Mines Branch Information Circular IC 311

MINERALOGICAL AND TEXTURAL STUDY OF THE PHOENIX COPPER ORES, SOUTH-CENTRAL BRITISH COLUMBIA

by

A.E. Johnson*

SUMMARY

Samples from the Phoenix copper deposit of the Granby Mining Company Limited were studied mineralogically using the ore microscope for identification except, in some instances, in which the identification was determined from quantitative analyses obtained by the electron microprobe.

Samples of both primary and oxide ore were examined. The assemblage of ore minerals and their textural relationships in the primary ore are relatively simple. Chalcopyrite, the only copper mineral identified in the primary ore, occurs essentially as clusters of grains forming irregular patches in a silicate matrix. Minor amounts of hematite and magnetite are accessory minerals in the primary ore. The secondary oxide ore contains a complex assemblage of copper-bearing iron oxides together with traces of malachite. Traces of native gold occur as inclusions in both pyrite and chalcopyrite.

---

*Research Scientist, Mineralogy Group, Mineral Sciences Division, Department of Energy, Mines and Resources, Canada.

INTRODUCTION

A mineralogical study of the Phoenix copper deposit was undertaken as part of a study of select stockwork and skarn deposits in south-central British Columbia.

The Phoenix deposit (formerly the Old Ironsides Mine, Seraphim, 1956) is at latitude 49° 05.8', longitude 118° 35.9' and is in N.T.S. block 82E/2E. It falls within the Boundary District of southern British Columbia and is about 3.5 miles east of the town of Greenwood.

Production of copper, gold, and silver was started in 1896 and has been sporadic since. It is currently being mined by the Phoenix Copper Division of the Granby Mining Co. Ltd.

The mine site was visited in the fall of 1969 by Dr. W. Petruk of the Mines Branch, Ottawa. Samples collected on this occasion have been used in this investigation.

GENERAL GEOLOGY AND ORE DESCRIPTION

The general geology of the Phoenix copper deposit is, in part, summarized here from the paper by Seraphim(1956). The deposit occurs in a sequence of volcanics and sediments. The Knob Hill Formation of Carboniferous or Permian age represents the base of this sequence and is composed of chert and volcanics. This is overlain by the Rawhide Formation, which is predominantly a shale and is transitional to the overlying, Middle Triassic, Brooklyn Formation which represents the top of the sequence. The Brooklyn Formation, which is host to the major copper deposits in the district, occurs in the immediate mine area and lies unconformably on the Knob Hill Formation. It consists principally of a chert sharpstone conglomerate and limestone, with lesser amounts of argillite and quartzite. The limestone member has been skarnified and silicified, particularly near the base, though no large intrusive bodies have been found nearby.

The deposit has generally been regarded as belonging to Lingren's pyrometasomatic class (Fahrni, 1966). Others have categorically included the Phoenix under the heading of "porphyry copper" in order to indicate that it is a large-tonnage low-grade deposit. Fahrni (1966) reported the mineralization as principally chalcopyrite, pyrite, specular hematite, magnetite, and pyrrhotite, occurring in an assemblage of metamorphic minerals which includes calcite, garnet, epidote, actinolite, and chlorite. Secondary copper ore was recovered during the initial open-pit mining and remnants of this material still exist. However, current mining is concentrated essentially on the primary ore.

The ore has been designated as an upper and a lower zone (Paxton, personal communication to Petruk). These zones are irregular in shape and discontinuous, the upper zone being calcareous and the lower being siliceous. The mineralization, which occurs as veinlets and disseminations in both zones, contains a higher ratio of hematite to magnetite in the calcareous zone than in the siliceous zone.

MINERALOGY AND TEXTURAL RELATIONSHIPS OF THE ORE SAMPLES

PRIMARY ORE

Twenty-four polished sections were prepared from seven samples of the primary ore. These samples were taken as being representative of the mineralization at the time the mine was visited. Samples were prepared in order to examine the non-silicate mineralogy and to characterize their textural relationships.

A sample of oxide ore was examined with the reflecting ore microscope, by X-ray diffraction, and with the electron microprobe to identify the major constituents and to determine their copper content.

The following ten minerals were identified in the samples of primary ore by means of the ore microscope; the native gold was confirmed by means of the electron microprobe.

Mineral Name	Composition	Mineral Name	Composition
Pyrite	FeS_2	Hematite	Fe_2O_3
Marcasite	FeS_2	Magnetite	Fe_3O_4
Chalcopyrite	$CuFeS_2$	Ilmenite	$FeTiO_3$
Mackinawite	$Fe_{1.06}S$	Native Gold	Au
Pyrrhotite	$Fe_{1-x}S$	Sphalerite	ZnS

Chalcopyrite, $CuFeS_2$

Chalcopyrite is the main copper mineral and is present in various textural relationships; it occurs essentially as clusters of grains forming irregular patches, up to several millimeters in diameter, in a silicate matrix (Figure 1). Within individual clusters, the chalcopyrite grains and the silicate matrix are coarser-grained at the centre and finer-grained towards the periphery (Figure 2). Chalcopyrite may also form as an interstitial filling within clusters of magnetite and/or hematite grains, all within a silicate matrix. Occasionally, chalcopyrite occurs as veinlets in fractured pyrite grains and, in some cases, forms an "ice-cake" texture with the pyrite. Relatively minor amounts of chalcopyrite occur consistently as discrete, well-rounded inclusions, less than 40 µ in diameter, within pyrite grains (Figure 3). In the case of euhedral pyrite grains, chalcopyrite, together with rounded silicate inclusions, often form in a zonal arrangement which parallels the outline of the grain (Figure 4).

