

NORDSTRANDITE FROM MONT ST-HILAIRE, QUEBEC

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ABSTRACT

Nordstrandite $\text{Al}(\text{OH})_3$ occurs as aggregates of tabular and blocky crystals in association with natrolite, tetranatrolite, analcime, sodalite, albite and microcline in pegmatites, miarolitic cavities and xenoliths in nepheline syenite at Mont St-Hilaire, Quebec. Single-crystal X-ray-diffraction studies confirmed the triclinic symmetry of the mineral. The reduced cell has a 6.148(2), b 6.936(2), c 5.074(1) Å, α 95.76(2), β 99.06(2), γ 83.30(2)° and $Z=4$. Crystal morphology indicates the presence of a centre of symmetry. The mineral is colorless, white and, rarely, beige, pink and pale green, transparent to translucent. The lustre is vitreous, slightly pearly on the perfect {110} cleavage. Hardness ~ 3 , $D(\text{meas.}) = 2.42 \text{ g/cm}^3$. Optically, the mineral is biaxial positive, α 1.580(1), β 1.583(1), γ 1.602(1), $2V$ 24°. Elongation (-), dispersion moderate, $r < v$. The orientation of principal vibration axes is defined by the spherical coordinates $X(-59^\circ, 37^\circ)$, $\bar{Y}(74^\circ, 64^\circ)$, $Z(174^\circ, 67^\circ)$. Electron-microprobe analyses of the blocky and tabular crystals gave Al_2O_3 65.6, 64.9; SiO_2 0.06, 0.98; CaO 0.00, 0.00; Na_2O 0.01, 0.02; FeO 0.00, 0.05, totals 65.67, 65.95 wt. %, respectively.

Keywords: nordstrandite, nepheline syenite, Mont St-Hilaire, Quebec, triclinic, physical and optical properties, electron-microprobe analyses.

SOMMAIRE

On trouve la nordstrandite $\text{Al}(\text{OH})_3$ en agrégats de cristaux tabulaires et massifs associée aux phases natrolite, tétranatrolite, analcime, sodalite, albite et microcline dans les pegmatites, les miaroles et les xénolithes de la syénite néphélinique au mont St-Hilaire (Québec). La diffraction sur monocristal confirme la symétrie triclinique de cette espèce. Les paramètres de la maille réduite sont a 6.148(2), b 6.936(2), c 5.074(1) Å, α 95.76(2), β 99.06(2), γ 83.30(2)°, $Z = 4$. La morphologie des cristaux indique la présence d'un centre de symétrie. La nordstrandite est incolore, blanche ou, plus rarement, beige, rose ou vert pâle, et transparente à translucide. Son éclat est vitreux, légèrement nacré sur le clivage parfait {110}. Dureté ≈ 3 , $D(\text{mes.}) 2.42$. Elle est optiquement biaxe positive, α 1.580(1), β 1.583(1), γ 1.602(1), $2V$ 24° avec allongement négatif et dispersion modérée, $r < v$. L'orientation des axes principaux de vibration se définit en coordonnées sphériques: $X(-59^\circ,$

$37^\circ)$, $\bar{Y}(74^\circ, 64^\circ)$, $Z(174^\circ, 67^\circ)$. L'analyse des cristaux massifs et d'aspect tabulaire à la microsonde électronique donne, respectivement, Al_2O_3 65.6, 64.9; SiO_2 0.06, 0.98; CaO 0.00, 0.00; Na_2O 0.01, 0.02; FeO 0.00, 0.05; total 65.67, 65.95% par poids.

(Traduit par la Rédaction)

Mots-clés: nordstrandite, syénite néphélinique, mont St-Hilaire, Québec, triclinique, propriétés physiques et optiques, analyse à la microsonde électronique.

INTRODUCTION

A quarter of a century ago Van Nordstrand *et al.* (1956) synthesized a new form of $\text{Al}(\text{OH})_3$; it was later named *nordstrandite* by Papée *et al.* (1958). Many natural occurrences have since been reported. According to Milton *et al.* (1975), these may be classified into three distinct types: (1) most commonly as a weathering product in bauxitic soils derived from limestones, *e.g.*, in Sarawak, Borneo (Wall *et al.* 1962), Guam (Hathaway & Schlanger 1962, 1965), Montenegro (Tertian 1966), Hungary (Náray-Szabó & Péter 1967), Croatia (Marić 1968), Jamaica (Davis & Hill 1973, as reported in Milton *et al.* 1975) and in the Sokolovsko-Sarbay magnetite mines, U.S.S.R. (Kulikova *et al.* 1974); (2) as a vein or fissure-filling mineral in dolomitic oil shale in the Green River Formation, northwestern Colorado (Milton *et al.* 1975); and (3) as an alteration product of dawsonite and alumohydrocalcite in New South Wales, Australia (Goldberry & Loughnan 1970, 1977). More recently, another type of occurrence of the mineral, in alkaline igneous rocks, was reported: Petersen *et al.* (1976) found nordstrandite as a late mineral in pegmatitic pockets in nepheline syenite at Narssárssuk, Greenland, and Sabina (1977) reported it as a vug mineral in the sodalite-bearing rocks at the Princess sodalite mine near Bancroft, Ontario.

