FERRO-FERRI-NYBØITE, NaNa₂(Fe²⁺₃Fe³⁺₂)Si₈O₂₂(OH)₂, A NEW CLINOAMPHIBOLE FROM MONT SAINT-HILAIRE, QUÉBEC, CANADA: DESCRIPTION AND CRYSTAL STRUCTURE

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Abstract

Ferro-ferri-nybøite, NaNa₂(Fe²⁺₃Fe³⁺₂)Si₈O₂₂(OH)₂, is a new mineral of the amphibole group from Poudrette quarry, Mont Saint-Hilaire, La Vallée-du-Richelieu RCM, Montérégie (formerly Rouville County), Québec, Canada. It occurs in an igneous microbreccia associated with a eudialyte-group mineral, an astrophyllite-group mineral, albite, and nepheline. Crystals are prismatic parallel to [001] with {100} and {110} forms and cleavage surfaces, and the prism direction is terminated by irregular fractures. Grains are up to 3 cm long, and occur as blocky aggregates. Crystals are black with a greyishgreen to black streak. Ferro-ferri-nybøite is brittle, has a Mohs hardness of 6 and a splintery fracture; it is non-fluorescent with perfect {110} cleavage, no observable parting, and has a calculated density of 3.424 g/cm³. Crystals show extreme optical absorption due to intervalence charge transfer, which inhibited measurement of optical properties.

Ferro-ferri-nybøite is monoclinic, space group *C2/m*, *a* 9.9190(5), *b* 18.0885(8), *c* 5.3440(3) Å, β 103.813(1)°, *V* 931.09 (13) Å³, *Z* = 2. The strongest ten X-ray diffraction lines in the powder pattern are [*d* in Å(*I*)(*hkl*)]: 8.520(100)(110), 3.162 (55)(310), 2.834(24)(330), 1.671(19)(461), 2.732(10)(151), 2.552(10)(202), 2.344(9)(351), 3.298(7)(240), 2.606(6)(061), 1.446(6)(661,4.10.0). Analysis by a combination of electron microprobe and Mössbauer spectroscopy gives SiO₂ 45.80, Al₂O₃ 3.11, TiO₂ 0.50, Fe₂O₃ 11.18, FeO 23.45, MnO 2.28, ZnO 0.12, MgO 0.23, CaO 0.99, Na₂O 8.01, K₂O 1.30, F 0.81, H₂O_{calc} 1.47, O ≡ F–0.34 sum 98.91 wt%. The formula unit, calculated on the basis of 24 (O + OH + F) with (OH + F) = 2 *apti* is (Na_{0.68}K_{0.27})_{S0.95}(Na_{1.83}Ca_{0.17})_{S2.00}(Mg_{0.06}Fe²⁺³,17Mn_{0.31}Zn_{0.01}Fe³⁺,1₃₆Ti_{0.06})_{S4.97}(Si_{7.41}Al_{0.59})_{S8.00}O₂₂(OH)_{1.58}F_{0.42})_{S18}O₂₂(OH)₂, is related to endmember nybøite, NaNa₂(Mg₃Al₂)Si₈O₂₂(OH)₂ by the substitutions Fe²⁺ → Mg and Fe³⁺ → Al.

Keywords: Ferro-ferri-nybøite, new amphibole, nybøite, electron-microprobe analysis, Mössbauer spectroscopy, crystal-structure refinement, Mont Saint-Hilaire, Canada.

INTRODUCTION

Amphibole compositions approximating NaNa₂ (Al₂Mg₃)(Si₇Al)O₂₂(OH)₂ were reported by Ungaretti *et al.* (1981) from the Nybø eclogite pod, Norway. The root-name "nyböite" was mentioned as being under consideration by the IMA (Ungaretti *et al.* 1981), and had been approved in 1980, but a full description was not published at that time (see detailed discussion

by Oberti *et al.* 2003). Despite subsequent reports on the occurrence, chemical composition, and crystal structure of this amphibole (*e.g.*, Hirajima *et al.* 1992, Pawley 1992, Hawthorne *et al.* 1996), a comprehensive description of "nyböite" was not reported until the formal description of "fluoro-nyböite" by Oberti *et al.* (2003). If this were not irregular enough, the previous IMA amphibole classification gave the root-name "nyböite" (Leake *et al.* 1997), whereas the current IMA