Pyrite, FeS_2

Several textural varieties of pyrite were recognized. Much of the pyrite occurs as individual grains (Figure 5) and/or clusters (Figure 6) scattered throughout the host rock. Some of these grains are distinctly euhedral and occur as both cubes and pyritohedrons. In some cases, hematite inclusions occur within individual pyrite grains and tend to cluster near the core of the grain leaving the margin relatively inclusion-free.

Marcasite, FeS_2

Scattered grains of marcasite were observed either as inclusions within pyrite grains or as irregular grains intergrown with pyrite.

Pyrrhotite, $Fe_{1-x}S$

Trace amounts of pyrrhotite occur only as discrete well-rounded inclusions (less than 30 μ in diameter) in pyrite, in some cases the inclusions also contain chalcopyrite and mackinawite.

Sphalerite, ZnS

Trace amounts of sphalerite occur either with chalcopyrite inclusions in pyrite or as discrete rounded inclusions, generally less than 30 μ in diameter, in pyrite.

Mackinawite, $Fe_{1.06}S$

Trace amounts of mackinawite occur only in association with chalcopyrite inclusions in pyrite. The mackinawite forms as irregular spindle-like inclusions within the chalcopyrite or, in some cases, as partial rims along the margins of chalcopyrite inclusions.

Hematite, Fe_2O_3

Hematite is a common constituent of the ore. As the specular variety, the hematite occurs as sheaf-like bundles of distinctly bladed grains (Figure 7). It commonly occurs as granular aggregates associated with magnetite. In some cases, hematite appears to have formed as a product of martitization, developing along the growth zoning and/or cleavage in the magnetite (Figure 8).

Relict grains of specular hematite occasionally occur in a chalcopyrite matrix (Figure 9). These grains are irregular in size, partly rounded, but distinctly bladed. In some grains, the chalcopyrite appears to penetrate along the twin planes in the hematite.

Magnetite, Fe_3O_4

Several textural varieties of magnetite were observed. Generally, the magnetite occurs as clusters of irregular grains; it often includes distinct euhedra (Figure 10) and is disseminated throughout the host rock. Sheaf-like bundles of bladed magnetite grains, containing relict hematite grains, appear to be the result of replacement of specular hematite (Figure 11). This replacement appears to be of an irregular nature and develops as patches of magnetite within the hematite which, as these merge, tend progressively to replace the original hematite grains (Figure 12). Some of this replacement is probably controlled by the twinning in the hematite and gives a rectilinear pattern to the patches of magnetite.

Native Gold, Au

Several relatively small grains (less than 40 μ in diameter) of native gold were observed as irregular but distinctly rounded inclusions in pyrite and as grains along grain boundaries between grains of either pyrite or pyrite and chalcopyrite. Electron microprobe analysis of one of these grains (Figure 13) indicated 97.35 wt% gold and 1.34 wt% silver.

Less frequently, gold is intimately associated with chalcopyrite, as partial fracture fillings. The grains of gold are generally attached to each other to form irregular veinlets.

OXIDE ORE

A mineralogical investigation was conducted on a single head sample of material that the mine personnel called "oxide ore". For the purposes of mineral identification, the combined use of the reflecting microscope, X-ray diffractometer, and electron microprobe were required.

TABLE 1

Partial Analyses of Copper Oxide Ore by Electron Microprobe

Material Examined[1]	Cu wt%	Fe wt%	Ca wt%	Si wt%	Mn wt%	Al wt%	Mg wt%
Goethite-like	n. d.	59.43	0.10	1.26	---	---	---
Goethite-like	3.10	58.60	0.24	1.84	---	---	---
Goethite	7.55	48.83	1.04	5.57	n. d.	n. d.	---
Goethite	1.50	54.21	0.16	1.86	1.29	0.51	---
Malachite	58.65	0.20	---	---	---	---	---
Malachite	58.32	0.47	---	---	---	---	---
Gangue[2]	7.89	40.43	0.65	5.83	n. d.	0.45	---
Gangue[2]	34.19	3.29	0.16	16.82	n. d.	1.96	---
Gangue[2]	2.31	16.59	0.03	11.97	---	6.98	7.61
Gangue[2]	10.27	8.48	4.54	13.12	---	2.06	3.67

1. Identification of material examined is tentative only.

2. Gangue refers to materials containing a relatively high Si content.

Polished sections contained a mixture of secondary minerals, i.e., goethite and, possibly, malachite, together with minerals also identified in the primary ore, viz., hematite, magnetite, chalcopyrite and pyrite. The sulphide grains are essentially free from secondary products, except for the "ice-cake" texture between pyrite which has been fractured and subsequently veined by hematite and/or goethite (Figure 14).

