CHALCOPYRITE AND PYRRHOTITE INCLUSIONS IN SPHALERITE

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Numerous investigators have described inclusions of chalcopyrite and pyrrhotite in sphalerite. Some explain them as having been formed by replacement whereas others believe they are due to unmixing from a solid solution. The writer has recently studied thin sections and polished surfaces of ores from the Cowboy Mine in southwestern Oregon and, for the ores studied, has reached the conclusion that laths and blebs of pyrrhotite have formed in sphalerite by replacement, whereas chalcopyrite inclusions in sphalerite have formed by exsolution.

Teas[2] examined a large number of specimens of sphalerite showing inclusions of chalcopyrite and from his study concluded that the chalcopyrite had replaced sphalerite. Newhouse[3] described inclusions of chalcopyrite in sphalerite that appear to be definitely related to veinlets of chalcopyrite cutting the sphalerite and Lasky[4] found swarms of tiny inclusions of chalcopyrite in sphalerite close to contacts with other minerals which he believed were formed by replacement. Schneiderhöhn[5] and Van der Veen,[6] on the other hand, favor the theory of unmixing. Van der Veen has called attention to an example showing inclusions of chalcopyrite and of pyrrhotite oriented along cleavage directions and twinning planes in sphalerite which he described as the result of segregation from a solid solution of $ZnS.xCuFeS_2 \cdot yFeS$. Schwartz[7] heated sphalerite with inclusions of chalcopyrite for three days at various temperatures

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Teas, L. P., The relation of sphalerite to other sulphides in ores: *Trans. A. I. M. E.*, vol. **49**, pp. 62–82, 1918.

[3] Newhouse, W. H., An examination as to the intergrowth of certain minerals: *Econ. Geol.*, vol. **21**, pp. 68–70, 1926.

[4] Lasky, S. G., in Loughlin, G. F., and others, Geology and ore deposits of the Magdalena Mining district, New Mexico: In preparation by U. S. Geological Survey.

[5] Schneiderhöhn, H., Entmischungserscheinungen innhalb von Erzmischkristallen, etc.: *Metal. und Erz.*, vol. **19**, p. 68, 1922.

[6] Van der Veen, R. W., Mineragraphy and ore-deposition, p. 46, Figs. 18 and 19, 1925. The Hauge-G. Naeff.

[7] Schwartz, G. M., Textures due to unmixing of solid solutions: *Econ. Geol.*, vol. **26**, p. 758, 1931.

without dissolving the chalcopyrite and concluded that for the present it seems that the specimens showing inclusions (of chalcopyrite) which lack relationships to veinlets or to grain boundaries may be doubtfully considered to result from unmixing.

The Cowboy mine is located near Takilma, Josephine County, Oregon. The ore, consisting chiefly of sulphides, forms a series of slightly curved lenslike bodies in serpentine near the contact with

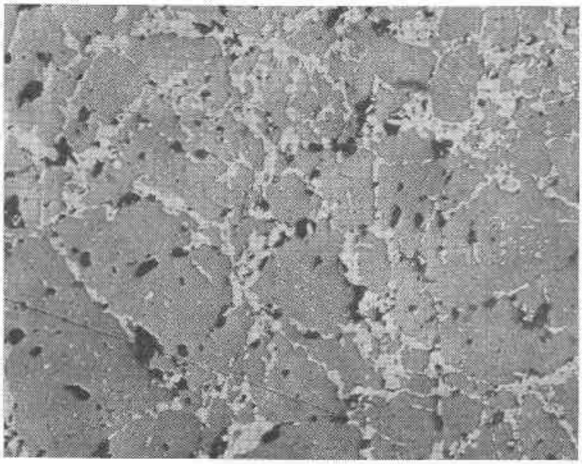

FIG. 1. Pyrrhotite (white) replacing sphalerite (gray) along grain boundaries and cleavage directions. Some of the tiny inclusions (white) oriented along cleavage directions are chalcopyrite. Black spots are holes. Nicols not crossed. Magnification 100 diameters.

fine grained greenstone. Below a depth of 50 feet the ore minerals are almost entirely hypogene. The abundant hypogene sulphides are chalcopyrite, cubanite, pyrrhotite, sphalerite, and cobaltite. Chalcocite occurs as a supergene sulphide and malachite, limonite, hematite, cuprite, and tenorite, are the more common oxidation products. The gangue minerals are serpentine, calcite, quartz, and epidote. The succession in the formation of the minerals was: serpentine, calcite, epidote, quartz, cobaltite, sphalerite, chalcopyrite and cubanite, pyrrhotite, sphalerite, and calcite. The succession was thrice interrupted by fracturing; once after the deposition of the gangue minerals, again after the deposition of cobaltite, and again after the deposition of the sulphides but before the introduction of the younger calcite. Sphalerite occurs twice in the succession, once after cobaltite and again following pyrrhotite. The late sphalerite, since it follows pyrrhotite late in the series, probably indicates a recurrence of higher temperature conditions. Both generations of sphalerite are similar in appearance and both contain blebs of chalcopyrite, and the older sphalerite, where pyrrhotite is known to be replacing it, contains oriented laths and blebs of

