THE MORPHOLOGY OF GORDONITE

F. H. Pough, *American Museum of Natural History, New York City.*

At the time of the discovery of the hydrous magnesium aluminum phosphate gordonite ($MgO \cdot Al_2O_3 \cdot P_2O_5 \cdot 9H_2O$) by Larsen and Shannon (1930), the material available for a crystallographic study was of poor quality. In the fall of 1936 the original locality at Fairfield, Utah, was visited by Arthur Montgomery and Edwin Over, and a quantity of new material was collected. Subsequent examination showed far better crystals of a number of the unusual phosphates of this locality than were found in any of the material used in the original descriptions. Gordonite was one of these minerals.

The phosphates form isolated nodules up to a foot in diameter. Most are smaller, however, and lie in apparent layers in an impure shattered limestone. The nodule-bearing bands are about a foot in thickness, with the concretions irregularly distributed through the soft rock.

All of the nodules were originally composed of variscite, which, through alteration, has given rise to the many unusual and sometimes unique phosphates. Pseudowavellite and wardite are the most abundant now present, often appearing to be the final stable alteration products. During the change, shrinkage took place with resultant cavities between the residual variscite and the enveloping pseudowavellite. In these cavities solutions of fluctuating composition penetrated the nodules and permitted the formation of crystals of some of the rarer minerals. One of the most notable is the gordonite, which is attached to either face, on the variscite or the pseudowavellite. Good crystals of wardite were also found, the morphology of which will be considered in a later paper.

Gordonite is thus easily recognized in the specimens from its characteristic relation to the variscite and the pseudowavellite. When pure and free from the matrix, it develops white transparent crystals, but it is gray when attached to the pseudowavellite or variscite. Free tips of the grayish crystals are often pale pink, but the color is only noticeable in the upper extremities of the crystal bundles where the crystals grew freely. Most of the crystals are grouped together in these bundles, radiating outward in sheaf-like aggregates with all the individuals of any group similarly terminated. A few crystals are perched sideways upon other crystals and are doubly terminated. They vary in size from individuals of 0.5 to 1 mm. and aggregates up to 5 or more mm. in length, down to extremely minute crystals. Measurements were made of all types of material; the extremely minute crystals gave slightly better results than the larger ones.

The tendency toward a sheaf-like growth was revealed in the individual crystals as well as in the clusters, for it was often observed that ρ readings in excess of 90° could be obtained through the entire revolution on the vertical circle. The variation was but a few minutes in most cases and presumably of no significance, aside from this characteristic.

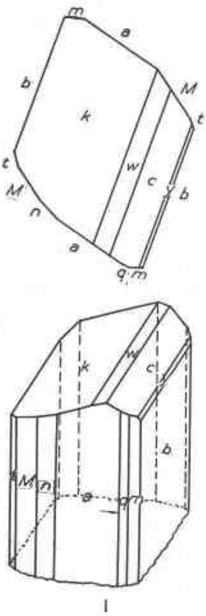

Fig. 1

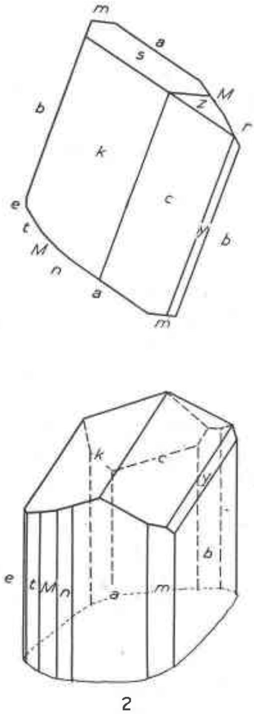

Fig. 2

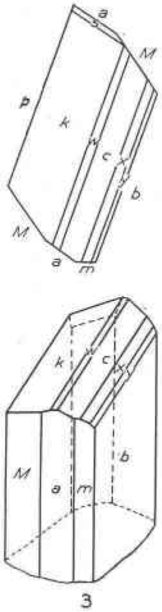

Fig. 3]

The crystals are all strongly striated and most are unsatisfactory for measurement. The main zone [001] is most strongly striated; the zone [100] is similarly marked and often gives no distinct signals. In the normal triclinic setting (Peacock, 1937) the prominent cleavage is {010}; there is also a fair cleavage {100} and a poor but distinct cleavage {001}. As shown by Larsen and Shannon (1930), gordonite resembles the chemically related triclinic species paravauxite (Gordon, 1923) in form and angles. This similarity appears in the triclinic projection elements of the two species in Gordon's setting:

