish $CuFeS_2$ from gold.

April, 1, 1964

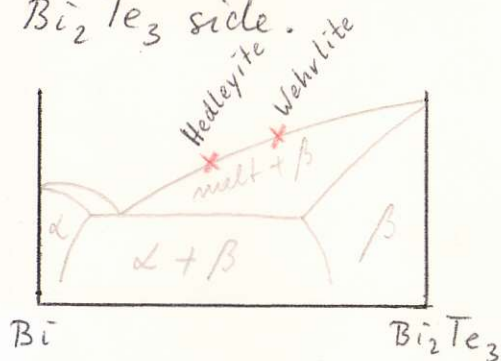
Hedleyite Bi_2Te_3 here.

H: A; color cream white, tarnishes readily to brown. Refl. A. 1. bluish grey - brown grey
 HNO_3 turns hedleyite grey brown and leaves a deeply scratched surface.

Hedleyite occurs in minute rounded grains disseminated in the gangue, elongated aggregates are observed along fractures. In a few large aggregates the anisotropism reveals the coarse granular structure. Grains have irregular boundaries.

Hedleyite is found in contact with gold, CuFeS_2 , MoS_2 , saffronite, cobaltite and skutterudite.

In both sides of the phase diagram $\text{Bi} - \text{Bi}_2\text{Te}_3$ occurs a field of limited miscibility, the larger one on the Bi_2Te_3 side.



Within the field of miscibility all mixtures may be expected and may occur. Its distinct compounds hedleyite and wohlerite have been described.

For the formation of hedleyite two possibilities are described.

a) formation under abnormal temperature and pressure

April, 1, 1964

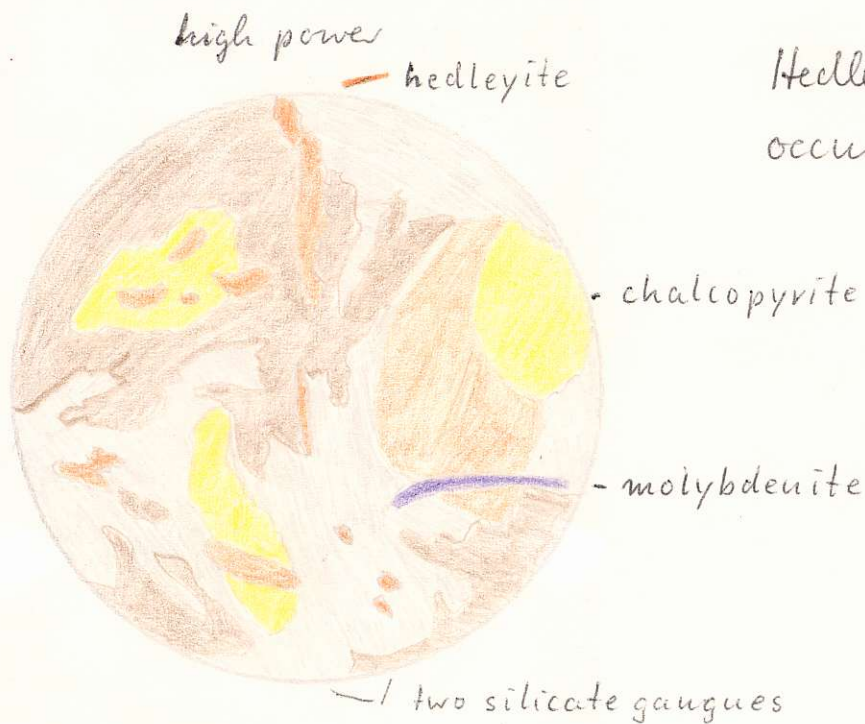
conditions.

or b) by diffusion of Bi-ions through the structure of Bismuth tellurium (Bi_2Te_3) during the cooling process.

Joseite B here.

the same microscopical properties as hedleyite. The mineral has not been found in the polished sections. It has only been recognized in the 7th x-ray check as continuation of hedleyite.

Joseite is characterized by some vacancies (schottky) in its lattice.



Hedleyite in its typical occurrences. Hedleyite seems to fall completely within the $CuFeS_2$ deposition because it occurs replacing $CuFeS_2$ and being replaced by $CuFeS_2$. Molybdenite transects hedleyite and is hence later.

April, 1, 1964

Molybdenite MoS_2 here.

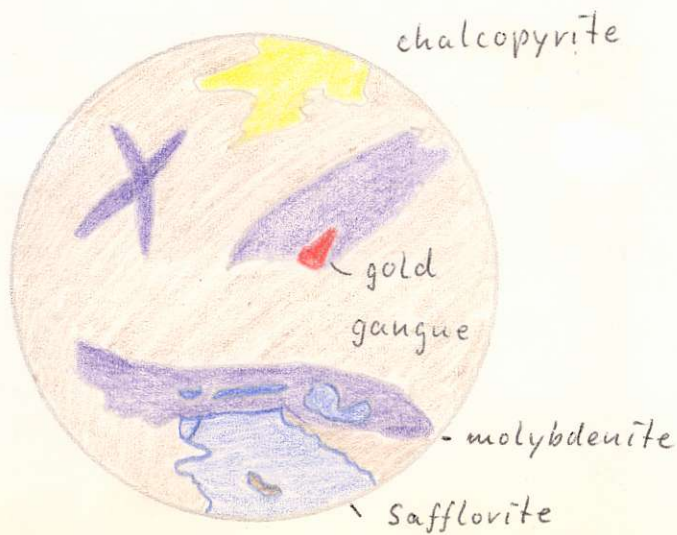
H: B color: white - greenish. The difference is caused by the strong pleochroism. Refl. 30% 37%

By not quite crossed nicols the P.L. shows deep blue and violet colors, very strong. The undulatory extinction is caused by the deformation of the plates.

Etlh reagents are all negative.

Molybdenite occurs as fine needles - these have a good polish - dispersed in the gangue. Two or more of the needles may crosscut each other and form thereby a starshaped aggregate. There are also many massive aggregates which reveal a "twinning" texture. This appearance is caused by parallel displacement of the plates

Molybdenite fills fractures and holes in sulfides and arsenides. There is no indication that MoS_2 has been replaced by any other mineral than gold, and this case is more likely a plating over.



occurrences of molybdenite and relation to gold and safflorite.

April, 1, 1964

Gold, Au cub.

H: B, color: golden yellow, sectile, isotropic.

No complete extinction will occur under crossed nicols

The color under crossed nicols is faint green. The mineral takes a good polish.

AgNO₃ is diagnostic in distinction to chalcocopyrite.

Gold occurs disseminated, often following minute cracks, through some sections and hand specimen. The flakes are even visible with the unaided eye. The grains are platy and irregular in their outline.

Gold is intergrown with CuFeS₂, hedleyite and molybdenite and occurs in an arsenopyrite fracture.

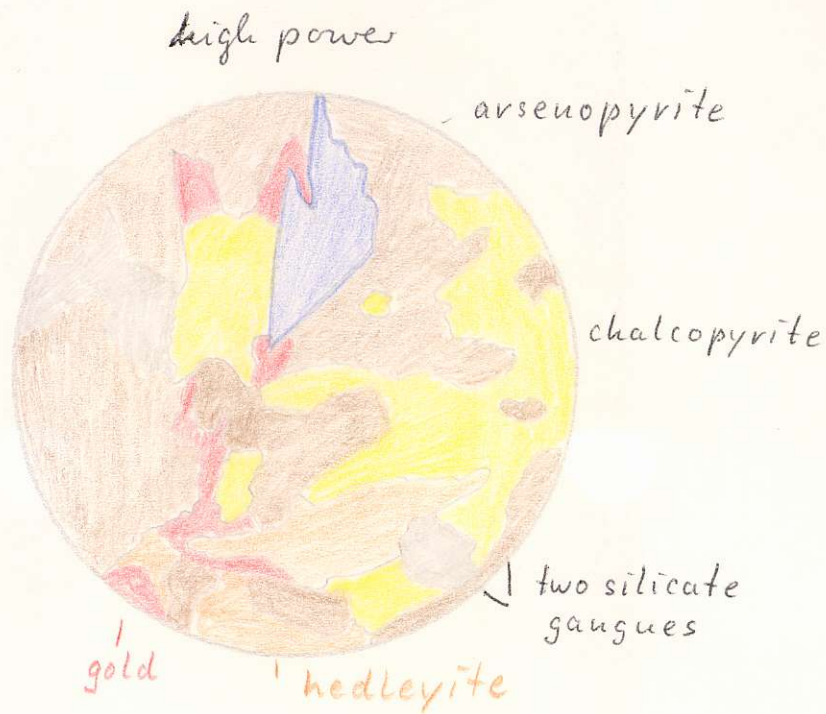
It seems that the presence of hedleyite favors the chance of seeing gold.

Arsenopyrite as source of the gold has been mentioned by Camsell (1910) in his description of Nickel Plate Mountain. There are two possibilities which may account for the incorporation of gold in arsenopyrite:

1) incorporation as solid particles not visible with the light microscope. Ivanoff 1951 showed with an electronic microscope that gold grains in the order of 10^{-6} cm (0.01 μ) occur in arsenopyrite.

April, 1, 1964

2) Edwards postulates solid solution of gold and $FeAsS$
No proof for this hypothesis has been established up
to date.



Gold in contact with
 $FeAsS$, Bi_7Te_3 , and
 $CuFeS_2$

April, 1, 1964

Genesis and Paragenesis

The pepperlike distribution or the "individualism" of the ore minerals leave many questions open. For example the contact between two of the most important minerals of the suite, Saffronite and Arsenopyrite, could nowhere be observed. The relation of Skutterudite to the other Co-Ni ores is obscure too.

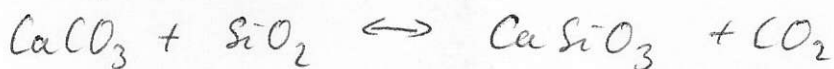
A short consideration to the skarn formation will be given here because skarn and ore mineralization are closely related. The skarn formation precedes the ore formation slightly as indicated by the replacing and crosscutting character of the sulfides, arsenides and tellurides. The common source for skarn and ore minerals is the underlying granodioritic intrusion.