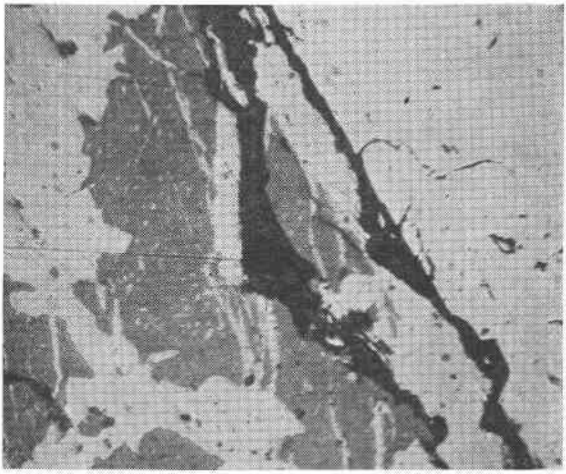

Fig. 2. Older sphalerite (gray), containing chalcopyrite blebs (white), partly replaced by chalcopyrite. Black spots are holes. Nicols not crossed. Magnification 400 diameters.

pyrrhotite; elsewhere the older sphalerite contains only inclusions of chalcopyrite. Some areas of the older sphalerite have been completely replaced by pyrrhotite with gradations into other areas where it is only partly replaced, principally along grain boundaries and cleavage directions (Fig. 1). Here in addition to the laths and blebs of pyrrhotite, the unreplaced sphalerite contains inclusions of chalcopyrite in about their usual abundance. In places remnants of the older sphalerite have been almost entirely replaced by chalcopyrite, but again there apparently is no increase in the number of chalcopyrite inclusions in the sphalerite remnants even next to veinlets of chalcopyrite (Fig. 2).

The younger sphalerite everywhere contains inclusions of chalcopyrite but none of pyrrhotite. Veinlets of it cut across contacts of pyrrhotite and chalcopyrite and no change in the number or arrangements of chalcopyrite inclusions is evident on either side of the contacts (Fig. 3). Some areas of younger sphalerite related to irregular fractures are surrounded by pyrrhotite and elsewhere by chalcopyrite, and in both associations the number and arrangement of inclusions of chalcopyrite are similar.

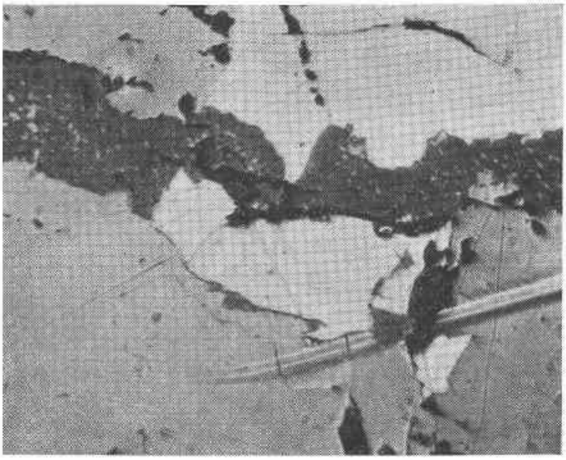

FIG. 3. Veinlet of younger sphalerite (dark gray) with inclusions of chalcopyrite (white) crossing chalcopyrite (white) and pyrrhotite (light gray). Nicols not crossed. Magnification 400 diameters.

SUMMARY

1. Since oriented laths and blebs of pyrrhotite occur in sphalerite only where pyrrhotite is known to be replacing sphalerite, the laths and blebs are believed to have been formed by replacement.

2. Inclusions of chalcopyrite occur in about equal abundance in both the older and the younger sphalerite. There is no apparent increase or decrease in the number of inclusions of chalcopyrite where different minerals replace the older sphalerite and, in addition, there is no apparent increase in the number of inclusions of chalcopyrite next to veinlets of chalcopyrite cutting the sphalerite. Therefore, in the ores under consideration, the inclusions of chalcopyrite are believed to have formed by some process of unmixing.

3. Where the younger sphalerite replaces pyrrhotite, the younger sphalerite contains as many inclusions of chalcopyrite as where it

replaces chalcopyrite. Therefore, in the ores studied, the number of inclusions of chalcopyrite has apparently not been influenced to a noticeable degree by the host mineral.

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HEAVY MINERALS OF THE COASTAL PLAIN OF MARYLAND

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The Coastal Plain of Maryland and contiguous states has been almost neglected by workers in sedimentary petrology. The one notable exception to this statement is furnished by Goldman's work on the Upper Cretaceous.[1] Wentworth and Campbell have considered, in a general way, the mode of formation of the Pleistocene terraces, omitting, however, any account of the heavy minerals contained therein.[2]

Lately, there have appeared two papers, one of which has for its purpose the description of minerals of the coastal terraces of Virginia (based on Wentworth's collections),[3] and another which makes passing reference to the mineralogy of the Eocene greensands of Virginia.[4] The present author wishes to animadvert on certain conclusions and methods found in these two papers, and to show the bearing on the problem of results attained in studying Maryland deposits of the same age. It is hoped that these results may be published in much greater detail later.

Eocene: Gunnell and Wilgus describe a modern beach glauconitic sand, confusingly said to have been collected from a shore bluff in the Aquia formation.[5] Their percentages show not a single typical heavy mineral, other than "ores," present. Glauconite, which may sometimes fall into the category of heavy minerals, composes 40 per cent of the sample.

The writer has examined ten samples of the Eocene from parts of southern Maryland adjacent to Virginia. The heavy mineral content of these samples is remarkably consistent in its general character, and may be averaged, for this purpose, as follows: