MICROSCOPICAL STUDY OF THE SHUIKOUSHAN LEAD-ZINC DEPOSIT IN CHANGNING DISTRICT, S. HUNAN

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Introduction

Shuikoushan is the most important and well known mining district for production of silver, lead, zinc and pyrite in China. It is situated at about 65 li N. E. of Changning, 90 li S. of Hengyang and 620 li from Changsha, the Capital of Hunan. It has been visited by many geologists and mining engineers. Much has been written about it, but the report[1] published by the Geological Survey of Hunan seems to furnish us with the best required informations. Two years ago, while making geological investigation in S. Hunan, Mr. H. S. Wang and the writer had an opportunity to visit this famous deposit and collect some specimens for laboratory study. In absence of Mr. H. S. Wang, the microscopical study was undertaken by the writer. The result of this study shows the existence of many minerals which were not reported before, and therefore a short note concerning chiefly the genesis and the mineralogical composition of the ore seems to be necessary.

The writer is deeply indebted to Prof. C. Y. Hsieh, Mr. T. L. Ho and Mr. H. J. Chu for their kindness in making many valuable suggestions and corrections throughout the work. To Mr. C. C. Wang, the writer is also indebted for placing part of his material under my disposal.

General Geology

The Shuikoushan is an old to maturely dissected mountainous region consisting of Shuikoushan proper as the most prominent hill and Lungwangshan, Maanshan and many others as subsidiary ones. Lungwangshan and Maanshan rise to 200-300 meters above the plain and Shuikoushan about 100

1. C. C. Liu and others, Report on the Shuikoushan lead and zinc mine, Hunan, Bull. No. 1, 1927, Geol. Surv. of Hunan.

meters. The region is composed of Devonian quartzite and shale, the Permian limestone and the coal series, and is intruded by a granodiorite; at many places these formations are overlain unconformably by Cretaceous red sandstone and Tertiary red clay.

The Upper Devonian quartzite is generally pinkish white in color and thick-bedded. It has been named as the Yolu (岳麓) quartzite by the Geological Survey of Hunan and is equivalent at least partly to the well known Wutung quartzite in Chekiang. Its outcrop extends nearly in a N-S direction beside the igneous body. Overlying this quartzite, there is a layer of siliceous shale of grayish white color.

The Permian limestone with a thickness of about 100 meters is massive and dark gray to black in color. It is largely metamorphosed into dolomite and marble. The Permian age of this limestone was assigned by Mr. C. C. Liu, although he has found no identifiable fossils. The lead-zinc deposits occur in this limestone.

The Permian coal series may be divided into two parts. The lower part at Shuikoushan is a light gray siliceous shale of more than 100 meters in thickness. The degree of silicification varies with the distance from the igneous body. The upper part at Lungwanshan consists of black and yellowish gray shales with some poorly preserved plant fossils which on tentative determination proved to correspond to the nearby Deoling (斗嶺) coal series of upper Permian age[1]. Total thickness is about 250 meters.

The Upper Cretaceous red formation lies unconformably on the Permian limestone, the coal series as well as the igneous body. Besides a layer of basal conglomerate, the rest is composed essentially of red sandstone interbedded at many horizons with red shale. It crops out on the east side of Shuikoushan region.

Small exposures of Pliocene red beds occur irregularly in the valley of Shuikoushan showing usually a gentle inclination. It is composed of fine, loose grains of sand and clay material. Formerly, Mr. Liu included this bed together with Cretaceous and called them collectively as Cretaceous red

1. Op. cit. p. 9.

formation[1]. But now we are having ample proof to believe that the former bed should be separated from the latter and is of Pliocene age. Total thickness is only about 5 to 6 meters.

Recent alluvium is scattered here and there upon the flood plain and the valley of Shuikoushan with perhaps only a small thickness.