The impure limestone bed has been fairly advanced transformed to skarn under the action of heat and pressure, probably before the volatiles of the magma escaped into the surrounding country rock ("autometasomatism")

For a typical skarn mineral like wollastonite

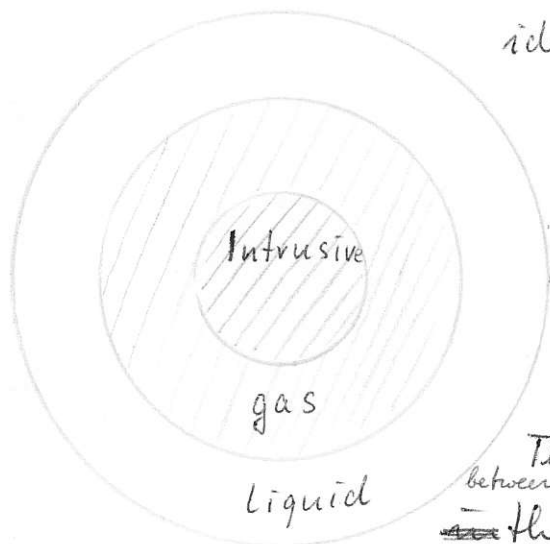
April, 1, 1964

such a process can be formulated:



The formation is mainly a function of the CO_2 pressure. By a CO_2 pressure = 0 the process of formation starts around 400°C . Temperature raises up to 800°C as pressure raises to 2000 kg/cm^2 (Eskola's pyroxene-hornfels-facies) The autometasomatism may account for the precedence of the skarn minerals in relation to the ore minerals.

When the country rock around the intrusion was saturated with metal bearing gaseous emanations true metasomatism may have added to the skarn formation (Hedenbergite) and finally has replaced the ore minerals.



idealized picture

the intrusive is surrounded by country rock saturated with gas - further away, as soon as the temperature drops below the ^{ore bearing matter} critical temp. of H_2O the gas will condense to a liquid

There should no great difference be expected ^{between} ~~the~~ reaction products ^{of gas and liquid} because gas and liquid are supposed to have the same density. Only

April, 1, 1964

the atomic order is different and would account for a slower reaction sequence in the liquid status.

The metal transfer is most readily described by the actions of metal halogenides. These, in gas phase or solution are precipitated by agents as H_2O and H_2S . This process is governed by the law of mass action.

For example: interaction between $CaCO_3 + 2H_2O + SiFe_4 \rightleftharpoons \underline{CaSiO_3} + 4HF + CO_2$ will yield for "true metasomatic" wollastonite.

Sulfide precipitation is analogue:

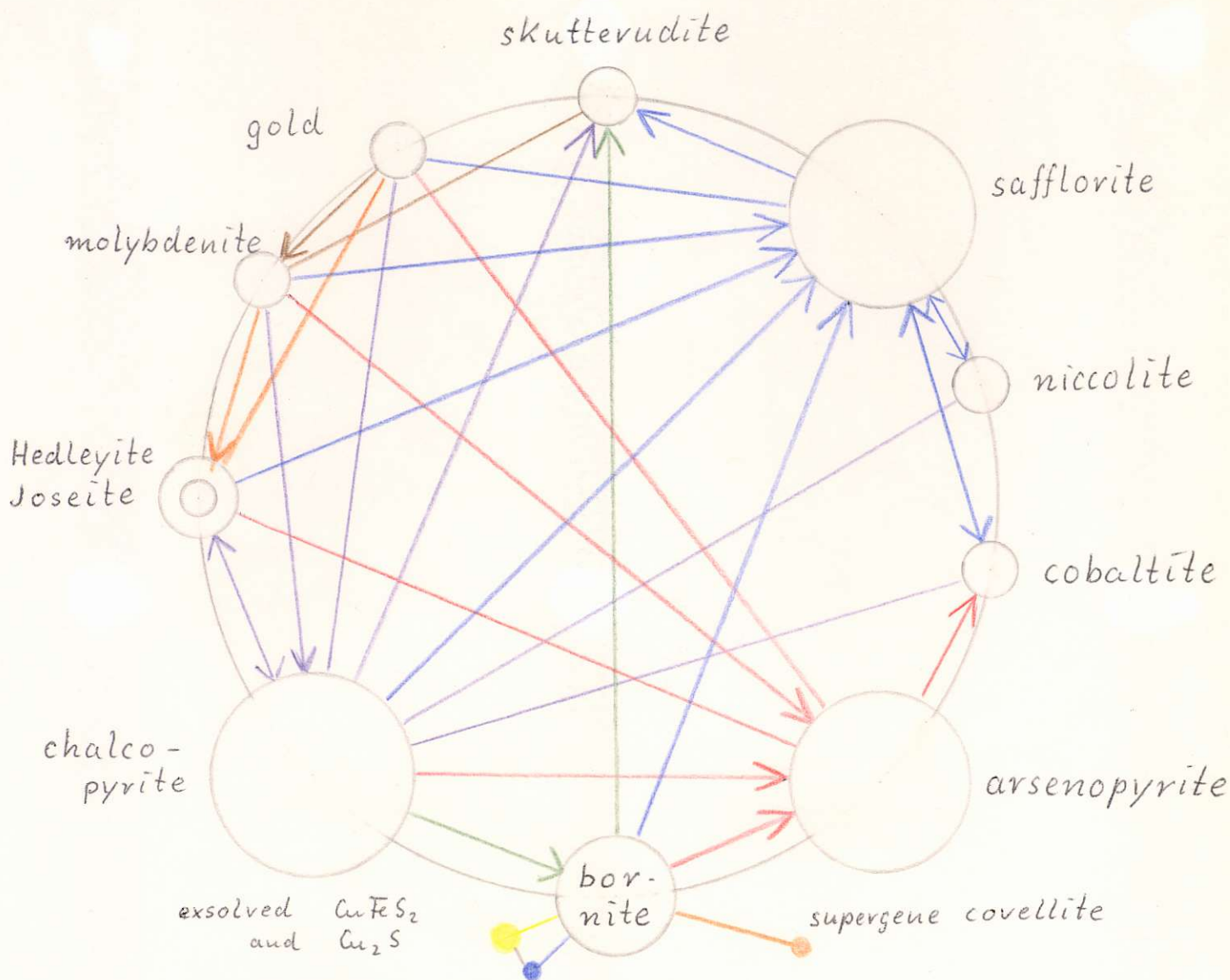


concentration on the left sides and abduction of the by-products on the right sides favor deposition of the underlined products.

Regarding the chemical composition of the present minerals we may classify them into three groups.

- | | |
|--|------------|
| 1) Ni-Co-arsenides
CoAs ₃ , CoAs ₂ , NiAs, CoAsS | As \gg S |
| 2) Fe, Cu, Mo-sulfides
MoS ₂ , FeAsS, Cu ₅ AsS ₄ , CuFeS ₂ , CuS, Cu ₂ S | S \gg As |
| 3) Bi-Tellurides and gold | — |

April, 1, 1964

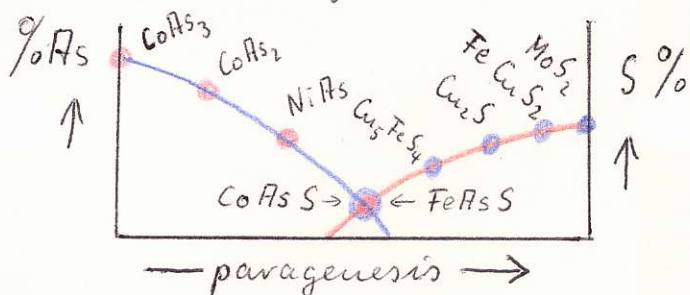


Comparing this willingly chosen order with the paragenetic sequence we notice a remarkable regularity. The minerals in the classification with the exception of MoS_2 read in the same order as the paragenetic sequence. MoS_2 changes the place with Bi-Telluride.

The Arsenic increase and the Sulfur decrease towards the older minerals is indicated in the

April, 1, 1964

following sketch.



The absence of Bi-Te-Sulfides or Bi_2S_3 in the deposit seems to indicate that sulfur was rare in the ore's source. We also may conclude on a shortage in iron. There are no continuations of Fe in the Ni-Co-minerals (microchemical and x-ray tests) and there is no basic Fe-mineral around like magnetite, hematite or pyrrhotite, as could be expected in this environment.

The fact that magnetite and pyrrhotite (the latter in mass) are reported from the adjacent Nickel Plate Mountain may indicate that the ore forming substance must have segregated before penetrating the country rock. A problem here is to account for the segregation of vapors under fairly high pressure. ~~Liquid~~ ~~minerals~~ May be scarcity and richness of iron within such a short distance can be explained more readily by the means of different chemical environment and remobi-

April, 1, 64

lization of iron from the sediments. However as a puzzle remains the scarcity of hedenbergite in the Nickel Plate Mtn. as well as in the French mine.

Diopside - garnet-skarn is thought to form in a temperature environment of 700-800°C and at pressures of about 2000 $\text{cm}^{-2} \cdot \text{kg}$. As described earlier mineralization and metasomatism have taken place under pneumatolytic action at the beginning and certainly ended in hypothermal emplacement of the Bi, Te and Au minerals. A fixed temperature in between is the bornite - chalcopyrite exsolution at 475°C. It also indicates a fairly steep temperature decline. Where to draw the line between pneumatolytic and hypothermal action is not certain because we don't know the composition of the ore forming substance and hence its critical point.

It would be worthwhile to know if there is a zoning in the French mine, according to the scheme of Butte, where the sulfur available is said to be responsible for it. Here the ~~ste~~ coincidence of steep temperature decline and the change of the As - S ratio might be regarded as favorable for a development of zoning. A systematic sampling could bring some light in this problem.

