

DESCRIPTIVE MINERALOGY OF PUGH QUARRY,
NORTHWESTERN OHIO: SPHALERITE¹DAVID F. PARR² and LUKE L. Y. CHANG, Department of Geology, Miami University, Oxford,
OH 45056

Abstract. The Devonian rocks at Pugh Quarry have three distinct types of sphalerite (banded massive, spheroidal, and tiny euhedral). Occurrence of the banded massive sphalerite is restricted to the mineral zone, predominantly as blebs in marcasite. The color of banded sphalerite ranged from nearly colorless to various hues of yellow. The replacement of banded sphalerite by marcasite was observed. The spheroidal sphalerite occurred in association with marcasite of euhedral habit. The spherules were small, the largest no greater than 1 mm across. Where present in great profusion, the sphalerite spherules merged together forming botryoidal surfaces. The euhedral sphalerite occurred in the voids of the sponge-like and stromatolitic dolostone below the mineral zone, and in a layer of soft laminated mud associated with the dolostone. The euhedral sphalerite was predominantly red-brown, and no crystals larger than 1 mm in maximum dimension were observed.

OHIO J. SCI. 78(5): 272, 1978

Sphalerite was found in cavities in all parts of Pugh Quarry. Along with marcasite (Parr and Chang 1977), it comprised nearly all of the sulfide mineralization. Sphalerite occurred in three distinct types. The banded sphalerite partially replaced by marcasite was the most unusual occurrence of this mineral at Pugh Quarry. Spheroidal aggregates of fine, radially grown crystals of sphalerite on dolostone matrix constituted the second type. Tiny euhedral crystals were the third type of sphalerite occurrence.

BANDED SPHALERITE

Sphalerite of this type was found only in the mineral zone (Parr and Chang 1977), primarily in the northeastern portion of the quarry. An additional restriction on the occurrence was that in every case, this type of sphalerite was intimately associated with banded marcasite. All specimens of banded marcasite examined (Parr and Chang 1977) contained fragments of at least a small quantity of this type of sphalerite.

¹Manuscript received June 6, 1977 and in revised form November 9, 1977 (#77-46).

²Present Address: Department of Geology, Wisconsin State University, Superior, WI 54880.

RELATION TO HOST ROCK

Where sphalerite occurred between the bands of marcasite and the dolostone host rock, replacement relationships could be observed between the two. Dolomite rhombs were commonly observed to be engulfed in the banded sphalerite. Many of these rhombs showed no feature indicating replacement by sphalerite, but others clearly showed dolomite corrosion illustrating the replacement relationship between the two minerals (fig. 1). Banded sphalerite was also found in the host dolostone. For the most part, the mineral appeared to be interstitial between oolites and was always in association with marcasite (fig. 6, Parr and Chang 1977).

COLOR AND SIZE

The color of banded sphalerite ranges from nearly colorless to various hues of yellow, even approaching orange. The banding characteristic of this type of sphalerite is emphasized in part by color variations. Thin bands of darker colored sphalerite, approaching red-brown, were observed in a few specimens. The variations in color observed in sphalerite are commonly attributed to the presence of trace elements (Deer *et al* 1962). Under short and long wave ultraviolet light, the

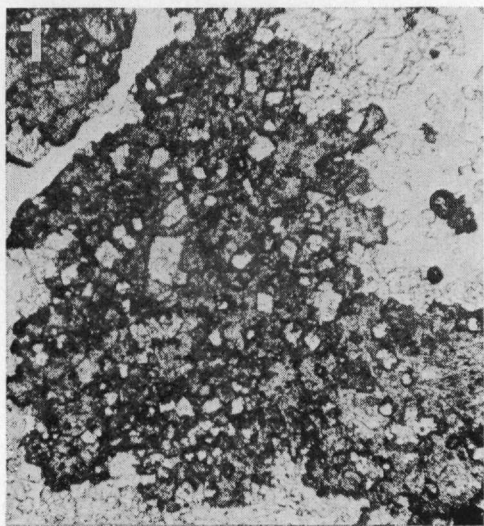


FIGURE 1. Thin section, sphalerite and dolomite. Corrosion of some of the dolomite rhombs is apparent. $\times 60$.

banded sphalerite fluoresces a dull red to reddish yellow. Variations in the fluorescence colors correspond to the bands observed in the sphalerite under normal light. The darker bands fluoresce a deep dull red whereas the light bands fluoresce reddish yellow.

