ON AMBLYGONITE

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ABSTRACT

Two new occurrences of amblygonite at Hebron and Newry, Maine, furnished measurable crystals. New elements based on x-ray study required a new orientation from that of Dana. Transformation from Dana to Richmond and Wolfe is as follows: 001/011/100. $a:b:c=0.7255:1:0.7028$; $\alpha=111°\ 59\frac{1}{2}'$, $\beta=97°\ 46\frac{1}{2}'$, $\gamma=68°\ 16\frac{1}{2}'$, $a_0=5.18Å$, $b_0=7.11Å$, $c_0=5.03Å$, $\alpha=112°\ 02\frac{1}{2}'$, $\beta=97°\ 49\frac{1}{2}'$, $\gamma=68°\ 07\frac{1}{2}'$. The cell contains $2[LiAlPO_4(OH,F)]$. The new angle table contains, besides the forms known previously, 10 new forms.

Amblygonite, a fluophosphate of aluminum, sodium and lithium, is an important constituent of lithium-bearing granite pegmatites. It has been found in many localities and is of commercial importance because of its high lithium content. The crystals are often of great size, and cleavage masses are familiar to all students of pegmatite minerals. But, although its chemistry and general physical properties are well known, detailed description of its crystal morphology has been lacking because adequate material for its study has never hitherto been found. It is now possible to supply this deficiency through the study of two new occurrences of amblygonite in the towns of Hebron and Newry in Maine. The two suites of crystals are widely different in character but yield crystallographic data which are entirely harmonious. As the material came to the Harvard Mineralogical Museum at different periods, the study of the two occurrences has been carried on independently and it is therefore presented, as it was written, in two parts.

PART 1. AMBLYGONITE FROM HEBRON, MAINE

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About five years ago the late W. D. Nevel of Andover, Maine, discovered a small pocket in the lithium pegmatite which he was working at Hebron. The walls of the cavity, consisting of quartz and microcline, were thickly encrusted with tiny sharp-pointed, white crystals whose identity remained unknown to Mr. Nevel and was established as amblygonite by Richmond. The entire contents of the cavity in the form of about twenty small fragments of the wall-rock coated with the crystals, were secured for the Harvard Collection in 1938 and bears the single catalogue number 94819.

The crystals of amblygonite are white, translucent to transparent, and

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vary in size from one-half to three millimeters in the direction of elongation [010]. They are generally attached to the matrix by one end of this *b*-axis and are of two types, although all prove to be twin crystals. The types differ chiefly in the degree of their tabular development, which is illustrated in the drawings (Figs. 1 and 2). In one they are thin-tabular parallel to the plane of composition of the twins $\{\bar{1}\bar{1}1\}$, and the individuals are either exactly symmetrical to this plane or approximately so. In the other type the flattening is parallel to the prism $\{110\}$ and the two individuals are of very unequal size. The two types are intermingled on the surfaces where they occur with no apparent difference in age. The faces of these tiny crystals are for the most part brilliant and plane, giving excellent reflections on the goniometer. But there are delicate striations in the prism zone [001], and one form is characteristically curved as described below.

Orientation of Amblygonite. Des Cloizeaux (1863) gave the first crystallographic setting based on measurements of cleavage only. He assigned the three cleavages which he found to $p\{001\}$, $m\{1\bar{1}0\}$, and $t\{110\}$. He established the presence of lamellar twinning in two directions, to which he assigned the symbols $L\{1\bar{1}1\}$ and $H\{\bar{1}11\}$. It may be worthy of note that the diagrammatic figure in Dana's *System* (Fig. 2) "after *Dx*" shows two cleavages and a large face *s*, which is an arbitrarily cut surface and not a cleavage. Des Cloizeaux wrote several papers on the mineral but seems never to have had crystals with determinable form. Groth (1889) and Goldschmidt (1886) retained this orientation, but the latter assigned different letters to the cleavage forms.

J. D. Dana (1873) seems to have been the first to measure a crystal of amblygonite. E. S. Dana (1892) remeasured this rough but definite crystal which came from Hebron, and from his contact measurements established the elements and forms which have been accepted since then by all authors. The elements are of necessity but first approximations to accurate values, a fact which should have been indicated by expressing them in terms of two places of decimals and the angles in whole degrees rather than in five place of decimals and fractions of a minute as Dana did. Later contributions to the morphology of amblygonite have been few. Schaller (1916) measured by contact rough crystals of sodium-rich members of the series upon which he found, besides forms already known, the side pinacoid $\{010\}$. Quensel (1937) and Tenger (1940) described the amblygonite of Värutrask, Sweden, on which the side pinacoid was also found as well as the additional new form $\{0\bar{1}1\}$. These writers employed Dana's position and elements.