The electron microprobe was used to identify the copper-bearing minerals. Partial analyses only were attempted, and the results were strongly affected by the hydrous nature of the material being tested; the results are shown in Table 1. It is apparent that the highest copper values were obtained in the malachite-like phases. The goethite and goethite-like phases (Figure 15) also contain significant amounts of copper. The gangue-like phases are mixtures of secondary iron minerals, such as goethite, together with quartz and unidentified minerals (Figure 16). Consequently, the copper content of this material is highly variable, and the copper values could be related to fine-grained intergrowths of malachite and/or copper-bearing goethite in an essentially silicate matrix.

A sample of the oxide ore was analyzed for gold and silver, the results are shown below. These results are interesting when compared with those reported by Seraphim(1956) for an essentially non-oxide ore.

Au-Ag ANALYSIS

Ore Type	Au (oz/ton)	Ag (oz/ton)
Oxide Ore	0.03	0.31
Non-oxide Ore[1]	0.04	0.50

[1] Seraphim (1956)

The oxide ore contains less gold and silver than the non-oxide ore; however, the silver:gold ratio is higher for the non-oxide ore.

DISCUSSION

The assemblage of ore minerals and their textural relationships are relatively simple in the primary ore. Chalcopyrite is the only copper sulphide identified. Texturally there is a suggestion of two ages of chalcopyrite relative to pyrite. One is represented by trace amounts of chalcopyrite which occur as small (less than 40 microns in diameter) inclusions within pyrite grains and appear to be contemporaneous with the pyrite. The other, which includes the bulk of the chalcopyrite occurs either as interstitial filling around pyrite grains or as veinlets in fractured pyrite grains and, consequently, appears to be later than the pyrite.

Hematite and magnetite represent the major iron-oxides in the primary ore but neither was observed in sufficient concentration to suggest their possible recovery as a source of iron. The magnetite and hematite appear to replace each other, resulting, in some cases, with hematite pseudomorphs after euhedral magnetite and magnetite pseudomorphs after bladed specular hematite.

The oxide ore is a secondary product that contains an assemblage of copper-bearing minerals and secondary iron oxides. The presence of malachite is suggested but was not confirmed by any of the analytical methods employed. The unstable nature of some of the minerals and consequent decomposition on exposure to the beam of the electron microprobe makes positive identification of the copper-bearing minerals difficult and suggests the presence of hydrous phases. The copper that is contained in the iron-oxide minerals probably forms complexes with these minerals instead of forming discrete copper minerals. The assays for gold and silver are lower in the oxide ore than in the non-oxide ore (Seraphim, 1956): this suggests that, during oxidation of th primary ore, copper was concentrated but gold and silver were removed.

The upper calcareous zone appears to have a higher hematite: magnetite ratio than the lower siliceous zone; this could be due to a higher partial pressure of oxygen in the calcareous zone at the time of mineralization.

The primary ore in this deposit is amenable to normal beneficiation methods, but the secondary oxide ore would require special treatment.

ACKNOWLEDGEMENTS

The author thanks the Granby Mining Company Limited and staff on behalf of Dr. W. Petruk for the assistance extended to him while visiting their mine and for their co-operation in obtaining the necessary sample material for this study.

The author thanks Messrs. P. O'Donovan and Y. Bourgoin for the preparation of polished sections, Mr. D.R. Owens for the electron microprobe analyses, Mr. R. Pinard for assistance in preparing the photomicrographs, and Mr. E. Murray for the X-ray diffractometer analyses. The above-mentioned personnel are all members of the Mineral Sciences Division staff.

REFERENCES

Fahrni, K.C., (1966): Geological relations at Copper Mountain, Phoenix and Granisle Mines: Can. Inst. Min. Met. Spec., V. 8, p. 315-320.

Graham, J., (1973): Chemical analysis report, Mineral Sci. Div., Mines Br., Energy, Mines and Resources, MS-AC-73-288.

Seraphim, R.H., (1956): Geology and copper deposits of the Boundary district, British Columbia: Trans.Can. Inst. Min. Met. V. 59, p. 384-394.

Sinclair, A.J., and Percy, G.R., (1969): Multiple regression analysis of precious metal values, Phoenix Mine, British Columbia: Econ. Geol., V. 64, p. 822-824.