As a whole, the Shuikoushan region may be described as exhibiting a semicircular dome structure. As a result of the igneous intrusion, the strata on both sides of the dome have been tilted and sometimes faulted. The massive quartzite has been tilted up on the west with its bedding plane dipping toward N. E. in one side and S. E. in another. Going N. E. or S. E. from the quartzite, there appear in succession discontinuous outcrops of Upper Devonian Siliceous shale, Permian limestone and coal series, the last mentioned bed being unconformably overlain by the Upper Cretaceous red beds and Tertiary red clay. Between Lungwanshan and Maanshan, there is a large and distinct fault with its strike following NE and SW direction. Many minor faults have been found in the underground of the mining district, but the displacements are rather small.

The Granodiorite Intrusion

The granodiorite occurs roughly as an elliptical laccolith, with a length about 2 km along the north-south direction and 1 km in east-west one It intrudes into all the formations except the Cretaceous and the Tertiary red beds. Near Laohuyen of the northern part of Shuikoushan two apophyses were found in Devonian beds. They have been deeply weathered to residual clay but showing still the characteristic feature of a decomposed granodiorite. Since the overlying Cretaceous formation is not affected by the granodiorite, so the age of the intrusion must be pre -Cretaceous and agrees closely with that found in other parts of the lower Yangtze valley region.

Megascopically, the granodiorite is a fine to medium grained rock with pinkish gray color due mostly to the presence of orthoclase. Biotite is much more abundant than hornblende. Quartz may be visible in hand specimens but actually is not so much as orthoclase. Sometimes the rock is spotted throughout with grains of pyrite. At the marginal portion of the laccolith, the texture

1. Op. cit. p. 9.

of the granodiorite becomes more or less porphyritic in character. At Chingshuitang a noticeable amount of grossularite in association with quartz and chlorite has been found at the contact zone of granodiorite and limestone.

Some specimens of fresh granodiorite from the drilling hole of Chingshuitang have been studied under the microscope and are found to contain the following minerals:

Plagioclase:—This mineral occurs in more or less tabular form and twinned after Albite law. Some of them show also the characteristic zonal structure. Section perpendicular to 010 shows extinction angles varying from 10° to 20°. According to these, it may be concluded that the feldspar in question belongs to oligoclase-andesine series with a composition about Ab 70%—An 30%.

Orthoclase:—Orthoclase is comparatively less in amount than plagioclase and occurs usually in allotriomorphic forms. Sometimes, it forms graphic intergrowth with quartz. Kaolinization and sericitization of orthoclase are not uncommon in most sections studied.

Quartz:—Quartz is present in small amount with granular form and contains sometimes inclusions. Its graphic intergrowth with orthoclase has been previously mentioned.

Biotite:—A small amount of biotite is present; though rather insignificant, it is still much more abundant than hornblende. It is brownish yellow in color, more or less tabular in form and with good cleavages along which calcite veinlets are usually penetrated. It alters sometimes to chlorite.

Hornblende:—Hornblende is rather large in form, and with marked pleochroism from green to pale brown. Part of it has been altered to chlorite.

The accessories are idiomorphic crystals of pyrite, magnetite, apatite, titanite and zircon present in the order of decreasing abundance.

The Ore Bodies

The ore bodies are found both on the north and the south contact with the main granodiorite intrusion. They occur as irregular replacement deposits in the Permian limestone and Devonian quartzite.

On the north side of the igneous body are situated the principal Shuikoushan galena-sphalerite-pyrite deposits. These ore bodies usually form large, irregular chambers and pockets in limestone, with a length of about 280 meters. The strike of the ore body is nearly the same as that of limestone, but the pitch of the ore shoot has a reverse direction as compared with the dip of limestone. It occurs at a depth from 50 meters to 10 meters below the ground surface. The average thickness of the ore body is about 50 meters. The chief ore minerals are pyrite, sphalerite and argentiferous galena with minor amount of copper bearing minerals as chalcopyrite, tetrahedrite, bornite and chalcocite. Pyrite, sphalerite and galena are frequently associated together and show in many cases a remarkable zonal arrangement. From the upper part of the ore body going downward, such structure can very well be seen even in hand specimen; at the same time there shows usually a gradual decrease of galena, sphalerite and an increase of pyrite toward the depth.

