

MCBURNEY, T. C., AND J. MURDOCH (1959) Haiweeite, a new uranium mineral from California. *Amer. Mineral.*, **44**, 839.

THE AMERICAN MINERALOGIST, VOL. 54, MAY-JUNE, 1969

TRIPHYLITE-SARCOPSIDE-GRAFTONITE INTER-
GROWTHS FROM CUSTER, SOUTH DAKOTA¹

DONALD R. PEACOR, *Department of Geology and Mineralogy, The University of Michigan, Ann Arbor, Michigan, 48104.*

ABSTRACT

Sarcopside occurs as crosscutting sets of laths, oriented approximately parallel to {112} of triphylite at the Bull Moose Quarry, Custer, South Dakota. The textural relations indicate an origin through exsolution and in this respect the material is similar to grafftonite-sarcopside and grafftonite-triphylite intergrowths. Grafftonite-sarcopside intergrowths are also found at the Bull Moose Quarry, as well as specimens showing the expected coexistence of all three phases.

Grafftonite, $(Ca, Mn, Fe)_3(PO_4)_2$, occurs as a primary mineral in pegmatites, generally in oriented lamellar intergrowths with an iron-rich member of the triphylite-lithiophilite series ($LiFePO_4$ - $LiMnPO_4$). Intergrowths of sarcopside, $(Fe, Ca, Mn)_3(PO_4)_2$, with grafftonite have recently been described as the ubiquitous mode of occurrence of sarcopside. Hurlbut (1965), Peacor and Garske (1964) and Čech, *et al.* (1962) have described such occurrences from pegmatites, and Olsen and Fredriksson (1966) have noted similar textures as occurring in meteorites. Intergrowths of both sets of minerals have been ascribed to exsolution from a single high-temperature phase, Hurlbut noting that grafftonite is the indicated "host" phase, on the basis of textural relations, in the case of grafftonite-sarcopside intergrowths.

The Bull Moose pegmatite quarry, Custer, South Dakota, is well known among mineral collectors as a source of specimens of unusual secondary phosphates such as hureaulite, strengite, tavorite, rockbridgeite and barbosalite. The abundant primary phosphate from which these were derived is generally referred to as "triphylite." The writer recently observed some unusual textural features in the primary phosphates, some resembling those involving sarcopside and grafftonite. All specimens were collected from the dump, where individual specimens are up to three or four feet in diameter. As described by the quarry owner, these materials were quarried out as several large single crystals from the

¹ Contribution No. 296, from the Mineralogical Laboratory, Department of Geology and Mineralogy, The University of Michigan, Ann Arbor, Michigan 48104.

intermediate pegmatite zone, adjacent to a large rose quartz core. They are similar in occurrence in this respect to the primary pegmatite phosphates triphylite, arrojadite, graftonite, sarcopside and others from a number of localities.

Material from one area of the dump, apparently all from the same large single crystal, resembles massive triphylite except that it contains sets of intersecting laths of a second mineral. The cross-cutting sets of laths are striking in appearance on the $\{100\}$ cleavage of triphylite, especially where the surface is superficially altered. Figure 1 is a photo-



FIG. 1. Polished section (24×25 mm) parallel to $\{100\}$ of triphylite, with sets of sarcopside laths. The indices of the lath planes are $\{112\}$.

graph of a polished slab cut approximately parallel to this cleavage. Individual laths are up to about 1 mm wide and may be several centimeters in width and length.

Weissenberg and precession photographs were obtained for both the massive cleavable material and for that occurring as laths. The resulting crystallographic parameters confirmed that the minerals are triphylite and sarcopside, respectively. Mrose and Appleman (1961) have shown that sarcopside is isotypic with triphylite, such that the six-fold coordinated, divalent (Fe, Mn, Ca) atoms of sarcopside replace Li and (Fe, Mn) of triphylite, except that charge compensation requires that only three-fourths of the sites are occupied. Single-crystal photographs

were also obtained using cleavage fragments of the two intergrown minerals. Axes corresponding in magnitude for each phase were parallel, confirming that there is general structural continuity across lath interfaces, as expected from the known structure relations. Although individual laths of sarcopside are roughly planar, interface surfaces are undulating in morphology. Optical goniometric data obtained by reflection from these surfaces yielded interface indices, $h:k:l$, in the approximate ranges $(0.6-1.0):1:(2.0-3.0)$. Thin sections cut approximately parallel to $\{100\}$ yielded a ratio of $k:l$ of 1:2, and sections normal to this direction provided a value of $h:k$ close to 1:1. Thus the undulating interface surfaces have indices approaching $\{112\}$ on the average, relative to both sarcopside and triphylite lattice parameters.