List of Minerals

- 1) Skutterudite $CoAs_3$
- 2) Safflorite $CoAs_2$
- 3) Niccolite $NiAs$
- 4) Cobaltite $CoAsS$
- 5) Arsenopyrite $FeAsS$
- 6) Bornite Cu_5FeS_4
- 7) Chalcocite Cu_2S
- 8) Covellite CuS
- 9) Chalcopyrite $CuFeS_2$
- 10) Hedyrite Bi_7Te_3
- 11) Joseite B $BiTe$
- 12) Molybdenite MoS_2
- 13) Gold Au
- 14) Malachite $Cu_2(OH)_2CO_3$

- | | | |
|-------------|--------------|-----------------------|
| <u>I</u> | Grossularite | $Ca_3Al_2(SiO_4)_3$ |
| <u>II</u> | Diopside | $CaMg(Si_2O_6)$ |
| <u>III</u> | Hedenbergite | $CaFe(Si_2O_6)$ |
| <u>IV</u> | Calcite | $CaCO_3$ |
| <u>V</u> | Wollastonite | $CaSiO_3$ |
| <u>VI</u> | Quartz | SiO_2 |
| <u>VII</u> | Limonite | $FeO(OH) \cdot nH_2O$ |
| <u>VIII</u> | Chlorite | $Mg(OH)$ -silicate |

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The ore deposits of Nickel Plate Mountain.

Can. Inst. Min. and Met. Trans. p. 524 ff.

Bostock, H.S. 1929

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Camsell, C. 1910

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GSC. Memoir No 2.

Dolmage. 1945

Contact metamorphism at Nickel Pl. Mt.

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Mason. B. 1962

Principles of Geochemistry

January, 8th 1964

Megascopic description

The handspecimens consist of massive magnetite ore as to ascertain by hardness and magnetism. The brownish violet tinge on parting planes as well as the brown streak let the presence of a titanium mineral assume. The ore must have been exposed to very high pressure as the partings reveal. Shear-planes are up to 1 cm^2 in sizes. There seem to exist 3 dominant directions of parting planes, each perpendicular on the other. If we regard a polished surface we recognize the dark grey blebs of spinels and the ilmenite which is darker than magnetite but has a higher lustre.

The distribution of these two minerals through the magnetite appears to be foliated, due to the above mentioned stress that caused the partings.

Its alteration products ~~are~~^{can be} recognized a rusty amorphous cover of limonite and a white amorphous coating. The latter one is probably due to Leucoseene.

Microscopic description

Estimation of the amount of minerals:

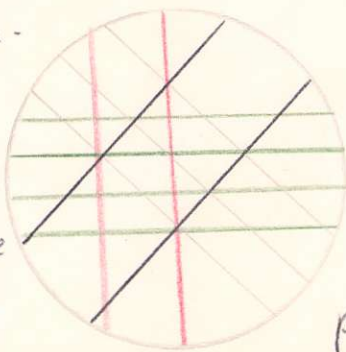
		<u>Previous investigation</u>
✓ Magnetite	69%	65
✓ Ilmenite	25%	30
✓ Spinel	5%	5
✓ Ti-Hematite ?	} 1%	dissolved hematite and dry maghemite
✓ Maghemite		
unknown		

January, 8th, 1964Magnetite Fe_3O_4 cub.

Refl: 21% ; Polish: poor ; Color: grey white with a slight brown tinge; Hardness: F; Streak: black; Refl. Pleo: / ; Anisotropism: very weak but distinct: dark - light.

Etch tests: conc. HCl darkens slightly grey-brown. conc HCl + SnCl_2 (1:1) darkens rapidly and stays brown-yellow. Gives the single grains different shades so that grain boundaries could be distinguished. Grain size reaches several mm. (One measured with ϕ of 3mm) ~~Because the other minerals are not effected by this~~ By etching the magnetite a lot more inclusions ^{and} exsolution textures could be recognized. Ilmenite exsolution follows the octahedral planes of the magnetite crystals.

orienta-
tion
of
exolu-
tion
lamellae



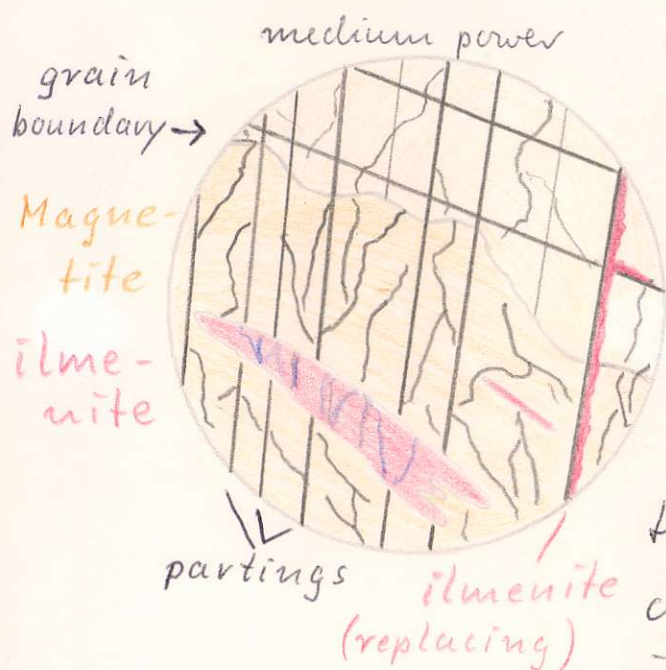
The picture is idealized since mostly one or two directions are overpronounced whereas the other 3 or 2 are represented with one or two lamellae per grain. Sometimes they are completely absent. The continuity of the lamellae is also highly variable - from microns to millimetres.

Besides these very fine lamellae the magnetite

January, 8th, 64

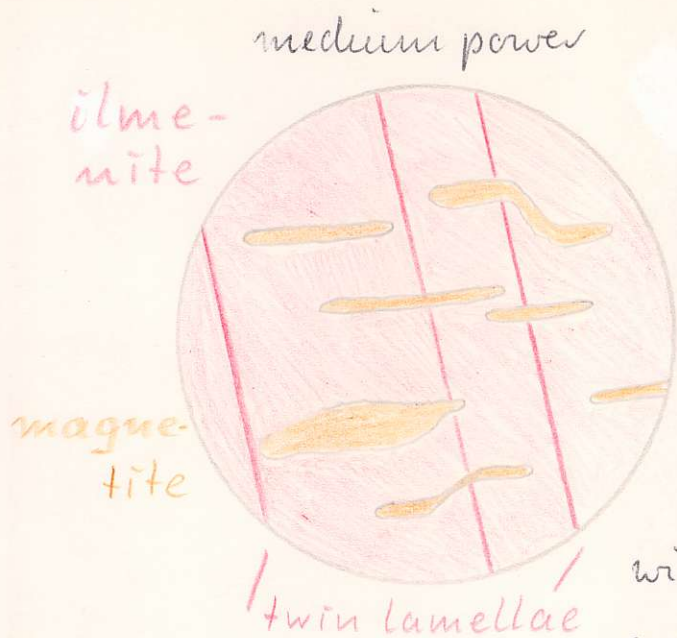
contains a few coarse ilmenite "bodies" that are due to exsolution.

Most of the ilmenite present within magnetite grains follows partings and cracks and reveals irregular replacement boundaries against its host.



The picture shows two grains of magnetite, the boundary was brought out by etching. Notice: the above grain shows two directions of partings and two weaker partings that do not cross the grain boundary. Also the crack pattern is slightly different in both grains.

On the right side ilmenite was introduced along a parting. It shows irregular termination to the right due to replacement. The small lamellae and the big grain reveal smooth boundaries, they are formed by exsolution. Remarkable is that the elongated grain shows undulating extinction parallel to the main-partings. (Demonstrated by the blue lines.) Because the "grain-boundaries" are very confuse I don't think that this effect is due to recrystallization.



This picture shows magnetite exsolved from the ilmenite lattice. These blebs appear to be a bit harder than the ilmenite matrix. Therefore I thought first of ~~magnetite~~ hematite. But since they react with $HCl + SnCl_2$ in the same way as magnetite I had to drop this

idea. The occurrence of magnetite as exsolution of ilmenite is very rare in the polished sections.

Finally magnetite has been observed in smallest particles in the spinel. Where these little blebs are lined up and apart from cracks this appearance is also due to exsolution.

So we have:

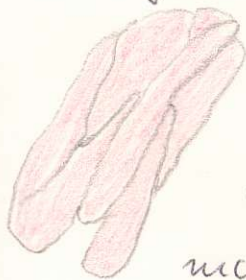
- 1) primary magnetite
- 2) magnetite exsolved from ilmenite
- 3) magnetite exsolved from ~~garnet~~ spinel.

These relations are useful for the determination of the temperature of formation.

Ilmenite FeTiO₃ here

- Hardn: G slightly higher than magnetite
- Polish: excellent, specially in contrast to magnetite
- Color: brown with a violet tinge
- Refl: 19% Pleochr: distinct brown yellow - violet
- Anisotr: strong, green grey - brown violet
- Twinning: fine and broad lamellae; continuous and discontinuous; partly bent.
- Int. Refl: not observed
- Etch tests: no effect.

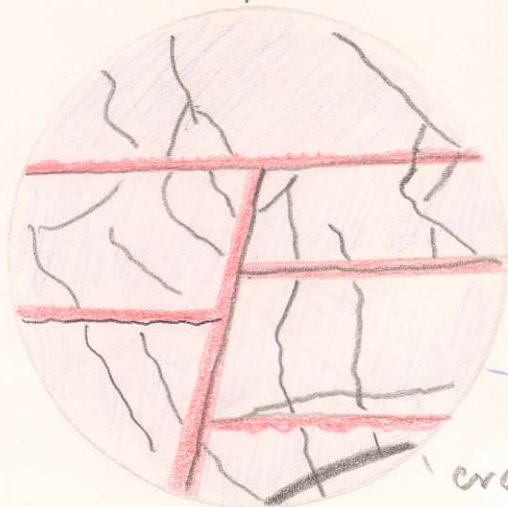
In several areas of the polished sections we ^{see} larger irregular concentrations of ilmenite. Here the ilmenite appears in large elongated grains irregularly intergrown with each other. Twin lamellae run sometimes through several grains. They may be considerably bent. The intergrowth with magnetite is irregular and mostly marked by a fracture.