In the oxidized and enrichment zones, we found many secondary minerals as smithsonite, anglesite, cerussite, malachite, covellite and chalcocite, the last two representing perhaps the secondary enriched minerals. Hydrolysed iron bearing minerals and iron oxide such as limonite and hematite are, no doubt, present in considerable amount.

Laohuyen is situated beside the N. W. apophyse of granodiorite and is about 1700 meters west of the main shaft of Shuikoushan. The pyrite ore occurs chiefly in quartzite but is near to the contact zone.

Lungwangshan is on the south side of the igneous body about 2300 meters distant from the Shuikoushan main shaft. The ore is chiefly pyrite and occurs as irregular chambers and pockets in quartzite. A small amount of ore occurs also in limestone as said by the old miners. At the time of our visit, this mine was flooded by water so we could not make personal inspection.

Iron caps or gossans are abundantly present in this region, especially in Lungwanshan and Laohuyen. Many of them stand up very high and make a conspicuous feature. We were informed that near Shuikoushan there existed also a conspicuous iron cap which was taken off by mining operation and at present no trace of it can be found.

MINERALOGY

In order to know more clearly about the genesis of the ore deposits, many polished and thin sections were prepared for microscopic study. The identification of minerals was confirmed sometimes by microchemical and spectroscopic analyses. The ore minerals will now be individually described as follows:—

Pyrite:—Pyrite is one of the most common minerals and is in constant association with sphalerite, chalcopyrite, and other sulphides, being especially more abundant in the lower part of the ore body. It shows idiomorphic forms with a size varying from 0.1 to 5 cm in diameter. It is usually badly shattered and in its interstices filled by sphalerite, chalcopyrite and galena.

Sphalerite:—Sphalerite is the most important zinc-bearing mineral of the region and is usually massive in character. It is dark brown in color and is translucent in thin section. The mineral seems to replace pyrite and being itself replaced by tetrahedrite, chalcopyrite and galena. In some specimens, fine chalcopyrite spots occur in sphalerite along its crystallographic directions; this kind of intergrowth is evidently the result of unmixing.

Tetrahedrite:—This mineral is fairly abundant in the section and is usually associated with sphalerite. The paragenetic relation between galena and tetrahedrite is sometimes obscure, it seems that they show overlapping relation.

The mineral shows a characteristic greenish tint under vertical illumination and therefore resembles greatly with Tennantite, yet to our surprise not a trace of arsenic can be detected either by microchemical or spectroscopic study. The mineral was formed evidently after sphalerite.

Galena:—Galena is one of the prinicipal ore minerals in the deposit. It is usually more abundant at the upper portion of the ore body and gradually decreases in amount downward. There is great variation in size ranging from 0.2 to 1.5 cm in diameter. It is argentiferous as is shown by echting test to be described later.

Argentite:—Argentite was not visible until being etched; it occurs in groups of silver white spots and fine lines arranged in some definite direction in galena. The etching was made by 1:1 solution of HNO_3; this structure is also the result of unmixing.

Chalcopyrite:—Chalcopyrite seems to have two stages of formation in the deposits. One is nearly contemporaneous with sphalerite while the other is definitely later than sphalerite and tetrahedrite.

Bornite:—Bornite has been found only in few specimens and is massive in form. It usually shows mutual boundary with the second stage chalcopyrite. Sometimes, it is replaced by chalcocite and covellite.

Chalcocite:—Chalcocite usually forms veinlets replacing chalcopyrite, tetrahedirte and bornite, and sometimes in fibrous form in the cavities.

Covellite:—The mineral is found in very small amount under the microscope and usually replaces bornite along the cracks or borders of the grains.

Malachite:—Malachite was found only in one specimen. It is the product of oxidation process of copper bearing minerals in presence of carbonate solutions.

