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CRYSTALLOGRAPHIC NOMENCLATURE AND TWINNING IN THE HUMITE MINERALS

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ABSTRACT

The several crystallographic settings previously used for the humite minerals have led to mistakes and confusion in space group, cleavage and twinning descriptions. The Taylor and West setting is preferred because it allows ready comparison of humites and structurally analogous olivines. Twinning on (001) in chondrodite yields single crystal diffraction patterns consistent with orthorhombic rather than monoclinic symmetry.

The humite minerals (norbergite, $Mg_2SiO_4 \cdot Mg(OH,F)_2$; chondrodite, $2Mg_2SiO_4 \cdot Mg(OH,F)_2$; humite, $3Mg_2SiO_4 \cdot Mg(OH,F)_2$; and clinohumite, $4Mg_2SiO_4 \cdot Mg(OH,F)_2$) are structurally similar to the olivine group minerals in that they consist of a hexagonal closest-packed array of anions, zig-zag chains of edge-sharing, M-filled octahedra and isolated tetrahedra (Ribbe, Gibbs and Jones, 1968). Norbergite and humite are orthorhombic and chondrodite and clinohumite are monoclinic with interaxial angles of approximately 109° and 101°, respectively.

During the course of a microprobe and single-crystal study of these minerals (Jones, 1968) it was noted that there is considerable confusion in the literature regarding the choice of crystallographic axes and space groups. Some of the choices which have been made are shown in Table 1. Apparently this profusion of axial choices has led to some of the mistakes found in descriptions of the humite minerals. Thus, as noted in Table 1, certain of the space groups adopted by Sahama (1953; after Strunz,

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TABLE 1. AXIAL LABELS AND SPACE GROUPS ASSIGNED TO THE HUMITE MINERALS BY VARIOUS AUTHORS. TAYLOR AND WEST'S (1929) CONVENTION PREFERRED.

Mineral	Approximate axial length (Å)	Axial labels and space groups				
		Taylor and West (1929) Bragg and Claringbull (1965)	Strunz (1949) Sahama (1953) Deer, Howie, Zussman (1962)	ASTM	Winchell and Winchell (1951)	Strunz (1957)
Norbergite	4.7	a	b ⎫	c ⎫	a	b ⎫
	10.2	b	c ⎬ (1)	a ⎬ (2)	b	c ⎬ (1)
	8.7	c	a ⎭	b ⎭	c	a ⎭
	Space Group	$Pbnm$	$Pbnm$[a]	$Pnma$	$Pbnm$	$Pmcn$
Chondrodite	4.7	a	b ⎫	b ⎫	b ⎫	b ⎫
	10.3	b	c ⎬ (1)	a ⎬ (3)	a ⎬ (3)	c ⎬ (1)
	7.9	c	a ⎭	c ⎭	c ⎭	a ⎭
	Space Group	$P2_1/b$	$P2_1/c$	$P2_1/a$	$P2_1/c$[b]	$P2_1/c$
Humite	4.7	a	b ⎫	c ⎫	a	b ⎫
	10.2	b	c ⎬ (1)	a ⎬ (2)	b	c ⎬ (1)
	20.9	c	a ⎭	b ⎭	c	a ⎭
	Space Group	$Pbnm$	$Pbnm$[a]	$Pbma$	$Pbnm$	$Pmcn$
Clinohumite	4.7	a	b ⎫	b ⎫	b ⎫	b ⎫
	10.3	b	c ⎬ (1)	c ⎬ (1)	a ⎬ (3)	c ⎬ (1)
	13.7	c	a ⎭	a ⎭	c ⎭	a ⎭
	Space Group	$P2_1/b$	$P2_1/c$	$P2_1/c$	$P2_1/c$[b]	$P2_1/c$
Forsterite	4.755	a	b ⎫	a	a	b ⎫
	10.21	b	c ⎬ (1)	b	b	c ⎬ (1)
	5.98	c	a ⎭	c	c	a ⎭
	Space Group	$Pbnm$	$Pbnm$[a,c]	$Pbnm$	$Pbnm$	$Pmcn$

[a] should be $Pmcn$.

[b] should be $P2_1/a$.

[c] Deer, Howie, and Zussman are consistent with Taylor and West.

The matrices for transformation to Taylor and West's settings are:

$$(1) \begin{bmatrix} 010 \\ 001 \\ 100 \end{bmatrix} \quad (5) \begin{bmatrix} 001 \\ 100 \\ 010 \end{bmatrix} \quad (3) \begin{bmatrix} 010 \\ 100 \\ 001 \end{bmatrix}$$

1949), by Deer, Howie and Zussman (1962), and by Winchell and Winchell (1951) are incorrect because of their choice of axes. In his description of chondrodite Kerr (1959) apparently adopts the same axial choices as Winchell and Winchell (1951), but he lists the interaxial angle β as 90°

and states (p. 351): "Although the mineral is monoclinic, the ∠ between the *a*- and *c*-axes is 90° (orthorhombic syngony)." His Figure 15–7 indicates that all interaxial angles are 90°, which is incorrect for chondrodite.

It is proposed that the axial choices of Taylor and West (1929) be accepted, as in Bragg and Claringbull (1965). Although their convention corresponds with neither the first nor the second setting for the monoclinic members, it is consistent with the accepted olivine notation and therefore permits direct comparisons between the humite minerals and the structurally similar olivines (*e.g.*, Ribbe *et al.*, 1968). Matrices for transformation from other settings are given as footnotes in Table 1.