Ilmenite occurs as finest ~~up to~~ lamellae up to irregular grains as exsolution product of magnetite (described there nearer)

As contrast to the exsolution pattern we have ilmenite filling partings and cracks in magnetite and ~~garnet~~ spinel.

low power



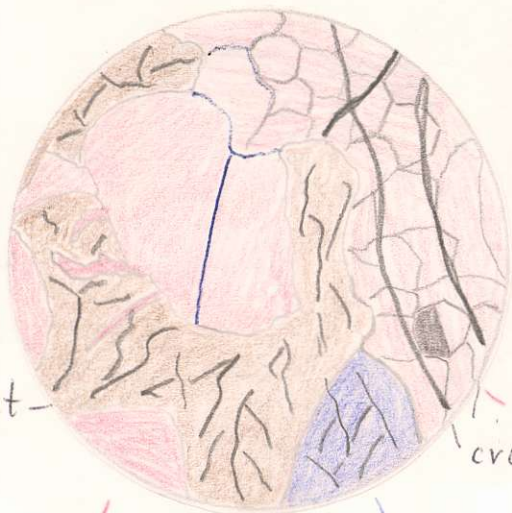
On one side the ilmenite reveals mostly a bit a ragged boundary against the magnetite. That is due to slight replacement.

- ilmenite filling partings
- magnetite

cracks

In one area of one of the polished sections ilmenite

medium power



is present as a thick band of small hexagons. Under special strong pressure the ilmenite has been recrystallized forming these hexagons.

garnet

- ilmenite hexagons

cracks

ilmenite magnetite

Special attention deserves one of these hexagons

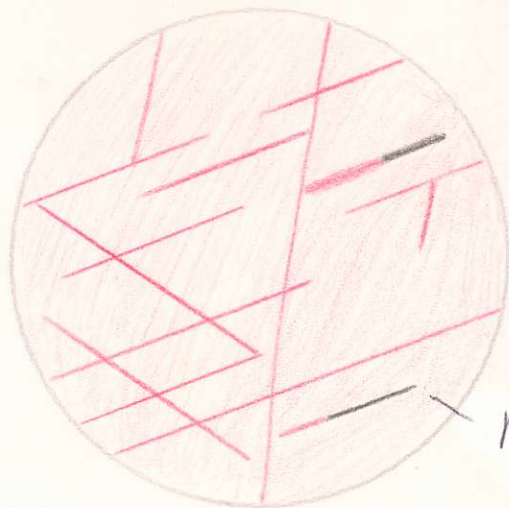


one half of which is occupied by an isotropic gray mineral. The grey

seems to be a bit too light for spinel. May be it is pseudobrookite pseudomorph after ilmenite. The grain is too small to be checked thoroughly.

The same phenomena just described

high power

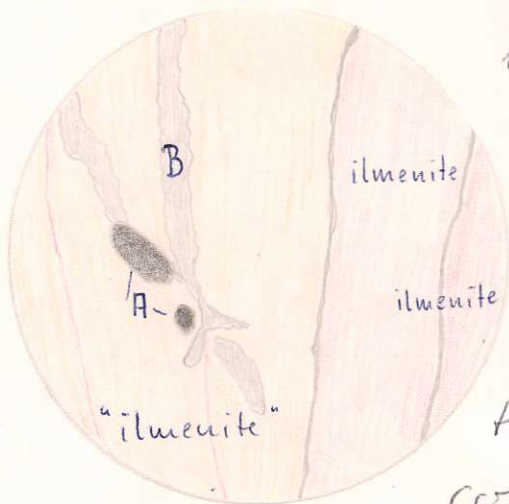


has been observed at the twin-lamellae. Two twin lamellae of this picture suddenly turn into the same grey mineral

- ilmenite + 3 directions of twin lamellae

pseudobrookite or spinel ?

high power



"A" in this picture seems to be again the same mineral. Here it is seen as exsolution drop-

lets of a somewhat white "ilmenite." Its Anisotropic colors are exactly the same as those of the ilmenite to the right. May be the brighter color is due to a change in the

Fe - Ti ratio. Mineral "B" is very

difficult to distinguish from this ilmenite. It is a bit more grey and probably the same as the later described "B".

Spinel (Hercynite) $FeAlO_4$ cub

Hardn: G, hardest of all minerals present

Color: dark grey

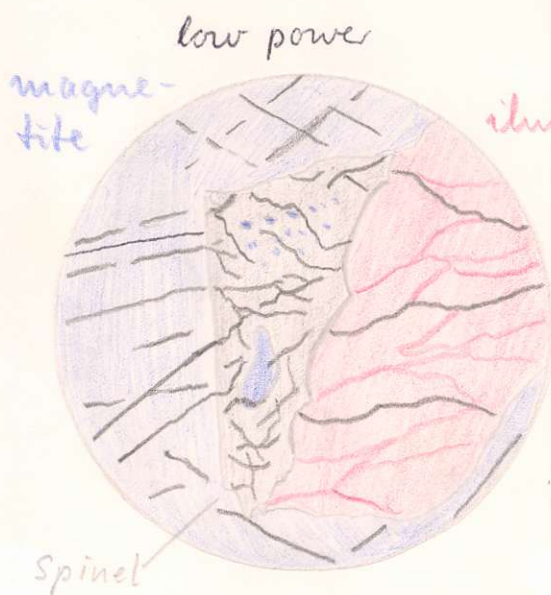
polish: fairly good, where not cracked

Pleochr. Anisotr. none

Int. Refl. not observed

Etch tests no effect.

The single grains have idiomorphic to hypidiomorphic outlines and are cataclastically broken. Some - times the fragments are torn apart. A good many of

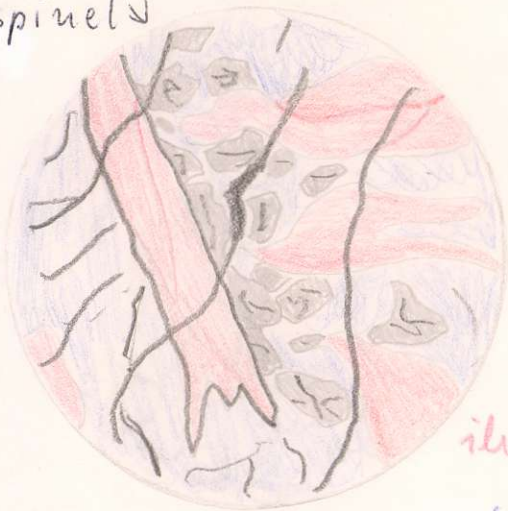


of the grains are deeply cor- roded. Corrosion may have taken place in an early mag- matic stage by the magma around in motion or it's sim- ply due to later replacement.

In the picture the spinel shows corrosion texture against ilme- nite. The spinel contains several

magnetite blebs. At least the small lined up drops at the upper end are due to exsolution. The large drop may be introduced along a fracture.

spinel ↓

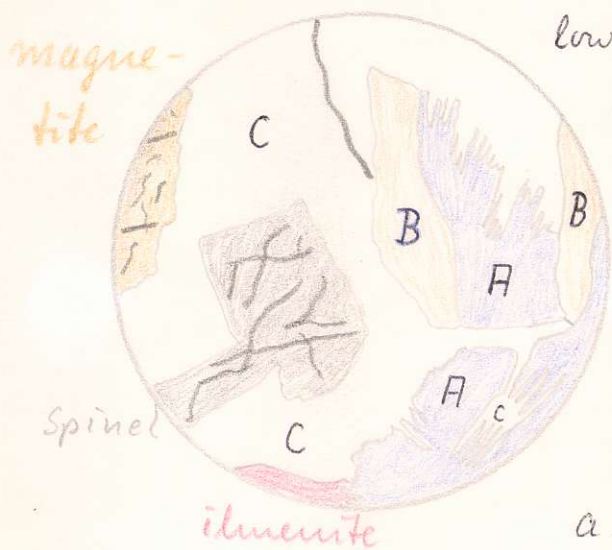


Here is a completely disintegrated spinel shown.

Under the heading ilmenite I mentioned grey exsolution products. These exsolution blebs can be found relatively often in the sections in both in magnetite and ilmenite. In the latter they are more common. A few of these blebs, where they are big enough and lay in the neighbourhood of an "early spinel", could be definitely distinguished as "exsolution spinels". The great many of them are too tiny to be checked.

Unknown minerals

In a bright crack in the border region of one of the polished sections was a suite of minerals that could not be distinguished. They reveal all hardness F to G and ~~one~~ could not be attacked by any etch reagent.



low power All three components in the picture - A, B, C - are isotropic. A seems to be slightly harder than B and C.

C is slightly lighter than ilmenite and pronounced white. A has a steely blue white color. B is a bit grey against A and C. It

is the darkest of the three - probably it is the same B as that mentioned under the ilmenite heading. The replacement pattern between A and C may be interpreted: A being replaced by C.

A could be Magnetite

C could be an isotropic Titanhematite.



magnetite

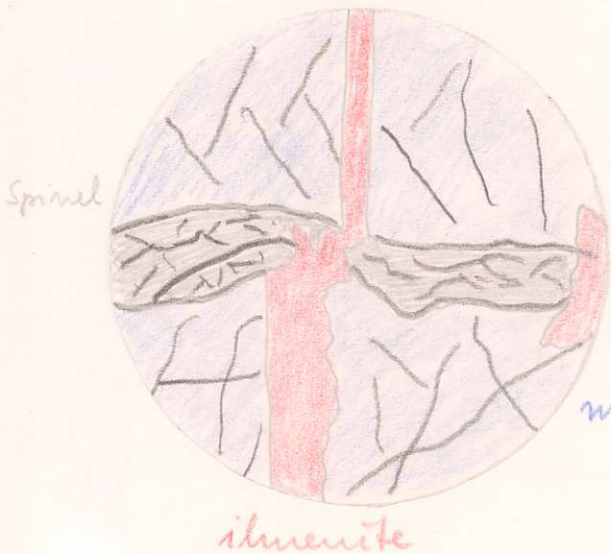
The whole section is crosscut by tiny cracks filled with - probably magnetite: They are good visible under high power and after etching the magnetite brown.

magnetite with exsolution - ilmenite

The ilmenite not traversed by partings is cut by such a "vein" of magnetite

Genesis and Temperature

low power



The picture gives a good demonstration of the sequence of crystallization:

Spinel - Magnetite \equiv deformation \equiv Ilmenite.

