MINERALOGIE, GEOCHRONOLOGIE, UND ERZLAGERSTÄTTEN

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COLLOFORM TEXTURES OF THE KREMNICA ORE VEINS

(Plate XIII—XVIII)

Abstract. Paper deals with colloform textures determined at Au—Ag—Sb deposit of Kremnica. Described are colloform textures of vein quartz, pyrite, marcasite, electrum. With the quartz are shown examples of various stages of SiO_2 gel recrystallizations and formation of metacolloidal quartz. Further characterized is colloform electrum and the importance of colloidal Au solutions for the origin of bonanzas is being emphasized.

Introduction

During the paragenetic studies of the Kremnica ore veins we came to the conclusion that colloform textures in the vein filling are very abundant. Their study provides an idea on the share of colloidal solutions in the whole of hydrothermal vein filling helping to supplement some questions on the genesis of this deposit.

Kremnica ore district is localized in the central part of Kremnické hory Mts., composing the northern group of Slovenské stredohorie neovolcanics. The ore district consists of several vein systems of epithermal subvolcanic charakter belonging to the metalogenic province of West-Carpathian Neogene subsequent volcanism. In this type of deposit the colloform textures have been determined in many cases thus showing colloidal nature of great deal of hypogene hydrothermal solutions. Numerous examples of epithermal colloform textures are given by W. Lindgren (1933) and many other authors. We may conclude that colloform textures for this type of deposits are among the charakteristic features.

The data on the colloform textures in the group of subvolcanic epithermal deposits of West-Carpathian neogen subsequent-volcanic metalogenic province however are very seldom. Several symptoms of colloform textures in the subvolcanic polymetallic ore veins of Banská Štiavnica were described by T. Jarchovský (1963). An important role to colloidal solutions is being ascribed by T. P. Ghiţulescu (1935) in the formation of auriferous veins of Muntofii Apuseni. His opinions are very close to those ours based upon the studies of similar vein types in Kremnica. E. Stoicovici and S. Gliszcinski (in F. V. Čuchrov 1955) described several examples of hydrothermal quartz, pyrite, chlorite and amorphous minerales precipitated in the form of hydrothermal gels from Valea Bradului and Capnic deposits. In the monography of A. Helke (1938) however dealing with the neovolcanic Au—Ag deposits of Carpathians the participation of colloidal solutions in the formation of the discussed type hydrothermal deposits has been underestimated in spite of the fact that many of the vein textures described are of colloform character.

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Brief Characteristics of the Deposit

The majority of fault fissure veins appear in lavas and pyroclastics of the Tortonian pyroxene andesites forming stratovolcanic complex intruded by a system of subvolcanic bodies. Numerous dykes of sarmatian rhyolites appears on ore bearing faults. The ore veins are with rhyolite dykes in paragenetic relationship. The ore district volcanics show widespread hydrothermal alteration. Besides the typical propylitization several zones of potassium replacement with adularia, sericitization, kaolinization, alunitization and silicification have been also determined.

The mined ore veins are arranged in two vein systems in the center of the ore district. By the study of vein filling textures the supply periods have been determined as given in Table 1. The data comprise parallelization of periods within the both vein systems.

Table 1

<table>
<tr><td></td><td colspan="8">Hypogene supply periods
>——— Time ———></td></tr>
<tr><td>1st vein system</td><td>carbonate</td><td>first quartz</td><td>second quartz</td><td>x. pyrite</td><td colspan="2">quartz-carbonate</td><td colspan="2">stibnite</td></tr>
<tr><td rowspan="2">2nd vein system</td><td rowspan="2"></td><td rowspan="2">first quartz</td><td colspan="2">second quartz</td><td rowspan="2">colloform</td><td rowspan="2">carbonate</td><td rowspan="2">stibnite</td><td rowspan="2">marcasite</td></tr>
<tr><td></td><td>x. productive subperiod</td></tr>
</table>

x. — periods with main supply Au, Ag.