Banded sphalerite at Pugh Quarry occurred predominantly as blebs in marcasite. The majority of the blebs were roughly 2 to 3 mm long by one mm or less wide (fig. 2). The blebs tended to be considerably longer than they were wide; the elongation being roughly parallel to the direction of elongation of the marcasite crystals (fig. 3). This direction was approximately perpendicular to the sphalerite banding and the free surface of the marcasite crust. Commonly the sphalerite blebs were teardrop-shaped masses with the small ends pointing in the convex direction of the banding (fig. 2).

HABIT AND FORM

The banding was represented by several physical characteristics of the banded sphalerite masses. Color variation within the blebs was the most apparent manifestation of the banding (fig. 2). Examination of polished sections revealed bands of lower reflectivity (darkest bands) con-

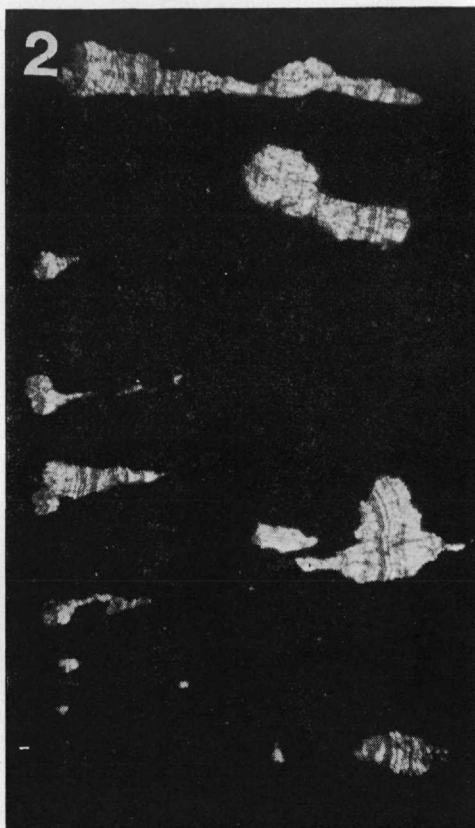


Figure 2. Thin section, one nicol. Blebs of banded sphalerite in marcasite. The elongated bleb shape, color banding, parallel character of bands, continuity of band sequence from one bleb to another, and bleb horizon are visible. Note the banding appears to be centered on a nucleation point near the base of the bleb. $\times 28$.

taining many small pits (fig. 4). A third type of concentric banding consisted of continuous narrow zones of larger pits or other open spaces (fig. 5). Apparently extremely small sphalerite crystal faces were developed on the surfaces of banded sphalerite bounding these zones of open space, producing a drusy texture. All banding observed in the blebs of sphalerite was concentric to an apparent nucleation point.

Hemispherical mounds of sphalerite commonly were scattered among the marcasite terminations on the surfaces of the crusts of marcasite (fig. 6). These mounds were the tops of blebs of sphaler-