Crystallization started out from a probably homogeneous melt

with settling down of spinel crystals. It is probably Hercynite which incorporated more iron in its lattice than it can keep under lower temperatures. This over-abundant Fe-content has been exsolved as magnetite drops. Schwartz gives 1000°C , Ramdohr only 800°C for the spinel - magnetite exsolution.

Magnetite crystallized next leaving an interstitial liquid gradually becoming richer in titanium. The slow cooling ratio allowed the Ti-rich liquid by processes of diffusion and migration to coalesce in several areas where it crystallized as ilmenite. Later on, this ilmenite might have been enlarged by migrated Ti-substance exsolved from the magnetite

January, 8th, 64

lattice. Ilmenite - magnetite exsolution starts below 800°C (Schwartz) [Randolph gives 700°C] if the Ti content in magnetite exceeds 7%.

Still in a very early stage the becoming ore body had been subjected to a very strong deformation indicated by the partings in the magnetite and the disintegration of the spinels. Parts of the congregated ilmenite either still mobile or remobilized were squeezed into partings and cracks. The development of the twin lamellae in ilmenite and their deformation also originated under strong pressure.

Later than the former minerals is the suite of unknown minerals filling a large crack. The magnetite let us suggest that in the later stage of crystallization more O_2 was available.

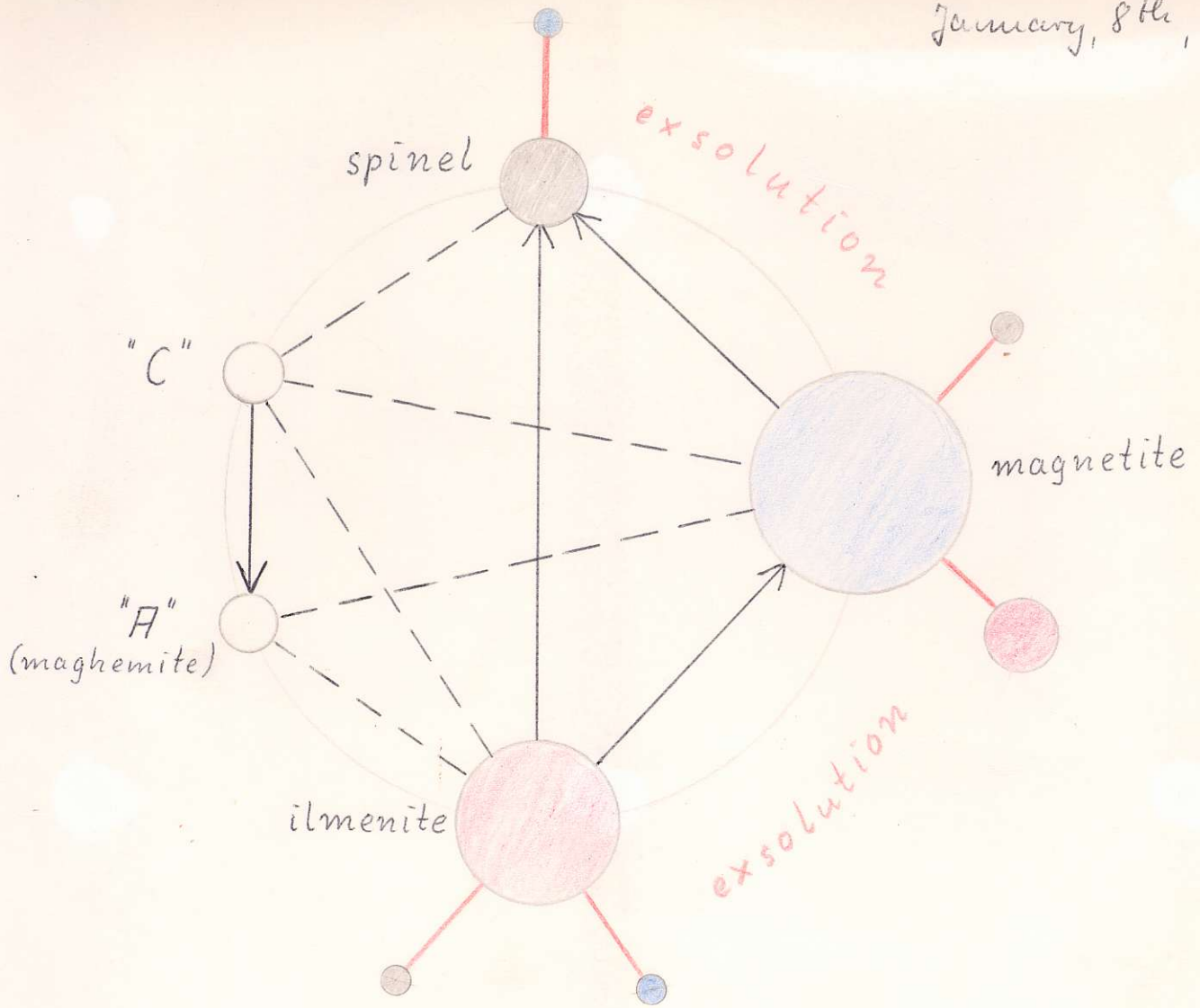
A deposit of such a mineral suite is either liquid magmatic or contact metasomatic in origin. The absence of any indicative skarn mineral and the lack of zoning texture as well as the high exsolution temperature magnetite - spinel let me a liquid magmatic deposit assume.

However definite decision should first made after field observations.

Literature:

- 1) 1913 U.S. Bureau of Mines Bull. 64
The Ti-Fe ores of the USA. Singewald
- 2) 1918 Economic Geology p. 419 - 446
Ti-Fe ores. Warren.
- 3) 1931 Econ. Geol. p. 739 - 763
Unmixing of Solid Solutions Schwartz
- 4) 1955 American Journ. of Science p. 497 - 532
Fe - Ti Buddington, Fahy, Vlissidis.

January, 8th, 64



A Very good
Rm
Feb 13/64

Megascopic description.

Deep alteration of all specimens causes a low physical strength. Microchemical tests on the alteration products indicated: Zn, Cd, Fe, Pb, and Cu. These elements may be due to: Greenockite (Zn, Cd, Fe, ^{smithsonite} yellow); Limonite (Fe, rusty brown); Cerussite (Pb, grey white) and Malachite (Cu, pale green).

Its primary minerals are to recognize 1) Sphalerite: a) massive coarse crystalline, forming a whole specimen alone. b) fine to coarse crystalline as replacement bands in the wallrock - a phyllite with chlorite alteration. 2) Galena (2) and Quartz (3) are the common associates in these bands. c) On a polished surface ZnS is often present as fragments "floating" in a mass of PbS or Boumorite.

4) Boumorite is a soft, brittle mineral with the luster of a Ni-Co-ore. Occurs around the ZnS or in small veins.

5) Tetrahedrite is to recognize at its dull gray color.

It mostly bears an alteration film of Cerussite, Limonite and Malachite.

Replacement may have taken place under fairly low pressure environment since a no.

Microscopic description

of vugs is present, either empty or filled with good crystallized Calcite.

duct indicated: In, Col, Fe, Pb, and Cu. These elements may be due to: fennuchite (In, Col, Fe, Pb, and Cu); limonite (Fe, mostly brown); hematite (Fe, grey white) and thalassite (In, pale green).

The primary minerals are to recognize 1) sphalerite: a) massive coarse crystalline, forming a white specimen above. b) fine to coarse crystal - line as replacement bands in the wall rock - a) pyrite with bluish alteration. b) galena (2) and quartz (3) are the common associates in these bands. c) On a polished surface Zn₂S is often present on fragments floating in a mass of PbS or Bornite.

4) Bornite is a soft, brittle mineral with the luster of a metallic ore. Occurs around the Zn₂S in small veins.

5) Tetrahedrite is to recognize at its dull grey color. It mostly bears an alteration film of limonite, hematite and thalassite.

Replacement may have taken place under fairly low pressure environment since a no.

Mineral Content of the polished Sections

Chute	1) 1) ZnS	30%
	2) Quartz	20%
	3) Boumonite	27%
	4) Galena	15%
	(5) Stephanite	5%
	6) Pyrite	1%
	7) CuFeS ₂	trace

2) 1) ZnS	35%
2) Boumonite	28%
3) Galena	27%
4) Quartz	5%
(5) Stephanite	3%
6) Pyrite	2%

3) 1) PbS	50%
2) Quartz	25%
3) ZnS	22%
4) Tetrahedrite	2%
5) CuFeS ₂	1%

4) 1) PbS	50%
2) Quartz	25%
3) ZnS	19%
4) Tetrahedrite	5%
5) CuFeS ₂	1%
6) Boumonite	1%
7) unknown	trace

5) 1) Boumonite	
2) ZnS	
3) Tetrahedrite	
4) Galena	
5) Quartz	

6) 1) ZnS	50%
2) Boumonite	30%
3) Galena	16%
4) Quartz	3%
5) Pyrite	1%

Handwritten notes:
 100%
 100%
 100%

- 7) 1) ZnS
- 2) Galena
- 3) CuFeS₂
- 4) Bornhorite
- 5) Tetrahedrite
- 6) Covellite
- 7) Fluorite


- 8) 1) ZnS 6%
- 2) Quartz 50%
- 3) Bornhorite 30%
- 4) Galena 10%
- 5) Fluorite 5%
- 6) Tetrahedrite 2%
- 7) CuFeS₂ 2%
- 8) Covellite 2%

- 9) 1) Sphalerite 95%
- 2) Quartz 5%

- 10) 1) Galena 70%
- 2) ZnS 22%
- 3) Quartz 5%
- 4) CuFeS₂ 1%
- 5) Covellite trace

This is
 actually
 manganite
 Pb, Sb + Cu
 sulfosalt.