Native copper:—This mineral in association with malachite occurs very rarely in the galena cavities. It is undoubtedly derived from the oxidation of primary copper sulphides.

Smithsonite:—It is seen in stalactitic form in galena or sphalerite cavities and also coats on quartz crystals in the vugs. It is yellowish brown in color and, no doubt, is the result of oxidation process of zinc bearing minerals.

Cerussite and anglesite:—They occur in galena cavities and the vugs. Cerussite forms stalactitic while anglesite massive deposit.

The presence of Ceragyrite was mentioned in Mr. C. C. Liu's report[1], but the writer was not able to find any in the specimens collected.

The gangue minerals:—Hematite and limonite are abundantly present in the oxidized zone. Quartz is very common in the deposits and by microscopic investigation, two stages of silicification may be distinguished. One is from the time a little earlier than pyrite till to the stage of crystallization

1. Op. cit. p. 15.

of sphalerite, and the other is at the end of deposition of the sulphides. Jasperoid limestone occurs sometimes near the contact zone. Calcite and siderite usually associate together and calcite seems to be more or less dolomitic in composition. The calcite veins are filled by siderite at the middle portion or along the contact of the veins. Grossularite in massive form occurs in the contact zone and is often associated with chlorite and quartz. Zeolites,* of red color and crystalized in radiated aggregates are found in one specimen and are associated with chlorite and calcite. Its relation with metallic sulphides can hardly be determined.

The sequence of hypogene sulphides beginning from the oldest are: 1. Pyrite, 2. Sphalerite, 3. Chalcopyrite, 4. Tetrahedrite, 5. Galena and Argentite, 6. Chalcopyrite, and 7. Bornite. Chalcocite, carbonates, sulphates and hydrolized minerals and oxides are of later origin formed by oxidation and enrichment processes.