The present paper describes the occurrence and properties of nordstrandite from the nepheline syenite at Mont St-Hilaire, Quebec. The mineral was first identified from this locality in 1971 and was documented by Chao & Baker (1979).

OCCURRENCE

At Mont St-Hilaire, nordstrandite occurs in pegmatites, miarolitic cavities and biotite-rich xenoliths in the nepheline syenite. The mineral is commonly associated with natrolite, tetranatrolite, analcime, sodalite, albite and microcline. At least one of the carbonate minerals calcite, siderite, dolomite, ancylite and dawsonite is always present in small amounts, except in xenoliths where apatite takes the place

of carbonates. Other minor minerals that may be present are aegirine, pyrite, zircon, rutile, fluorite, an unidentified mineral UK43 (Chao & Baker 1979), a nordstrandite-like phase of composition $\text{Al}(\text{OH})_3$ and an iron aluminum member of the serpentine group. The mineral commonly forms tabular rhombic microcrystals in random aggregates in cavities and interstices of natrolite, analcime or albite (Figs. 1a, 1b). The mineral also forms globular aggregates and radiating clusters commonly with a core of

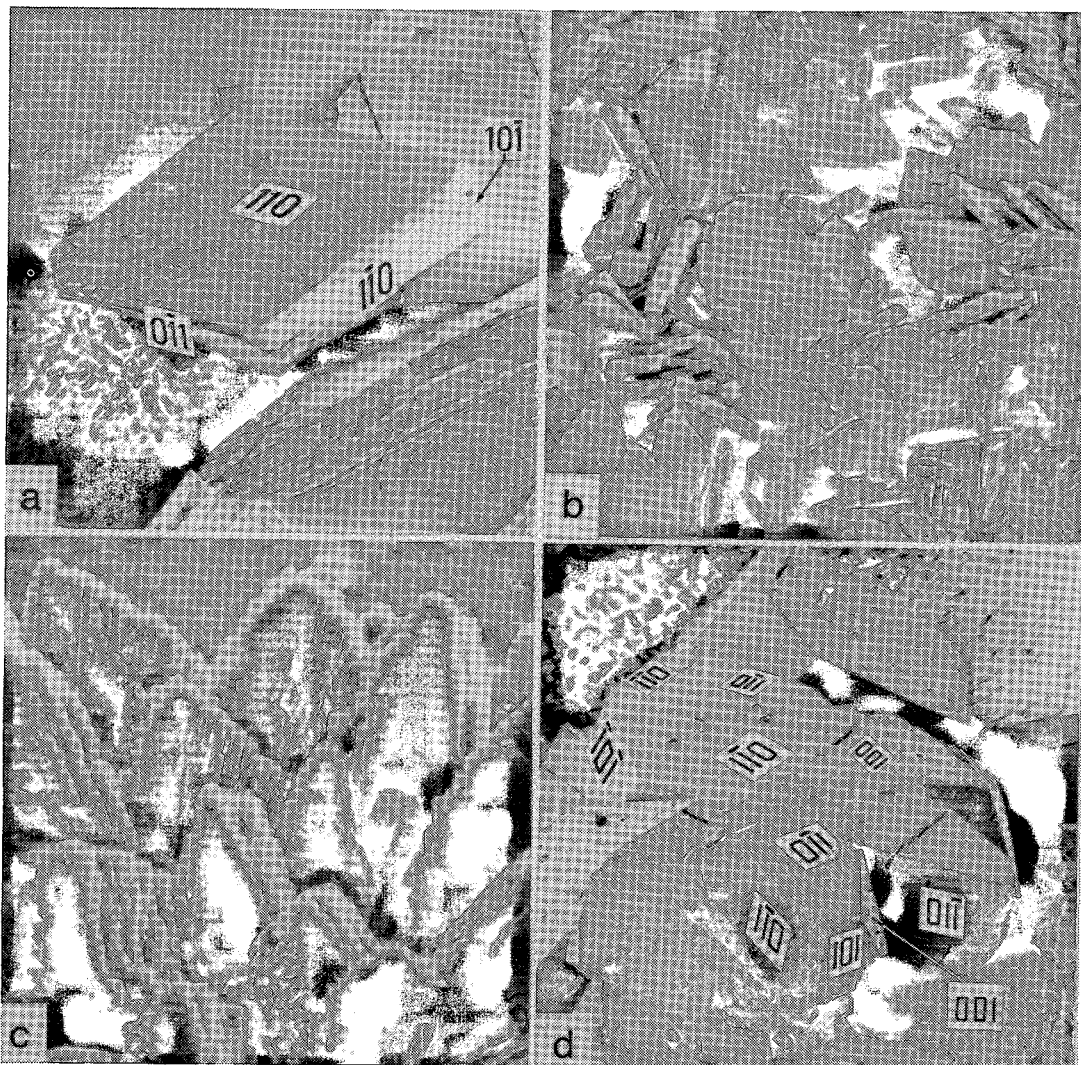


FIG. 1. SEM photomicrographs of nordstrandite, Mont St-Hilaire, Quebec. (a) Tabular rhombic crystal on natrolite (massive) and tetranatrolite (fibrous); long dimension of crystal approximately 0.5 mm. (b) Random aggregates of tabular crystals; average size 0.2 mm. (c) Parallel growths of tabular rhombic crystals in a globular aggregate. (d) Blocky crystals; largest crystal approximately 1.5 mm long.

analcime or siderite. In some aggregates the individuals are not recognizable even with high magnification under the scanning electron microscope. In others, "leaves" formed by sub-parallel to parallel growths of small, tabular, rhombic crystals are apparent (Fig. 1c). Nordstrandite less commonly forms relatively larger (1-2 mm) crystals of a distinct blocky habit (Fig. 1d) in natrolite vugs. These crystals are translucent to opaque with a transparent outer zone. The opaque parts of the crystals contain numerous minute needle-shaped inclusions of dawsonite, randomly arranged.