To avoid confusion, new letters have been assigned to all the forms.

The transformation formulae leading to the correlations of Table 1 are as follows:

Des Cloizeaux to Dana	$200/\bar{1}\bar{1}0/002$
Des Cloizeaux to Richmond and Wolfe	$002/\bar{1}\bar{1}2/200$
Dana to Richmond and Wolfe	$001/011/100$

TABLE 1. AMBLYGONITE: CORRELATION OF SETTINGS

Richmond	Cleav.	Des-cloizeaux	Cleav.	Dana	Cleav.
c 001	Imperf.	*m* $1\bar{1}0$	best	*a* 100	Less perf. than *c*
**b* 010		—		—	
a 100	Perf.	*i*	3d best	—	Not given
w 110	Good	*p* 001	2d best	*c* 001	Perf.
W $1\bar{1}0$	None	—		*e* $0\bar{2}1$	"As good as *a* sometimes"
o 011		—		*m* 110	
d $0\bar{1}1$	Distinct	*t* 110	bad	*M* $1\bar{1}0$	Difficult
u $0\bar{2}1$		—		*z* $1\bar{2}0$	
r 111		*L* $1\bar{1}1$	(Twin.)	*l* 101	As twin plane
t $\bar{1}11$		*H* $\bar{1}\bar{1}1$	(Twin.)	*h* $\bar{1}01$	As twin plane
**s* $\bar{1}21$		—		—	

* Denotes new form.

The results of our x-ray cell determination require a new orientation to satisfy the conventional rules for the triclinic system. It proved that Dana's elements, transformed to the new position, were very similar to the new elements derived from the x-ray and morphological studies.

X-Ray Lattice Constants. The crystal used in the determination of the lattice constants was the smaller individual of a twin. This crystal was colorless and flawless, exhibited no evidence of twinning under the microscope, and was 0.25 mm. in its greatest dimension. Rotation, zero and first-layer line Weissenberg photographs were taken about three zone axes, which proved to be the three shortest non-coplanar identity periods and therefore the crystallographic axes.

The measured and calculated values obtained from these photographs are summarized as follows:

$$a_0=5.18,\ b_0=7.11,\ c_0=5.03\text{Å}$$
$$a_0:b_0:c_0=0.729:1:0.709;\quad \alpha=112°02\tfrac{1}{2}';\quad \beta=97°49\tfrac{1}{2}';\quad \gamma=68°07\tfrac{1}{2}'$$
$$a^*:b^*:c^*=0.970:0.755:1;\quad \alpha^*=69°19\tfrac{1}{2}';\quad \beta^*=90°14\tfrac{1}{2}';\quad \gamma^*=110°29\tfrac{1}{2}'$$

These constants agree closely with the morphological elements (Table 3).

Crystal Measurements. Some thirty crystals from Hebron were measured in two positions on the two-circle goniometer. At first, before the best setting had been determined, crystals were set up with the dominant zone containing the twin plane vertical. This proved to be equivalent to Dana's setting in second permutation, that is with the zone [010] Dana, [011] Richmond, vertical.

The proper orientation having been determined by the x-ray study, the crystals were remeasured in the chosen position with the results summarized in Table 2. The observed angles of the forms marked with an asterisk in that table constituted the basis for calculation of new elements which are shown in Table 3, together with the angles calculated from them for the various known forms shown in Table 1.

TABLE 2. AMBLYGONITE: SUMMARY OF MEASURED AND CALCULATED ANGLES

Form	No. Faces	Measured Range		Weighted Mean		Calculated	
		ϕ	ρ	ϕ	ρ	ϕ	ρ
*c 001	60	19°28′– 19°58′	21°25′–22°08′	19°46½′	21°59′	19°46½′	21°59′
b 010	8	359 22 – 0 56	90°00′	0 10	90 00	0 00	90 00
*a 100	60	110 12 – 110 29	90 00	110 21	90 00	110 21	90 00
w 110	42	65 21 – 65 38	90 00	65 28	90 00	65 30	90 00
W $1\bar{1}0$	28	139 48 – 140 22	90 00	139 58	90 00	140 08	90 00
o 011	1	6° 38′	50 42	6 38	50 42	6 33½	50 06
*d $0\bar{1}1$	60	162 13 – 162 24	24 08 –24 20	162 19	24 12½	162 19	24 12½
*t $\bar{1}\bar{1}1$	60	−94 20 – −94 34	39 52 –40 15	−94 28½	40 09	−94 28½	40 09
s $\bar{1}21$	16	−135 22 – −136 58	49 21 –51 18	−135 43	50 01	−136 06	50 30

* Fundamental angles used for calculation.
b an *s* arc new forms.