Genesis and Paragenesis of the Ores

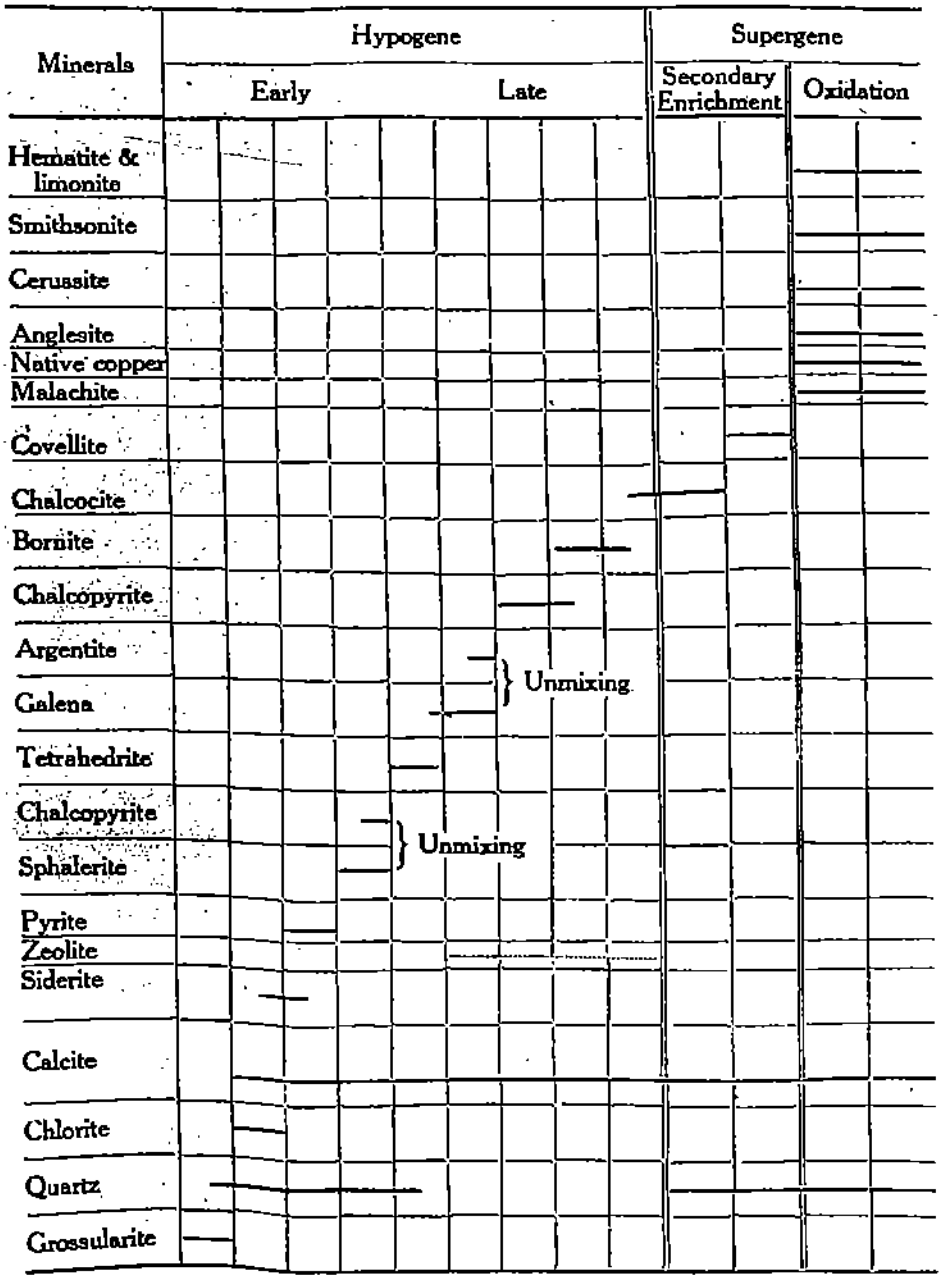
From a geological as well as microscopical study of the ore deposits, it is concluded that two distinct types may be distinguished, namely: (1) The galena-sphalerite-pyrite deposits in limestone of Shuikoushan proper, (2) The pyrite deposit in quartzite or sandstone of Laohuyen and Lungwanshan. These two types of deposits are evidently of hydrothermal origin and judging from their mineral association they belong most probably to mesothermal type. They have been formed during one general period of mineralization and have had a common origin in connection with the granodiorite intrusion. The difference of the ores is probably due to difference in physical conditions of the wall rocks.

