

ART. VIII. — *Crandallite, a New Mineral*; by G. F. LOUGHLIN and W. T. SCHALLER.*

Introduction.—To the long list of unusual minerals in the Tintic mining district, Utah, which has recently been augmented by A. H. Means†, another is here added—*crandallite*, named after Mr. M. L. Crandall, until recently engineer for the Knight Syndicate of Provo, Utah, who did much to aid in the recent study of the district by the U. S. Geological Survey.

Occurrence.—Crandallite is a hydrated phosphate of aluminum and calcium, and has apparently resulted from the alteration of a pre-existing non-fibrous mineral similar to goyazite‡ (hamlinite). The new mineral was found by Mr. Loughlin in vein material on the dump of the Brooklyn mine, in the monzonite area of the district $1\frac{1}{2}$ miles east of Silver City. The mine workings were inaccessible and only a small amount of ore was available for study on the dump. In this ore the new mineral was very scarce.

Crandallite occurs in compact to cleavable masses without distinct crystal outline, and partly fills irregular-shaped cavities in a quartz-barite ore aggregate, resting indifferently on any of these minerals and to a minor extent replacing them. The cavities, some of which are almost completely filled by crandallite, measure from a few millimeters to six centimeters in diameter. The ore minerals of the vein include principally pyrite with considerable enargite and small amounts of galena and zinc blende. The crandallite is covered by a crust of tenorite half a millimeter thick (partial analysis of impure sample gave: CuO, 80.12; H₂O, 4.02; P₂O₅, 1.44; insol., 2.94), which in turn is coated by a film of greenish copper minerals.

According to these relations crandallite is later than the undoubted primary (hypogene) minerals of the vein, and earlier than the common secondary (supergene) minerals. So far as its composition is concerned it may be either the latest of the primary or the earliest of the secondary minerals.

The hand specimen suggests that crandallite has a platy structure, yielding smooth cleavage surfaces, but when any of

* Published by permission of the Director U. S. Geol. Survey.

† Means, A. H. Some new mineral occurrences of the Tintic mining district, Utah, this Journal (4), xli, 125-130, 1916.

‡ The suggestion was made by W. T. Schaller (ibid., (8), xxxii, 359, 1911; U. S. Geol. Survey, Bull. 509, p. 70, 1912) that hamlinite was probably identical with goyazite. The name goyazite (1884) has priority over the perhaps better known name hamlinite (1890); Farrington (ibid., xli, 358, 1916) has recently questioned this proposed identity. See paper in the following number.

these plates are crushed and examined microscopically it is seen that they are composed of fibrous aggregates, the fibers, extremely fine, being generally in radiated groups. The conclusion reached is that crandallite is a fibrous mineral, resulting from the alteration of a pre-existing mineral of similar chemical composition to which belong the platy structure and smooth cleavage surface.

Description.—The exterior surface of the crandallite lining, which is about a millimeter thick, is uneven to imperfect botryoidal, but the cross sections of the lining show a distinct straight lamellar structure, the individual plates being about a fourth of a millimeter across and considerably less in thickness. The part of the lining next to the rock is compact and waxy looking whereas the last formed part of the lining seems to be more distinctly and coarsely crystallized and somewhat whiter in color. When crushed and examined under the microscope, however, the two parts appear the same and the apparent differences seen in the hand specimen can no longer be noted. The crushed fragments, observed under the microscope, have no regular boundaries and are irregular in shape with only a faint suggestion of the lamellar structure seen on the hand specimen. The new mineral on the hand specimen closely resembles a crust of very fine-grained dolomite or calcite; in thin section or in crushed fragments, with nicols crossed, a striking resemblance to some chalcedony is noted.

The color is white to light gray with shadings into yellow and brown. The streak is white. The luster is dull, somewhat greasy in the more compact, and somewhat pearly in the coarser lamellar variety. Almost opaque on the hand specimen, the crushed fragments are transparent to opaque under the microscope, the opacity being caused by minute indeterminate inclusions, many of them apparently unreplaced ore minerals. The mineral, free from any inclusions, is colorless and transparent in thin pieces. The cleavage on the hand specimen is distinct and the cleavage faces have a decidedly pearly luster. The direction of the cleavage is basal, such fragments, which are unaltered, being isotropic and yielding a uniaxial positive interference figure. This basal cleavage is believed to be the cleavage of the original mineral (goyazite ?), whose alteration has yielded crandallite. The cleavage of crandallite could not be determined. The density was not determined, on account of the scarcity of the material and because of the many impurities. The brittle mineral has a hardness of about 4.