TABLE 3. AMBLYGONITE: ANGLE-TABLE

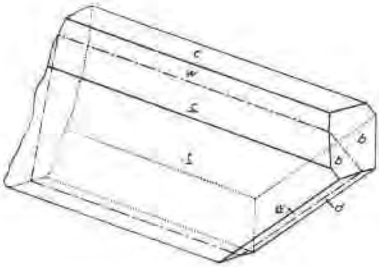
Amblygonite—(Li, Na)$AlPO_4$(OH,F)
Triclinic: pinacoidal—$\bar{1}$
$a:b:c=0.7255:1:0.7028$; $\alpha=111°59\frac{1}{2}'$; $\beta=97°46\frac{1}{2}'$; $\gamma=68°16\frac{1}{2}'$
$p_0:q_0:r:=0.9669:0.7495:1$; $\lambda=69°22'$; $\mu=90°13'$; $\nu=110°21'$
$p_0'=1.0427$, $q_0'=0.8083$; $x_0'=0.1366$, $y_0'=0.3800$

Forms		φ	ρ	A	B	C
c	001	19°46½′	21°59′	90°13′	69°22′	—
**b*	010	0 00	90 00	110 21	—	69°22′
a	100	110 21	90 00	—	110 21	90 13
***Z*	120	37 56½	90 00	72 24½	37 56½	69 13
w	110	65 30	90 00	44 51	65 30	74 51
W	1̄10	140 08	90 00	29 47½	140 08	100 54½
o	011	6 33½	50 06	100 32	40 21	29 01½
***q*	021	3 55	63 27	104 40	26 49	42 33
d	01̄1	162 19	24 12½	75 22	112 59½	43 37½
u	02̄1	173 42	51 12½	69 32½	140 46½	71 24½
r	111	53 27½	54 12½	63 42	61 07	37 20½
***f*	2̄23	− 80 51½	27 33	116 59	85 47	37 48
t	1̄11	− 94 28½	40 09	125 49½	92 53	52 26½
***v*	3̄32	−102 14½	53 41½	132 46½	99 50½	67 05½
**s*	1̄21	−136 06	50 30	108 00	123 47	70 57½
***g*	1̄22	−125 02½	23 16½	102 58	103 07	43 02
***k*	3̄52	−129 31	59 53	115 44	123 23½	79 13½
***x*	2̄31	−125 58	66 00½	120 26½	122 27	84 35
***i*	5̄72	−123 46	70 11	123 28½	121 31½	88 13½

* New forms (Richmond & Wolfe).
** New forms (Palache).

The elements of Dana recalculated to the new position by means of the transformation matrix Dana to Richmond = 001/011/100 are as follows and show close agreement with the new elements:

$$a:b:c=0.7314:1:0.7027$$
$$\alpha=111°45',\ \beta=97°48\frac{1}{2}',\ \gamma=65°03\frac{1}{2}'$$



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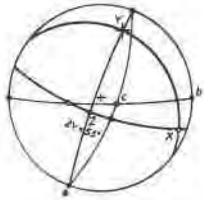

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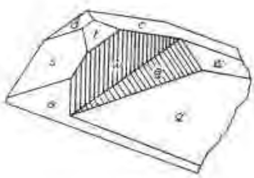

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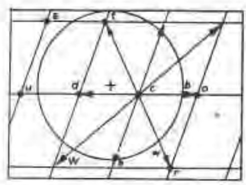

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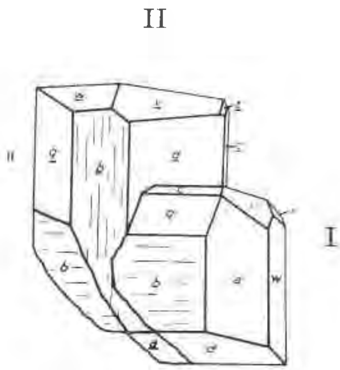

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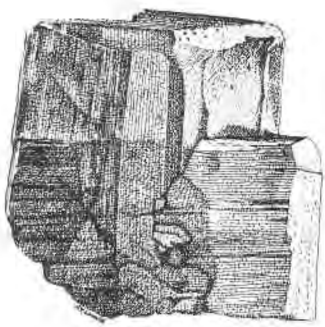

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FIG. 1. Amblygonite, Hebron. Twin crystal of type 1. Axonometric projection.