The mineral far prevailing is hydrothermal quartz together with pyrite and arsenopyrite. Other sulphides of base metals and Ag Minerals appear only accessorily. Electrum accompanied by a diverse association of sulphides and sulphosalts reached its maximum in the pyrite and productive subperiods. The pyrite period produced in the first vein system contents rich electrum concentrations with particles dimensions within the scope of microscopic examination. The productive subperiod of the second vein system yields electrum bonanzas with Au content of several percents. The Au, Ag supply in the younger periods decreases heavily on the account of stibnite, dolomitic calcite and dolomite. A more detailed study on the genetic problems was given in the previous paper (M. Böhmer 1961).

The Share of Colloidal Solutions in the Hypogene Mineralization of Kremnica Ore Veins

Both mega and microscopic observations show a very extensive distribution of colloform textures over the deposit. Their characteristics is given below.

In the ore field peripheries brownish opal appears frequently together with a common opalization of volcanics mainly pyroclastics. In the ore veins opal occurs in the lower temperature supply periods: quartz-carbonate, stibnite, productive subperiod and most frequently in the colloform period.

The colloform mineralizing period is remarkable because of its massive colloform SiO_2 forming various characteristic colloform configurations. Microscopic examinations showed about 50% SiO_2 still in opal form, while the rest recrystallized into a fine grained aggregate of xenomorphic shape wiht an average size of grains 0,01 mm. The pigmentation of fine dispersed clay minerals within the original SiO_2 gel caused the white porcellaneous appearance of quartz. Characteristic examples of this period are given on Plate XIII.

More frequent than opal are chalcedony and lutecite, as the most typical gangue for stibnite period. These minerals appear also in the pyrite and quartz-carbonate periods formig botryoidal textures.

In spite of no postmineralization metamorphic effects observed trough hout the ore field the original SiO_2 gels were preserved in relatively small amounts being replaced by widespread recrystallized gels of SiO_2. In such metacolloidal quartz aggregates the relicts of the primary colloform textures may be traced only after indirect symptoms. Most frequent are the relics of colloform textures occuring in thin sections of vein quartz as dust-like particles adsorbed on the primary colloidal configurations distributed in thin bands. During the subsequent recrystallization the grains of metacolloidal aggregate grew without respect disconformably across the primary colloidal structures. Such quartz aggregates may be found mainly in the subsurface parts of veins showing that the majority of SiO_2 here appearer in colloidal form.

In the quartz of metacolloid origin frequently textures similar to those described by O. D. Levickij (1955) from vein quartz of Sn-deposits may be observed. In such quartz automorphous or hypautomorphous crystals with interspace filled with colloform quartz may be observed megascopically. Under the microscope they show regular extinction of hypautomorphous quartz sections surrounded by zoned quartz. The individual zones following at the beginning the shapes of hypautomorphous quartz grains, form various concentric zoned and sphaerulitic configurations during the subsequent development stage (Plate XIV and XV). In this kind of zoned quartz first the radiate-fibrous and undulating extinction is characteristic and xenomorphous granular aggregate in the final stage. Such phaenomena may be explained by the change of physico-chemical conditions after the crystalization of certain part of crystalline quartz took place the formation of colloidal SiO_2 solutions instead of ionomolecular ones. In this case the ionic solutions gave birth to the automorphous and hypautomorphous quartz crystals with regular extension. The SiO_2 gel in the grains interspace shows various degrees of recrystallization: quartz with fibrous extinction, quartz with iregular mosaic extinction and xenomorphous granula aggregate. These development stages of metacolloidal quartz may be seen on Plate XIV, fig. 2 and Pl. XV, fig. 2. The examples demonstrate a complicated character of hydrothermal processes with both ionic and colloidal SiO_2 solutions and the different recrystallization stages of SiO_2 gels up to a complete wipe-out of the original colloform textures.

Among the ore minerals the colloform textures may by frequently found in pyrite forming often concentric, zoned, spheroidal shapes. The colloform texture appears clearly after acid etching (Pl. XVI, fig. 1) sometimes also by megascopic texture examination (Pl. XVI, fig. 2). Representative colloform pyrite occurs mainly in the pyrite and stibnite mineralizing periods. In the stibnite period reniform melnikovite configurations appear beside the metacolloidal pyrite.

As frequent phaenomena marcasite of dropstone shape with recrystallized gel may be observed.