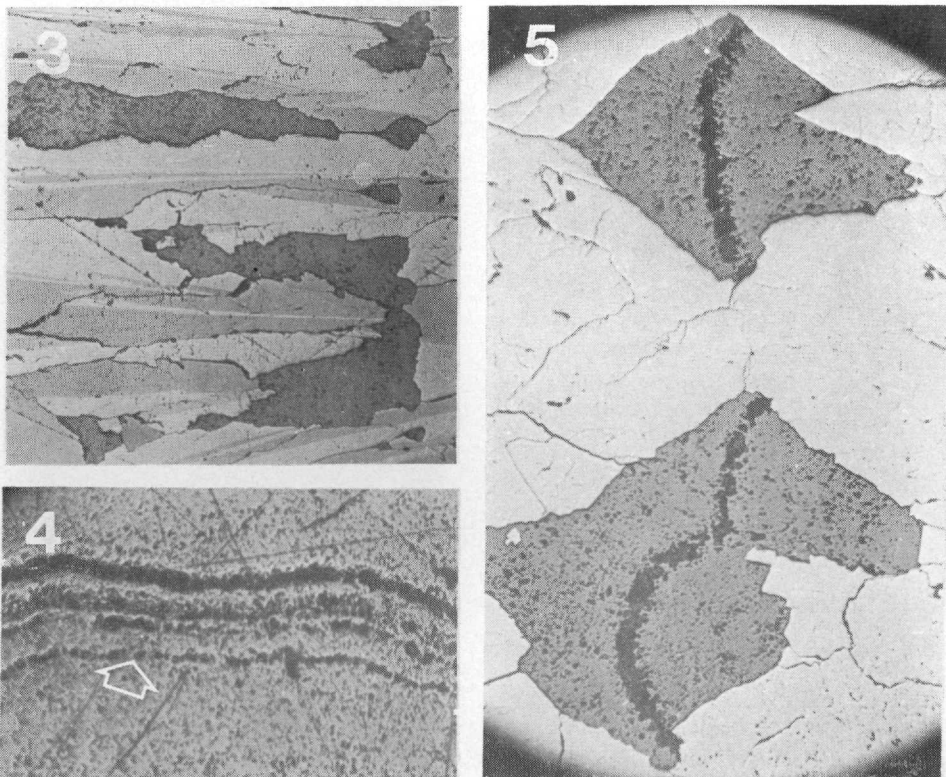


FIGURE 3. Polished section, crossed nicols. Blebs of banded sphalerite in marcasite. Note horizons of small banded sphalerite blebs, twinned character of the marcasite crystals, parallelism of the direction of elongation of both sphalerite blebs and marcasite crystals, and continuity of marcasite crystals through the sphalerite bleb horizon. $\times 32$.

FIGURE 4. Polished section, one nicol. Banded sphalerite bleb. Bands of low reflectivity (arrow) caused by numerous small pits in the sphalerite are visible. $\times 32$.

FIGURE 5. Polished section, one nicol. Banded sphalerite blebs in marcasite. Note the band of large pits in banded sphalerite and continuity of pit bands in the two separate blebs. $\times 32$.

ite which could be seen to extend down into the marcasite crust a short distance. The surface of these sphalerite mounds was composed of numerous extremely small crystal terminations, which gave the surface a delicate velvety appearance.

RELATIONSHIP BETWEEN BANDED SPHALERITE AND MARCASITE

The occurrence of banded sphalerite in the study area was obviously not unique. The paragenetic relationship between it and marcasite (Parr and Chang 1977), replacement of the former by the latter, was unusual. To our knowledge, previous investigators have not made reference to the paragenetic situation in which marcasite replaces sphalerite. Ramdohr (1969)

stated, "marcasite is often precipitated as an incrustation upon such mineral species which themselves are not involved in these replacement phenomena, e.g., on sphalerite." Our interpretation runs contrary to what is apparently the general thought to be the paragenetic relationship between these two minerals. The evidence we obtained is presented below:

1. Banded sphalerite was almost completely replaced by marcasite in all specimens examined. The sphalerite not replaced occurred as blebs scattered throughout the marcasite crusts. Commonly, certain horizons within the marcasite contained a greater number of blebs than the remainder of the marcasite

crusts. The horizons along which the sphalerite blebs were concentrated were not flat, rather they closely followed the contours of the surface of the replacing marcasite.

No variations in band color, polishing characteristics, curvature, or thickness were observable at or near the marcasite-sphalerite interface. If the relationship between the two minerals in question was the result of contemporaneous precipitation, variations in the character of the bands in the sphalerite could be expected along the interface between the two minerals. Slight differences in the solutions precipitating the two minerals would very likely cause the bands to show some variation in one or more of the characteristics noted above in the vicinity of the interface. No features indicating the impingement of marcasite on sphalerite during growth were observed. The bands simply end, apparently cut off by the marcasite (fig. 2, 4, and 5).

2. The arcuate features described here as banding were not random phenomena, different in different blebs in a given specimen. Sequences of bands with some arrangement of wide, narrow, dark, light, high polish, low polish, were observed in one bleb, and can be observed in similar sequence in other blebs in the same horizon. In many specimens a particular band or series of bands could be traced across a prepared section in a manner similar to that used in correlating tree rings and varved sediments (figs. 2 and 5).

Commonly blebs were close enough to one another in the prepared sections that several could be examined simultaneously under low magnification. In addition to the obvious correlation of band sequences in the different blebs, it was apparent from the curvature of the bands in adjacent blebs that they were at one time joined together, forming a continuous band across the specimen (figs. 2, 5, and 7). The points at which the bands formerly joined were now occupied by marcasite replacement. Examination of figures 2, 5, and 7 dispels the alternate explanation that the marcasite in some way physically displaced the blebs from one another. There was no hint of a jigsaw

puzzle-type fit between the different blebs in a horizon.

3. Nearly complete spherules and hemispherules of banded sphalerite extended from the host rock a short distance up into the marcasite crust. Invariably, portions of these structures were truncated by the enclosing marcasite (fig. 8). Several of these spherulites clearly showed selective replacement of certain sphalerite bands by marcasite. Bands which have been selectively replaced may correspond to areas of numerous pits. The replacement marcasite found in this relation followed the curvature of the remaining sphalerite bands.

4. Zimmerman and Amstutz (1973) described a paragenetic relationship between banded sphalerite and marcasite in which distinct crystal faces of marcasite could be seen projected up into sphalerite. They interpreted this relationship as indicating that the banded sphalerite was later than the marcasite. The polished sections and thin sections prepared for this study were specifically examined for this relationship. Isolated examples showing marcasite crystal faces projecting into the concave, lower side of banded sphalerite blebs were observed. The vast majority of the blebs, however, showed no indication of the presence of marcasite crystal faces intruding into them from any direction. The sphalerite-marcasite interface was characteristically a nongradational irregular surface showing embayments of one mineral into the other. This line of evidence while not totally conclusive, indicates, for the most part, that the sphalerite is not overgrown on the marcasite, but rather that it is being replaced by it.

5. Polished sections of marcasite containing sphalerite blebs, examined between crossed nicols, showed the variations in the orientation of the individual marcasite crystals composing the specimen. Most of the marcasite crystals were oriented with their direction of elongation parallel to the direction of elongation of the sphalerite blebs. This direction was perpendicular to the termination surface of the marcasite crust. Twin laminae within the individual crystal units were also clearly apparent in the polished sections.

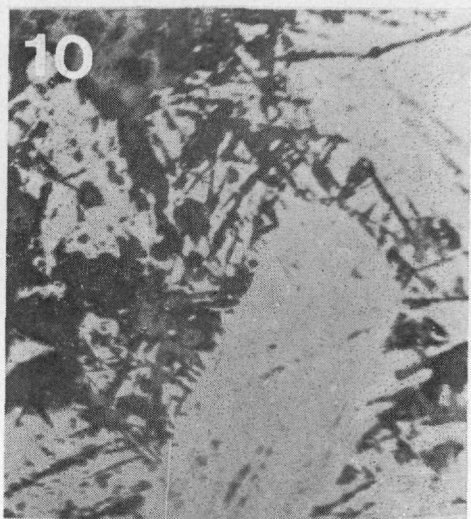
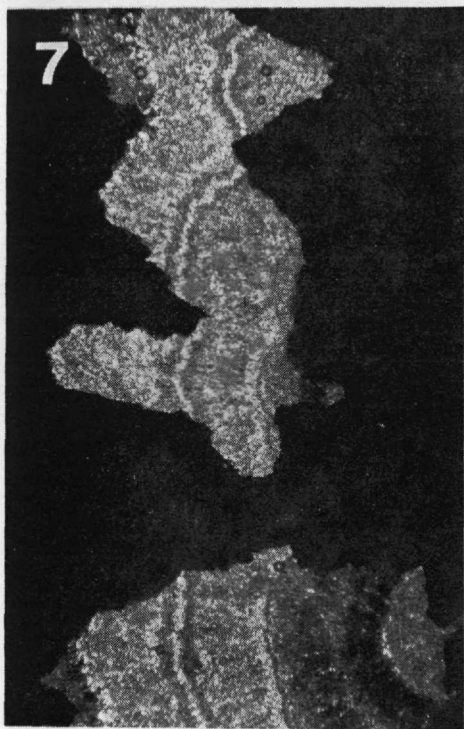
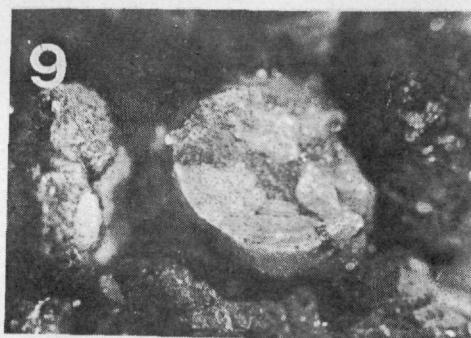
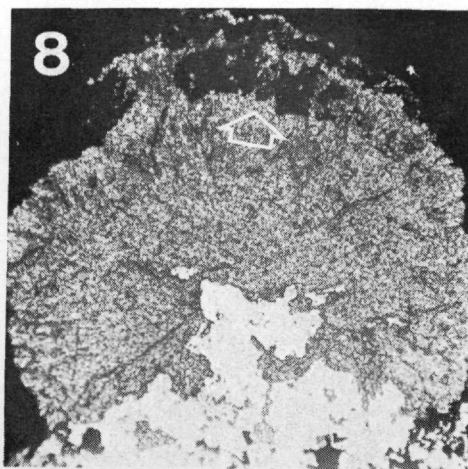