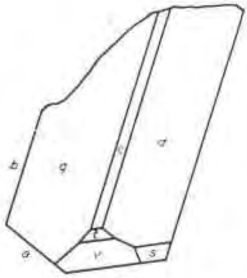
FIG. 2. Amblygonite, Hebron. Twin crystal of type 2. Axonometric projection, viewpoint at the back.

FIG. 3. Amblygonite. Gnomonic projection of crystal forms.

FIG. 4. Amblygonite. Optical orientation in stereographic projection.

FIG. 8. Amblygonite twin crystal, Newry. Same as No 9. A drawing by A. T. Lougee from about the viewpoint of Fig. 9.

FIG. 9. Amblygonite twin crystal, Newry Harvard University No. 95852. Axonometric projection, viewpoint at the right and behind a normal to the side pinacoid.



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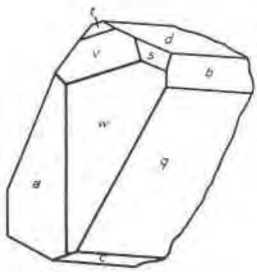

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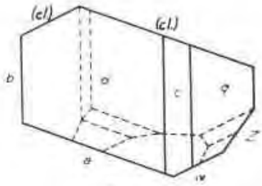

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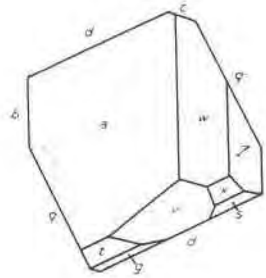

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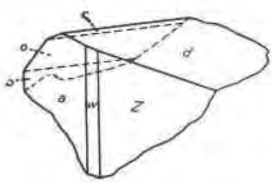

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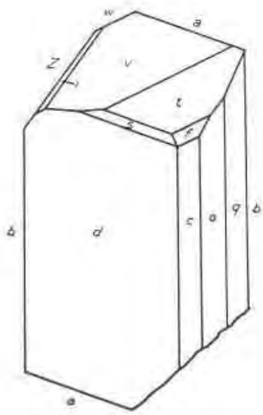

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FIG. 5*a*. Amblygonite, Newry. Crystal of Mr. Ford. Orthographic projection normal to the prism zone (back to front). 5*b*. Axonometric projection, viewpoint at the back.

FIG. 6. Amblygonite, Newry, Harvard University No. 97058. Orthographic projection normal to prism zone.

FIG. 7. Amblygonite, Newry. Crystal of Brush Collection. Orthographic projection. *a*. Plan. *b*. Elevation.

FIG. 10. Amblygonite, Newry. Crystal of Mr. Bjareby. Axonometric projection, viewpoint at the back.

The new form $s\{\bar{1}21\}$ was seen only on crystals of type 2. It is always present as a large curved plane, showing evidence of solution. The reflections were very unsatisfactory, and only on two crystals were sufficiently good signals obtained to identify the form.

The form $b\{010\}$, which has previously been found only by Quensel (1937) is confined to crystals of type 1. It was measured on eight crystals and varied from a point of light barely visible on the goniometer to a well-formed plane face. It was generally coated with a film of sericite which, however, could be removed with a sharp blade; the face then gave adequate signals. Typical development is shown in Fig. 1.

Figure 3 shows the forms of Table 1 in gnomonic projection in the new orientation.

Twinning. As already stated, the crystals are always twinned. The twin law is that originally announced by Des Cloizeaux with twin and composition plane $t(\bar{1}\bar{1}1)$. The index, 1, of this twin and the obliquity, about $1\frac{3}{4}°$, indicate the probable frequency of the twinning according to this law. The twin law $r(111)$, also described by Des Cloizeaux as twin lamellae, has an index of 1 and an obliquity of about $3\frac{1}{2}°$, which perhaps explains the rarity of this twinning as compared with the former law.