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amphibole classification gives the root-name nybøite (Hawthorne *et al.* 2012) to the composition NaNa₂ (Al₂Mg₃)(Si₇Al)O₂₂(OH)₂. As part of a preliminary examination of the crystal chemistry of amphiboles from Mont Saint-Hilaire, Quebec (Taylor 1999), a sample from an igneous breccia was found to contain an amphibole-group mineral whose chemical composition resembles that of nybøite, but which shows dominance of Fe²⁺ and Fe³⁺ at the C position of the amphibole formula. Here, we report on the characterization and occurrence of the new clinoamphibole species, ferro-ferri-nybøite.

The new species and the new name (Hawthorne *et al.* 2012) have been approved by the International Mineralogical Association Commission on New Minerals and Mineral Classification (2013-072). Holotype material is deposited in the mineral collection of the Department of Natural History, Royal Ontario Museum, 100 Queens Park, Toronto, Ontario, M5S 2C6, Canada, catalogue number M55980.

OCCURRENCE

The sample of ferro-ferri-nybøite was discovered in the Poudrette quarry, Mont Saint-Hilaire, La Valléedu-Richelieu RCM, Montérégie (formerly Rouville County), Québec, Canada, in an igneous breccia collected by Dr. P. Tarassoff (Beaconsfield, Quebec) on 29 July, 1995. It occurs as anhedral to subhedral, stubby crystals up to 3×3 cm, but most averaging 0.5×0.5 cm. The mineral is jet-black in color, and occurs in association with an astrophyllite-group mineral, a reddish to brownish eudialyte-group mineral, albite, and nepheline. A secondary amphibole is also present, but it is distinct in that it occurs as euhedral, prismatic greenish-brown crystals that average $100 \times 300 \ \mu m$ in size. Paragenetically, ferro-ferri-nybøite is the earliest mineral formed and it commonly shows evidence of having been subsequently overgrown by nepheline.

PHYSICAL AND OPTICAL PROPERTIES

Ferro-ferri-nybøite is black with a vitreous luster. It has a greyish-green to black streak and shows no fluorescence under long-wave or short-wave ultraviolet light. Grains are prismatic parallel to [001] with {100} and {110} forms and cleavage faces, and the prism direction is terminated by irregular fractures. They are up to 3 cm long and occur as blocky aggregates. Ferro-ferri-nybøite has a Mohs hardness of ~6 and is brittle with a splintery fracture; it has the characteristic perfect {110} cleavage of amphiboles, intersecting at ~56°. The calculated density (using the empirical formula and the single-crystal cell-dimensions) is 3.424 g/cm^3 .

We were unable to measure the optical properties of this amphibole despite extensive effort. The crystals show extreme optical absorption due to intervalence



FIG. 1. The ⁵⁷Fe Mössbauer spectrum of ferro-ferri-nybøite.

charge transfer. When attempting to measure extinction curves on a spindle stage, the strongly anisotropic absorption due to IVCT was superimposed on the extinction curves, giving curves with two sets of maxima and minima (instead of the one set normally observed). In addition, the resultant maxima and minima were displaced (by an undetermined amount) from their ideal positions. Consequently, we could not properly orient the crystals optically so as to measure their optical properties. We tried crystals as small as 5 microns in size, but could not eliminate this effect. In tiny grains and on the thin edges of larger grains, the amphibole is strongly pleochroic in shades of dark greenish blue to black.