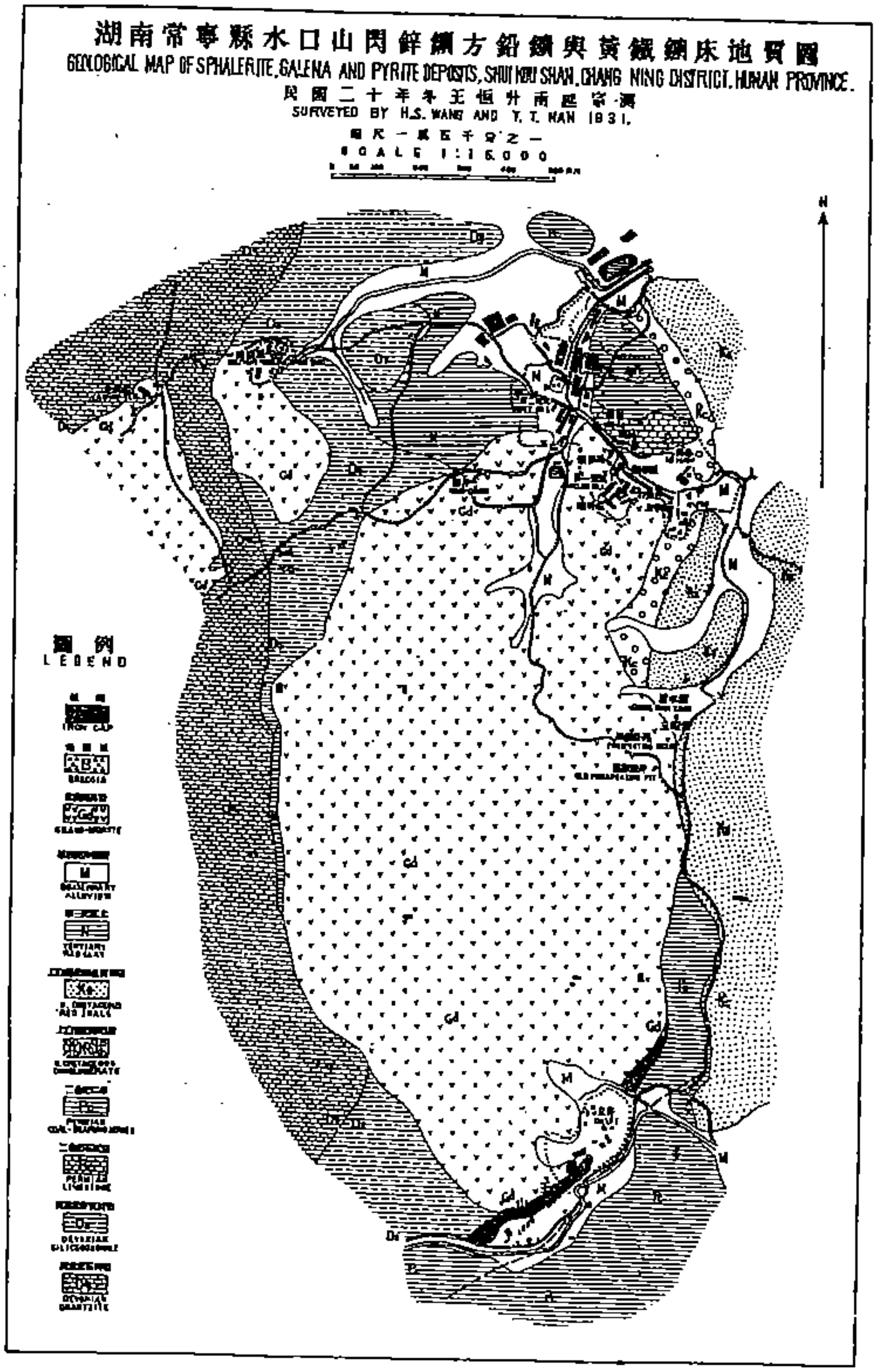
From what has been described, the order of events may be briefly sketched as follows; (1) the intrusion of the granodiorite body and the accompanied shattering and alteration of the adjacent sediments, (2) the cooling and crystallization of granodiorite and the intrusion of the residual magma in the form of apophyses, (3) the intrusion of ore-bearing solutions along fissures in limestone as well as in quartzite with the deposition at first of pyrite and sphale-

* The presence of zeolite in the Shuikoushan deposit was first noted by Mr. H. M. Meng of the National Research Institute of Geology, Academia Sinica.

rite, and was followed by silver-lead ores. It is probable that at the time when pyrite and sphalerite ores were deposited, the physical conditions in those places like Laohuyen and Lungwangshan were unfavorable for the deposition of lead-silver ores. It was not until the temperature and possibly also the pressure in this zone had been reduced, before silver-lead ores could be deposited. Fissuring and faulting continued and finally the ores were oxidized and enriched by the surface solutions.

Table showing paragenesis of the minerals in the Shuikoushan Lead-Zinc Deposits, S. Hunan.




湖南常寧縣水口山閃鋅鑛方鉛鑛與黃鐵鑛床地質圖
GEOLOGICAL MAP OF SPHALERITE, GALENA AND PYRITE DEPOSITS, SHUI KOU SHAN, CHANG NING DISTRICT, HUNAN PROVINCE.
SURVEYED BY H.S. WANG AND Y. T. NAN 1931.
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Explanation of

Plate II.

PLATE II

Fig. 1. Pyrite filled by numerous veinlets of chalcopyrite. × 150.