Cleavage of Amblygonite. Dana gives four cleavages for amblygonite, which are entered in Table 1 after the forms. In the Richmond column are entered the cleavages determined with exactness on the Newry crystals to be later described. It will be seen that they agree except for Dana's cleavage $(0\bar{2}1)$. There is no cleavage on $W(1\bar{1}0)$, Richmond's equivalent to this form. On the other hand, the perfect cleavage on (100) Richmond, which would be $(0\bar{1}1)$ in Dana position, is not represented among Dana's cleavages. We believe that Dana's cleavage $(0\bar{2}1)$ should have been reported as $(0\bar{1}1)$. Quensel (1937) reports this form but says nothing about cleavage parallel to it.

Optics. The indices of refraction of amblygonite were obtained on small grains by the immersion method and are not materially different from those already published (Larsen and Berman, 1925).

The optical orientation was determined on a small untwinned crystal which was mounted on the universal stage. The observed data are summarized in Table 4. The optical orientation and the positions of the optic axes, as referred to the principal crystallographic planes, are shown stereographically in Figure 4.

TABLE 4. OPTICAL ORIENTATION OF AMBLYGONITE

	ϕ	ρ	
X	$19\frac{1}{2}°$	83°	Positive
Y	$-72\frac{1}{2}°$	69°	$2V=55°\pm2°$
Z	130°	21°	

Unit Cell. In the following table is given an analysis by Penfield of amblygonite from Hebron. From this analysis and a newly determined specific gravity on the crystals described, the unit cell contents are given in the last column. The unit cell of amblygonite contains 2[$LiAlPO_4$ (OH,F)]; in the analysis of the table OH:F$\sim$2:1.

TABLE 5. CONTENT OF THE UNIT CELL OF AMBLYGONITE

	1	2	3		4	5	
Al_2O_3	33.90	34.01	0.334	Al	0.668	1.97	2
Li_2O	9.24	9.29	0.310 }	Li	0.642	1.89	2
Na_2O	0.66	0.66	0.011 }				
P_2O_5	47.44	47.60	0.335	P	0.670	1.97	2
H_2O	5.05	5.06	0.282	H	0.564	1.66 }	2
F	5.45	5.47	0.287	F	0.287	.84 }	
	101.74	102.09		O	3.150	9.27	10
Less O for F	2.08	2.09					
	99.66	100.00					

1. Amblygonite, Hebron. Penfield, anal. (Anal. No. 6 in Dana, p. 782.)
2. Computed to 100%.
3. Molecular proportions.
4. Atomic proportions.
5. Number of atoms in unit cell, using molecular weight of 294.11 (derived from cell volume of 159.11Å^3 and specific gravity 3.05 as newly determined on the crystals).

PART 2. AMBLYGONITE FROM NEWRY, MAINE

CHARLES PALACHE

Crystals of amblygonite of really spectacular quality were found during 1940 and 1941 in a new pit opened for feldspar on Newry Mountain about two hundred yards east of the old Nevel pollucite quarry. The crystals are found in pockets in the pegmatite up to about two feet square and are attached to the feldspar walls. With them, besides quartz and beryl, have been found small amounts of triphyllite, apatite of pale violet color, small amounts of eosphorite, cassiterite, and rhodochrosite. The identification of the mineral as amblygonite was first made by Mr. M. E. Bailey of Andover, Maine. Through him and Mr. F. D. McAllister of the same place, and through Mr. E. F. Miller of Rumford Point, the Superintendent of the quarry, the writer has been able to examine a considerable number of crystals, and the Harvard Mineralogical Museum has acquired two of the better specimens. A third crystal of equal quality has been loaned by the Brush Collection of Yale University through Dr. George Switzer. A fourth crystal was loaned by Mr. H. A. Ford of Boston. The following description is based chiefly on the four largest and finest crystals; other smaller ones have also been loaned for examination and have yielded valuable measurements. The writer's thanks are gratefully extended to the numerous collectors who have thus made it possible to secure a representative series of specimens of this new and unprecedented find.

The crystal of Mr. Ford, the largest of the four, is a nearly flat slab measuring 11 by 8.5 cm. and 4 cm. thick. As shown in Fig. 5 *a* and *b*, the dominant zone is parallel to the *a*-axis. The largest planes are the two faces of *q*{021}, which are further characterized by the more or less uniform coating of brownish eosphorite which renders them entirely matte. The forms *d*, *a*, and *w* are glassy and brilliant, in marked contrast to the faces of *q*.

