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DESCRIPTIVE MINERALOGY OF PUGH QUARRY, NORTHWESTERN OHIO: CALCITE, DOLOMITE AND FLUORITE[1]

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Abstract. Calcite is by far the most abundant mineral in the Devonian rocks at Pugh Quarry. The large crystals, from 5 mm to 10–15 cm long, are predominantly brown with wide variations in hue and intensity. The small crystals, smaller than 5 mm, range from colorless to gray-yellow to pale yellow. Both large and small crystals consist almost entirely of scalenohedral forms (dog-tooth spar habit). The most common and most easily recognized type of twinning in the large crystals is on the (0001) plane. Both dolomite and fluorite are minor minerals at Pugh Quarry, although fluorite is found in all parts of the Quarry. Dolomite crystals occur as secondary encrusting material and are most common in vugs.

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In this third paper on the mineralogy of Pugh Quarry, calcite, dolomite and fluorite are described. The quarry is located in the SW½, SW¼, Sec. 6, T.4N, R.9E in Milton Township, Wood Co., Ohio. Its sulfide mineralization, including marcasite, pyrite, and sphalerite has been previously described (Parr and Change 1977, 1978).

CALCITE

Calcite was by far the most abundant mineral in the Devonian rocks at Pugh Quarry. Based on crystal size, calcite could be divided into two distinct groups; large crystals (maximum dimension >5 mm) and small crystals (maximum dimension <5 mm).

LARGE CALCITE CRYSTAL

Large crystals were most abundant in the eastern portion of the north wall of the quarry where cavities and collapse breccias are common.

Relation to Host Rock. Examination of thin sections across critical crystal-matrix interfaces revealed no evidence of replacement activity. Commonly the large crystals were attached directly to the dolostone with no material in between (fig. 1). In some cases, however, randomly oriented, anhedral grains of cal-

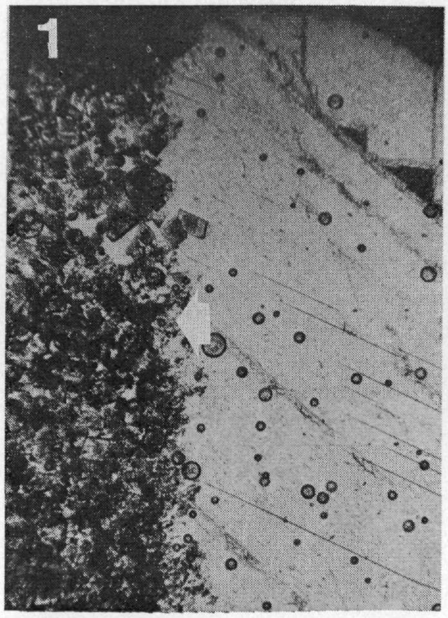

FIGURE 1. Thin section, one nicol. Large calcite crystals on dolostone. Note the lack of any substance separating the body of the large crystal from the dolostone (arrow). ×25.

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cite were located between the crystals and the dolostone host rock (fig. 2). Large calcite crystals also have developed on marcasite and sphalerite crystals. However, there is no strong evidence suggesting over crystallization of the older marcasite-sphalerite by the younger large calcite crystals. Although fragments of marcaiste were included in the basal portions of a few large calcite crystals, the marcasite crystals appeared to be clastic particles derived from collapse reecciation of the dolostone which preceded calcite crystal formation.

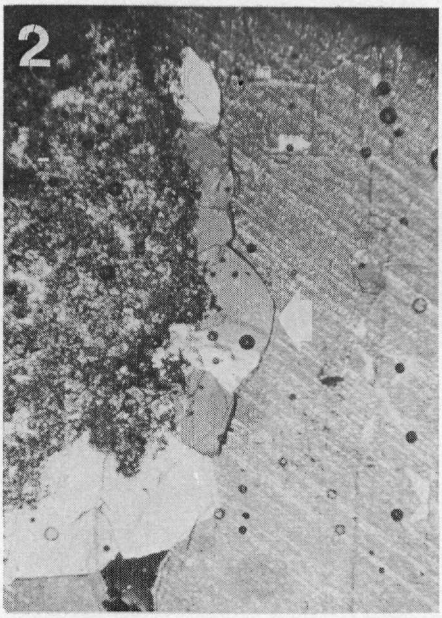


FIGURE 2. Thin section, crossed nicols. Large calcite on dolostone. Note the layer of anhedral calcite separating the body of the large crystal from the dolostone (arrow). ×25.