FIGURE 6. Marcasite and remnant bodies of banded sphalerite. Note the encroachment of marcasite into the spherical and hemispherical bodies of banded sphalerite. $\times 4$.
 FIGURE 7. Thin section, one nicol. Banded sphalerite blebs enclosed in marcasite. Note the banded features and the continuity of band sequences of bands in different blebs. $\times 25$.
 FIGURE 8. Thin section, one nicol. Banded sphalerite spherule partially enclosed in marcasite. Note selective replacement (arrow) of banded sphalerite by marcasite along certain bands. $\times 60$.
 FIGURE 9. Marcasite replacing banded sphalerite. Note the veinlets of marcasite cutting large spherulite of banded sphalerite and the continuation of bands in sphalerite across marcasite veinlets. $\times 4$.
 FIGURE 10. Polished section, one nicol. Shredded island texture, marcasite replacing banded sphalerite. $\times 185$.

On the basis of continuity of interference colors and the continuity of twin laminae, it was possible to trace individual crystal units of marcasite through their entire length. Many crystals of marcasite could be traced without interruption through the entire thickness of the crust from the dolostone-marcasite interface up to the termination surface of the crust. If the horizon of sphalerite blebs mentioned above were the result of alternating precipitation of marcasite and sphalerite, a general interruption in the continuity of the marcasite crystals should have been found at the horizons of sphalerite blebs. No indication of any interruption of the marcasite crystals at the bleb horizon was observed, clearly indicating that the formation of the marcasite was not interrupted by periodic deposition of sphalerite.

6. Several textural relationships diagnostic of the replacement of one mineral by another were observed in the specimens prepared for microscopic study. These include: a. a large spherulite of sphalerite approximately 6 mm in diameter cut by veinlets of marcasite (fig. 9), [The banded characteristics described above are present in this sample.] b. shredded island texture (Ramdohr 1969, p. 206) (fig. 10), c. skeletal growth of marcasite in sphalerite (fig. 11), d. feathery intergrowth of marcasite and sphalerite (fig. 12), and e. gradational surface between marcasite and sphalerite. The evidence presented above, when considered collectively, strongly indicates the replacement of sphalerite by marcasite.

SPHEROIDAL SPHALERITE

Specimens with sphalerite occurring as crystal aggregates in the form of spheroidal bodies were found in the mineral zone in the northeastern area of the quarry. The sphalerite spherules were associated in every case with marcasite crystals of the euhedral habit. Spheroidal sphalerite aggregates were not found in any other part of the quarry or in any other stratigraphic horizon.

RELATION TO HOST ROCK

All examples of this sphalerite show the spheroidal bodies directly on the dolostone. No evidence indicating the

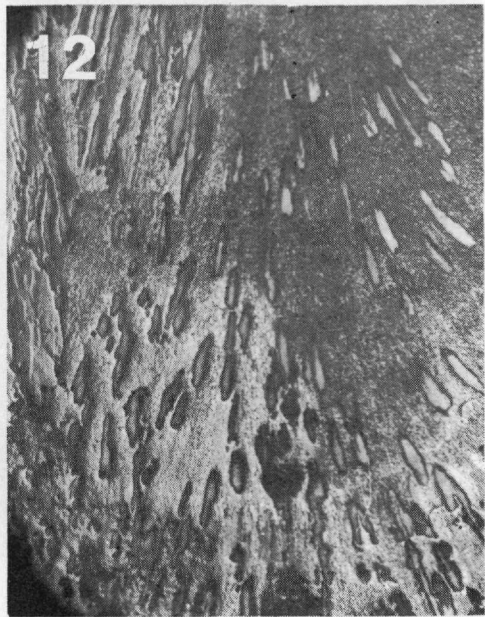
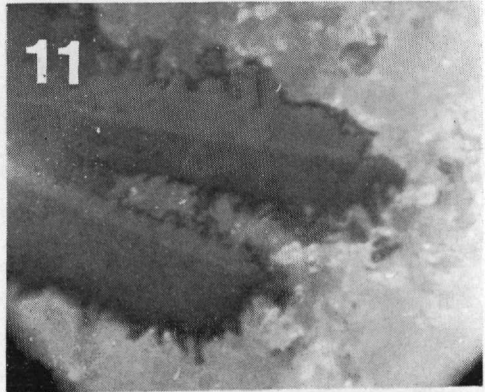


FIGURE 11. Polished section, crossed nicols. Skeletal growth of marcasite in banded sphalerite. Marcasite replacing sphalerite. Note the twinning in marcasite. $\times 350$.