The crystal secured from Mr. Bailey (No. 97058) is the second largest of the four, measuring about 7 by 5.5 by 4 cm. It is doubly terminated in respect to the *a*-axis but shows cleavage and contact surfaces on one end and side. It is shown in its true proportions in Fig. 6.

The Yale crystal is only slightly smaller, measuring 6 by 5 by 4 cm. It is doubly terminated on the *c*-axis and is bounded on the back by a clean cleavage break. Figure 7 *a* and *b* reproduces it. Both these crystals are greenish yellow in color, transparent in part though with many flaws, and have for the most part brilliant reflecting faces although, as will be shown, some of the bounding forms are consistently dull. If one were to seek for a familiar mineral to which to compare their appearance one might think of the larger Westfield datolites, perhaps. But no close comparison occurs to the writer.

The second Harvard specimen (No. 95852) is a twin crystal, the two individuals quite distinct in their upper portions, interpenetrating in their lower parts. The pen-and-ink drawing by A. T. Lougee, reproduced in Fig. 8, gives an excellent idea of the specimen. The reproduction is nearly natural size, the group having a maximum (diagonal) diameter of 6 cm. and a thickness of 2.5 cm. No one, however familiar he might be with the ordinary macroscopic crystals of amblygonite which are opaque and have faces devoid of luster, could possibly suspect the nature of this crystal. It looks more like a large specimen of twin adularia from Switzerland than any other familiar mineral. The terminal portions of both components of the twin are clear and almost colorless, the basal portions slightly opaque and of faintly yellowish color. Most of the faces are plane and brilliantly reflecting, only the side pinacoids and one brachydome being matte so that they could only be measured by attaching slips of glass to their surfaces. The drawing shows well how these latter faces are striated and how the lineation due to this stands in the two individuals almost at right angles. It also brings out the apparent coplanar relation of the pinacoids on the two portions of the twin. The principal elongation of both individuals is in the direction of the brachyaxis as best shown in Fig. 9.

The removal of the crystal group from the matrix to which it must have been attached by its basal portion developed many cleavage planes of high perfection. Study of these together with contact measurements enabled the nature of the forms and the probable twin law to be worked out approximately by inspection. However, it was found possible to mount the unwieldy crystal on the two-circle goniometer. Reflections were satisfactory, but of course the measurements were less exact than would have been the case from a smaller crystal owing to the long traverses needful to bring different parts of the crystal, especially of the twin, into reflection. The three larger crystals could only be measured with the contact goniometer, but by using the measurements of the twin their forms could be established with reasonable certainty.

The crystal was set on the goniometer with individual I in normal position, that is with its prism zone vertical; individual II in twin position has its prism zone almost horizontal. Figure 9 is a clinographic projection from a point of view well behind the *b*-axis while the sketch, Fig. 8, is taken from about the same point of view but more nearly normal to *b*.

The nature of the intergrowth is such that neither member of the twin shows any faces in front of the brachydome zone [100]. Both members were measured with the same setting on the goniometer. Table 6 containing the measurements is, however, divided into two parts somewhat differently arranged, each containing the faces of one individual.

TABLE 6. MEASUREMENTS OF AMBLYGONITE TWIN

a. Individual I in normal position

		Measured		Calculated	
		ϕ	ρ	ϕ	ρ
b	010	0°53′	90°00′	0°00′	90°00′
b′	$0\bar{1}0$	180 00	90 00	180 00	90 00
c	001	18 25	22 20	19 46½	21 59
a′	$\bar{1}00$	− 69 52	90 00	− 69 39	90 00
w′	$\bar{1}\bar{1}0$	−114 50	90 00	−114 30	90 00
d	$0\bar{1}1$	161 13	23 51	162 19	24 12½
**q*	021	3 50	64 28	3 55	63 27
**v*	$\overline{33}2$	−102 18	53 45	−102 14½	53 41½
**x*	$\overline{23}1$	−126 25	65 00	−125 58	66 00½

b. Individual II in twin position

		Measured		Calculated (approx.)		Nearest face in normal position			
		ϕ	ρ	ϕ	ρ			ϕ	ρ
c	001	−114°25′	89°10′	−114°30′	89°44′	*w*	$\bar{1}\bar{1}0$	−114°30′	90°00′
b	010	not measured		0 00	87 00	*b*	010	0 00	90 00
a	100	154 55	26 05	155 15	27 00	*d*	$0\bar{1}1$	162 19	24 12½
w	110	12 45	22 35	20 02	22 00	*c*	001	19 46½	21 59
d	$0\bar{1}1$	− 70 45	86 40	− 71 30	87 00	*a′*	$\bar{1}00$	− 69 49	90 00
t	$\bar{1}\bar{1}1$	− 94 16	40 13	− 94 28½	40 09	*t*	$\bar{1}\bar{1}1$	− 94 28½	40 09
v	$\bar{3}\bar{3}2$	− 80 55	28 00	− 79 30	28 00	none near			

Examination of the first part of Table 6 shows good agreement between measured and calculated position angles both for the known forms and the three new forms marked with asterisk. No face of the form *t*{$\bar{1}\bar{1}1$} was found on the normal individual because the corner where it might have occurred was chipped away.

The second group of angles in part *b* of Table 6 requires explanation. It was secured by plotting the normal forms on a stereographic projection of 20 cm. diameter, and then introducing the same forms in twin position. The position angles of these forms in twin position could then be read off with an accuracy of about one-half degree. The considerable labor of accurate calculation of these positions seemed disproportionate to its value.

The determination of the twin plane is established by the fact that *t*{$\bar{1}\bar{1}1$} on the twin crystal falls exactly in the calculated position of this form in normal position. This form is the equivalent in Richmond's new setting of Des Cloizeaux's plane of lamellar twinning, *H*{$\bar{1}\bar{1}1$}.

From the third column of Table 6 it is seen that important forms fall in twin position very near to normal forms. Most noteworthy of these coincidences are *c*{001} with *w*{110} twinned and *a*{100} with *d*{001} twinned. These four forms all have cleavage of varying degrees of perfection as shown in Table 1; and the near coincidence of these unlike cleavages, seen wherever a fracture plane crossed the boundary between the two individuals, is good proof of the correctness of the various form determinations of Table 6 and of the identity of the plane of twinning.

Further measurements were secured on six crystals, for the most part small and of poor quality, which are contained in Table 7.

TABLE 7. MEASUREMENTS OF SIX CRYSTALS OF AMBLYGONITE

		No.	Qual.	Mean ϕ	Mean ρ	Range ϕ	Range ρ
c	001	5	fair	19°28′	21°43′	18°35′–21°07′	19°40′–22°44′
a	100	10	good	110 23	90 00	109 48 –111 00	— —
b	010	4	v. poor	0 04	90 00	0 00 – 0 12	— —
w	110	7	fair	65 13	90 00	63 19 – 66 28	— —
o	011	1	poor	5 18	49 23	—	—
d	$0\bar{1}1$	3	good	162 16	24 23	162 12 –162 18	24 19 –24 30
t	$\bar{1}\bar{1}1$	4	fair	– 93 34	40 22	92 12 – 94 34	40 09 –41 15
**g*	$\bar{1}\bar{2}2$	1	v. poor	–117 53	21 10	—	—
**f*	$\bar{2}\bar{2}3$	1	v. poor	– 79 19	28 30	—	—
**v*	$\bar{3}\bar{3}2$	1	good	–102 13	53 50	—	—
**k*	$\bar{3}\bar{5}2$	1	poor	–130 40	60 00	—	—
**i*	$\bar{5}\bar{7}2$	1	v. poor	–123 39	70 00	—	—

Contact measurements for some of these forms and for the three new forms for which no position angles were obtained will be found in the description of the individual forms which follows.

Characteristics of the forms.

c{001} is always present and always brilliant. It varies from a line face to one of considerable breadth.

b{010} is always present and sometimes dominant. It is always completely matte and is generally striated in [100].

a{100} is present on all crystals and is generally the largest face in the prism zone. It is brilliant, usually smooth, and shows a pearly luster owing to the perfect cleavage parallel to it. It is separated from the prism {110} on several crystals by a striated area which sometimes forms a shallow groove.

w{110} is also always present and usually constitutes with the two preceding forms the prismatic zone. It is always bright and of high luster but may be vertically striated over part of its area, or show slight unevenness.