MÖSSBAUER SPECTROSCOPY

Fragments of ferro-ferri-nybøite were ground with an agate mortar and pestle, placed on a Pb ring (2 mm inner diameter), and secured in place with tape. The Mössbauer spectrum was acquired in transmission geometry at room temperature using a ⁵⁷Co(Rh) point source, and the spectrometer was calibrated with the room-temperature spectrum of α -Fe. The spectrum was analyzed in terms of a Voigt-function-based quadrupole-splitting distribution (Rancourt & Ping 1991) using the RECOIL® software package. Figure 1 shows the Mössbauer spectrum of ferro-ferri-nybøite fit to a model having two generalized sites. The Fe²⁺ site (dashed line) has three Gaussian components and

TABLE 1. CHEMICAL COMPOSITION (wt.%) AND
UNIT FORMULA (apfu) FOR FERRO-FERRI-NYBØITE

SiO ₂	45.80	Si	7.41
TiO ₂	0.50	Al	0.59
Al ₂ O ₃	3.11	Sum T	8.00
Fe ₂ O ₃	11.18		
FeO	23.45	Al	0.00
MnO	2.28	Ti ⁴⁺	0.06
ZnO	0.12	Fe ³⁺	1.36
MgO	0.23	Fe ²⁺	3.17
CaO	0.99	Mn	0.31
Na ₂ O	8.01	Zn	0.01
K ₂ O	1.30	Mg	0.06
H ₂ O	1.47	Sum C	4.97
F	0.81		
-O=F	-0.34	Ca	0.17
Total	98.91	Na	1.83
		Sum B	2.00
		Na	0.68
		К	0.27
		Sum A	0.95
		(OH)	1.58
		F	0.42
		Sum W	2.00

TABLE 2.	X-RAY POWDER DIFFRACTION DATA FO	R
	FERRO-FERRI-NYBØITE	

l _{est.} *	d _{meas} A	d _{calc} A	h	k	
100	8.520	8.502	1	10	0
4	4.822	4.816	2	0	0
5	4.524	4.522	0	4	0
3	3.430	3.431	1	3	1
7	3.298	3.297	2	4	0
55	3.162	3.161	3	1	0
4	2.992	2.994	2	2	1
24	2.834	2.834	3	3	0
3	2.742	2.742	Ī	3	1
10	2.732	2.733	1	5	1
6	2.606	2.607	0	6	1
3	2.599	2.597	2	4	1
10	2.552	2.553	Ž	0	2
5	2.402	2.401	3	5	0
9	2.344	2.345	Ī	5	1
2	2.304	2.306	Ī	7	1
1	2.286	2.287	Ī	1	2
2	2.197	2.197	1	7	1
4	2.186	2.185	2	6	1
2	2.085	2.086	2	0	2
3	2.045	2.045	3	5	1
1	2.022	2.022	4	0	2
2	1.961	1.961	4	2	1
3	1.885	1.885	4	6	1
2	1.835	1.836	4	4	1
3	1.809	1.809	0	10	0
2	1.753	1.753	5	1	2
2	1.693	1.693	2	10	0
	1.693	1.693	Ż	8	2
1	1.684	1.683	Ī	9	1
19	1.671	1.672	4	6	1
1	1.648	1.648	4	8	0
3	1.621	1.621	1	11	0
3	1.605	1.605	6	0	0
		1.596	Ī	5	3
5	1.539	1.540	6	0	2
2	1.524	1.525	Ż	6	3
	1.524	1.524	5	5	1
2	1.520				
2	1.507	1.507	0	12	0
4	1.463	1.464	3	11	0
6	1.446	1.447	6	6	1
	1.446	1.446	4	10	0

*The ten most intense lines are bolded.

the Fe³⁺ site (dash-dot line) has one Gaussian component. We do not know the relative recoil-free fractions of Fe²⁺ and Fe³⁺ in ferro-ferri-nybøite, but measurements on riebeckite (Eeckhout & De Grave 2003) suggest differences on the order of 10%. Using these in conjunction with the area ratio derived from the Mössbauer spectrum of ferro-ferri-nybøite gives an Fe^{3+}/Fe^{tot} value of 0.30(2).