Very interesting however are the colloform textures of the visible electrum from the second vein system productive subperiod bonanzas. Here the texture of electrum veinlets, grains and sheets appears clearly on the etched surfaces of polished sections. (Etching with vapours of diluted aqua regia.)

By the above mentioned etching electrum surface is covered by thin film of Ag-chlorides up to dark thick film after further application. The zoning determined by etching shows the inhomogenity of electrum chemical composition. Portions higher in Ag content appear more dark than those lower in Ag. The Kremnica electrum shows constantly inhomogene chemical composition with zoning of various morphological types. Characteristic examples of electrum zoning of the productive subperiod are given on Plate XVII and XVIII.

The zoning in general may be formed either by the zoned growth of individual crystals or mineral aggregate composing zones or finally by rhythmical coagulation of gels. In our case mineral individuals showing regular crystallographic structure after etching were very seldom. The individual zones are very thin with typical rounded forms without grains iterrupting the zone limit. They usually conform with the morphology of the place of precipitation. All these observations confirmed the colloform origin of the studied textures that were formed by the rhytmic coagulation of colloidal electrum with variable Au-Ag ratio in particular zones. The gel of electrum most probably recrystallized later into an aggregate (light and dark particles Pl. XVIII, fig. 1). Remarkable is the conspicuous colloform concentric texture of electrum replacing pyrite (Pl. XVIII, fig. 2) showing the activity of hydrothermal solutions containing colloidal electrum and replacing sulphide minerals.

According to K. B. Krauskopf (1951) (also C. Frondell 1938) the colloidal Au in laboratory experiments shows very good stability even in high temperatures if protected by protective colloides for example SiO_2. The author stated further, that Au from ionic solutions precipitated usually into colloidal form and as such was transported in hydrothermal solutions in higher concentrations. Colloidal Au may also remain in suspension untill a substantial cooling of the hydrothermal solution.

The above observations are in full agreement with paragenetic studies of hydrothermal gold formations where the majority of gold is being precipitated usually in the final stage of the youngest mineralizing periods. The same may be demostrated also at the Kremnica deposit. Electrum occurs here as one of the yougest minerals of both the pyrite and productive subperiods. The following supply periods represented already substantially different stage of mineralization with Au, Ag content strongly decreasing mainly in favour of Sb.

The data concerning the colloform Au textures in hydrothermal deposits are in general relatively seldom. The hypogene Au, Ag migration by the formation of Kremnica ore veins is being explained as follows: The transportation of Au and Ag originated at the beginning by ionic hydrothermal solutions. In recent times this form is believed to carry thiosulphate complexes (I. G. Tjurin 1963). Due to physico-chemical conditions mainly the decrease of temperature and pressure started the formation of electrum sol, colloidal electrum coagulation at certain places of vein structures and later changes based mostly upon recrystallization. The formation of electrum sol and its subsequent migration occured probably during a long way of ascending hydrothermal solutions. This stage seems to be uniform for the whole deposit. The electrum sol has been adsorbed during crystallization or coagulation of other vein components. This type of electrum adsorbed as crystallosol occurs mainly in pyrite, arsenopyrite and vein quartz, leading to gold concentrations of an average 2—3 gr Au/t. In some parts of vein structures with favourable conditions a more intense coagulation of colloidal electrum occured at the end of supply period and low temperature conditions. The result of such mineralization were bonanzas of megascopic gold appearing mainly in the productive subperiod of the second vein system. The concentrations are multiplied by $n \times 10^4$ as compared with disseminated submicroscopic gold. The unusual electrum concentration in bonanzas typical for epithermal deposits may be explained by the Au transportation in the form of colloidal solutions.

Basing upon the above facts we suggest that localization of rich electrum bonanzas is controlled by the conditions of coagulation of colloidal electrum obviously due to several agents.