Textural relationships indicate that the order of crystallization of the essential minerals in the nordstrandite associations is microcline, albite, natrolite or analcime or sodalite, tetranatrolite, carbonates and nordstrandite. Pyrite and serpentine are the only minerals formed later than nordstrandite. Thus, the occurrence and paragenesis of nordstrandite at Mont St-Hilaire are similar to those at Narssârssuk, Greenland (Petersen *et al.* 1976).

CRYSTALLOGRAPHY

Considerable confusion regarding the unit-cell data of nordstrandite exists in the literature, as shown in Table 1. From powder-diffraction data of synthetic nordstrandite, Lippens (1961) derived a monoclinic cell that

resembles the gibbsite cell. However, not all the powder-diffraction lines could be indexed satisfactorily on the basis of Lippens's cell. The triclinic nature of nordstrandite was first recognized by Saalfeld & Mehrotra (1966) from a Weissenberg single-crystal X-ray study of the natural material from Sarawak. Their proposed cell, doubly primitive but not body-centred, was adopted by Roberts *et al.* (1974) in the *Encyclopedia of Minerals*, but the symmetry of the mineral was erroneously recorded as monoclinic. A body-centred triclinic cell was later established by Saalfeld & Jarchow (1968) in their structure determination; this cell has since been referred to by several authors (*e.g.*, Peterson *et al.* 1976). In an independent attempt to determine the crystal structure of the mineral, Bosmans (1970) derived another cell from powder-diffraction data of a synthetic material. The cell was considered to be the reduced cell despite a doubling of the *c* axis indicated by electron diffraction. The reduced cell of Bosmans was adopted in the Powder Diffraction File, but it is now apparent that it is only a subcell.

Much of the confusion was apparently caused by the lack of good single crystals; hence the cell data were obtained mostly from powder-diffraction work. The well-formed crystals of nordstrandite from Mont St-Hilaire made it possible to re-examine its cell geo-

TABLE 1. CELL DIMENSIONS OF NORDSTRANDITE

	1	2	3	4	5	6
<i>a</i> (Å)	8.63(2)	8.893	8.752(9)	5.082	5.114	6.148(2)
<i>b</i>	5.01(2)	5.004	5.069(5)	5.127	5.082	6.936(2)
<i>c</i>	19.12(3)	10.237	10.244(13)	4.980	5.127	5.074(1)
α (°)		92.93	109.326(88)	93.67	70.27	95.76(2)
β	92.00	110.38	97.662(95)	118.92	74.00	99.06(2)
γ		90.53	88.340(84)	70.27	58.47	83.30(2)
<i>V</i> (Å ³)	826.17	426.30	424.97	106.13	106.09	211.47(7)
<i>Z</i>	(16)	8	8	2	2	4
Transformation matrix to the present cell	?	$\frac{1}{2} \frac{1}{2} \frac{1}{2}$ 0 1 $\frac{1}{2}$ $-\frac{1}{2} -\frac{1}{2}$ 0	$\frac{1}{2} \frac{1}{2} \frac{1}{2}$ $-\frac{1}{2} \frac{1}{2} \frac{1}{2}$ 0-1 0	-1 1-1 0 1 1 1 0 0	-1 0 1 1-1 1 0 1 0	1 0 0 0 1 0 0 0 1
Inverse matrix	?	$\frac{1}{2} -\frac{1}{2} -\frac{1}{2}$ $-\frac{1}{2} \frac{1}{2} -\frac{1}{2}$ 1 1 1	1-1 0 0 0-1 1 1 1	0 0 1 $\frac{1}{2} \frac{1}{2} \frac{1}{2}$ $-\frac{1}{2} \frac{1}{2} -\frac{1}{2}$	$-\frac{1}{2} \frac{1}{2} \frac{1}{2}$ 0 0 1 $\frac{1}{2} \frac{1}{2} \frac{1}{2}$	1 0 0 0 1 0 0 0 1
Cell type	?	Doubly primitive, not I-cell	Doubly primitive, I-cell	Sub-cell	Tri-acute sub-cell	Reduced cell

- Lippens (1961), for synthetic nordstrandite. The powder patterns cannot be indexed on the basis of this cell.
- Saalfeld & Mehrotra (1966).
- Saalfeld & Jarchow (1968).
- Bosmans (1970). The cell was thought to be the reduced cell but electron diffraction revealed the doubling of *a*.
- Bosmans (1970). The cell may be transformed to 4 by the matrix 010/001/110
- This study.

metry by single-crystal X-ray diffraction using a precession camera. Six crystals were studied and numerous photographs taken with various important zone axes as the precession axis. The triclinic body-centred cell of Saalfeld & Jarchow (1968) was duly confirmed, and the true reduced cell with $Z=4$ was established. The relationship of this reduced cell to the cells reported by other authors is given in the form of transformation matrices in Table 1. The reduced cell of nordstrandite is related to the monoclinic cell of gibbsite by the matrix $1\bar{1}0/00\bar{1}/110$. This relationship is supported by the almost identical nature of the $hk0$ reciprocal lattice net of nordstrandite and the $h0l$ net of gibbsite.

To compare the cell parameters of nordstrandite from different localities, we indexed the published powder-diffraction data sets with reference to the reduced cell and used them to refine the cell parameters by a least-squares method. The results are presented in Table 2. The comparison shows a significantly larger variation in a than in b and c . It is also interesting to note that the cell volume of all natural nordstrandite is slightly smaller than that of the synthetic material, a reflection, perhaps, of the substitution of Si for Al in the natural mineral.

The X-ray powder-diffraction data for nordstrandite from Mont St-Hilaire are given in Table 3. They are essentially identical to those of the synthetic material, the mineral from Guam and other localities.

Morphologically, the rhombic tabular crystals are bounded by a well-developed $\{110\}$, moderately developed $\{1\bar{1}0\}$ and $\{0\bar{1}1\}$, with or with-

out a poorly developed $\{101\}$ (Fig. 1a). In contrast, the most prominent forms on the blocky crystals (Fig. 1d) are $\{0\bar{1}1\}$ and $\{1\bar{1}0\}$, followed by $\{101\}$ and $\{001\}$, with $\{110\}$ being the least prominent form. A poorly developed $\{010\}$ is present on some crystals. The form $\{1\bar{1}0\}$ is invariably striated parallel to $\{110\}$. Crystals of both habits appear to possess a centre of symmetry, consistent with the results of the crystal-structure analyses by Saalfeld & Jarchow (1968).

The interfacial angles of a blocky crystal were measured using a two-circle optical goniometer. The observed (ϕ , ρ) angles are in good agreement with the angles calculated from the cell parameters (Table 4). No goniometry measurements were made for the tabular crystals, as the only suitable crystal was broken when it was detached from the matrix. The forms present on the tabular crystal were, therefore, determined by X-ray precession goniometry by shooting X-rays along several zone axes of the broken crystal.

PHYSICAL AND OPTICAL PROPERTIES

Nordstrandite from Mont St-Hilaire is colorless, white and, rarely, pink, beige and pale green. The color of the pale green variety has been shown by scanning electron microscopy and X-ray diffraction to be due to a thin coating of an iron aluminosilicate mineral of the serpentine group. The lustre of the mineral is vitreous and is somewhat pearly on the perfect $\{110\}$ cleavage. The Mohs hardness is close to 3. The density, determined by the flotation method, is 2.42 g/cm³, in agreement with the

TABLE 2. DIMENSIONS OF THE REDUCED CELL OF NORDSTRANDITE*

	1	2	3	4	5	6	7	8	9
$a(\text{\AA})$	6.125(4)	6.137(1)	6.148(2)	6.148(2)	6.156(3)	6.149(2)	6.141(8)	6.167	6.163(2)
b	6.923(3)	6.927(2)	6.936(2)	6.933(2)	6.928(6)	6.934(2)	6.932(5)	6.924	6.931(3)
c	5.082(2)	5.075(1)	5.074(1)	5.079(1)	5.078(2)	5.078(1)	5.087(6)	5.082	5.081(2)
$\alpha(^{\circ})$	95.67(4)	95.82(2)	95.76(2)	95.80(2)	95.76(5)	95.79(3)	95.93(7)	95.62	95.70(3)
β	98.88(4)	98.93(2)	99.06(2)	98.93(2)	98.97(4)	98.92(3)	98.62(8)	99.08	98.92(3)
γ	83.53(4)	83.35(2)	83.30(2)	83.22(2)	83.38(6)	83.30(3)	83.33(9)	83.27	83.32(3)
$V(\text{\AA}^3)$	210.8(1)	210.93(6)	211.47(7)	211.61(6)	211.7(2)	211.72(7)	211.8(2)	212.11	212.24(9)

* Refined by a least-squares method using x-ray powder diffraction data from the following sources:

1. Sokoļovsko-Sarbay magnetite mines, USSR (Kulikova *et al.* 1974).
2. Southeast Dinarides, Croatia (Maric 1968).
3. Mont St-Hilaire, Quebec (this study).
4. Guam (Hathaway & Schlanger 1962, 1965).
5. West Sarawak, Borneo (Saalfeld & Mehrotra 1966).
6. West Sarawak, Borneo (Wall *et al.* 1962).
7. Sydney Basin, Australia (Goldberry & Loughnan 1977).
8. Narssarsuk, Greenland (Peterson *et al.* 1976). Calculated from parameters of the I-cell, $\alpha = 8.715(4)$, $b = 5.082(5)$, $c = 10.248(6)\text{\AA}$, $\alpha = 109.56(6)$, $\beta = 97.34(5)$, $\gamma = 88.06(3)^{\circ}$.
9. Synthetic nordstrandite (Bosmans 1970).

TABLE 4. FORMS AND ANGLES FOR NORDSTRANDITE FROM MONT ST-HILAIRE, QUEBEC

Forms	ϕ_{obs}	ϕ_{calc}	ρ_{obs}	ρ_{calc}	A_{calc}	B_{calc}	C_{calc}
001	62.3	62.02	10.1	10.26	81.52	85.21	--
010	--	0	--	90.00	95.90	--	85.21
100	--	95.90	--	90.00	--	95.90	81.52
110	52.0	52.0	90.0	90.00	43.90	52.00	79.90
110	134.6	134.65	90.0	90.00	38.75	134.65	86.95
011	167.0	166.31	34.0	33.96	79.25	122.87	37.66
101	89.8	90.09	44.1	44.86	45.43	90.06	36.06

A=*hkl* Δ 100; B=*hkl* Δ 010; C=*hkl* Δ 001.

values reported for the mineral from other localities (2.41–2.43 g/cm³).

Optical properties of the mineral were determined on a spindle stage. Crystals previously oriented by X-ray goniometry were reoriented with the aid of extinctions and interference figures to rotate about the optic normal. Indices of refraction and 2*V* were measured in sodium light, and all immersion liquids were checked with a refractometer. In white light a moderate, asymmetrical dispersion $r < v$ was observed. The orientation of the optical indicatrix with respect to the reduced cell is shown in Figure 2, and is defined by the spherical coordinates $X(-59^\circ, 37^\circ)$, $Y(74^\circ, 64^\circ)$, $Z(174^\circ, 67^\circ)$. The physical and optical properties of nordstrandite from Mont St-Hilaire are compared with those of the mineral from other localities in Table 5.

The sign of elongation of the nordstrandite crystals from Mont St-Hilaire is negative (length-fast), consistent with that of the mineral from Guam (Hathaway & Schlanger 1965), but opposite that of the acicular crystals from Greenland (Petersen *et al.* 1976). Our examination of the nordstrandite from Guam confirmed the report by Hathaway & Schlanger. Moreover, nordstrandite from Bancroft, Ontario, and in specimens from Narssárssuk, Greenland (41217 and 41251 in the collection at the National Museum of Natural Sciences, Ottawa) also gave negative elongation. Thus, there is little doubt that the acicular crystals studied by Petersen *et al.* (1976) are elongate along a different crystallographic direction, perhaps the *b* axis of the reduced cell. The angle $Z \wedge b$, estimated from the stereographic projection (Fig. 2), is about 23°, close to the maximum extinction angle of about 20° observed by these authors for their material.