- - - -

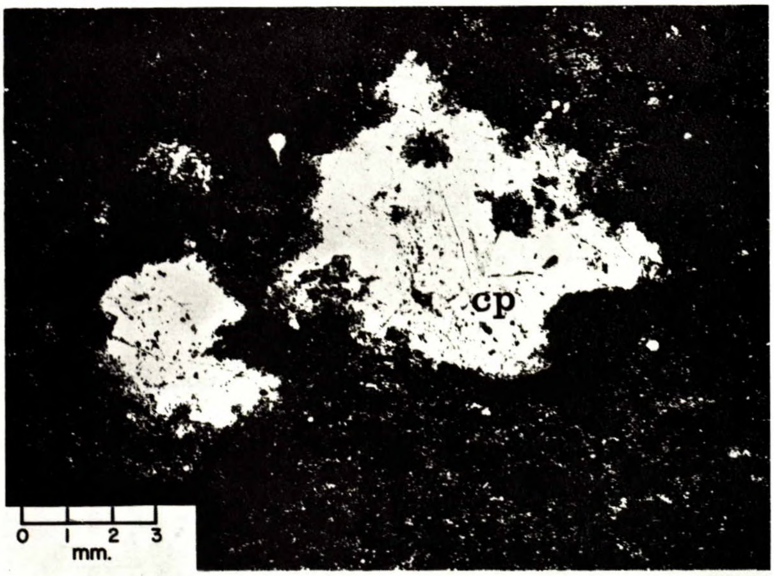

Figure 1. Photomicrograph showing irregular patches and dissemination of chalcopyrite (cp) in a silicate matrix (dark grey).

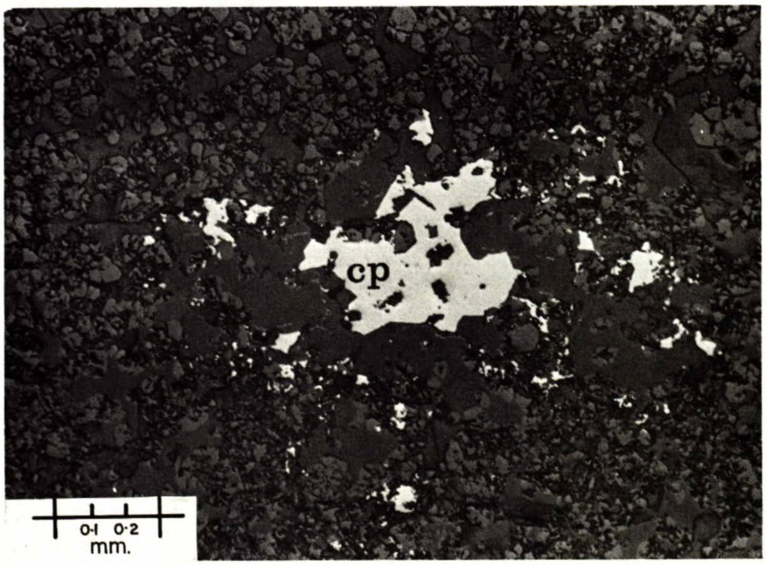

Figure 2. Photomicrograph showing interstitial chalcopyrite (cp) in a silicate matrix (grey). The grain size of both chalcopyrite and silicate decrease towards the periphery. Black spots represent pits.

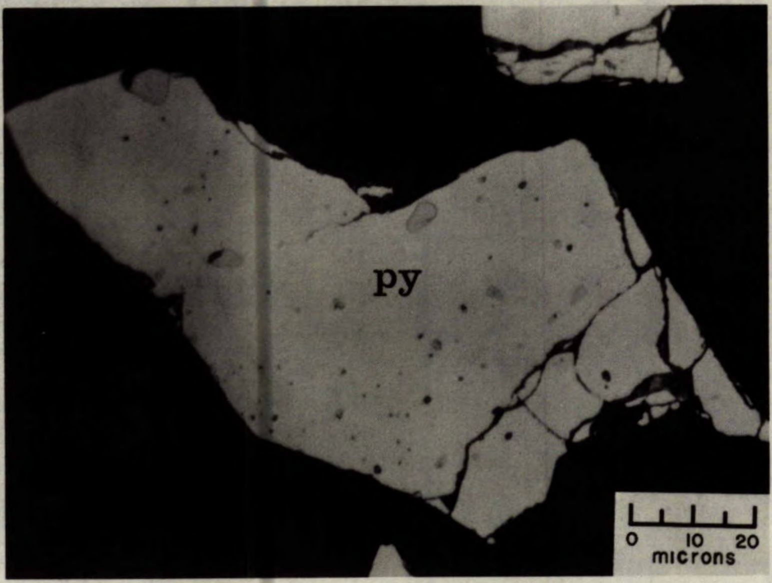

Figure 3. Photomicrograph showing rounded chalcopyrite inclusions in pyrite (py). Black area represents gangue.