In the first place as the general agent — decrease of pressure and temperature must be mentioned leading to the decrease of solubility and under certain conditions even to the formation of colloidal phases. These agents seem to be responsible for the more frequent occurence of electrum bonanzas in the subsurface parts of the second system ore veins at the end of the second quartz period of mineralization. Coagulation of electrum sol may have occured due to several agents. The reaction of electrolytes may have been for example the cause of gold concentrations at the crossings of two fissure systems. In subsurface conditions on the other hand vadose waters may have reacted in the form of electrolytes. The influence of several mutually coagulating dispersed phases may have been also important for example positively charged colloids of the iron hydrous oxides as indicated by the fact that rich electrum concentrations in pyrite period are accompanied by hypogene goethite. As a further important agent may be considered crystallization or coagulation of SiO_2 in the role of protective colloid. Within the second quartz period electrum appeared as the last constituent in the productive subperiod. The effect of filtration may have acted in cases where the electrum bonanzas have occured under the cover of fault — clays such as the gold concentrations underneath the low angle fault structures of the second vein system. As demonstrated by the photomicrographs colloidal electrum coagulated strongly by the influence of older generations of sulphides as an example of topomineral effect.

Concerning the distribution of rich ore bonanzas a whole complex of agents must be taken into consideration. The principles based upon paragenetic studies of the ore veins may replace the empiric principles applied previously in ore prospecting of Kremnica deposit.

Conclusion

According to the distribution of colloform textures in Kremnica ore veins we suggest that one part of vein filling minerals coagulated from colloidal solutions. Colloform textures appear mainly in quartz, chalcedony, pyrite, marcasite and visible electrum from bonanzas. The distribution of colloform textures shows that the ratio of colloidal solutions in general is higher in subsurface parts and in younger mineralizing periods even to their predominance over the ionic solutions. In spite of the young age (Sarmatian—Upper Caenozoic) of Kremnica deposit the coagulated gels are recrystallized with colloform textures preserved only in relicts.

Although the colloform textures indicate clearly the important part of colloids in Kremnica hypogene minaralization the crystallization from ionic solutions — for example of vein quartz — may also be proved beyond any doubt. The mineral filling originated alternatively from ionic-molecular and colloidal solutions under the controll of changing physico-chemical conditions. The vague limits between these two types of solutions are indicated by the zoned texture of quartz individuals where the internal parts with crystalline texture pass gradually into metacolloidal periphery. (The same in G. G. Gruškin, I. G. Chelˈvas 1951.)

The origin of electrum bonanzas may be explained on the basis of proved colloform textures due to the formation of highly concentrated colloidal solution of electrum during the low temperatures in the final stage of Au supply. These concentrated solutions deposited electrum in limited parts of veins with favourable conditions.

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Review by M. Koděra.

Explications of the Plates

Plate XIII

Fig. 1. Ore vein symmetrical crustified texture: Periphery 1st quartz period covered by coarse grained 2nd period quartz terminated in vugs. Colloform supply period in the center. Reduced 4×. Kremnica, Ferdinand shaft, Gold Vein. — Fig. 2. Crustified texture of the 2nd quartz period. Vugs covered by colloform period. Natural size. Kremnica, Ferdinand shaft, Gold Vein. Photo L. Oswald.

Plate XIV

Fig. 1. Coarse grained quartz with peripheral zoning. Kremnica, Václav adit, Stibnite Vein. Thin section magnified 25×. — Fig. 2. Zoned quartz of metacolloidal character Ibid. with fig 1, Nicols x. Photo L. Oswald.

Plate XV

Fig. 1. Zoned, metacolloidal quartz showing iregular extinction. Kremnica, Šturec, Schrämen Vein outcrop. Thin sec. magnified 50×. — Fig. 2. Ibidem, Nicols x. Photo L. Oswald.

Plate XVI

Fig. 1. Sphaerolitic texture of colloform pyrite in quartz after structural etching. Kremnica, Ludovika shaft, Schrämen Vein. Polished sec. magnified 130×. — Fig. 2. Colloform, sphaerolitic and botryoidal textures of pyrite in stibnite supply period. Pyrite — light gray, stibnite gray, quartz dark gray. Kremnica, Václav adit, Stibnite Vein. Natural size. Photo L. Oswald.