ELECTRON-MICROPROBE ANALYSES

Nordstrandite from Mont St-Hilaire was analyzed with an electron microprobe using a defocused beam. Natural gibbsite (for Al), kyanite (Si), anorthite (Ca), albite (Na) and olivine (Fe) were used as standards with jadeite

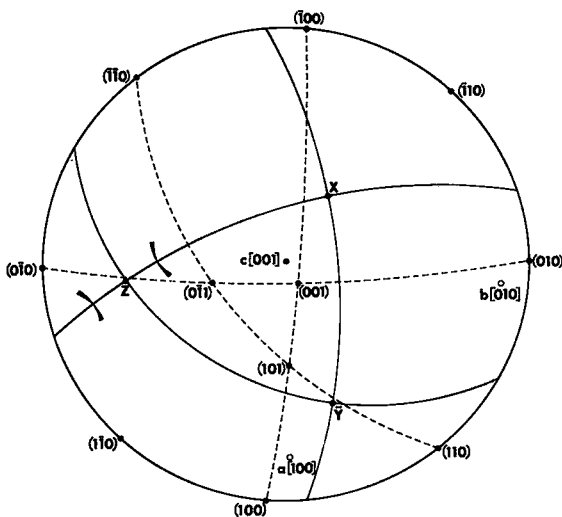


FIG. 2. Stereographic projection of crystallographic and optical elements of nordstrandite.

and the nordstrandite from Guam as internal standards. The analyses for the blocky and tabular crystals are, respectively, Al₂O₃ 65.6, 64.9; SiO₂ 0.06, 0.98; CaO 0.00, 0.00; Na₂O 0.01, 0.02; FeO 0.00, 0.05; totals 65.67, 65.95 wt. %. The H₂O contents were not determined because of the small amount of sample available. Both analyses compare favorably with the theoretical Al₂O₃ content of 65.36% for Al(OH)₃. The higher SiO₂ content of the tabular crystal is probably not related to crystal habit because the nordstrandite from Guam, which has a similar tabular habit, has only 0.02% SiO₂.

POLYMORPHISM IN Al(OH)₃

It is commonly accepted that Al(OH)₃ exists in three structural forms, namely, bayerite, gibbsite and nordstrandite. They differ essentially in the stacking of the layers of hydroxyl ions. Bayerite is believed to have the brucite structure with the stacking sequence ABAB typical of the hexagonal closest packing (Yamaguchi & Sakamoto 1958, Lippens 1961). The structure of gibbsite, as determined by Megaw (1934) and refined by Saalfeld & Wedde (1974), is based on the stacking sequence ABBA. Speculations on the basis of X-ray powder-diffraction data suggested that nordstrandite has a structure with mixed bayerite and gibbsite layers of ABABBABA, but structure determination using single-crystal X-ray-diffraction intensity data (Saalfeld & Jarchow