Color. The crystals were predominantly brown but with wide variations in hue and intensity. The color, as observed on crystal faces and cleavage surfaces, was a blend of several internal zones and appeared darker than the overall color. The color and zonation of color was most readily seen on cleavage surfaces or on sections of crystals cut perpendicular to the c-axis. The opacity varied from translucent to transparent.

The overall color of the large crystals apparently was affected by included hydrocarbon material. Higher concentrations of this material, zonally arranged, produced darker brown bands within the crystals. When cleavage fragments large enough to show this feature were heated, the brown color disappeared completely, leaving the fragments colorless and highly fractured. When cleavage sections were examined under ultraviolet light, the darker brown bands fluoresced a weak dull red color under long wave ultraviolet light, yet the same areas fluoresced a strong orange color under short wave light. After illumination by either long or short wave ultraviolet light, the outer one to two millimeters of the crystals showed a weak cream to greenish white phosphorescence which lasted only about 7 seconds. No phosphorescence of the darker brown bands was observed.

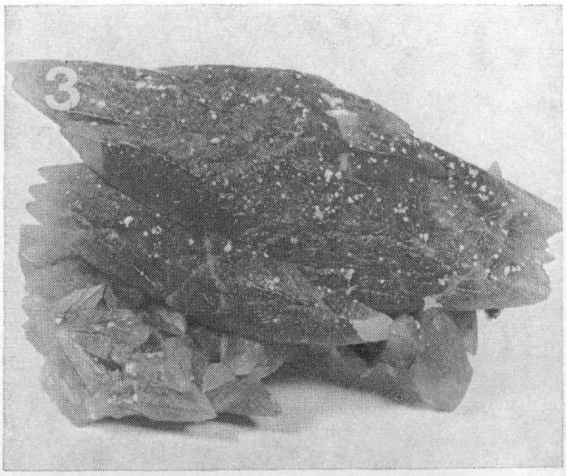
Fluid inclusions were observed in many thin sections. There was no apparent correlation between the abundance of the fluid inclusions and the darker brown bands.

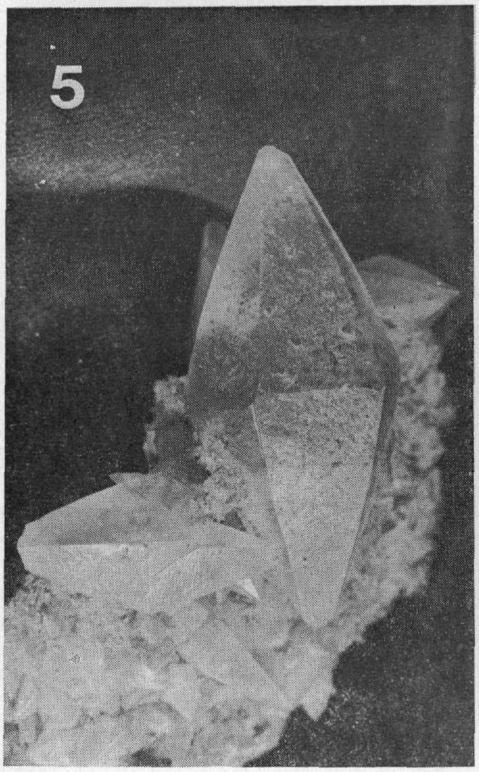
Size. Large calcite crystals were defined as being longer than 5 mm along the c-axis. Crystals in the 10 to 15 cm length range were not uncommon (fig. 3). Several large crystals had cleaved naturally and had been displaced along or perpendicular to cleavage planes (fig. 4). The surfaces exposed by the cleavage of the crystals had been *healed* by subsequent growth of calcite onto the cleavage surfaces.

Habit and Form. The crystal habit was restricted to the dog-toothed spar type, common to calcite from many localities. The crystal faces consisted almost entirely of scalenohedral forms modified by the development of numerous vicinal faces. Doubly terminated and twinned crystals were common (figs. 3 and 5), many of these had multiple terminations resulting from extensive parallel and subparallel growth (fig. 6).

Forms on the large calcite crystals could not be determined using an optical goniometer or even a contact goniometer because of the large size of the crystals and the curved, rough, and dull character of the crystal faces.

Twinning. The most common and most easily recognized type of twinning





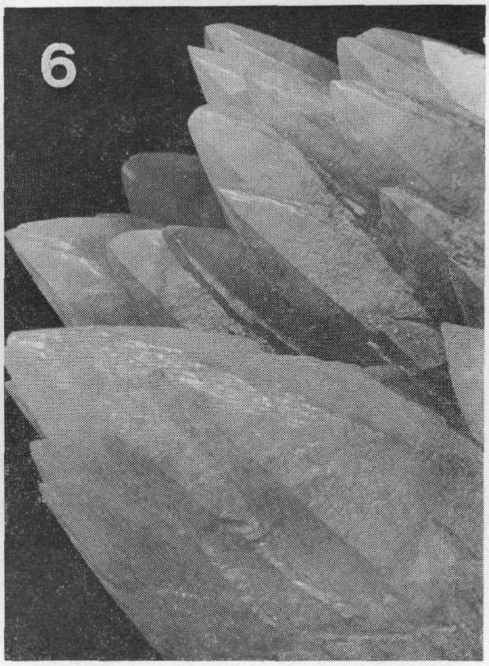


FIGURE 3. Large calcite-dog-tooth crystals. Note parallel growth and multiple terminations on the crystal. ×0.3.

FIGURE 4. Large calcite crystal, dog-tooth habit. These crystals have been broken and displaced along cleavage planes (arrows). Subsequent calcite growth has covered the cleavage surfaces with numerous smaller terminations showing distorted growth and many vicinal faces. ×0.5.

FIGURE 5. Twinned large calcite crystal, dog-tooth habit. The "straight line" contact between the northern and southern hemipshere crystal forms can be seen. Note the dark material included near the crystal surface. ×1.2.

FIGURE 6. Large calcite crystal, dog-tooth habit. Note multiple terminations of the crystals and extensive parallel growth. ×1.2.

present in the large calcite crystals was on the (0001) plane. Equatorial girdles of the twinned crystals were characterized by reentrant angles on alternate corners of the 6-sided crystals. The contacts between northern and southern hemipshere forms on the twinned crystals resulted in the formation of morphological zones, the axes of which lie in the (0001) plane and were perpendicular to the c-axis of the crystal (fig. 5).

Etching of $\{01\bar{1}1\}$ cleavage surfaces showed 6 wedge shaped sections, each of roughly equal area. The sectors were distinguishable from one another by different reflectance in their etched surface (fig. 7). Each sector was separated from the adjacent sector by lines which connected opposing interfacial angles formed by the scalenohedral faces. The etch properties of the sectors indicated that opposing sectors were in similar orientation. Thus, the 6 sectors may be represented as 3 pairs of similar sectors (fig. 7).

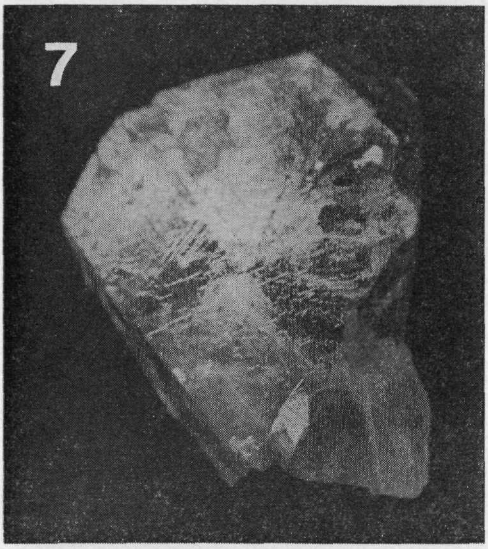


FIGURE 7. Polished and etched cleavage section of large calcite crystal. Six sectors are visible. The similarity of opposing sections can be seen. ×1.9.

The twinning was restricted to the interior portion of the crystals, as the outer margins of the crystals, which have been previously described as the zone of phosphorescence, did not show the diagnotic etch features.

SMALL CALCITE CRYSTAL

Calcite crystals included in this group were by far the most abundant and widely distributed in the quarry. The small crystals occurred in the mineral zone of the Anderson dolomite (Parr and Chang 1977) throughout the quarry as well as in small cavities in the overlying Dundee limestones.

Relation to Host Rock. Small calcite crystals encrusted both the dolostone host rock and earlier formed minerals. The encrustations were relatively thin, being no more than 3 to 4 mm thick. Examination of thin sections recealed that randomly oriented, ahedral calcite crystals projected into the open space (fig. 8). In addition, small calcite crystals served as filling material in the interstitial spaces in the dolostone.

Color. The small crystals ranged from colorless to gray-yellow to pale yellow. A minimal pale yellow fluorescence and a cream white phosphorescence were observed when small crystals were examined under both short and long wave ultraviolet light. The phosphorescence was extremly weak and short-lived; detectable for only a few seconds.

Habit and Form. The dog-tooth (scalenohedral) crystal habit of the small calcite crystals was remarkably uniform throughout the quarry (fig. 9). The rounding off of alternate interfacial edges between the scalenohedral faces was predominant, but this modification did not affect the overall dog-tooth appearance. Attempts to determine the interfacial angles of forms failed because the surfaces of the crystals had been naturally etched to a such degree that reflectivity became very poor.

Relation to Other Minerals. Small calcite crystals were thinly scattered over marcasite surfaces (fig. 10), and also over fluorite crystals (figs. 11 and 12). When the small calcite crystals were found in association with barite mineralization, small spherulites of barite were commonly completely or partially enclosed in the small calcite crystals. Barite crystal clusters were also found perched on the small calcite crystals (fig. 9). This relationship indicated that these two minerals were forming contemporaneously,

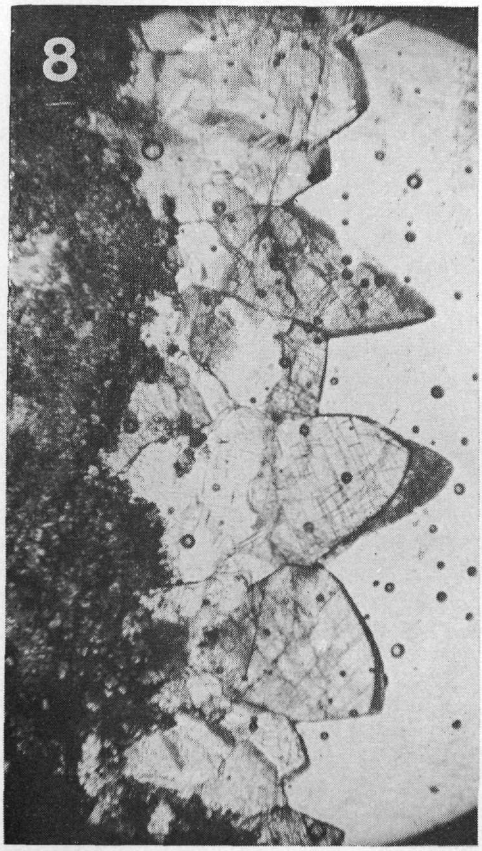


FIGURE 8. Thin section, one nicol. Small calcite crystals on dolostone. Dark circles are air bubbles. ×25.
FIGURE 9. Small calcite crystals, dog-tooth habit, with spherulites of barite included in and perched on the calcite crystals (arrows). ×3.9.

with barite minrealization continuing after calcite stopped forming.