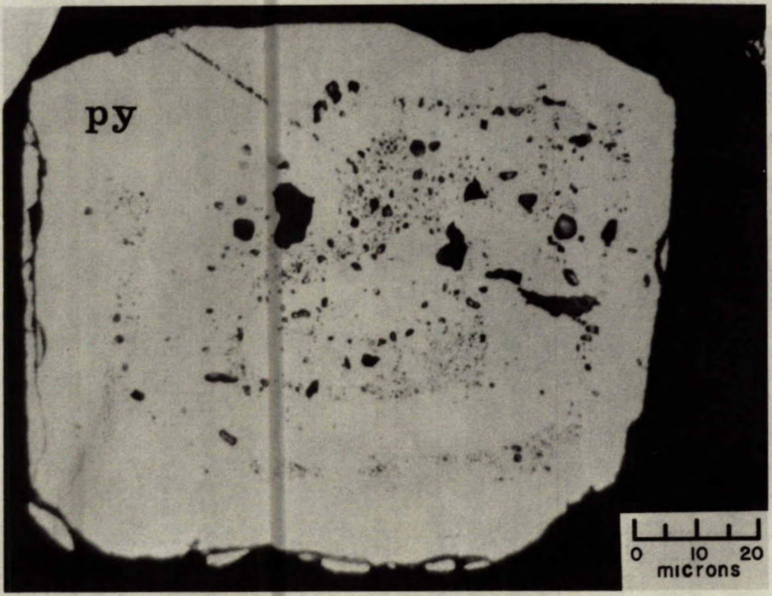

Figure 4. Photomicrograph showing zonal arrangement of rounded chalcopyrite and silicate (black) inclusions in pyrite (py). Outer black area represents gangue.

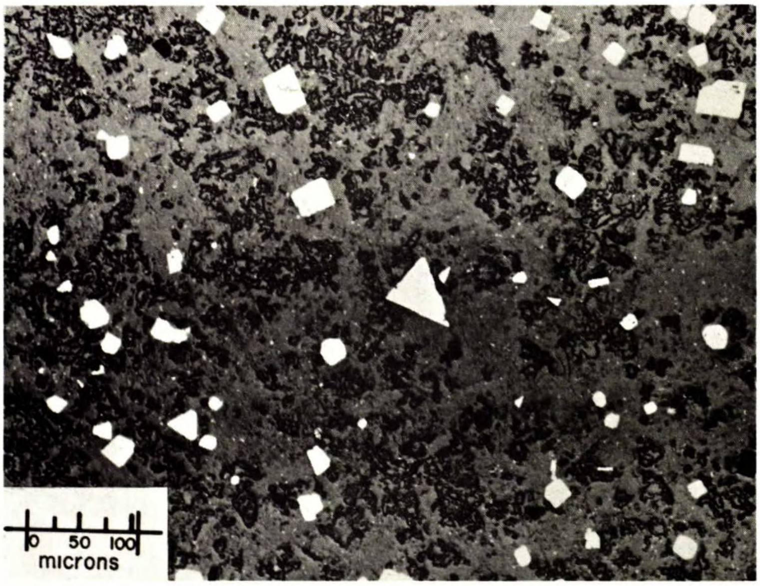

Figure 5. Photomicrograph showing euhedral pyrite grains (white) in a silicate matrix. Black spots represent pits.

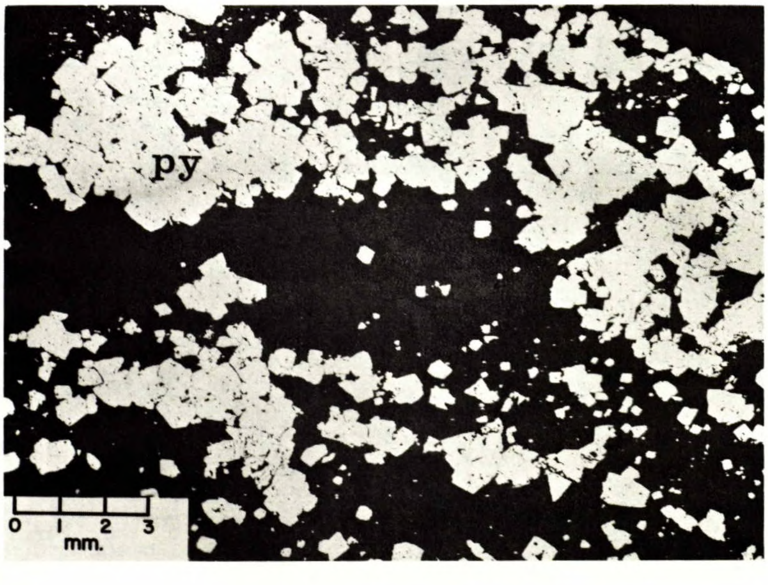

Figure 6. Photomicrograph showing clusters of pyrite (py) including distinct euhedral grains in a silicate matrix.

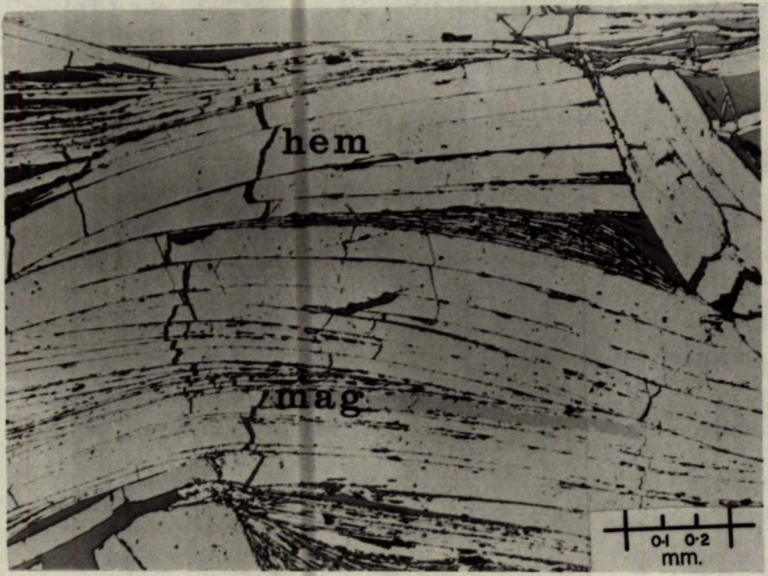

Figure 7. Photomicrograph showing sheaf-like bundles of platy specular hematite (hem), with partial replacement by magnetite (mag) Dark grey represents gangue and black spots, pits.

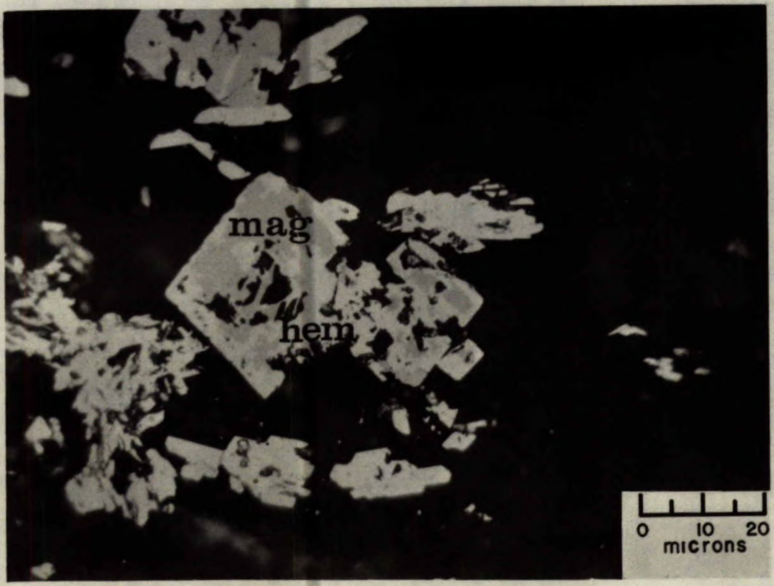

Figure 8. Photomicrograph showing martitization of euhedral magnetite (mag) by hematite (hem). Black areas represent gangue.

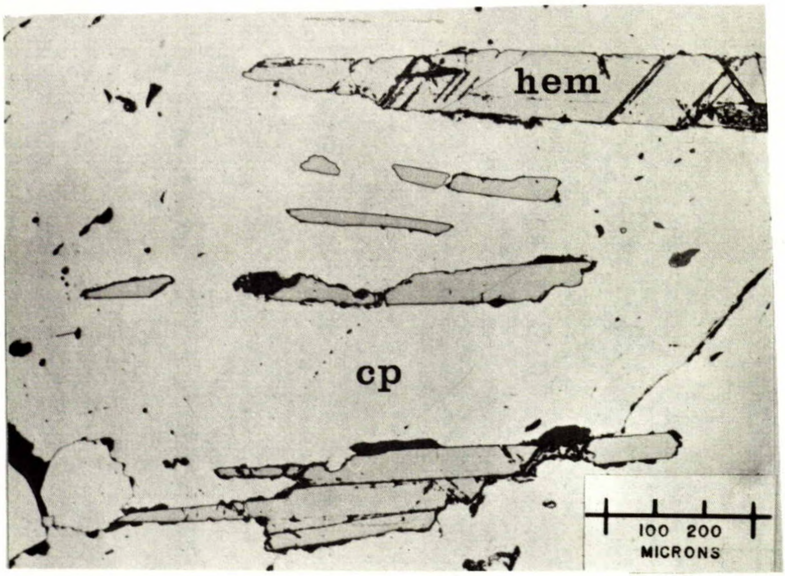

Figure 9. Photomicrograph showing relict grains of hematite (hem) in chalcopyrite (cp). Grey inclusions represent gangue, and black areas, pits.

