WARDITE FROM BERYL MOUNTAIN, NEW HAMPSHIRE*

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ABSTRACT

Wardite in well-formed, white to colorless crystals has been found in a pegmatite at Beryl Mountain near West Andover, New Hampshire. Tetragonal-pyramidal, $P4_1$. The forms present are: $c\{001\}$, $a\{010\}$, $m\{110\}$, $u\{011\}$ and $t\{012\}$. $a_0=7.04$ Å, $c_0=18.88$ Å; $a:c=a_0:c_0=1:2.6818$. Composition: Al_2O_3 38.70, FeO 0.26, MgO 0.21, Na_2O 7.51, K_2O 0.16, P_2O_5 35.12, H_2O 17.88, which gives the formula $NaAl_3(PO_4)_2(OH)_4 \cdot 2H_2O$, with 4 formula weights in the unit cell. G=2.81 measured and calculated. nO=1.5940, nE=1.6040 $\pm$0.0005.

Active mining of beryl at Beryl Mountain near West Andover, New Hampshire, during the past few years has uncovered several interesting minerals. The most unusual for this pegmatite is a single specimen composed mostly of quartz with an area on one side about 10×15 centimeters, coated with white to colorless crystals of wardite. This is the third locality for wardite. The original description was by Davison (1896) of material from Fairfield, Utah. Wardite from the same locality has subsequently been studied by Larsen and Shannon (1930), Pough (1937), and Larsen (1942). The mineral soumansite, described by Lacroix (1910) from Montebras, France, was shown by Larsen and Shannon to be identical with wardite.

Morphology. The Beryl Mountain wardite is in well-formed crystals ranging from 1 millimeter to 10 millimeters in a maximum dimension. These crystals are much larger than those earlier described; the largest crystals from Fairfield are slightly over 1 millimeter in maximum dimension. The Beryl Mountain crystals are similar to those described by Pough (1937) and are dominated by the pyramids $\{012\}$ and $\{01\bar{2}\}$ as shown in Figs. 1 and 2. Some crystals show sharp signals from the faces of $\{011\}$ and $\{012\}$ whereas others give a continuous signal train between the faces of these two forms. Although $\{010\}$ is more commonly present than $\{110\}$, the faces are of poorer quality than those of the first-order prism. Pough did not observe $\{110\}$ on Fairfield crystals; none of the forms he considered doubtful was found on crystals from Beryl Mountain. Although the crystal class is tetragonal-pyramidal, the crystals are symmetrically developed with the same forms at opposite ends of the c axis.

From single crystal x-ray measurements Larsen (1942) calculated the axial ratio as $a_0:c_0=1:2.6818$. Pough, by taking the c value as one half

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the true unit, calculated from morphological measurements: $a:c = 1:1.3117$. Larsen made the reasonable assumption that the ratio from x-ray data was more accurate than that derived from morphology because of the " . . . poor quality of the crystals and the great range of

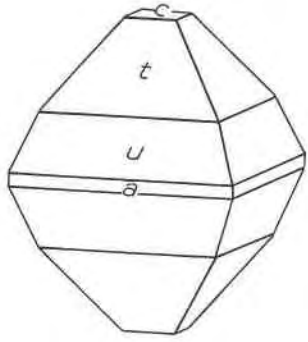

FIG. 1

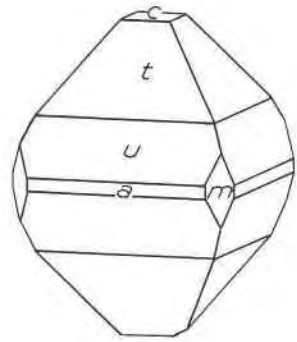

FIG. 2

Wardite crystals, Beryl Mountain.

Pough's measured values." The transformation of Pough to Larsen (100/010/002) gives for Pough's dominant form, t {0.13.12} the symbol {0.13.24}. Larsen assumed that this should probably be {102} and calculated for it the ρ value using his axial ratio.

In the present study seven of the best wardite crystals from Beryl Mountain were measured on the two-circle goniometer. The results are given in Table 1.

TABLE 1. WARDITE—$NaAl_3(PO_4)_2(OH)_4 \cdot 2H_2O$, TETRAGONAL-PYRAMIDAL—$P4_1$
(measured and calculated angles)

Form	No. of faces	Measured range ρ	Measured mean ρ	Calculated angles* ϕ	Calculated angles* ρ
c 001	7	—	—	—	0°00′
a 010	8	—	—	0°00′	90 00
m 110	6	—	—	45 00	90 00
u 011	6	69°12′–69°52′	69°35′	0 00	69 33
t 012	21	53 7 –53 38	53 20	0 00	53 17

* From Larsen (1942) with $p_0 = 2.6818$ and $a:c = 1:2.6818$.