**Z*{120}. This new prism is developed as a broad, matte face on the two large crystals shown in Figs. 6 and 7. It was determined by contact measurement. $bZ=\phi=37°\ 30'$, Cal.$\phi=37°\ 56\tfrac{1}{2}'$.

o{011} was seen twice as a long and narrow, matte face on both top and bottom of the crystal of Fig. 6. Established by a contact measurement $co=30°$, Cal. $C=29°\ 01'$. One position angle was also obtained for it (Table 6).

d{$0\bar{1}1$} is one of the largest and most brilliant faces on every crystal. It is sometimes, however, etched over part of its surface.

q{021} is a new brachydome found on nearly every crystal and largely developed as shown in the figures. However, it is always matte and was determined by contact measurement. $ca=43°$, Cal. $C=42°\ 33'$. On the twin crystal, Table 5, one position angle was obtained by use of a glass slip attached to it.

t{$\bar{1}\bar{1}1$} is a brilliant face, always present, varying from a narrow line to a broad surface. On most twin crystals its simultaneous reflection on the two individuals identifies it at once.

**g*{$\bar{1}22$}. This new pyramid occurs as a narrow, matte face truncating the edge *dt*. Measured (mean of 2) *d-g*=27° 30′, Cal. 27° 36′. It was further established by one position angle, shown in Table 7.

**f*{$\bar{2}23$}. This new form is seen on several crystals truncating the edge *ct* but too narrow for satisfactory contact measurement. One position angle is given for it in Table 7.

**v*{$\bar{3}\bar{3}2$}. This new pyramid is one of the important forms in the development of every crystal. It is often the largest terminal face except *d*, is frequently bright, and was determined by measurement on the twin crystal as shown in Table 6. Again it may be quite dull and striated lightly parallel to its intersection with *c* and *t* in the zone [$\bar{1}10$].

**k*{$\bar{3}52$}. This new pyramid was seen twice as a narrow truncation of the edge *bv*. Contact measurement *vk*=23°, Cal. 23° 33′. One good position angle is also shown in Table 7.

**x*{$\bar{2}\bar{3}1$}. A new pyramid established by its measurement on the twin, Table 6. It was checked by contact measurements. *a-x*=120°, A=120° 20′; *b-x*=123°, B=122° 27′.

s{$\bar{1}21$}. This pyramid was found but once, on the Yale crystal, Fig. 7. Established by contact measurements *a-s*=110°, Cal. *A*=108° 00′; *b-s*=125°, Cal. *B*=123° 47′. On this crystal the forms *v*, *x*, and *s* merge in a curved surface not shown in the drawing. A similar curvature is present but not figured on the twin crystal.

**i*{$5\bar{7}2$}. This new and weak form was seen twice truncating the edge *sk*. One position angle for it is shown in Table 7. It was measured once by contact on the edge between *v*($\bar{3}\bar{3}2$) and *Z*($\bar{1}\bar{2}0$). *v-i*=27°, Cal. 25° 02′. Thus it is established as lying in two zones.

Examination of Tables 6 and 7 in comparison with Table 3 will show that all the forms listed for amblygonite from Hebron by Richmond and Wolfe have been found on Newry crystals except *W*{$1\bar{1}0$}. In addition, eight forms new to the species have been found, the angles for which have been calculated on their elements and are presented in Table 3.

Twinning. Of the seventeen crystals which were examined in this study, five proved to be twinned, always according to the same law as found on the Hebron crystals, twin plane ($\bar{1}\bar{1}1$). The development of twinning is extremely varied. The twin described at length and figured was the only one seen which presented clearly separated individuals. Two others nearly as large were seen, but they had imperfect faces or cleavage surfaces. In both there was more complete intergrowth of the two individuals, somewhat in the nature of a "graphic" structure, so that small points of one individual projected from larger surfaces of the other. In one crystal there were three small inserts visible in the base of the crystal, parallel to one another as far as could be seen, and in twin relation to the main crystal.

Amblygonite of an entirely different quality from the crystals described above is represented by a specimen found at the Newry Quarry by Mr. Gunnar Bjareby and loaned to the writer for study. The specimen consists of a crystal fragment measuring about 8 by 6 by 4.5 cm. which occurred embedded in feldspar from which it had been partially freed. It is white and opaque with plane but entirely matte faces. The general form is that of a nearly square pyramid with two edges truncated by narrow faces. Contact measurements and the study of the cleavage finally established the forms present to be as shown in Fig. 10, all of which are known on the better crystals. The specimen is very similar in appearance to feldspar and might easily be mistaken for it.

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