Gordonite (Pough)

$$p_0'=1.496,\ q_0'=0.755;\ x_0'=0.383,\ y_0'=0.275;\ \nu=73°19\tfrac{1}{2}'$$

Paravauxite (Gordon)

$$p_0'=1.5012,\ q_0'=0.7183;\ x_0'=0.3715,\ y_0'=0.2382;\ \nu=75°15'.$$

In the normal setting the elements and indices of both species are related to Gordon's setting by the transformation:

Gordon to Pough: 100/110/001

By graphical solution the mean measurements on the common forms, $c\{001\}$, $b\{010\}$, $a\{100\}$, $y\{011\}$, $k\{0\bar{1}1\}$, $M\{1\bar{1}0\}$, give the approximate projection elements:

$$p_0'=1.469,\ q_0'=0.755;\ x_0'=0.383,\ y_0'=0.275;\ \nu=102°49'$$

leading to the polar and linear elements:

$$p_0:q_0:r_0=1.3287:0.6829:1;\ \lambda=\ 75°36',\ \mu=\ 73°35',\quad \nu=102°49',$$
$$a:b:c:=0.5192:1:0.6942;\ \alpha=109°27',\ \beta=110°57\tfrac{1}{2}',\ \gamma=\ 71°40\tfrac{1}{2}'$$

Table 1 summarizes the measurements on thirteen crystals of gordonite; table 2 is a formal angle-table for the accepted forms. It will be seen that the calculated co-ordinate angles mostly lie well within the measured range. In addition to the nineteen accepted forms, measurements were obtained corresponding roughly to the symbols $\{510\}$, $\{4\bar{7}0\}$, $\{1\bar{4}0\}$, $\{\bar{1}01\}$, $\{\bar{2}\bar{1}1\}$. These must be regarded as uncertain forms until better measurements are made.

TABLE 1. GORDONITE: TWO-CIRCLE MEASUREMENTS ON THIRTEEN CRYSTALS

Forms	No. of faces	Measured Range		Measured Mean	
		φ	ρ	φ	ρ
c 001	10	53°18′– 56°17′	24°22′–26°00′	54°47′t	25°14′
b 010	26	—	—	0 00	90 00
a 100	12	104 14 –101 13	—	102 49	90 00
m 110	7	74 02 – 75 05	—	74 47	90 00
j $5\bar{1}0$	1	—	—	108 00	90 00
p $4\bar{1}0$	2	110 06 –110 32	—	110 19	90 00
i $3\bar{1}0$	2	111 09 –112 30	—	111 50	90 00
n $2\bar{1}0$	3	114 46 –117 18	—	116 22	90 00
l $3\bar{2}0$	2	118 19 –119 54	—	119 06	90 00
M $1\bar{1}0$	17	126 07 –129 03	—	127 07	90 00
r $2\bar{3}0$	2	134 16 –135 44	—	135 00	90 00
t $1\bar{2}0$	6	141 05 –143 04	—	142 46	90 00
d $1\bar{3}0$	3	149 35 –150 33	—	150 05	90 00
f $1\bar{5}0$	1	—	—	161 11	90 00
e $1\bar{7}0$	4	164 18 –166 08	—	165 13	90 00
x 013	1	37 08 – 38 18	32 10 –32 25	37 43	32 18
y 011	4	19 15 – 22 33	46 03 –48 50	20 47	47 51
w $0\bar{5}6$	4	133 05 –135 35	26 53 –27 47	134 03	27 21
k $0\bar{1}1$	11	139 14 –146 54	30 52 –33 02	141 42	31 20

Table 2. Gordonite—$MgO \cdot Al_2O_3 \cdot P_2O_5 \cdot 9H_2O$
Triclinic; pinacoidal—$\bar{1}$
$a:b:c=0.5192:1:0.6942$; $\alpha=109°27'$, $\beta=110°57\frac{1}{2}'$, $\gamma=71°40\frac{1}{2}'$
$p_0:q_0:r_0=1.3287:0.6829:1$; $\lambda=75°36'$, $\mu=73°35'$, $\nu=102°49'$
$p_0'=1.469$, $q_0'=0.755$; $x_0'=0.383$, $y_0'=0.275$