Mineral Description

- 1) Sphalerite pitted surface, polysynthetic twinning very often to observe, strongly corroded grains of varying size. contains emulsion (plebs) of $CuFeS_2$ and Cu_2FeS_4 exsolution.
- 2) Galena fine polish, cleavage and triangular pits often to observe, myrmekitic intergrowth with Stephanite.
- 3) Boumonite $2PbS \cdot Cu_2S \cdot Sb_2S_3$ white bluish with a green tint. Hardness C, Reflectivity: 36%; Pleochroism: weak
 A.I. distinct pale blue - brownish yellow (purplish) twinning very common, also the characteristic parkett twinning to observe  fairly good polish, surface traversed by minute cracks.

Etch tests: HNO_3 fumes slowly and stains brown
 Aqua regia stains purplish gray to ind.

- 4) Quartz old generation strongly cracked and corroded. young generation starts idiomorphic growth (see later)
- 5) Tetrahedrite euhedral grains or big formless plebs.
- 6) Stephanite $5Ag_2S \cdot Sb_2S_3$ fine polish, Refl. 30 distinct darker than galena, gray-green color
 Pleo: weak A.I. distinct blue gray - brown
 no internal reflection, a very fine twinning is common.
 Etch tests: $HNO_3 - HCl - FeCl_3$ are neg.
 KCN stains dark gray
 KOH stains ind. to black.

The reflection color and the A.I. colors do not correspond with the violet tints given in Uytendboogardt. The colors here observed would fit better in Miargirite. But for Miargirite is no twinning described and the negativity of all etch test with the exception of KCN and KOH is only characteristic for Stephanite.

- 7) $CuFeS_2$ as emulsion drops and exsolution in ZnS often at the boundary of ZnS and Tetrahedrite as irregular shaped grains may be due to rim reaction.
- 8) Pyrite FeS_2 yellow white, good polish, isotropic, reflectivity 54%; Hardness F. idiomorphic as cubes and in a foreign coat - after Arsenopyrite

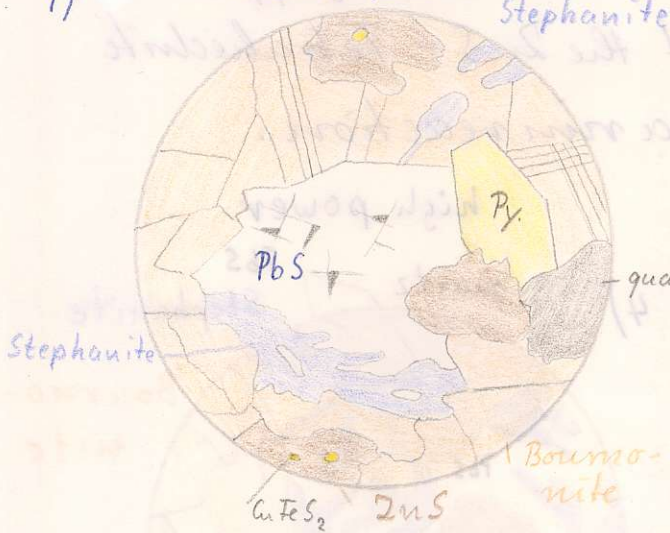


Etch tests: HNO_3 fumes tarnish with very slow eff.
 $KMnO_4$ and H_2SO_4 develops texture

- 9) Fluorite dark grey, good polish, brown red internal reflection. Hardness about C, invading galena after cleavage.
- 10) Covellite CuS H: B+ indigo blue small scales, fine polish, Plev: high, A.I.: extremely high: orange, reddish brown. only observed in Fluorite.

Genetic Sequence

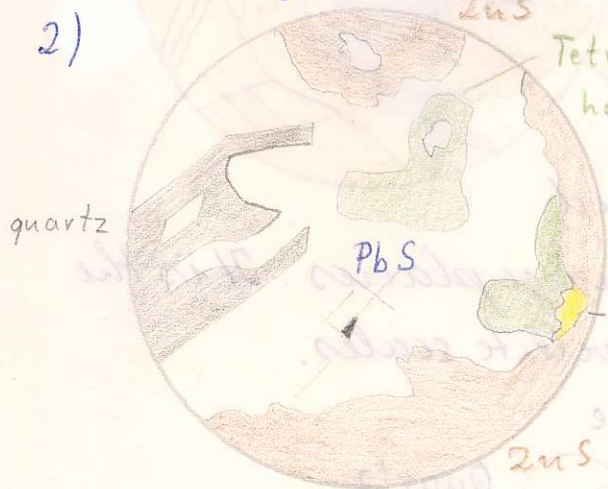
1) medium power



Pyrite and quartz are the first minerals having been deposited since they are replaced by Sphalerite. The relationship between Pyrite and quartz is not quite certain. The mutual boundaries let assume a nearly simultaneous precipitation.

2)

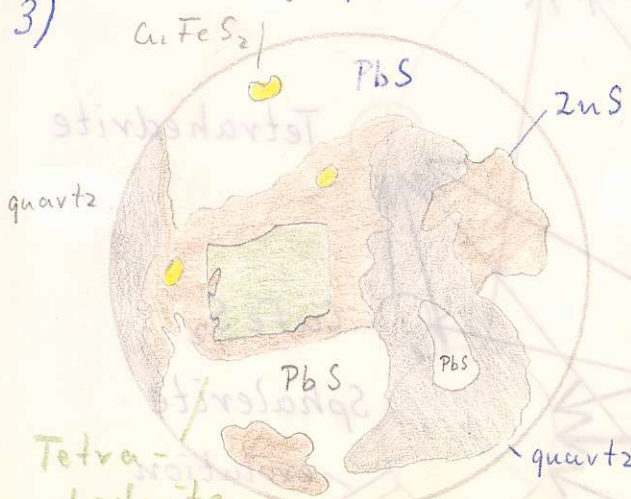
high power



There exists a definite younger generation of quartz, shown by growing idiomorphic crystals replacing Galena

3)

high power



Tetrahedrite predates Sphalerite as shown in 3) where it is included in ZnS and where ZnS has started replacement of the euhedral grain.

Sphalerite is strongly corroded and torn apart by Bourmonite, Galena and Stephanite.

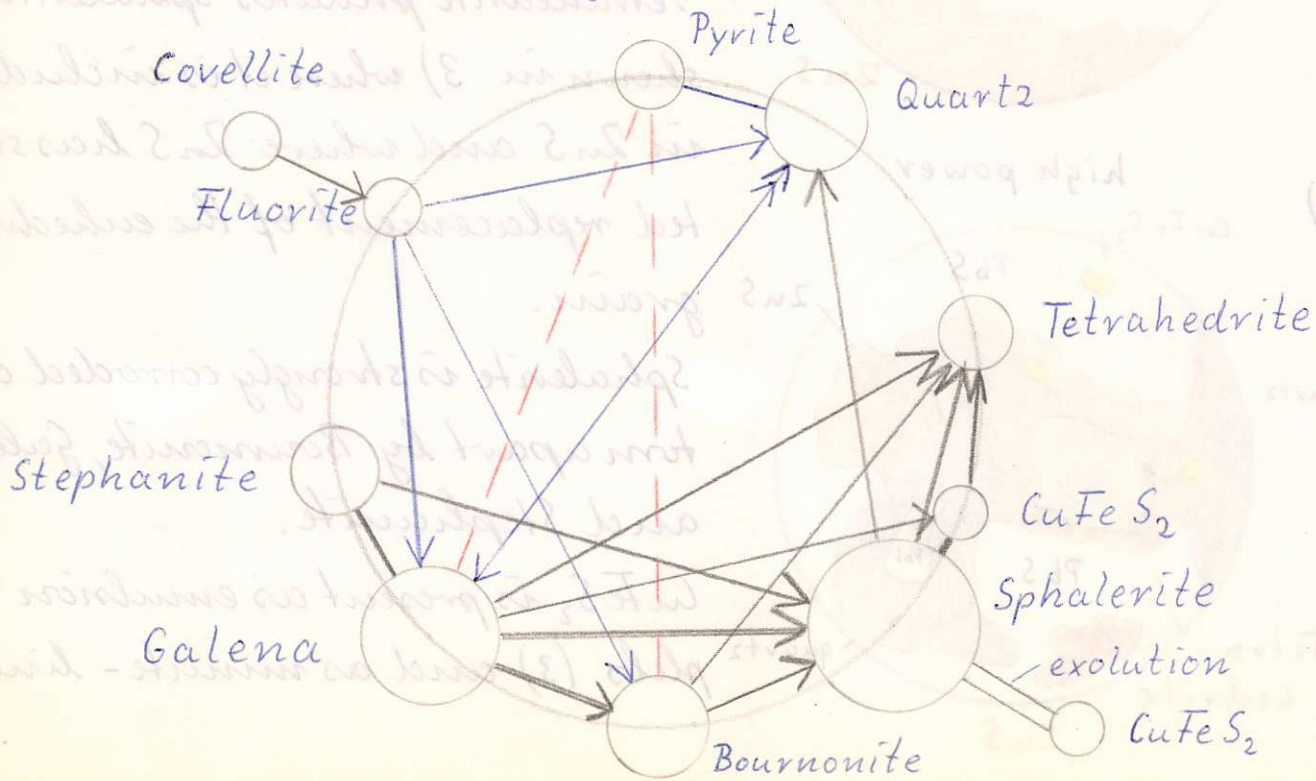
CuFeS₂ is present as emulsion plebs (3) and as minute-lined up

exsolution grains in sphalerite. Hence both types are of the same age as the ZnS. Further $CuFeS_2$ appears as small irregular grains at the ZnS - Tetrahedrite boundary (2) may be due to a rim reaction.

Bourbonite is replaced by Galena and Stephanite. The latter two reveal an intimate - in some places nearly myrmekitic-intergrowth, caused by simultaneous depositions.



The Fluorite replaces quartz and galena - starting out from cleavage planes. It is the host for the minute supergene Covellite scales.



Dec. 20th 1963

- 9 -

The mineral content and the kind of replacement of the wallrock indicate a hydrothermal deposit. Hence we have ^sexsolution texture, $ZnS - CuFeS_2$, the cooling gradient was fairly high. This and the previously mentioned low pressure environment point to a deposition in low depth.