Fig. 2. Sphalerite (dark gray) with chalcopyrite dots replacing pyrite (triangular form) and itself being replaced by galena (white). × 150.

Fig. 3. Galena (white) replacing sphalerite (dark gray). × 150.

Fig. 4. Sphalarite (dark gray) with numerous dots of chalcopyrite (unmixing). It is replaced by tetrahedrite (gray) and galena (white). × 150.

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Explanation of Plate III.

PLATE III

Fig. 1. Galena veinlets penetrating through sphalerite which contains chalcopyrite dots. × 150.

Fig. 2. Needles and spots of argentite (white) in galena (dark) become conspicuously shown after etched with 1 : 1 nitric acid. They are the result of numixing. × 130

Fig. 3. Irregular veinlets and spots of argentite in galena. Etched section same as Fig 2. × 130.

Fig. 4. Fine dots of argentite in galena. Etched section. × 45.

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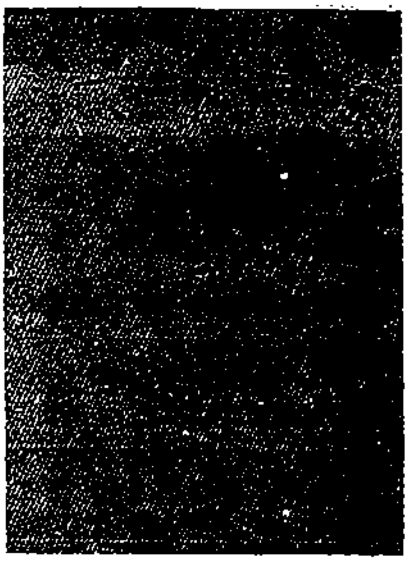
PLATE IV

Fig. 1. Tetrahedrite (gray) replaced by galena (white) and chalcopyrite (grayish white). The former is not quite well shown in this section and forms only a small portion.

Fig. 2. Tetrahedrite (gray) and galena (white) replacing sphalerite (dark gray). Black is gangue matter. × 150.

Fig. 3. A nearly contemporaneous relation or intergrowth between chalcopyrite (gray) and bornite (dark gray) × 150.

Fig. 4. Veinlets of chalcocite penetrate through chalcopyrite (light gray) but end abruptly at tetrahedrite (gray) showing phenomena of selective replacement. × 130.



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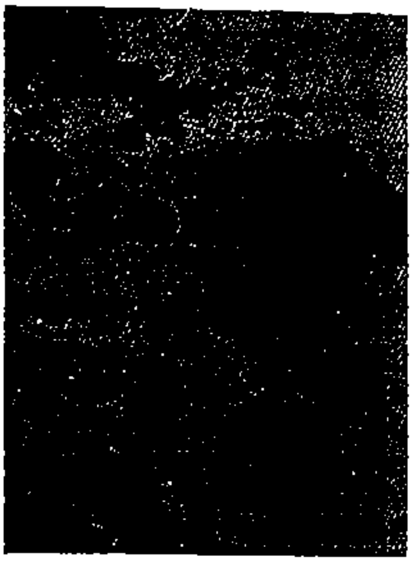

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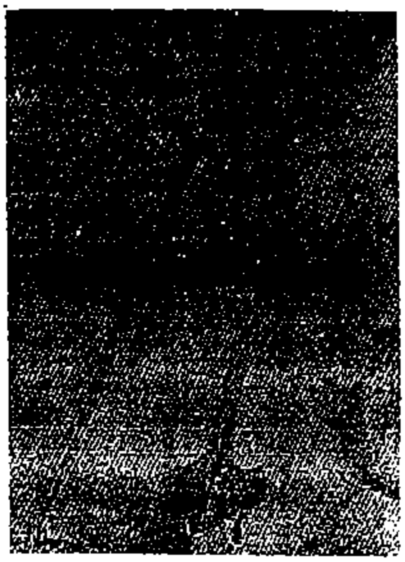

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