Specimens from other areas of the dump very closely resemble the sarcopside-graftonite intergrowths from East Alstead, N. H. (Hurlbut 1965, Peacor and Garske, 1964). Alternating laths of sarcopside and graffonite are up to 1 mm thick and may be continuous for several square inches. The identities of the minerals were confirmed through series of Weissenberg and precession photographs using cleavage fragments from individual laths. Both the lamellar type 1 and more patchy type 2 intergrowths described by Hurlbut were observed.

Specimens from a third area of the quarry dumps which at first sight appeared to be homogeneous proved to have a more complex multiphase structure. Figure 2 is a thin section of this material as cut approximately

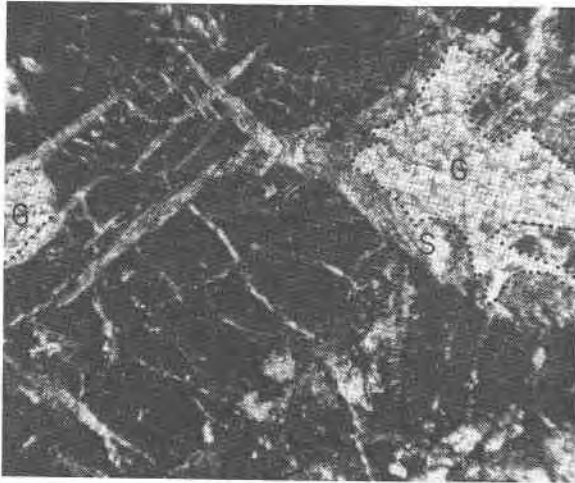


FIG. 2. Thin section (crossed polars, 3.5×2.7 mm.) with triphylite at extinction, sarcopside (S) and graffonite (G). The boundary between the two grains of graffonite and sarcopside is dotted for emphasis.

parallel to what appeared to be the principal cleavage, as for the section shown in Figure 1. All three of the phases graftonite, triphylite and sarcopside are represented. The principal phase is triphylite, shown in extinction position in Figure 2. The simultaneous extinction in thin section and continuous cleavage in hand specimen demonstrate the single crystal nature of this phase. Graftonite occurs as very irregularly shaped masses scattered through the triphylite, all grains showing approximately simultaneous extinction. Sarcopside again appears as sets of intersecting laths in the triphylite. Grains of graftonite are usually rimmed with sarcopside laths which continue into the triphylite, but only rarely cut across graftonite.

The textures described above are consistent with a two-step process of formation in which graftonite and triphylite are the originally formed phases, perhaps through exsolution. It should be noted, however, that both the lamellar and "patchy" intergrowth textures do not necessarily derive from subsolidus exsolution. Such textures are known to occur, for example, through eutectic crystallization. At a later stage the sarcopside exsolved from triphylite to form the sets of intersecting laths. Such a sequence is consistent with the structures of these phases. Calvo (1968) showed that the graftonite structure is stabilized by the presence of the relatively large Ca ion in seven-fold coordination, and that this structure is markedly different from that of sarcopside and triphylite. The latter two phases are isotypic, however. Triphylite has the olivine structure and is stabilized by the presence of univalent lithium. Sarcopside contains only divalent cations with Fe^{2+} predominating, all of which have radii consistent with octahedral coordination. Thus triphylite forms in proportion to the amount of remaining divalent octahedrally coordinated cations. Limited solid solution such as that involving Ca in octahedrally coordinated sites of sarcopside and triphylite make the process more complex but the nature of the crystal structures does serve to give a good qualitative explanation of the relations.

REFERENCES

- CALVO, C. (1968) The crystal structure of graftonite. *Amer. Mineral.*, **53**, 742-750.
- ČECH, F., K. PADERA, AND P. POVONDRA (1962) The sarcopside problem. *Acta Univ. Carolinae Geol.*, **3**, 145-157.
- HURLBUT, C. S. (1965) Detailed description of sarcopside from East Alstead, New Hampshire. *Amer. Mineral.*, **50**, 1698-1707.
- MROSE, M. E., AND D. E. APPLEMAN (1961) Crystal structure and crystal chemistry of sarcopside $(\text{Fe, Mn, Ca})_3(\text{PO}_4)_2$ (abstr.) *Prog. Amer. Crystallogr. Ass. Ann. Meet.*, 18-19.
- OLSEN, EDWARD, AND KURT FREDRIKSSON (1966) Phosphates in iron and pallasite meteorites. *Geochim. Cosmochim. Acta*, **30**, 459-470.
- PEACOR, D. R., AND DAVID GARSKE (1964) Sarcopside from Deering and East Alstead, New Hampshire. *Amer. Mineral.*, **40**, 1149-1150.