There is no direct temperature indication ~~or~~. We may therefore assume deposition anywhere through the hydrothermal scale. The higher hydrothermal part may be excluded because of the low Fe content of the ZnS .

mesothermal type

A -
RMT
Jan. 3/64

Nov. 20th 1963

Megascopic description

1) The 2 specimens 2-4

Both are composed of massive ore. Very few quartz grains could be recognized. A carbonate - green-brown appears in cracks or holes on the outside. It is crystalline has a H: 3-4 and effervesces with HCl. The ore consists mostly of $CuFeS_2$ and ZnS . Cleavage planes of the latter are up to 4 mm in ϕ . Veins of native Pg pinkish and sectile are cutting the massive sulfides. Pg grains are disseminated through the whole specimen. Small part times euhedral crystals of a dull black mineral are scattered through the sulfides. (prismatic shape, H:6)

Further there is a white sulfide to recognize, very soft, sub sectile, probably Cu_2S . Alteration covered the specimens with a black coat probably Cu_2S . A green-blue secondary mineral coats mainly the ZnS . It is probably a Copper mineral. For Malachite the color is a bit strange!

2) The nickel ore specimen.

Deeply altered wall rock containing large amounts of

Chlorite. \square cuts may reveal chloritized Biotite.
Clay minerals may also be present. Niccolite, white nickel-Co ores and CuFeS_2 are scattered over the whole specimen. Circular accumulations of niccolite and white nickel ores are to observe as well as skeletal growth of a white Ni-Co-ore. Parts of the rock are carbonated. The Annabergite on the surface points out that we have mainly Ni-ores. Nevertheless under the Binocular some minute Erythrite crystals could be detected. Sphalerite and the same green crystalline carbonate, described in the former specimens, were recognizable.

3) limestone 2-4

The specimen consists of massive limestone in which is a small vein of CuFeS_2 and soft but brittle Ruby silver accompanied by a glassy calcite.

4) The breccia vein

A fissure in limestone is filled with large crystalline fragments of CuFeS_2 , Pyrite (both blackcoated) and very soft sectile Hg_2S . A clay mineral is probably due to former feldspar. The fragments are cemented with a very coarse crystallized Calcite. (open space filling) at both edges of the fissure CuFeS_2 is fine disseminated in limestone.

Mineral content of the polished sections

Section X ₁		Section X ₂	
1) Sphalerite	40%	1) Quartz	60%
2) Galena	30%	2) Marcasite	23%
3) Marcasite	25%	3) Galena	17%
4) Quartz	5%	4) CuFeS ₂	trace
5) CuFeS ₂	trace	5) Pyrite	trace

section 10		section 511	
1) Calcite	50%	1) Calcite	65%
2) Sphalerite	15%	2) Niccolite	25%
3) Niccolite	12%	3) Rammelsbergite Safflorite	5%
4) CuFeS ₂	10%	4) CuFeS ₂	2%
5) Rammelsberg. Safflorite	5%	5) Skutterudite	2%
6) Skutterudite	5%	6) Galena	1%
7) Galena	2%	7) (Marcasite)	1%
8) Quartz	1%	8)	

section 100	
1) Quartz	45%
2) CuFeS ₂	27%
3) Argentite	8%
4) Silver	20%
5) Sphalerite	trace

→ continued

section 2-4

- 1) Sphalerite 62%
- 2) $CuFeS_2$ 19%
- 3) Galena 8%
- 4) Tetrahedrite 4%
- 5) Silver 2%
- 6) Argentite 2%
- 7) Quartz 2%
- 8) Calcite trace
- 9) Ruby Silver trace

section 101

- 1) Sphalerite 60%
- 2) $CuFeS_2$ 15%
- 3) Galena 7%
- 4) Argentite 6%
- 5) Silver 4%
- 6) Tetrahedrite 4%
- 7) Ruby Silver 2%
- 8) Quartz 2%

section 101

- 1) Quartz 42%
- 2) $CuFeS_2$ 27%
- 3) Argentite 8%
- 4) Silver 20%
- 5) Sphalerite trace

Description of the microscopical features
of the observed minerals.

1) Quartz: Refl: 5%, Color: dark gray, H: F
intern. refl. very colorful.

as idiomorphic grains (sect. x_1); in (2-4) such grains
show strong corrosion, inclusion of $CuFeS_2$; in x_2 it
is a complete mass, traversed by younger quartz veins
revealing irregular shaped grains.

2) Calcite: Refl: 6%; Color: pale grey; H: C
Pleo.: dist.; Friso: covered by white intern. refl.

only in (2-4) as single hypidiomorphic grains. The lar-
ger part is massive and shows a mosaic like pattern
under $\times\times$ microl.

HCl effervesces.

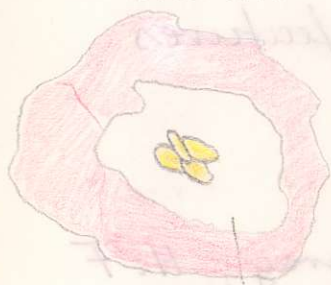
3) Marcasite: Refl: 52%; Color: yellow; H: E

Pleo: distinct; Friso: very high: blue-yellow-
purple. Polish: bad, because of the high number of

polysynthetic twin lamellae. Grains are eido-
morphic to subidiomorphic. The yellow grains in sect.
511 included in Skutterudite were distinct as mar-

section 511

niccolite



Skutterudite

casite, because of their enormous high pleochroism. Millerite is not supposed to have such high pleochroism. The grains were too small for an etch or microchem. test.

etch tests: HNO_3 : low eff. stains brown to irid. $\text{H}_2\text{SO}_4 + \text{KMnO}_4$ develops texture.

4) Sphalerite: Refl. 19% ; Color: gray ; H: D ; isotropic, yellow-red intern. refl. very seldom ; Polish: fair ; polyhedral twin lamellae are common in (2-4). Contains often rounded inclusions of CuFeS_2 . Partly they are the product of exsolution, specially where they are lined up after the ZnS -cleavage.

etch tests: H1 may develop texture or twin lamellae.

5) Chalcopyrite tetr. Refl: 43% ; Color: yellow ; H: C Anisotr.: only under high power to notice. Polish: fine. intimate intergrowth with ZnS . In (10) it appears scattered over the section.

Etch test: HNO_3 fumes, tarnishes slowly.

Aqua regia may develop granular texture.

6) Galena cub.: Refl: 43%; color, white; H: B isotropic; cleavage and triangular pits are mostly developed. Polish: very fine.

in (2-4) Zn S starts replacement of galena through the cleavage. Rimmed by Ag_2S (101) and showing rounded inclusions of Ag_2S and Ruby silver.

Etch tests: HNO_3 stains black. HCl furnishes brown to irid. FeCl_3 furnishes irid.

7) Niccolite trig. 52% refl; color: brownish pink; pitted surface; H: E; Pleo: strong; Anisotrop: strong: yellow-greenish - violet blue.

In (10 and 511) some rosette like aggregates with radiated texture are observed. The niccolite is rimmed by Rammelsbergite, due to change in the mineral solution and replacement. The position of Rammelsbergite is sometimes overtaken by ~~Skutterudite~~ Skutterudite.

Etch tests: HNO_3 eff. quickly; HCl stains brown to irid.; $\text{H}_2\text{SO}_4 + \text{H}_2\text{O}_2$ brings out cleavage.

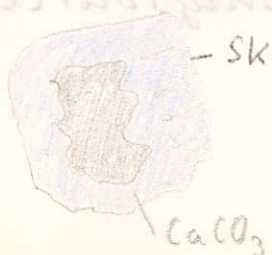
8) Rammelsbergite, Saffronite ortho; Refl: 60; Color: pure white, H: E; Polish good, sometimes pitted. Refl. Pleoc: very weak; Aniso: strong pinkish-brown to blue, reveals a fine mosaic like grainage. The microlite is mostly rimmed by Rammelsbergite. Where larger grains are formed it is not possible to say if it's Saffronite or Rammelsbergite. The Aniso. distinguishes both from the isotropic Skutterudite. Skeletal texture, due to incomplete replacement, may be formed by both minerals.



etch tests: HNO_3 strong eff. developing of lamellar texture; $FeCl_3$ stains brown and brings out the grains.

10) Skutterudite cub. Refl. 61% Color: white, H: E good polish, sometimes pitted; isotropic. In a few places (511) all mentioned Ni-minerals are intergrown.

etch test: conc. HNO_3 etches - difference to Cobaltite.



- Skutterudite forms the so called atoll structure. a idiomorphic or hypidimorphic grain being replaced in the centre by $CaCO_3$.

11) Tetrahedrite cub. Refl. 27% Color: olive gray, H: D isotropic, very fine polish.

present as rounded inclusions in ZnS, in PbS it is mostly corroded, relief against galena. Intern. refl. was not observed.

etch tests: HCl tarnishes brown and blue ind.
HNO₃ fumes tarnish ind.

12) Silver cub. Refl. 85% Color: pink; H: B distinct anisotropic, fair polish showing ind. surface. present as irregular shaped grains or dendritic aggregates, sectile, a few twin lamellae were observed.

etch tests: HNO₃ eff. and blackens;
KCN tarnishes slightly; H₂O₂ stains brown to ind.

13) Ruby silver Refl: ~ 30%; Color: gray-brown. H: B good polish; Pleo: weak - green gray - blue gray. Anisotr. distinct: lavender violet - yellow gray green. Scarlet red intern. refl. very seldom observed.

On the basis of this Anisotropism colors it could be Polybasite. present as inclusions in galena or intergrown with Tetrahedrite and Argentite.

etch tests: HNO_3 fumes tarnish, HCl the same;
KCN quickly blackens; FeCl_3 tarnishes ind.
Stromeyerite is in this area a very common mineral. The optical data fit also exactly for this mineral. Hence it might be possible that at least a part of the grains distinguished as Polybasite are Stromeyerite. The lack of intern. refl. favours this but is no proof.

14) Argentite Refl. 32; Color: gray green; H: 17
has always a bad polish, that makes it easy to distinguish from Ruby silver; surface is scratched and rough. Forms rounded plebs in galena and spalerite. minus silver and is replaced by Ag.

