SUPPLEMENTARY NOTES ON AXINITE

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The following notes supplement a recent paper (1937) on the crystallography of axinite. The question of symmetry was purposely not broached in the original paper since the issue seemed unclear. The new forms and confirmatory measurements have only recently become available. The remaining points refer to more or less inaccessible observations which had escaped my notice. For calling attention to the two neglected settings of axinite by Fedorov full credit is due to Professor Wartan N. Lodočnikow of Leningrad, who was also kind enough to refer me to his paper (1927) describing twinning and a new form on axinite.

Symmetry

Despite the fact that there are several early notices of a positive pyroelectric effect in axinite (Hintze, 1897), pointing to the absence of a symmetry centre and therefore to the pedial (hemihedral) class of the triclinic system, axinite is generally accepted as belonging to the pinakoidal (holohedral) class and was given as such by the present writer. This contradiction was realized at the time and an effort was made to obtain new observations which might decide the question. Crystals of axinite from near Easton, Pennsylvania and mangan-axinite from Franklin, New Jersey, were sent to Dr. Sterling B. Hendricks, Bureau of Chemistry and Soils, Washington, D.C., who kindly undertook to make tests for pyro- and piezoelectricity, using recently described methods. The following are excerpts from Dr. Hendricks' privately communicated reports:

> Jefferson tested the piezoelectric character of the two axinite specimens, using an oscillator of the type recommended by Giebe and Scheibe [1925]. The result was negative under conditions that gave a positive test on meta nitro aniline which shows a weak piezoelectric behaviour. I tested the pyroelectric character after the Martin [1931] method. . . . A negative result was obtained under conditions that gave positive results for alunite and jarosite.—Jan. 26, 1937.
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> I was aware that axinite has been described as being pyroelectric and I for one think that the former tests are correct. . . . We place absolutely no faith in the tests [Giebe and Scheibe; Martin] or in our ability of applying them. However we always make them since a positive result is undeniable.—Feb. 4, 1937.

Thus, although Dr. Hendricks made it clear that negative pyro- and piezoelectric tests are valueless, it seemed that the early positive result lacked confirmation and that, therefore, there was insufficient ground for questioning the accepted pinakoidal symmetry of axinite.

It was overlooked, however, that Martin himself (1931) reported a positive pyroelectric effect in axinite, thus confirming the early work. Since a positive result is undeniable we must, according to accepted theory, place axinite in the pedial class in which each form is represented by a single plane (pedion). Although it might prove possible, by an extended research, to fix the position of a unique polar axis in axinite and separate the apparently pinakoidal forms into positive and negative pedions, this would be a difficult and perhaps unprofitable undertaking.

Crystallographic Settings

In addition to the seventeen settings of axinite previously discussed or briefly mentioned (1937), three more have come to the writer's attention: two by Fedorov, much of whose valuable work is inaccessible in America, and one by Schiebold who gives lattice dimensions for axinite in a new setting in a long footnote to an extended paper on the feldspars.

Fedorov (*1901*): In his earlier setting Fedorov treats axinite as a hypo-hexagonal species with a four-index notation. It would be difficult to derive the transformation to the normal setting in this case, and of little value, since Fedorov later abandoned the hypo-hexagonal setting in favour of a happier orientation.

Fedorov (*1920*): In his monumental work *Das Krystallreich* Fedorov treats axinite as a hypo-cubic species and relates his setting to that of Dana (1892) by the transformation:

Dana to Fedorov: $\bar{2}00/002/110$

Since the transformation Peacock to Dana is $010/\overline{21}0/001$ (Donnay, 1937) we have, by multiplication of matrices, Peacock to Fedorov: $0\bar{1}0/001/\bar{1}00$, giving the inverse transformation:

Fedorov to Peacock: $00\bar{1}/\bar{1}00/010$

This transformation simply represents an interchange of axes; and thus we see that, in this case, Fedorov's "richtige Aufstellung" is the same as the writer's "normal setting" except in the purely arbitrary matter of naming the axes of the lattice cell.

Schiebold (*1931*): This setting, given by structural lattice dimensions which will be considered later, can be related to ours only if we assume that Schiebold's axial angle $\gamma=[100]:[010]$ is the supplement of the proper value. Such errors are common in the literature of axinite. In that case the transformation is:

Schiebold to Peacock: $00\bar{1}/010/100$

which likewise simply represents an interchange of axes.

Thus, in all, we have six settings of the correct lattice cell: Miller (1852), Goldschmidt (1886), Goldschmidt (1897), Fedorov (1920) Schiebold (1931), Peacock (1937). This clearly shows how important it is to follow some simple rules, as proposed in the normal setting, that admit only one of the twenty-four orientations in which a given triclinic cell may be placed.[1]

Fundamental Angles

In an extended work on the morphology of axinite, which appeared while the writer's paper was in press, Heritsch (1937) tabulates the mean values for a series of new measurements on four of the principal forms on axinite crystals from six localities. Heritsch uses the orientation of Goldschmidt (1897) which is related to ours by the transformation:

Goldschmidt to Peacock: $\bar{1}00/0\bar{1}0/001$

Heritsch's angles compare with the calculated values of Miller (Goldschmidt, 1897) and Palache (Peacock, 1937) as follows:

Heritsch			Miller (Gdt.)		Palache		
Form	180°−ϕ	ρ	180°−ϕ	ρ	Form	ϕ	ρ
a 101	− 75°52′	49°09′	− 75°56′	49°10′	*y* $\bar{1}01$	− 75°45½′	49°13½′
o 112	−126 08	31 14	−126 11	31 19	*o* $\bar{1}\bar{1}2$	−126 01	31 16
x $1\bar{1}1$	− 41 10	59 35	− 41 12	59 36	*x* $\bar{1}11$	− 41 09	59 39½
s $1\bar{2}1$	− 26 09	68 33	− 26 11	68 32	*s* $\bar{1}21$	− 26 10	68 34½

The three sets of angles are very nearly alike and thus we have confirmation of the accuracy of Palache's definitive elements which were based on a judicious combination of many old and new measurements.

Forms

From Heritsch's careful study we may add four well established new forms to Palache's list:

$K_0\{3\bar{2}0\}$ Heritsch = K: $\{3\bar{2}0\}$ Palache
I $\{212\}$ Heritsch = I: $\{\bar{2}\bar{1}2\}$ Palache
Λ $\{\bar{1}02\}$ Heritsch = Λ: $\{102\}$ Palache
Ξ $\{302\}$ Heritsch = Ξ $\{\bar{3}02\}$ Palache

Heritsch also accepts two previously reported forms which are not mentioned by Palache. Neither of these seems sufficiently well sup-

[1] Take the axis of the main zone as [001]. Let (001) slope front-right. Make [010] longer than [100].

ported to be included in the list of accepted forms; they may be retained as uncertain, subject to confirmation.

s{$\bar{1}$73} Flink (1916), setting of Dana (1892) = {$\bar{3}\bar{1}$3} Palache. Such confusion surrounds the indices of this form (Heritsch, 1937, p. 264) that it is better regarded as uncertain.

χ{$\bar{3}$13} Lodočnikow (1927), setting of Schrauf (1870) = {$\bar{1}\bar{3}$2} Palache. Determined once with the microscope on a minute grain.

Lattice Dimensions

The lattice dimensions of axinite given by Schiebold (1931, p. 311, footnote 36) are based on previously unpublished measurements by Schiebold and Eulitz on a crystal from Bourg d'Oisans. The method of measurement and limits of error are not stated. Replacing Schiebold and Eulitz's original value for the axial angle γ by its supplement and transforming the elements according to the formula already given we have

	Schiebold & Eulitz (1931)		Peacock (1937)
	Original	Transformed	
a_0	8.966Å	7.020Å	7.151Å
b_0	9.017Å	9.017Å	9.184Å
c_0	7.020Å	8.966Å	8.935Å
α	102°38′	91°49′	91°52′
β	82°01′	97°59′	98°09′
γ	88°11′ [91°49′]	77°22′	77°19′

the satisfactory comparison given above. The writer's values were obtained from Weissenberg photographs about each of the three principal lattice axes, giving accurate duplicate values for the spacings of the axial planes and precise values, independent of the external geometry, for the reciprocal axial angles.

Twinning

In stating that axinite is free from twinning (1937, p. 591) the writer was unaware of a paper by Lodočnikow (1927) who described twinning in a single grain of axinite (0.1 mm.^{2}) in a rock section, on the basis of observations with the microscope and universal stage. In Schrauf's notation Lodočnikow determined the composition plane of the intergrowth as (110) and the twin axis as the edge (110)/($\bar{3}$13) = [3$\bar{3}$4]. In our notation the twin law would be: twin axis [023]; composition plane (100).

While admiring the skill with which this observation was made and the ingenuity of the argument leading to the symbol ($\bar{3}$13), which is further advanced as the new form χ, we feel that Dr. Lodočnikow's twin law requires confirmation on goniometrically measurable crystals.

Summary

To an earlier account of the crystallography of axinite (1937) the following may be added. Symmetry: pedial rather than pinakoidal. Forms: $K:\{3\bar{2}0\}$, $I:\{\bar{2}\bar{1}2\}$, $\Lambda:\{102\}$, $\Xi\{\bar{3}02\}$ (Heritsch, 1937); uncertain: $\{\bar{3}\bar{1}3\}$ (Flink, 1916), $\{\bar{1}32\}$ (Lodočnikow, 1927). Twinning (requires confirmation): twin axis [023], composition plane (100) (Lodočnikow, 1927).

Three previously overlooked settings of axinite are given: Fedorov (1901), Fedorov (1920), Schiebold (1931). Palache's geometrical elements are confirmed by new measurements (Heritsch, 1937). Previously unnoticed lattice dimensions (Schiebold and Eulitz, 1931) are in essential agreement with Peacock's structural elements.

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