Forms		φ	ρ	*A*	*B*	*C*
c	001	54°19½′	25°14½′	73°35′	75°36′	0°00′
b	010	0 00	90 00	102 49	0 00	75 36
a	100	102 49	90 00	0 00	102 49	73 35
m	110	73 19½	90 00	29 28½	73 19½	66 13
j	$5\bar{1}0$	108 25	90 00	5 36	108 25	75 31
p	$4\bar{1}0$	109 46	90 00	6 57	109 46	76 00
i	$3\bar{1}0$	111 57½	90 00	9 08½	111 57½	76 48½
n	$2\bar{1}0$	116 09	90 00	13 20	116 09	78 23
l	$3\bar{2}0$	120 04	90 00	17 15	120 04	79 54½
M	$1\bar{1}0$	127 02½	90 00	24 13½	127 02½	82 41
r	$2\bar{3}0$	135 31	90 00	32 42	135 31	86 15½
t	$1\bar{2}0$	142 02½	90 00	39 13½	142 02½	89 01½
d	$1\bar{3}0$	151 04	90 00	48 15	151 04	92 52
f	$1\bar{5}0$	160 45	90 00	57 56	160 45	96 56½
e	$1\bar{7}0$	165 40½	90 00	62 51½	165 40½	98 56
x	013	36 01½	33 04½	77 35	63 48½	11 47
y	011	20 24	47 42	84 24	46 07	29 29
w	$0\bar{5}6$	132 45½	27 33	66 22½	108 18	32 42
k	$0\bar{1}1$	141 25	31 33	65 51½	114 08½	38 33

In the vertical zone, the dominant form is *b*{010}, which has broad faces giving somewhat confused signals in most cases, because of the outwardly curving surface already mentioned and other irregularities. The luster on this surface is pearly, as in paravauxite; this, together with the prominent cleavage {010}, makes orientation of the crystals easy.

The form next in frequency in the vertical zone is *a*{100}, which, in combination with *b*{010}, determines the outlines of the crystals. The form *a* is about half as frequent as *b*; it is rarely plane, and usually shows a series of striations parallel to the prism edges, resulting in a train of reflections rather than a single sharp signal. A brilliant signal comes in the proper place in the train, however.

Equally common in occurrence is *M*{$1\bar{1}0$}, which is often the same size as *a* and similar in appearance. It is likewise striated, and exact measurement is not easy. This is probably the form to which Larsen refers in his brief angle-table as {490}.

The form *t*$\{1\bar{2}0\}$ is much rarer and usually narrower than *M* and *a*. It is also striated vertically and gives a train of reflections in which the reflection from $(1\bar{2}0)$ stands out as a sharp signal on many of the crystals. In gordonite, as in paravauxite, all of the vertical planes except *m* lie in the negative quadrants (2 and 4). Since the symbolization of a large number of complex forms would be quite futile, only the simpler and more prominent ones have been accepted. Most of these were observed several times in fair position on different crystals. The symbols of the vertical zone do not conform to the normal complication series of Goldschmidt; they do, however, exactly fit the Harmonic-Arithmetic series of Peacock (1936), thus indicating that the chosen vertical axial planes are axial planes of the structural lattice.

On the terminations the base is sometimes lacking, the entire crystal being truncated by a large face *k*$\{0\bar{1}1\}$. The face is plane, usually without striations, and gives excellent signals. Next in frequency and importance in this zone is the *c*{001}, which is rarely as large as *k*. It is often striated parallel to its intersection with *b* and *k*. Third in frequency in this zone is *y*{011}, which, though frequently present, is invariably a narrow line form, giving a poor signal. Sometimes the termination of a gordonite crystal resembles the vertical zone in the multiplicity of its striations, a continuous train of reflections extending from *c*, rarely even from *k*, to *y*. Two more forms were observed several times in this train, *w*$\{0\bar{5}6\}$ and *x*{013}. Both were present as distinct forms, but only on the crystals presenting the strongly striated terminations. The terminal forms *s*$\{\bar{2}\bar{1}1\}$ and *z*$\{\bar{1}01\}$ are very rare. The form *s*$\{\bar{2}\bar{1}1\}$, already observed by Larsen and Shannon, was found on several crystals in one radiating aggregate; *z*$\{\bar{1}01\}$ was seen once as a small face.

Many crystals of gordonite are terminated wholly by *k*$\{0\bar{1}1\}$. Another common habit is shown in fig. 1. The habit shown in fig. 2 is rare. The usual appearance of crystals with *s*$\{\bar{2}\bar{1}1\}$ is shown in fig. 3 in which *s* appears as a large pyramidal face truncating the edge between *k* and *a*′.

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References

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