Etch tests: KCN slowly or quickly dark brown
Aqua regia tarnishes iridescent.

The genesis of the polished sections is discussed in 3 groups:

- 1) sections x_1 ; x_2 revealing a small vein, rhythmic banded.
- 2) 2-4; 100; 101 massive ore no particular structure or test.
- 3) 10; 511 nickel minerals revealing a full texture and uncomplete replacement.



The quartz crystallized first, forming the edge of the vein and revealing colloform texture. Movements gave rise to small cracks in the quartz. They were filled with a secondary coarse grained quartz carrying minute amounts of pyrite and $CuFeS_2$. Marcasite (exception) being the oldest of the sulfides (except of the minute amounts in the quartz) reveals hypidiomorphic to idiomorphic grains. Sphalerite containing some emulsion drops of $CuFeS_2$

seemed to fill completely the space between both marcasite edges until galena started replacement from the boundary $ZnS - FeS_2$.

2) group, sections 2-4; 100 and 101

In section 2-4 already megascopic observation shows a vein like distribution of $CuFeS_2$ through the sphalerite. That is a good evidence, that ZnS preceded the $CuFeS_2$. Some idiomorphic ZnS edges favour this statement.

But in 100 the judgement is not as easy. The intimate intergrowth of $CuFeS_2$ and ZnS with an equal large number of large inclusions in each other leads to the assumption that both crystallised at the same time. A relative fast temperature decay prevented the complete segregation and separation of the liquids.

Tetrahedrite replaced both, $CuFeS_2$ and ZnS .

(fig. A and C) Definitely later than the former cited minerals is galena. It replaces all of them. (A) closely related to the galena are the ruby silver, (Stromeyerite) and Pb_2S . At higher temperature galena is capable to solve a large excess of Pb , PbS and S . By cooling down Pb - and Pb_2S - liquid segregate. The rest of the

Ag content in galena - specially such acquired by replacing Tetrahedrite - appears as small exsolution drops of ruby Ag or Ag_2S or Ag. The main mass of the silver bearing fluid replaces dominantly galena, but also tetrahedrite, sphalerite and $CuFeS_2$. (ABCDE)

Again definitely later Ag disseminated or moved on fractures through the ore. In 100 nearly all Ag is rimmed by Ag_2S (D) but the reversed case is observed too. (E)

The Ag_2S rimming may be due to adsorption of S from the surrounding Sulfides. Case E may be a starting replacement of Ag_2S by Ag.

group 3) reveals a completely different association.

The sequence: Miccolite - Rammelsbergite, Safflorite - Skutterudite - $CuFeS_2$, ZnS , - $CaCO_3$

First miccolite ate itself into the wall rock and formed irregular shaped assemblages of several grains or irregular stars with radiated structure. An increase in the Ag ratio of the mineralizing fluid lead to precipitation of rammelsbergite - Safflorite, either rimming miccolite or as separate aggregates. The skeletal growth in some places is due to incomplete replacement.

A further increase in the Ag ratio precipitated

Skutterudite. It forms part times idiomorphic grains or rims the miccolite like rammelsbergite. (F)

$CuFeS_2$ and ZnS form an intimate "eutectic" intergrowth. This reveals again a rapid cooling down of the mineralising fluid and hence a crystallisation not far below the surface.

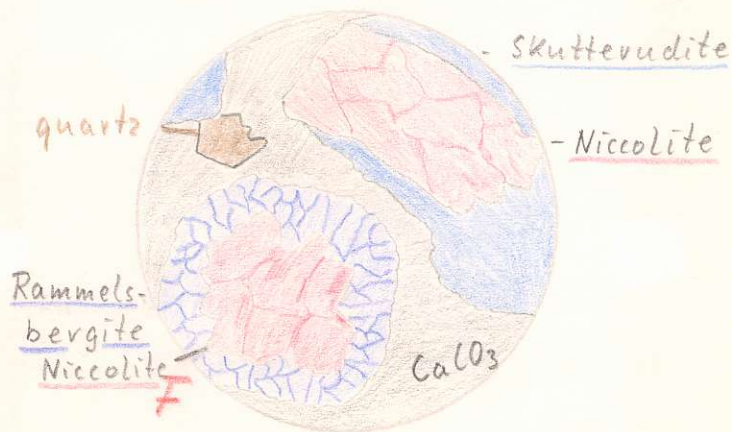
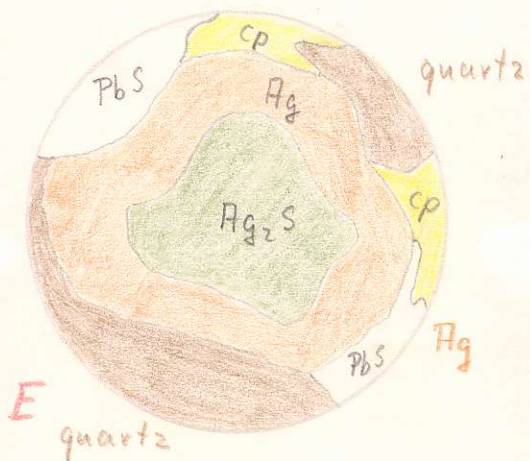
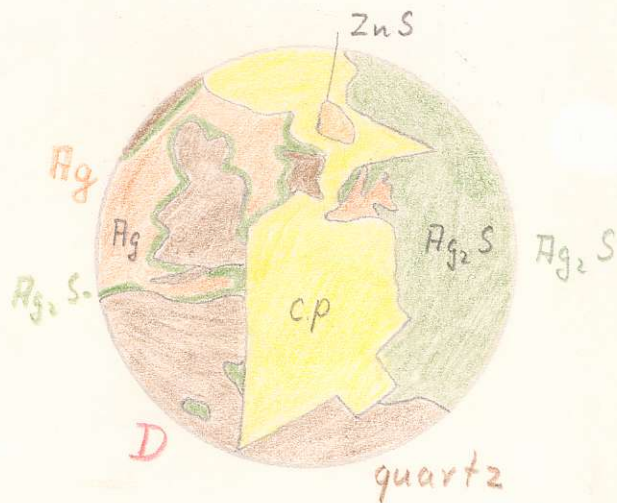
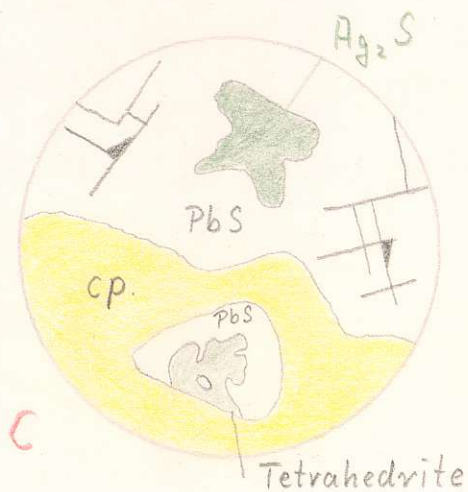
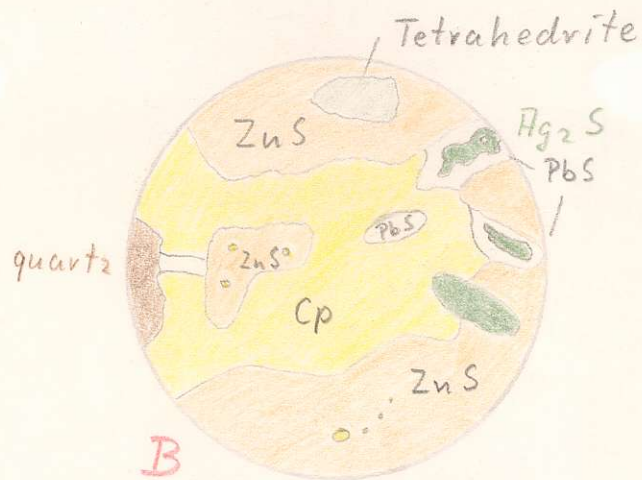
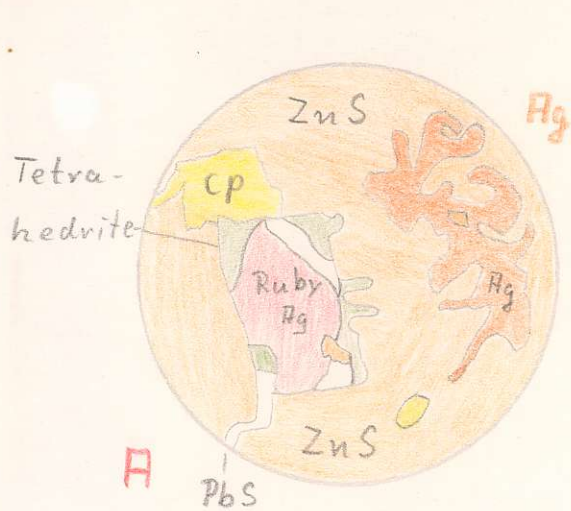
The youngest mineral is the calcite which has replaced large masses of $CuFeS_2$ and ZnS .

Calcite forms also the core of several miccolite aggregates and of idiomorphic Skutterudite grains - so called a loll texture. If the $CaCO_3$ replaced the nickel ores directly from the centre or if the nickel ores grew around an unknown mineral now being replaced by Calcite can't be stated. The last case is described in literature more often.

How to link these 3 groups together?

group 3) seems either to belong to a different mineralisation period or it represents a very early stage of the mineralisation period of group 1) and 2). In all cases group 3) is deposited at a much higher temperature than 1) and 2).

group 1) may be derived by an earlier mineralising



Scale?

of a Fe-rich group 2 into partial solutions. So, 1) being rich in Fe and poor in As, Cu, Ag.

In using Schneiderhöhn's classification I would like to put the ores in the Co-Ni-Ag-As formation of hydrothermal origin.

For group 3) we have to assume a kata- to mesothermal depositions (because of the Ni-minerals) Group 1) and 2) may be classified as meso- to epithermal. (epith. Ag and possibly Ag₂S)

A
RMT
Nov. 30/63
Can you show the
paragenetic sequence in
a Van der Weerd diagram?