TABLE 3. SELECTED X-RAY POWDER DIFFRACTION DATA FOR NORDSTRANDITE

<i>hkl</i>	1 Mont St-Hilaire Quebec			2 Guam		3 Sarawak Borneo		4 Sydney Basin Australia		5 Croatia		6 Synthetic	
	<i>d_{calc}</i>	<i>d_{obs}</i>	<i>I_{obs}</i>	<i>d_{obs}</i>	<i>I_{obs}</i>	<i>d_{obs}</i>	<i>I_{obs}</i>	<i>d_{obs}</i>	<i>I_{obs}</i>	<i>d_{obs}</i>	<i>I_{obs}</i>	<i>d_{obs}</i>	<i>I_{obs}</i>
110	4.785	4.779	100	4.789	100	4.78	vs	4.79	100	4.782	100	4.791	100
110	4.320	4.317	30	4.322	12	4.33	s	4.34	20	4.318	40	4.320	27
011	4.208	4.223	20	4.207	10	4.206	s	4.20	12	4.207	40	4.205	18
101	4.161	4.168	5	4.156	7	4.153	s	4.15	12	4.162	40	4.160	12
011	3.886	3.890	10	3.887	4	3.886	m	3.865	8	3.883	30	3.888	11
101	3.597	3.603	10	3.600	4	3.600	m	3.600	6	3.597	30	3.609	8
020	3.432	3.428	5	3.429	4	3.425	m	3.435	3	3.432	20	3.427	5
111	3.356							3.320	2				
120	3.125					3.140	vw						
200	3.020	3.019	5	3.022	2	3.023	w	3.040	3	3.021	20	3.028	3
121	2.852	2.852	5	2.850	2	2.849	w	2.860	2	2.848	20	2.848	3
								2.785	3				
211	2.705	2.708	3	2.704	1	2.704	Bw					2.710	3
210	2.665			2.663	<1	2.637	w						
002	2.496			2.497	<1							(2.501)	1
121	2.482	2.484	10	2.480	3	2.479	Bm	2.484	3	2.479	30	2.480	12
211	2.453	2.443	5	2.450	1	2.445	w	2.445	1	2.454	20	2.455	8
220	2.392												
112	2.392	2.392	40	2.392	9	2.392	s	2.393	10	2.392	70	2.393	27
211	2.322	2.323	1	2.349	<1	2.330	vw					2.333	5
211	2.261	2.263	40	2.263	15	2.261	s	2.269	9	2.261	70	2.271	29
130	2.216	2.219	1			2.225	w					2.217	3
031	2.149	2.147	5	2.148	1	2.148	vw	2.152	2			2.146	3
122	2.114	2.112	1			2.097	vw					2.113	2
212	2.074											2.074	3
112	2.070			2.033	<1								
031	2.017	2.017	30	2.016	8	2.016	s	2.018	10	2.015	50	2.016	24
310	1.988	1.983	1			1.982	vw					(1.991)	2
301	1.971					1.959	vw					1.975	1
022	1.943	1.944	3	1.9434	<1	1.939	vw					1.945	5
222	1.902	1.899	30	1.9008	8	1.899	s	1.902	10	1.898	50	1.902	19
310	1.880			1.8797	<1							(1.877)	2
320	1.820											1.821	2
202	1.798			1.8017	<1					1.799	40	1.804	3
132	1.781												
301	1.778	1.779	15	1.7807	5	1.779	ms	1.783	7			1.784	13
040	1.716	1.716	1	1.7152	<1	1.715	vw					1.715	1
312	1.702												
311	1.697	1.698	2	1.7016	<1	1.704	w					1.704	2
141	1.671	1.670	7	1.6706	2	1.672	w					1.668	4
231	1.654												
013	1.649			1.6518	<1	1.653	vw			1.652	20	1.653	3
231	1.632											1.632	2
321	1.620												
321	1.618											1.616	1
132	1.614												
222	1.594	1.594	7	1.5948	2	1.593	wm	1.599	2	1.593	20	1.598	5
222	1.592												
132	1.574												
123	1.572	1.571	2	1.5722	<1	1.574	w	1.575	1	1.572	20	1.572	4
213	1.564												
240	1.563											1.560	1
132	1.556												
141	1.549	1.550	5	1.5495	1	1.549	wm	1.547	1	1.547	20	1.547	6
411	1.514												
141	1.513	1.513	10	1.5134	4	1.513	m	1.515	2	1.511	30	1.517	7
213	1.478	1.478	10	1.4773	3	1.477	m	1.475	2	1.476	30	1.479	6
332	1.465	1.464	1	1.4638	<1	1.465	vw					1.465	2
312	1.440												
330	1.440												
123	1.439	1.438	15	1.4395	5	1.440	ms					1.441	14
123	1.438												
241	1.430			1.4273	1	1.429	wm					1.430	5
240	1.430												
033	1.403	1.403	2	1.4037	1	1.405	w					1.404	3
303	1.387	1.386	1	1.3866	<1	1.387	vw					1.388	2
150	1.369	1.370	1			1.373	vw					1.370	1
042	1.362												
322	1.360											1.365	1
323	1.354												
213	1.354												
223	1.353	1.353	3	1.3534	<1	1.353	w						
422	1.353												
251	1.305	1.305	5	1.3051	1	1.305	m						

332	1.277						
341	1.274		1.2753	<1	1.276		vw
332	1.249						
004	1.248	1.248	5	1.2499	1	1.250	wm
043	1.248						
014	1.247						
242	1.242					1.242	vw
323	1.228	1.227	3	1.2257	1	1.226	wm
422	1.226						
114	1.216	1.217	1			1.216	w
341	1.216						
440	1.196			1.1969	1	1.197	
521	1.193	1.195	5	1.1936	1	1.192	Bm
350	1.193			1.1936	1	1.192	
152	1.183	1.183	2	1.1832	<1	1.183	wm
						1.175	vw
				1.1615	<1	1.162	wm
				1.1146	<1	1.116	wm
						1.078	wm
						1.052	wm
						1.010	m