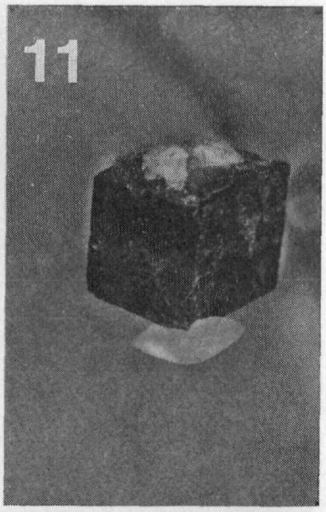
Rarely were small calcite crystals found growing on the large calcite crystals, and nowhere did the small crystals encrust the large crystals completely as they did other earlier minerals. Where the small crystals were present on the large crystals, they occurred as isolated individuals or as small isolated clusters of crystals. Nevertheless, the evidence indicated that the large crystals preceded the small crystals. Several lines of indirect evidence can be gathered to support this proposal:

(a) Small clusters of barite were found as inclusions in the small calcite crystals (fig. 9). Similar small inclusions of barite were found in the outer zone (1 to 2 mm) of the large calcite crystals, but no barite was found deeper in the interior of the large crystals than 1 to 2 mm zone (fig. 13).

(b) The phosphorescence of the small calcite crystal was identical to that of the outer zone of the large calcite crystals.

(c) Examination of the outer zone of the large crystals revealed that this zone was distinctly paler in color than the interior of the crystals. The color of this zone was similar to the color of the small calcite crystals.

Each of these lines of evidence indicates that the small calcite crystals, the outer zone of the large calcite crystals, and the



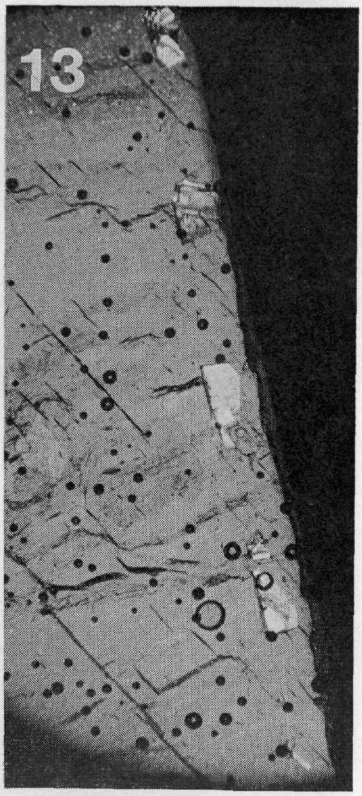
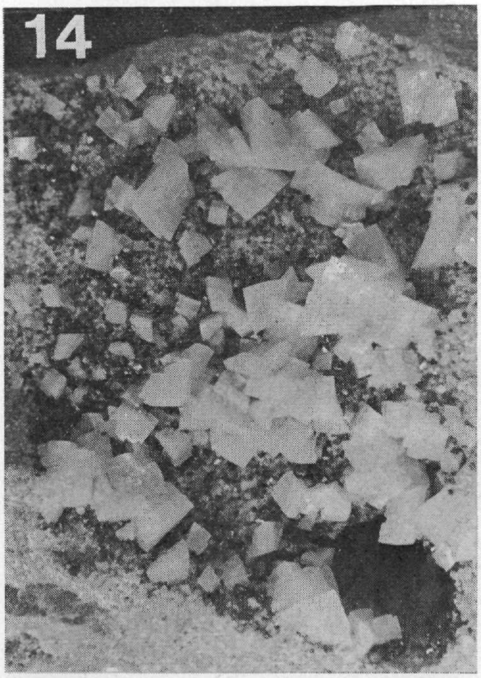


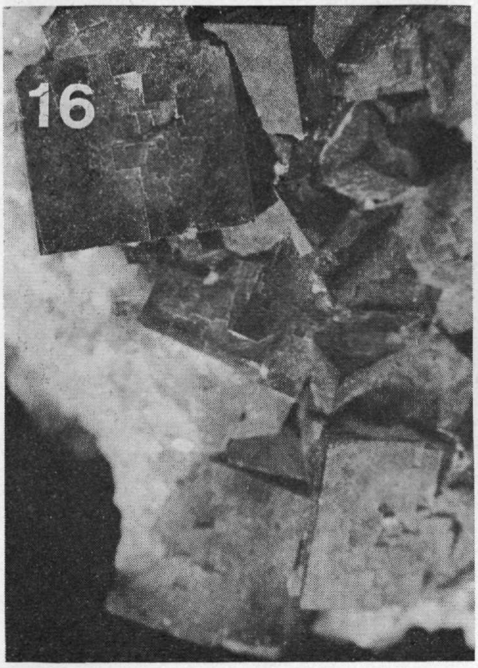
FIGURE 10. Small calcite crystals, dog-tooth habit, on fracture surfaces of marcasite breccia clasts. ×2.