TWINNING

The numerous axial labels have also led to confusing descriptions of twinning. For example, Deer, *et al.* (1962) describe simple and multiple twinning on (001) for chondrodite and clinohumite; this is correct if Taylor and West's (1929) axial notation is used, but is not consistent with
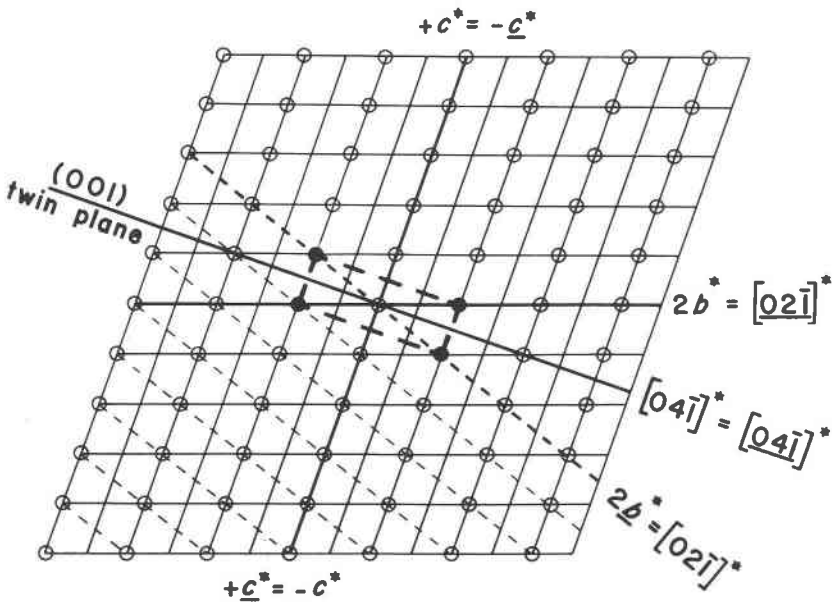

FIG. 1. Parallel twinning on (001) in chondrodite as seen on the b^*c^* reciprocal lattice plane. The vectors $[02\bar{1}]^*$ and $-c^*$ of one twin lamella (solid lines) coincide in magnitude and direction with the vectors $2b^*$ and $+c^*$ of the other twin lamella (dashed); space group symmetry requires that for diffractions of the form $0kl$, $k = 2n$ (circled). This results in the superposition of diffraction spots from both twin lamellae and a pseudo-orthorhombic cell (outlined) with b_{ortho} parallel to $[04\bar{1}]^*_{mono}$.

the axial notation adopted by Deer *et al.* They also report twinning on (105) and ($\bar{3}$05) for chondrodite and on ($\bar{1}$03) for clinohumite. These are consistent with the notation adopted by the ASTM for chondrodite, by Winchell and Winchell (1951), and by Tilley (1951), but not with their own choice of axes. Heinrich (1965) apparently adopts Sahama's choice of axes, yet he describes twinning on (001), (105), and (305) for chondrodite although with Sahama's choice of axes it should be (100), (501), and (503). Using Taylor and West's notations, the twin planes in chondrodite are (001), (015), and (0$\bar{3}$5); in clinohumite, (001) and (0$\bar{1}$3).

Twinning on (001) was encountered during single crystal X-ray studies of chondrodite and provides an example of pseudo-symmetry. When parallel twinning of this type occurs, the vector [02$\bar{1}$]* of one lamella coincides in magnitude and direction with the vector $2b^*$ of the other lamella (Fig. 1). Since space group extinctions from each lamella allow diffraction from planes $0kl$ only if $k = 2n$, diffraction spots from one twin are superposed on those from the other. $0kl$ X-ray photographs thus show intensities and distribution of spots consistent with a pseudo-orthorhombic cell. In upper level photographs of (001)-twinned chondrodite, $2mm$ symmetry is present but systematic extinctions do not correspond to any space group extinction rules. When either (015) or (0$\bar{3}$5) are twin planes such a phenomenon does not occur and diffraction spots from each lamella should be distinct. Twinning on (015) and (0$\bar{3}$5) was not observed in the present study.

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A RAPID VISUO-COLORIMETRIC METHOD FOR THE DETERMINATION OF PHOSPHATE IN PHOSPHATIC ROCKS

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ABSTRACT

A rapid field method for determining P_2O_5 in phosphatic rocks based on visual colorimetry has been developed. After dissolution of the sample in dilute nitric acid, the color due to organic matter is removed and an aliquot of the solution reacted with a mixed molybdivanadate reagent. The intensity of molybdivanadophosphoric acid is matched with standards similarly prepared. The results by the method are well within normal sampling errors. It has proved very useful in quickly evaluating the phosphate potentialities of an area.

INTRODUCTION

The Geological Survey of India is currently engaged in a rapid assessment of the rock phosphate potential of the Mussoorie area in the Uttar Pradesh. This work has already involved analysis of several thousand samples. For quick determination of the P_2O_5 content, even under field conditions, a rapid, simple and moderately accurate method has been developed. A three-man team can analyse 120 to 150 samples daily under field conditions, compared with only 10 samples by the gravimetric magnesium pyrophosphate method. The results, though they may deviate by 1–2 percent from the actual phosphate content, can help to quickly assess the potentialities of an area.

In the present method, the sample is digested with nitric acid, color due to organic matter removed and a mixed molybdivanadate reagent added to an aliquot of the solution. The yellow color of molybdivanadophosphoric acid (Mission, 1908) is matched with standards.

EXISTING METHODS

In our early prospecting for rock phosphate the method of Shapiro (1952) was used. In this method, a small quantity of finely powdered rock, measured by a scoop, is shaken with a prepared molybdivanadate reagent in nitric acid. The weight of the sample so measured is about 6