FIGURE 12. Polished section, crossed nicols. Feathery intergrowth of marcasite replacing banded sphalerite. $\times 32$.

replacement of dolostone by sphalerite was noted. Thin sections showed sharp euhedral rhombs of dolostone to be incorporated into the basal portion of the sphalerite spherules, but these rhombs did not show any corrosion features indicative of a replacement origin.

COLOR AND SIZE

The color of the sphalerite spherules was predominantly a drab yellow, the

color being subdued by the influence of brown tint. Generally the surface of the spherules, being the result of many tiny crystal terminations, lacked the strong resinous luster characteristic to sphalerite. The sphalerite was translucent but definitely not transparent. When illuminated by long wave ultraviolet light, the sphalerite weakly fluoresced a dull red. No phosphorescence was observed. The spherules examined were small, the largest no greater than 1 mm across. Most of the spherules were considerably smaller than this, being just visible without a microscope.

HABIT AND FORM

The crystal aggregates included in this group had a spherical to hemispherical form regardless of the size of the body (fig. 13). Fibrous to accicular sphalerite crystals radiated from a central point near the contact point between the sphalerite and host rock. Apparent on some aggregates of this type are concentric shells of dark and light sphalerite.

Extremely fine sphalerite crystal terminations bound the surfaces of these bodies (fig. 13). The minute size of the crystals and their terminations, which compose the spheroidal aggregates, prohibited the

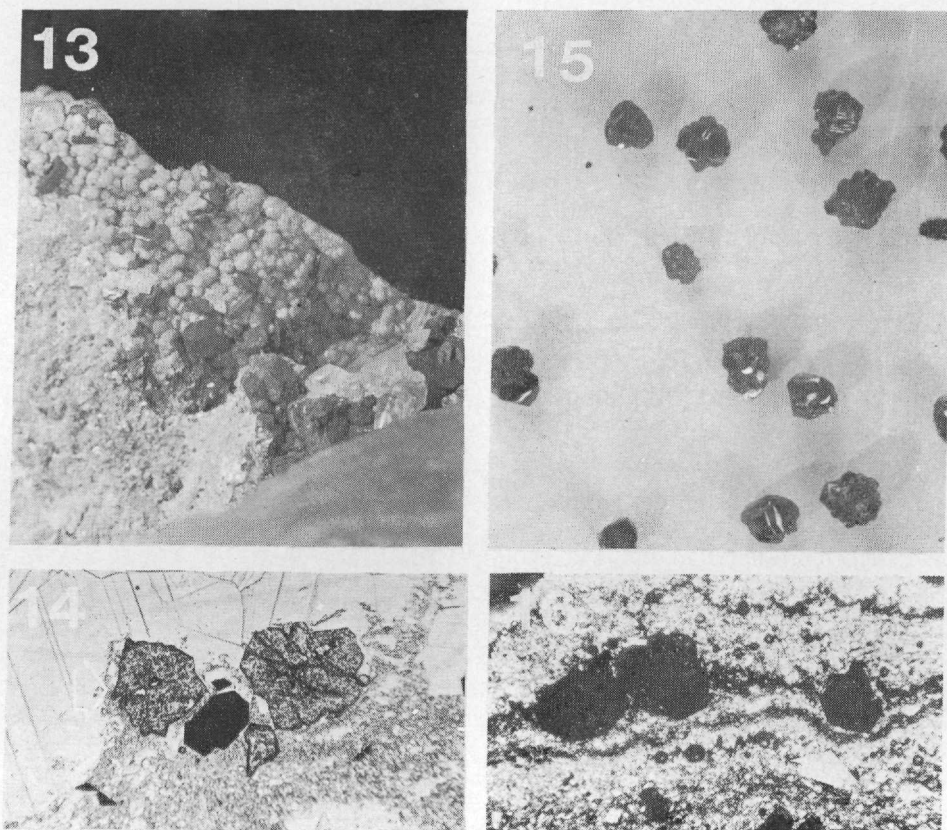


FIGURE 13. Sphalerite spherules and marcassite on dolostone. Note the very fine sphalerite crystal terminations on the hemispherical bodies of sphalerite. $\times 2.2$.