FIGURE 11. Small calcite crystals, dog-tooth habit, on cube of brown fluorite. ×4.

FIGURE 12. Encrustment of small calcite crystals on fluorite. ×2.

FIGURE 13. Thin section, crossed nicols. Barite crystals in the outer zone of large calcite crystal. ×25.





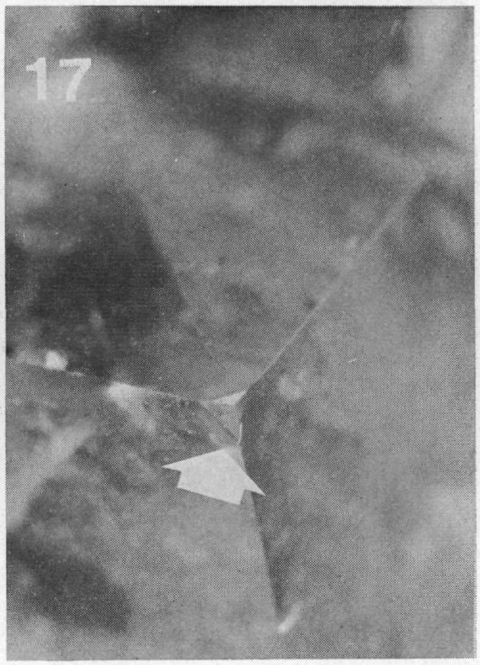


FIGURE 14. Dolomite crystals and marcasite crystals on dolostone. Note the characteristic saddle shape of the dolomite crystals. ×1.8.

FIGURE 15. Fluorite on dolostone. Note zone of clear fluorite over central core of brown fluorite (arrow). ×2.6.

FIGURE 16. Fluorite on dolostone. Note hopper growth in central portion of the large crystal. ×3.1.

FIGURE 17. Fluorite. Note trapezohedral corner modifications (arrow). ×10.

barite were all being formed contemporaneously.

DOLOMITE

Dolomite crystals occurring as secondary encrusting material were most common in vugs in the Dundee Formation. They had white to pinkish-white color and were saddle-shaped crystals about 5 mm in maximum dimension (fig. 14). The scarcity of good specimens of dolomite crystals made it difficult to define its paragenetic position among Pugh minerals. On the few specimens examined, dolomite appearred to be later than the fluorite, but earlier than the small calcite associated with it.

FLUORITE

Fluorite was a relatively uncommon mineral at Pugh Quarry, but was found in all parts of the quarry. Brown, colorless, pale blue, and dark blue to purple fluorite all were found, with brown by far the most abundant. Dark blue to purple fluorite was the least common. The colorless and pale blue fluorite occurred commonly as an outer zone over an inner core of brown fluorite (fig. 15). Morrison (1935) attributed the brown color of fluorite from Clay Center, Ohio (30 miles northeast of Pugh Quarry) to included bituminous matter. Haberlandt (1940), Mueller (1952), Ford (1955) and others have attributed blue and brown colors in fluorite to organic materials of some type.

The fluorite crystals found at Pugh Quarry ranged in size from microscopic cubes to cubes more than 1 cm on an edge (figs. 15 and 16). Cubes 1 to 2 mm on an edge were the most common size found in the quarry.

Brown fluorite occurred only as cubic crystals with no modifying forms observed. The cubic faces, (100), characteristically showed vicinal features. Commonly, the central portions of the faces had moderate hopper development (fig. 16). The colorless and pale blue fluorites, occurring as zoned overgrowth on brown cubes, exhibited a dominantly cubic habit, but with trapezohedral modifications (fig. 17). The modification was always minor and had a maximum dimension less than 0.5 mm.

Specimens containing fluorite associated with other minerals indicated that fluorite formation preceded that of calcite and celestite. No specimens were found which defined the relationship between fluorite and barite. It was inferred from the barite-calcite relationship that fluorite preceded barite.

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