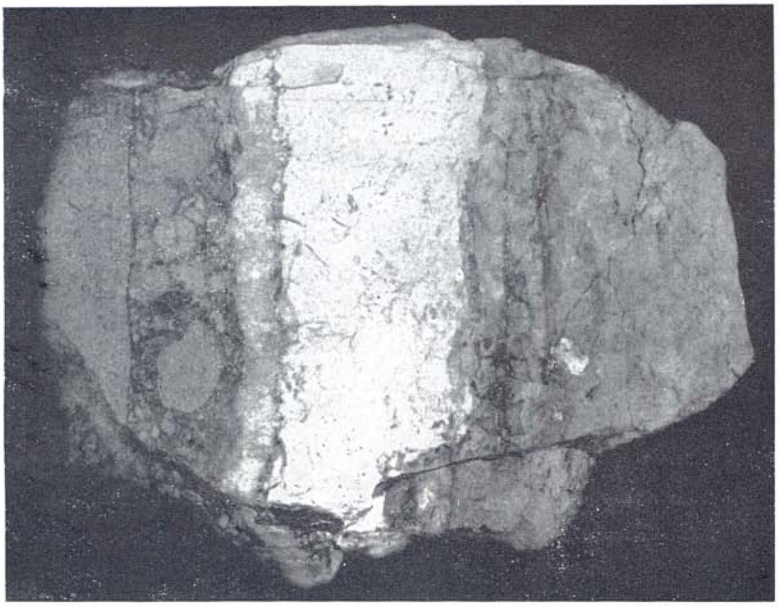
Plate XVII

Fig. 1. Colloform electrum replacing pyrite along the stringer after structural etching. Kremnica, Ferdinand shaft, Gold Vein. Polished sec. magnified 43×. — Fig. 2. Colloform texture of electrum sheet inside of vug of the productive subperiod, quartz after structural etching Kremnica, Ferdinand shaft, Gold Vein. Polished sec. magnified 136×. Photo L. Oswald.

Plate XVIII

Fig. 1. Zoned, colloform electrum of inhomogeneous texture after structural etching. Kremnica, Ferdinand shaft, Gold Vein. Polished sec. magnified 136×. — Fig. 2. Colloform electrum showing concentric zoning and replacing pyrite, after structural etching. Kremnica, Ferdinand shaft, Gold Vein. Polished sec. magnified 136×. — Photo L. Oswald.

Translated by J. Kováčik.



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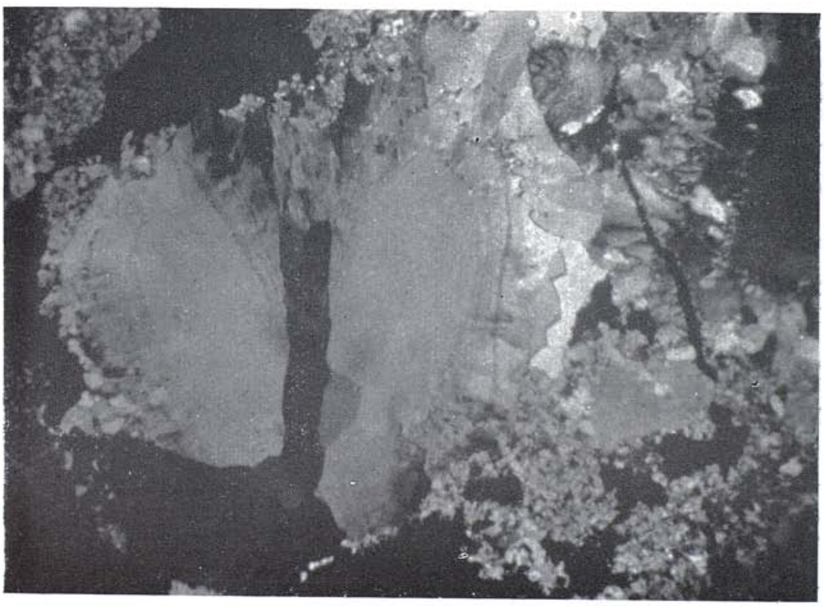

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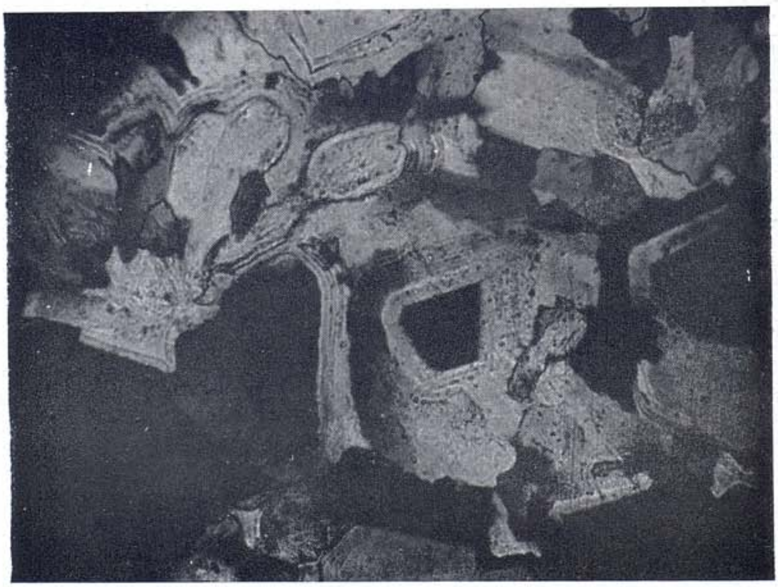

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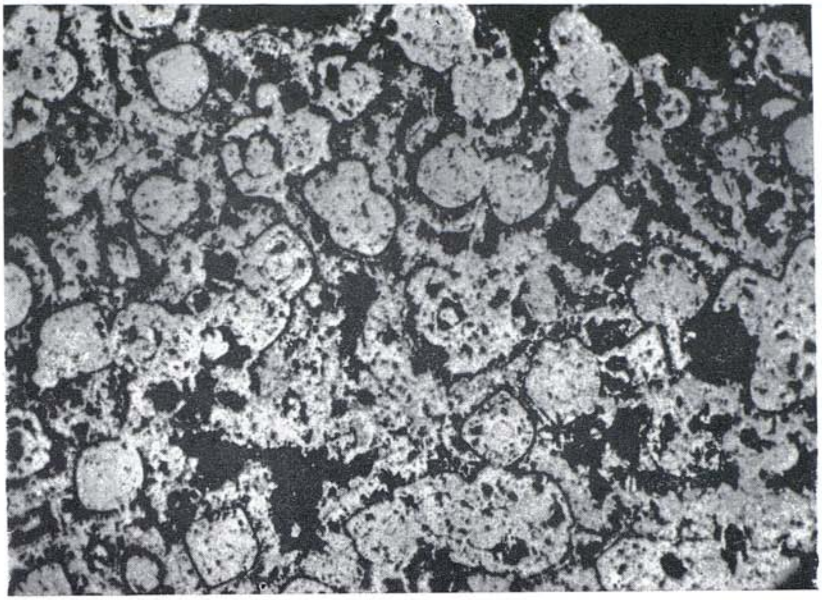