CHEMICAL COMPOSITION

Ferro-ferri-nybøite was analyzed using a Cameca SX-100 operating in the wavelength-dispersive mode with an excitation voltage of 15 kV, specimen current 10 nA, beam diameter 5 µm, peak-count time 20 s, and background-count time 10 s. The following standards and crystals were used for $K\alpha$ X-ray lines: Si, Ca: diopside, TAP, LPET; Ti: titanite, LPET; Fe: fayalite, LLiF; Mn: spessartine, LLiF; Mg: forsterite, TAP; Na: albite, LTAP; Al: andalusite, TAP; F: fluoro-riebeckite, LTAP; Zn: gahnite, LLiF; K, orthoclase, PET. Data reduction was done using the $\varphi(\rho Z)$ procedure of Pouchou & Pichoir (1985). The average of 10 analyses on a single grain is given in Table 1. The Fe^{3+} :(Fe^{2+} +Fe³⁺) ratio was derived by Mössbauer spectroscopy. The chemical formula was calculated on the basis of 24 (O + OH + F) with OH + F = 2 apfu (atoms per formula unit) and is as follows: ${}^{A}(Na_{0.68}K_{0.27})_{\Sigma 0.95}(Na_{1.83}Ca_{0.17})_{\Sigma 2.00}(Mg_{0.06}Fe^{2+}_{3.17}Mn_{0.31}Zn_{0.01}Fe^{3+}_{1.36}Ti_{0.06})$ $\Sigma_{4.97}(Si_{7.41}Al_{0.59})_{\Sigma_{8.00}}O_{22}(OH_{1.58}F_{0.42})_{\Sigma_{2.00}}$

X-RAY POWDER DIFFRACTION

The powder-diffraction pattern was recorded using a D5000 Bruker powder diffractometer (Ni-filtered CuK α radiation, $\lambda = 1.54178$ Å). No internal standard was used. The indexed powder pattern is listed in Table 2. Unit-cell parameters refined from the powder data (Table 2) are as follows: *a* 9.918(1), *b* 18.087(2), *c* 5.342(1) Å, β 103.81(1)°, *V* 930.6(1) Å³. The pattern was indexed on the space group *C2/m* as indicated by single-crystal structure refinement.

CRYSTAL-STRUCTURE REFINEMENT

A crystal was attached to a tapered glass fibre and mounted on a Bruker P4 diffractometer equipped with a 4K CCD detector (Mo $K\alpha$ radiation). A total of 8188 intensities was collected to 65° 2 θ using 10 s per 0.2°

frame, with a crystal-to-detector distance of 5 cm. Empirical absorption corrections (SADABS; Sheldrick 2008) were applied and equivalent reflections were corrected for Lorentz, polarization, and background effects, averaged and reduced to structure factors. The unit-cell dimensions were obtained by least-squares refinement of the positions of 6593 reflections with I > $10\sigma I$ and are given in Table 3, together with other information pertaining to data collection and structure refinement. All calculations were done with the SHELXTL PC (Plus) system of programs; R indices are of the form given in Table 3 and are expressed as percentages. The structure was refined to convergence by full-matrix least-squares methods with anisotropicdisplacement parameters for all atoms except those in the A cavity. At a later stage of refinement, difference-Fourier maps showed a weak density maximum approximately 1 Å from the O(7) anion. This maximum was entered into the structure model as an H atom and its parameters were refined with the soft constraint that the O(7)-H distance be approximately 0.98 Å. The structure converged to a final R_1 index of 3.14%. Refined atom coordinates and anisotropic-displacement parameters are listed in Table 4; selected interatomic distances and angles are given in Table 5. A table of structure-factors and a cif file may be obtained from The Depository of Unpublished Data on the MAC website [document ferro-ferri-nybøite CM52_10.3749/canmin.1400057].

DERIVATION OF SITE POPULATIONS

Site populations were derived from the results of EMP analysis and structure refinement. The refined <T-O> distances (Table 5) indicate the presence of appreciable Al at the *T* sites, in accord with the chemical formula (Table 1). Using the regression equation given by Hawthorne & Oberti (2007), and the ^[4]Al content indicated by the unit formula of ferro-ferri-nybøite, we obtain a calculated value for <T-O> of 1.638 Å, in accordance with the observed value of 1.639 Å.