Optical properties.—The white or gray crandallite is colorless and non-pleochroic under the microscope. The material analyzed contained a considerable amount of impurities, chiefly quartz, with a little barite and traces of sulphides. The

crandallite was in irregular granular or cryptocrystalline masses, many of which showed distinctly on high magnification a fibrous structure in large part radiating. The individual fibers are very minute and it was not possible to isolate on the glass slide a fragment or fiber which was composed of only one unit. The refractive indices of the mineral showed a minimum of 1.585 and a maximum of 1.595, the birefringence of the material ranging from zero to a maximum of about 0.01. Some of the material appears amorphous, but it may be very

FIG. 1.

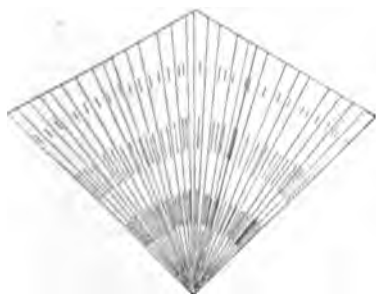


FIG. 2.

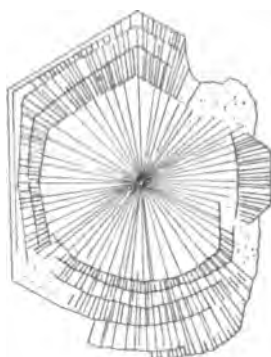


FIG. 1. A portion of a hexagonal crystal, basal section, showing concentric, radiating fibrous structure. A pseudomorph of crandallite (fibrous) after goyazite (?).

FIG. 2. A crystal plate showing fibrous structure, and with a birefracting center with isotropic rim. A pseudomorph of crandallite (fibrous) after goyazite (?).

finely cryptocrystalline. The fibers apparently have parallel extinction and the elongation is negative.

Some of the crandallite on the hand specimen which appeared better crystallized than the material analyzed, was crushed and examined optically. In this crushed material were found several irregularly shaped to poorly defined hexagonal plates which were isotropic, uniaxial, positive, and which on edge gave parallel extinction and a moderate birefringence (estimated as about 0.01-0.02). The refractive index varied from about 1.605 ± 0.005 to 1.62. Some of these plates were uniform in structure and isotropic; others showed a concentric, radiating, fibrous structure (fig. 1), and were either isotropic (index about 1.605 ± 0.005) or else feebly birefracting. A single crystal plate showed an inside area which was feebly birefracting, the fibers giving parallel extinction while the outside rim was isotropic, although both parts showed a distinct fibrous structure as shown in fig. 2.

Pyrognostics.—Heated in a blowpipe flame, crandallite decrepitates somewhat, then exfoliates slightly and fuses to an opaque white enamel, coloring the flame intermittently a pale green (phosphorous) with occasional flashes of red (calcium, strontium). In a closed tube decrepitation occurs with the liberation of water. Soluble in acids.

Chemical composition.—The results of the analysis are as follows, the material being dissolved in acids and the insoluble residue filtered off and weighed. The insoluble residue consisted of 97 per cent SiO_2 , the remainder being barite with traces of sulphides.

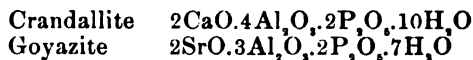
Analysis of Crandallite. [W. T. Schaller, analyst.]

	Analysis	Same with insoluble deducted			Ratios
Insol.	35.13				
Al_2O_3	25.16	38.71	0.379	0.379	1.96 or 2×0.98
CaO	4.88	7.50	.134	.178	.92 or 1×0.92
SrO	1.44	2.21	.021		
MgO	0.61	0.94	.023		
P_2O_5	17.61	27.09	.191	.215	1.11 or 1×1.11
SO_3	2.47	3.80	.047		
$\text{H}_2\text{O}-$	0.84	1.29	.072		
$\text{H}_2\text{O}+$	12.26	18.86	1.048	1.048	5.43 or 5×1.09
	<hr/> 100.40	<hr/> 100.40			

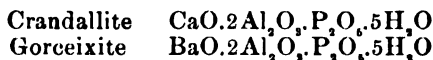
An inconclusive test for rare earths (probably cerium) seemed to show their presence to a slight extent but the identification was not verified. Barium could not be detected in the acid-soluble part, neither was any barium sulphate precipitated on solution of the mineral. The barium sulphate in the insoluble residue was in relatively large cleavage plates, plainly derived from the mineral barite.