It will be noted that the measured ρ of t {012} is close to the calculated value and proves that this is the true symbol as assumed by Larsen. Weissenberg photographs of Beryl Mountain wardite proved to be iden-

tical to those taken by Larsen on a Fairfield crystal. The cell dimensions: $a_0 = 7.04$ Å ± 0.02, $c_0 = 18.88$ Å ± 0.02 yield the ratio $a_0 : c_0 = 1 : 2.6818$. Although the crystals from Beryl Mountain are of much better quality than those from Fairfield, it seems unwise to use their measurements to introduce a new morphological axial ratio but rather to assume as correct, for both unit cell and morphology, the ratio given above.

Chemical composition. A chemical analysis of wardite from Beryl Mountain was made by F. A. Gonyer in connection with the present study. It is given in Table 2 with two earlier analyses.

TABLE 2. CHEMICAL ANALYSES OF WARDITE

	1	2	2a	3	4	5
Al_2O_3	38.25	36.54	36.6	38.25	38.70	38.43
FeO	0.76	—	—		0.26	
CaO	—	3.30	3.0	none	—	
MgO	2.40	—	—	.33	0.21	
CuO	0.04	—	—		—	
Na_2O	5.98	6.68	7.0		7.51	7.79
K_2O	0.24	0.73	0.6		0.16	
P_2O_5	34.46	34.76	34.9	34.58	35.12	35.68
H_2O	17.87	17.85	17.9		17.88	18.10
	100.00	99.86	100.0		99.84	100.00
Sp. Gr.	2.77	2.81			2.81	2.81

1. Davison (1896)—Fairfield, Utah.
2. Shannon (Larsen and Shannon, 1930)—Fairfield, Utah.
2a. Analysis 2 corrected for impurities.
3. Gonyer—(Partial analysis), Fairfield, Utah.
4. Gonyer—Beryl Mountain, New Hampshire.
5. Calculated composition: $NaAl_3(PO_4)_2(OH)_4 \cdot 2H_2O$.

The above table shows striking differences in analyses of wardite from Fairfield, Utah; Davison giving MgO = 2.40 per cent with no CaO and Shannon giving CaO = 3.30 per cent with no MgO. Larsen and Shannon state that Davison's analysis " . . . was probably made on a less pure sample." In order to determine which of these analyses is more probably correct, Gonyer made a partial analysis of Fairfield wardite. He found no CaO and only 0.33 per cent of MgO. The analysis, therefore, checked neither of the earlier ones but did agree closely with the analysis of wardite from Beryl Mountain.

In Table 3 the analysis of Beryl Mountain wardite is given recalculated to 100 per cent. Using these percentages and the molecular weight of the unit cell (1593), the number of atoms in the unit cell was calcu-

lated and is given in column 4. If it is assumed that these numbers represent the integers 12, 4, 8 and 32, respectively, the composition of wardite can be written as: $NaAl_3(PO_4)_2(OH)_4 \cdot 2H_2O$ with 4 formula weights in the unit cell. Larsen (1942) wrote the formula based on the analysis of Shannon as: $CaNa_4Al_{12}(PO_4)_8(OH)_{18} \cdot 6H_2O$. However, the the specific gravity calculated for this formula and the unit cell volume is 2.87. Using the same volume for the unit cell, but with the formula, $NaAl_3(PO_4)_2(OH)_4 \cdot 2H_2O$, the calculated specific gravity is 2.81. This agrees exactly with the measured specific gravity of wardite from Beryl

TABLE 3. WARDITE: ATOMS PER UNIT CELL

	Analysis 4 of Table 2 reduced to 100 per cent	Molecular ratios	Atomic ratios	Atoms/unit cell
Al_2O_3	38.76	.3802	.7604	12.1
FeO	0.26	.0036	.0036	
MgO	0.21	.0052	.0052	
Na_2O	7.52	.1139	.2278	3.8
K_2O	0.16	.0017	.0034	
P_2O_5	35.18	.2477	.4954	7.9
H_2O	17.91	.9950	1.990	31.6
	100.00			

Mountain as well as that from Fairfield, Utah, as reported by both Larsen and Shannon (1930) and Larsen (1942).

Optical Properties. The optical properties of wardite from Beryl Mountain compared with those of wardite from Fairfield, Utah (Larsen and Shannon) are:

Beryl Mountain		*Fairfield, Utah*
nO 1.5940	±.005 uniaxial (+)	1.590 ±.005 uniaxial (+)
nE 1.6040		1.599

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