1. This study. $\text{CuK}\alpha$ radiation, $\lambda = 1.5418\text{\AA}$, 114.6mm Gandolffi camera, NBS Si as internal standard, visual intensities.
2. Hathaway & Schlanger (1962, 1965). $\text{CuK}\alpha^1$ radiation, $\lambda = 1.54050\text{\AA}$, diffractometer cutoff $2^\circ(2\theta)$.
3. Wall *et al.* (1962). Fe radiation, 114.8mm camera, s = strong, m = moderate, w = weak, v = very, B = broad.
4. Goldberry & Loughnan (1977). Sample from the Glen Alice area near Mt. Canobola.
5. Marić (1968). Diffractometer data, $\text{CuK}\alpha$ radiation.
6. Bosmans (1970). Diffractometer data, $\text{CuK}\alpha$ radiation, $\lambda = 1.5418\text{\AA}$, quartz as internal standard, net integrated intensities.

1968) showed the stacking in nordstrandite to be ABBCCA.

The polymorphism in $\text{Al}(\text{OH})_3$, however, is apparently more complicated than is generally believed. A triclinic "hydrargillite" from Schischimsk, Urals, with a 17.338, b 10.086, c 9.730 Å, α $94^\circ 10'$, β $92^\circ 08'$, γ $90^\circ 00'$ and $Z=32$ was reported by Saalfeld (1960) as forming oriented intergrowths with gibbsite. In a private communication (1979), Saalfeld stated

that many years later the same triclinic phase with the same oriented intergrowths with gibbsite was found again in a bauxite deposit in India. Despite the scanty data available, this triclinic phase is almost certainly not nordstrandite, as the powder pattern of nordstrandite cannot be indexed on the basis of the large triclinic cell.

Recently, an unidentified mineral, UK45, from Mont St-Hilaire (Chao & Baker 1979)

TABLE 5. OCCURRENCES AND PHYSICAL PROPERTIES OF NORSTRANDITE

	1 Mont St-Hilaire Quebec	2 Guam	3 Rio Blanco Colorado	4 Sarawak Borneo	5 Narsarsuk Greenland	6 USSR	7 Croatia
Occurrence	Nepheline syenite	Limestone solution cavities	Fissure-fillings in dolomitic marlstone & oil shale	Limestone residual soil	Pockets in nepheline syenite	Carbonate rocks solution cavities	Limestone terra rossa
Habit	Tabular & blocky xls	Aggregates of bladed & flamboyant xls	Platy & fibrous aggregates	Rhombic xls, polycrystalline aggregates	Spherules, sheaf-like aggregates of acicular xls	Stringers, aggregates of acicular xls	Leaf-like aggregates
Color	Colorless, white, pink, pale green	Colorless, white	White	Colorless, pink	Cream, snow-white	White	White, pink
Hardness	~ 3	3	--	--	--	--	--
D(meas)/ cm^3	2.42	2.43		2.43	2.41		2.5
R.I. α	1.580(1)(Na)	1.580(4)		1.580	1.579(2)(Na)	1.58	1.565-1.570
β	1.583(1)	1.580(4)	1.570	1.581	1.579(2)	1.58	1.565-1.570
γ	1.602(1)	1.596(4)		1.613	1.584(1)	1.596	1.585-1.590
$2V_Z$ meas	24°	low		18°			$10-40^\circ$
calc	21.9°	0°		10.2°	0°	0°	
Elongation	(-)	(-)			(+)		

1. This study
2. Hathaway & Schlanger (1962, 1965)
3. Milton *et al.* (1975)
4. Wall *et al.* (1962)
5. Petersen *et al.* (1976)
6. Kulikova *et al.* (1974)
7. Marić (1968)

has been established to be a new polymorph of $\text{Al}(\text{OH})_3$. The mineral is triclinic with a 5.002, b 5.175, c 4.980 Å, α 97.50°, β 118.60°, γ 104.74° and $Z=2$, distinct from all known phases of $\text{Al}(\text{OH})_3$ including the triclinic "hydrargillite" of Saalfeld. Moreover, a nordstrandite-like mineral has been found in association with nordstrandite on a specimen from Mont St-Hilaire. It occurs as powdery sprays and as spherulitic aggregates of extremely fine-grained crystals. Its composition is close to $\text{Al}(\text{OH})_3$, and its powder diffraction pattern is very similar to that of nordstrandite. The major difference in the X-ray powder pattern occurs in the shift of some moderately strong lines by up to 0.05 Å in either direction. Some lines are noticeably diffuse. This mineral, tentatively designated UK51, is thus most likely a new phase of $\text{Al}(\text{OH})_3$, perhaps a phase with stacking disorder. A full description of these phases from Mont St-Hilaire will be presented in forthcoming papers.

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