Minor Ti was assigned to M(2) in accord with the site occupancy generally found in monoclinic

a (Å)	9.9190(5)	crystal size (μm)	200 × 200 × 330
b	18.0885(8)	radiation/monochromator	Mo <i>K</i> α/Graphite
с	5.3440(3)	No. unique reflections	1402
β (°)	103.813(1)	No. $I_{o} > 4\sigma I$	1382
V (Å ³)	931.09(13)	R _{merge} %	1.88
Sp. Gr.	C2/m	Robs %	3.14
Z	2	R _{all} %	7.21
$D_{ m calc}$ (g cm ⁻³)	3.424		

TABLE 3. MISCELLANEOUS INFORMATION FOR FERRO-FERRI-NYBØITE

	x	У	Z	U ₁₁	U ₂₂	U ₃₃	U ₂₃	U ₁₃	<i>U</i> ₁₂	U _{eq}
<i>T</i> (1)	0.27830(7)	0.08604(4)	0.29111(13)	0.0079(3)	0.0062(3)	0.0065(3)	0.0002(2)	0.0009(2)	0.0001(2)	0.00703(18)
T(2)	0.28889(7)	0.17093(4)	0.80075(13)	0.0081(3)	0.0084(3)	0.0079(3)	-0.0002(2)	0.0021(2)	-0.0011(2)	0.00808(18)
<i>M</i> (1)	0	0.09148(3)	1/2	0.0118(3)	0.0102(3)	0.0086(3)	0	0.00319(19)	0	0.01009(19)
<i>M</i> (2)	0	0.18347(3)	0	0.0082(3)	0.0069(3)	0.0088(3)	0	0.00238(18)	0	0.00791(18)
M(3)	0	0	0	0.0116(4)	0.0069(4)	0.0085(4)	0	0.0017(3)	0	0.0091(3)
M(4)	0	0.27795(9)	1/2	0.0203(9)	0.0130(8)	0.0210(9)	0	0.0134(6)	0	0.0167(5)
O(1)	0.1096(2)	0.09085(10)	0.2069(4)	0.0097(8)	0.0119(9)	0.0086(8)	-0.0006(6)	0.0016(7)	-0.0012(6)	0.0102(4)
O(2)	0.12071(19)	0.17298(10)	0.7349(4)	0.0093(8)	0.0113(8)	0.0113(8)	-0.0013(7)	0.0012(7)	0.0002(7)	0.0108(4)
O(3)	0.1099(3)	0	0.7074(5)	0.0227(13)	0.0216(13)	0.0218(13)	0	0.0046(11)	0	0.0221(6)
O(4)	0.3650(2)	0.24827(11)	0.7975(4)	0.0165(9)	0.0111(9)	0.0141(9)	-0.0019(7)	0.0064(7)	-0.0054(7)	0.0134(4)
O(5)	0.3476(2)	0.12845(12)	0.0800(4)	0.0125(9)	0.0185(10)	0.0125(8)	0.0056(7)	0.0029(7)	0.0007(7)	0.0145(4)
O(6)	0.3394(2)	0.11873(11)	0.5821(4)	0.0132(9)	0.0165(10)	0.0133(9)	-0.0056(7)	0.0034(7)	-0.0003(7)	0.0143(4)
O(7)	0.3327(3)	0 ` ´	0.2940(6)	0.0134(13)	0.0098(12)	0.0221(14)	0	0.0023(11)	0	0.0155(6)
н	0.213(2)	0	0.754(10)	0.01500(0)	. ,	. ,		. ,		
A(2)	Ô	0.5127(5)	Ô Í	0.0171(15)						
A(m)	0.0368(17)	1/2	0.091(3)	0.0171(15)						
A(m)'	0.085(5)	1/2	0.160(7)	0.0171(15)						