Genetic relations.—The ratios of the analysis yield the formula $\text{CaO} \cdot 2\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 5\text{H}_2\text{O}$ with slight replacement of CaO by SrO and MgO , and of P_2O_5 by SO_3 [or more exactly of $(\text{HPO}_3)''$ by $(\text{SO}_3)''$].

This type of formula is slightly different from that of goyazite (hamlinite),



but is of the same type as that of gorceixite.



In an earlier paper it was suggested* that gorceixite was the barium equivalent of goyazite (hamlinite) and that its formula should be written $2\text{BaO} \cdot 3\text{Al}_2\text{O}_3 \cdot 2\text{P}_2\text{O}_5 \cdot 7\text{H}_2\text{O}$. The original analysis gives ratios which do not support this suggestion but lead to the formula $\text{BaO} \cdot 2\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 5\text{H}_2\text{O}$. Thin sections of gorceixite are stated to have shown an aggregate of minute, colorless, irregular grains, therefore, apparently not fibrous. The question thus arises: What is the systematic position of gorceixite? Does it belong in the alunite-bendantite group with goyazite (hamlinite), plumbogummite, and florencite, and would another analysis on pure material agree better with the type formula, $2\text{RO} \cdot 3\text{Al}_2\text{O}_3 \cdot 2\text{P}_2\text{O}_5 \cdot 7\text{H}_2\text{O}$; or is gorceixite, with the formula $\text{BaO} \cdot 2\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 5\text{H}_2\text{O}$, a fibrous alteration product of a pre-existing unknown mineral of the goyazite type of formula; or is gorceixite a non-fibrous mineral, with the formula $\text{BaO} \cdot 2\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 5\text{H}_2\text{O}$, as independent genetically as goyazite and not a fibrous alteration product of some pre-existing mineral of a similar chemical composition?

The formulas of goyazite and gorceixite have been discussed by Farrington† in a recent paper. The three analyses (by H. W. Nichols) of Brazilian favas given by Farrington represent well the composition of the favas but are of no value for the elucidation of the composition of any mineral. His material was not examined optically to see if it was homogeneous or free from impurities. The analysis of Fava No. 2 baffled interpretation so that Farrington concluded that "this fava was evidently a mixture." Of Fava No. 3 he finally states: "Of its optical properties nothing can be stated since, unfortunately, all the substance of the fava was used for the chemical analysis."

The homogeneity and character of transparent minerals can be so easily and quickly determined by the present day facilities for microscopic examination (imbedding in oils of known index) that it is a matter of regret that mineralogical papers are still published with detailed and careful chemical analyses of material which has not been first submitted to microscopic examination.

The fibrous plumbogummite, described by Lacroix‡ (hitchcockite?), may represent a distinct species related to plumbogummite as crandallite is to goyazite.

A sulphate mineral possibly related to crandallite was described

* Schaller, W. T., The alunite-bendantite group, this Journal, (3), xxxii, 359, 1911. In Mineralogical Notes, Series 2, U. S. Geol. Survey, Bull. 509, p. 76, 1912.

† Farrington, O. C., Studies of Brazilian favas, this Journal, (4), xli, 355, 1916.

‡ Lacroix, A., Minéralogie de la France, vol. IV, p. 586, 1910.

by Lindgren* as a basic hydrous strontium sulphate which occurs as an impalpable white powder covering granular celestite, in a vein on level 7 of the Ironclad Mine, Cripple Creek, Colorado. Under the microscope the mineral was seen to consist of short and extremely delicate white fibers of very feeble double refraction and an extinction which is probably parallel. An analysis by W. T. Schaller of a very small quantity gave: SrO, 25.1; CaO, 15.1; Al₂O₃, 13.9; MgO, 2.5; SO₃, 13.9; H₂O (107°), 0; H₂O (ignition), 24.1; total, 94.6. No water was lost at 100° and at 260° only 1.49 per cent H₂O was driven off. No test for phosphoric acid was made and the material was too limited in quantity and of too undetermined purity for these figures to have much more than a qualitative value.

The relations of these minerals, especially of the fibrous ones to those not fibrous (those of the alunite-bendantite group), are not at all clear, but the composition of crandallite seems to indicate that there is a definite group of fibrous minerals which are closely related in the type of formula to those of the alunite-bendantite group and yet seem to be very distinct therefrom and to probably result from their alteration.

*Lindgren, W., and Ransome, F. L., *Geology and gold deposits of the Cripple Creek district, Colorado*. U. S. Geol. Survey, Prof. Paper 54, p. 125, 286, 1906.