FIGURE 14. Thin section, one nicol. Euhedral marcassite and euhedral sphalerite crystals on stromatolitic dolostone matrix. Note complex nature and shape outline of the sphalerite crystals (arrow) and the general lack of included dolomite rhombs. $\times 35$.

FIGURE 15. Euhedral sphalerite crystals washed from the mud layer. Note complex nature of these crystals. $\times 10$.

FIGURE 16. Thin section, crossed nicols. Euhedral sphalerite crystals in mud layer. Note distorted mud laminae around sphalerite crystals. $\times 25$.

determination of the crystal forms. Where present in great profusion, the sphalerite spherules merged together, forming botryoidal surfaces.

EUHEDRAL SPHALERITE

Crystals representing this type were observed only in the strata lower than the mineral zone in the northeastern area of the quarry. The rock in which the crystals were found was an extremely porous gray brown stromatolitic dolostone (fig. 2, Parr and Chang 1977). Associated with this rock type was a layer of soft laminated mud about 20 mm thick, which contained large numbers of euhedral sphalerite and marcasite crystals no larger than 1 mm.

RELATION TO HOST ROCK

Sphalerite crystals occurring in the voids of the sponge-like and stromatolitic host rock did not show evidence indicating replacement formation (fig. 14). Some of the crystals had engulfed microscopic dolomite rhombs. These rhombs did not show embayments, rounded crystal edges, or other replacement features. Most commonly the crystals were found disseminated randomly throughout the vugs in the rocks. High concentrations of sphalerite crystals were observed on some of the stromatolitic laminae.

Crystals from the laminated mud layer showed no evidence of attachment to any solid object (fig. 15), and appeared to have grown free in the mud. Thin sections of the mud and its contained sphalerite crystals support the conclusion that the mineral is authigenic. Distortion of mud laminae could be seen near the crystal, suggesting crystal growth in place (fig. 16).

The composition of the mud layer which contained the sphalerite crystals is interesting. It is predominantly composed of small dolomite rhombs with much interstitial hydrocarbon material. The laminae were defined more by the variance in the concentration of this organic material than by the variation

in the particle size of the dolomite rhombs. Also included in the mud were calcite crystal aggregates greater than 1 mm.

COLOR AND SIZE

The color observed on the euhedral sphalerite crystals was predominantly a red-brown with some crystals approaching a golden brown. Most crystals were nearly transparent and some were completely so. One characteristic of the sphalerite crystals was their uniformity of size. No single crystals were observed larger than 1 mm in maximum dimension, most were considerably smaller.

HABIT AND FORM

Faces of the dodecahedral form dominated the crystals and served to control the basic habit of most of the crystals. In addition to the dodecahedral form, many vicinal faces, curved faces, and conical forms were observed on the crystals. The conical form was produced by rounding together of the {113} and {011} forms (Palache *et al* 1944). Twining, common in sphalerite, has given many of these crystals a complex appearance.

Acknowledgments. The authors are indebted to Drs. James Bever and Charles Kahle for their assistance and advice. Special thanks go to the Pugh Quarry Company for its cooperation.

LITERATURE CITED

- Deer, W. A., R. A. Howie and M. A. Zussman 1962 *Rock-Forming Minerals*, Vol. 5, Non-Silicates. Longmans, London, 351 pp.
- Palache, C., H. Berman and C. Frondel 1944 *System of Mineralogy*, 7th edition, John Wiley, New York, 1124 pp.
- Parr, D. F. and L. L. Y. Chang 1977 Descriptive mineralogy of Pugh Quarry, northwestern Ohio: Marcasite and pyrite. *Ohio J. Sci.* 77: 213-222.
- Ramdohr, P. 1969 *The Ore Minerals and Their Intergrowths*. Pergamon Press, London, 1169 pp.
- Zimmerman, R. A. and G. C. Amstutz 1973 Intergrowth and crystallization features in the Cambrian mud volcanoes of Decaturville, Missouri, U.S.A. p. 339-350. *In: Amstutz, G. C. and A. J. Bernard (eds), Ores in Sediments*. Springer-Verlag, New York.