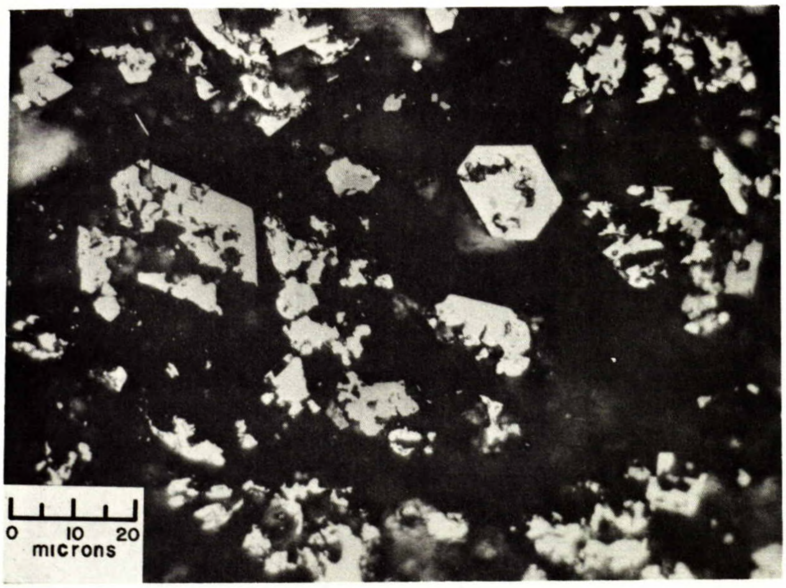

Figure 10. Photomicrograph showing euhedral magnetite grains (medium grey) in silicate (dark grey to black). Light grey represents hematite.

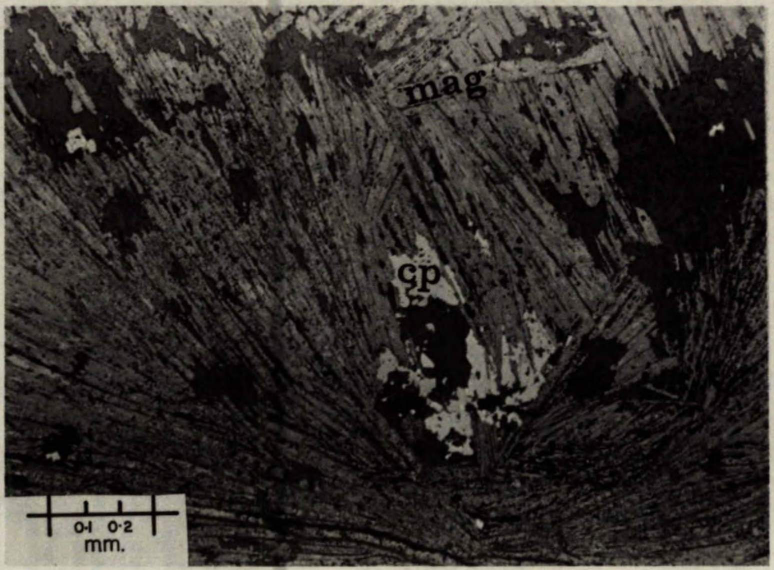

Figure 11. Photomicrograph showing sheaf-like bundles of bladed magnetite grains (mag) containing relict patches of hematite. Chalcopyrite (cp) forms interstitial filling. Dark grey represents gangue and black areas, pits.

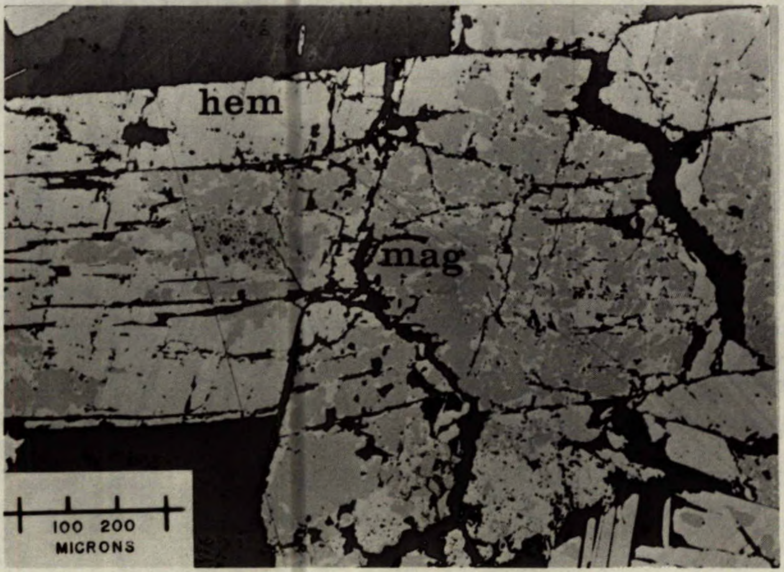

Figure 12. Photomicrograph showing magnetite (mag) replacement of specular hematite (hem).

