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CRANDALLITE (PSEUDOWAVELLITE) FROM GARDNER MINE RIDGE, LAWRENCE COUNTY, INDIANA*

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Crandallite, $CaAl_3(PO_4)_2(OH)_5H_2O$, was found as a minor constituent of a brown, allophane-rich variety of hydrated halloysite (endellite) in the course of an *x*-ray investigation of clay samples from Gardner Mine Ridge, Lawrence County, Indiana (sec. 21, T. 4 N., R. 2 W.). Inasmuch as crandallite and pseudowavellite may be considered a single species (Palache, et al., 1951, p. 837), this positive identification of crandallite confirms a suggestion by Callaghan (1948, p. 34) that pseudowavellite may be present in a clay sample from Gardner Mine Ridge.

The dominant clay mineral at Gardner Mine is hydrated halloysite. Concentrations of hydrated halloysite are localized in restricted lenses and pockets stratigraphically at, or just above, the Mississippian-Pennsylvanian unconformity. A pebbly facies of the Mansfield formation overlies the clay deposits and occurs as discontinuous and irregular seams and lenses within the clay itself. The character of the sedimentary rocks beneath the clay is not known definitely, but it is probably underlain by the Mississippian Beaver Bend limestone.

The hydrated halloysite can be divided into three varieties on physical appearance:

1. Bluish-white, microgranular, nodular variety with distinct conchoidal fracture.
2. White, massive, granular variety.
3. Brown, massive, granular variety.

Callaghan (1948) described these deposits in detail.

Crandallite has been identified only in the brown, massive, hydrated halloysite. Thin section studies have not been made of this variety because of its extreme friability, and consequently the exact habit of the crandallite is not known. However, it has been shown by microscopic examination that a considerable amount of the crandallite is associated with grains of allophane, which may comprise as much as 50% of the brown variety of hydrated halloysite. Some crandallite may also be intimately mixed with the hydrated halloysite.

Grains of crandallite are composed of subparallel to radiating acicular crystals (0.05×0.001 mm.) and display a characteristic wavy extinction.

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The grains themselves vary from elongate arcuate fragments (0.1×0.05 mm.) with well rounded edges to equidimensional clay size particles. No recognizable interference figure was obtained. Refractive indices range from 1.620–1.630±.002, and birefringence is weak.

Two grains were noted that did not have the characteristic wavy extinction of crandallite. These grains were biaxial negative with a 2V of 34°±3° as measured on a universal stage. This mineral may possibly be lewistonite or dehrnite.

The *d*-spacings from *x*-ray patterns of the Indiana crandallite correspond closely to those of McConnell's pseudowavellite (1942, p. 652). The A.S.T.M. *d*-spacing card titled "crandallite" (no. 5-0615) differs significantly from the card titled "pseudowavellite" (no. 2-0738). If crandallite and pseudowavellite are the same mineral species, then the A.S.T.M. card file is in error for one of the minerals.

Gibbsite occurs, intermixed with granular hydrated halloysite, as a crust on the nodular variety of hydrated halloysite, and may be an alteration product of the latter. The brown hydrated halloysite owes its color to iron oxides which also coat the quartz grains of the associated Mansfield sandstone. Allophane is found in both the brown and the white granular varieties of hydrated halloysite.

Two samples of allophane from Gardner Mine Ridge contained 9.51% and 10.57% P_2O_5 (Callaghan, 1948, p. 33; and White, 1953, p. 636). Callaghan (1948, p. 35) thought that the P_2O_5 in the allpohane was due to the presence of evansite. These same chemical analyses, however, show 2.86% and 2.37% CaO; thus some, if not all, of the P_2O_5 is tied up in crandallite rather than in evansite. In another sample of allophane from Gardner Mine Ridge, Ross and Kerr (1934, p. 146) found 7.15% P_2O_5 and no CaO; this allophane probably contained evansite and no crandallite. The crandallite, at least in part, is an alteration product of the evansite.

Crandallite or pseudowavellite has been described from Hesse-Nassau, Germany (Kosmann, 1869, p. 799), Silver City, Utah (Loughlin and Schaller, 1917), Amberg, Bavaria (Laubmann, 1922), Fairfield, Utah (Larsen and Shannon, 1930, p. 317), Llallagua, Bolivia (Gordon, 1944, p. 336), Thiès, French West Africa (Visse, 1952; Capdecomme, 1952, 1953; Capdecomme and Pulou, 1954), and Paraíba, Brazil (Murdoch, 1955, p. 57). The occurrence at Gardner Mine Ridge most closely resembles that at Thiès, where the deposit is believed to have originated from a phosphate rich residual soil.

At the present time a detailed investigation is in progress to describe and determine the origins of the minerals at Gardner Mine Ridge, with particular emphasis on the phosphate minerals.

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RELATION OF IONIC RADIUS TO STRUCTURES OF RARE-EARTH PHOSPHATES, ARSENATES, AND VANADATES*

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Several investigators have reported data on the crystal structures of rare-earth phosphates (Carron and others, 1958), arsenates (Strada

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