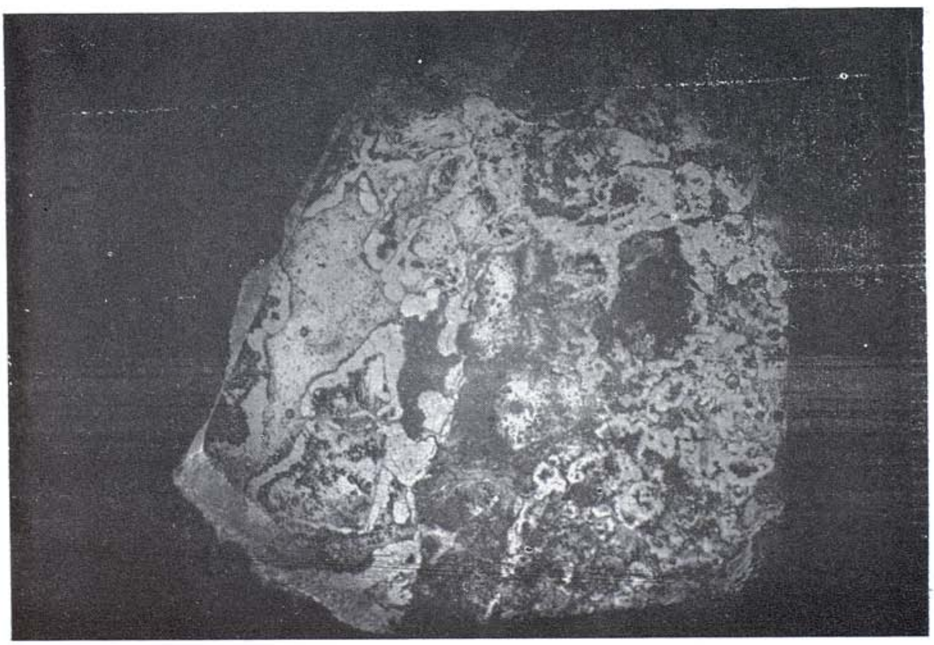

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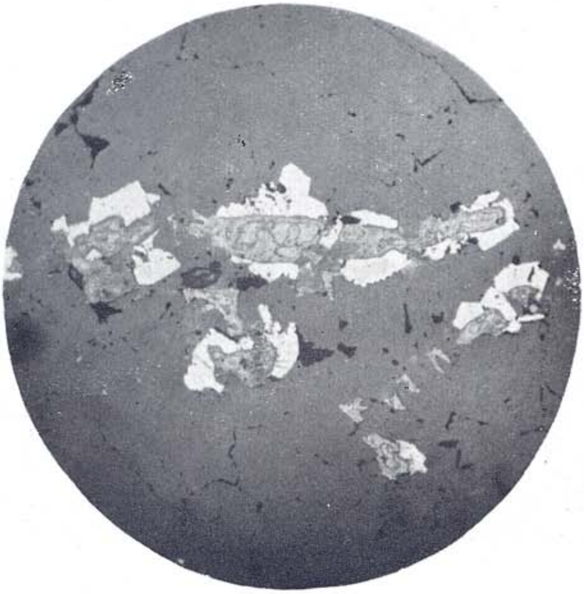

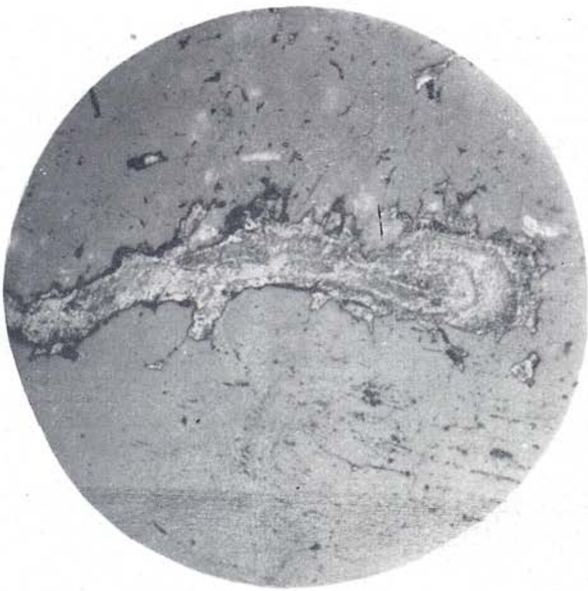

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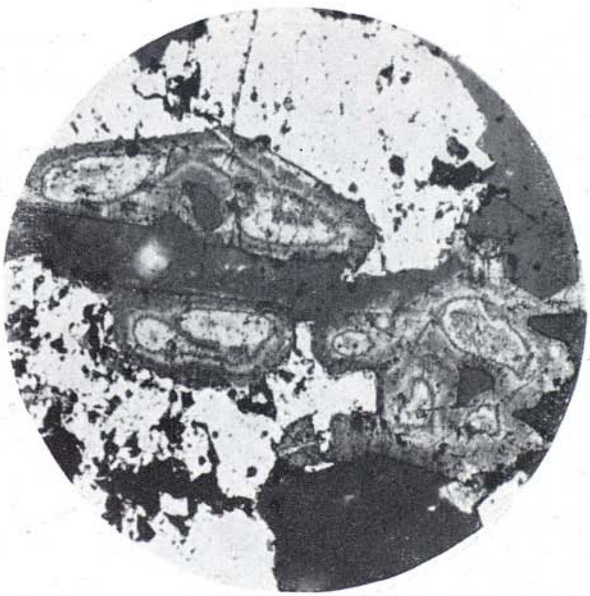

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