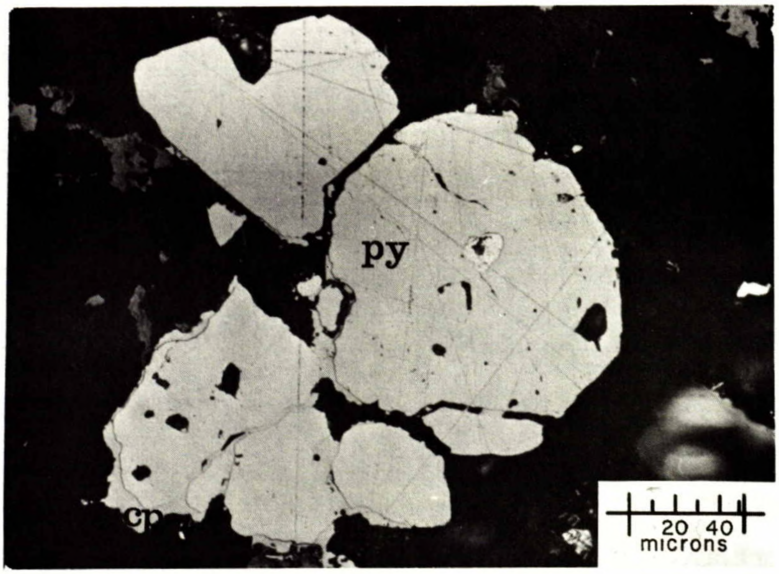

Figure 13. Photomicrograph showing a rounded inclusion of native gold in pyrite (py). Chalcopyrite (cp) partly rims individual pyrite grains. Black areas represent gangue.

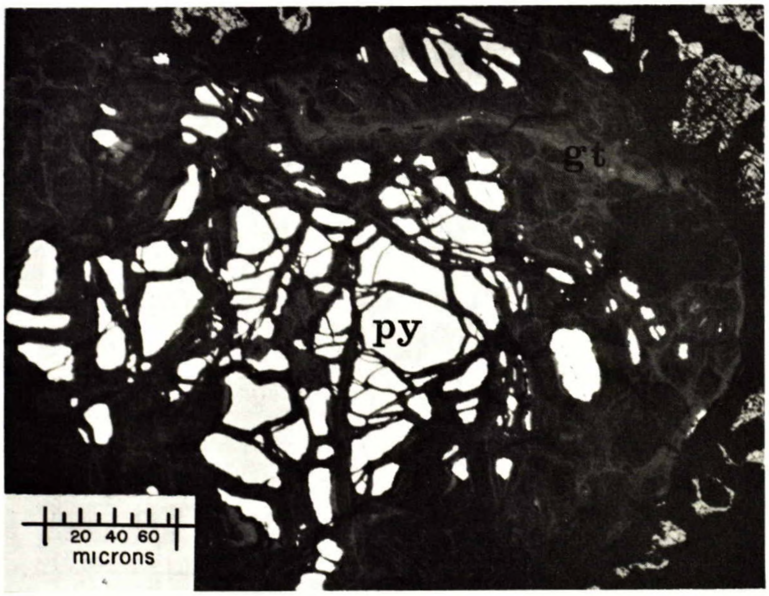

Figure 14. Photomicrograph showing "ice-cake" texture of pyrite (py) in secondary iron oxides including mainly goethite (gt), and gangue (dark grey).

Figure 15. Photomicrograph showing goethite and goethite-like material (light medium grey) partly rimmed by gangue (dark grey). Primary hematite (hem) occurs in bundles of irregular grains. Black areas represent mounting material.

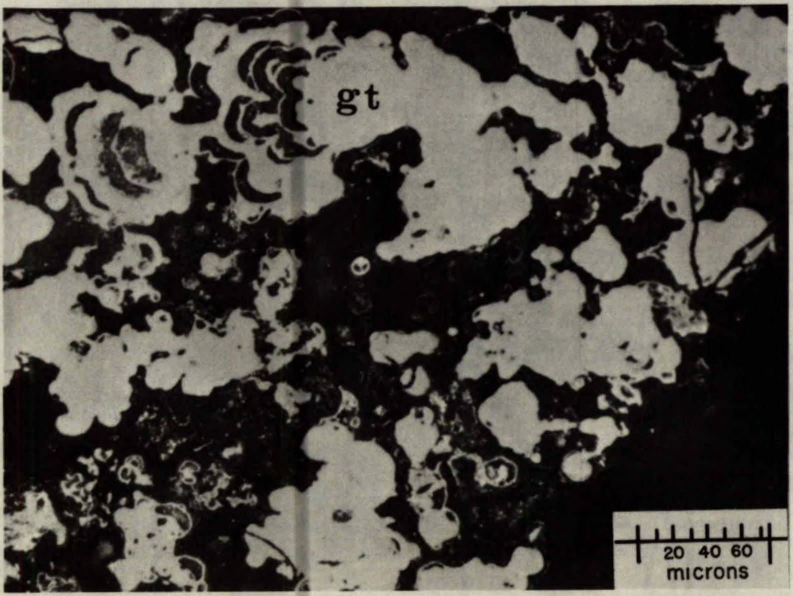

Figure 16. Photomicrograph showing colloform aggregate of goethite (gt) and gangue-like material (light to medium grey). Black material represents mounting material.

AEJ/PG