TABLE 4. ATOM COORDINATES FOR FERRO-FERRI-NYBOITE

<i>T</i> (1)–O(1)	1.628(2)	<i>M</i> (1)–O(1)	×2	2.109(2)	A(2)–O(5)	×4	2.676(7)
<i>T</i> (1)–O(5)	1.644(2)	<i>M</i> (1)–O(2)	×2	2.113(2)	A(2)–O(6)	×4	3.084(6)
<i>T</i> (1)–O(6)	1.638(2)	<i>M</i> (1)–O(3)	×2	2.139(2)	A(2)-O(7)	×4	2.553(3)
<i>T</i> (1)–O(7)	1.647(1)	< <i>M</i> (1)–O>		2.120			
< <i>T</i> (1)–O>	1.639				A(m)-O(5)	×2	2.837(4)
		<i>M</i> (2)–O(1)	×2	2.153(2)	A(m)-O(5)	×2	2.978(4)
T(2)-O(2)	1.621(2)	M(2) - O(2)	×2	2.070(2)	A(m)-O(6)	×2	2.856(12)
T(2) - O(4)	1.592(2)	M(2) - O(4)	×2	1.948(2)	A(m)-O(7)		2.514(8)
T(2) - O(5)	1.656(2)	< <i>M</i> (2)–O>		2.057	A(m)-O(7)		2.678(8)
T(2) - O(6)	1.669(2)				A(m)-O(7)		3.23(2)
< <i>T</i> (2)–O>	1.635	<i>M</i> (3)–O(1)	×4	2.129(2)			
		M(3)–O(3)	×2	2.108(3)	A(m)'-O(5)	×2	2.81(1)
		< <i>M</i> (3)–O>		2.122	A(m)'-O(5)	×2	3.26(3)
					A(m)'-O(6)	×2	2.56(2)
		<i>M</i> (4)–O(2)	×2	2.430(2)	A(m)'-O(7)		2.73(2)
		M(4) - O(4)	×2	2.359(2)	A(m)′-O(7)		2.76(3)
		<i>M</i> (4)–O(6)	×2	2.560(2)	A(m)'-O(7)		2.83(4)
		< <i>M</i> (4)–O>		2.45			

TABLE 5. SELECTED INTERATOMIC DISTANCES (Å) FOR FERRO-FERRI-NYBØITE

amphiboles (Hawthorne 1983, Oberti et al. 1998, Oberti et al. 2007), and Fe* (= Fe + Mn + Ti) was assigned to M(2) to fill the site and reflect the refined site-scattering value. The $\langle M(2)-O \rangle$ distance of 2.057 Å (Table 5) indicates a significant amount of small (trivalent) cations at M(2) in accordance with the presence of major amounts of Fe^{3+} in this amphibole (Fig. 1). The only way we can differentiate between $^{[6]}$ Fe²⁺ (r = 0.78 Å) and ${}^{[6]}\text{Fe}^{3+}$ (r = 0.645 Å) (radii from Shannon 1976) is by using the relation between the $\langle M(2) - O \rangle$ bond length and the aggregate radii of the constituent M(2)cations (Hawthorne & Oberti 2007): $\langle M(2)-O \rangle =$ 1.476 + 0.845 $\langle r^{M(2)} \rangle$, R = 0.991, $\sigma = 0.005$ Å. Substituting the $\langle M(2) - O \rangle$ distance of 2.057 Å into this equation gives us the mean radius of the aggregate M(2) cations: 0.688 Å. The M(2) site is occupied by 0.06 Ti (Table 6) and the balance of the cations are Fe^{2+} (= a *apfu*) and Fe^{3+} (= 1.94 - a *apfu*). Thus $0.06 \times 0.605 + 0.78 \times a + (1.94 - a) \times 0.645 = 2 \times 0.688$ Å. Solving for a, we get M(2) = 0.66 Fe²⁺ + 1.28 Fe³⁺ + 0.06 Ti *apfu*.

The observed site-scattering values at the M(1)and M(3) sites (Table 6) indicate that the small amount of Mg present occurs at the M(3) site, as the refined site-scattering value of 24.7 *epfu* is slightly less than that expected for complete occupancy of the site by Fe (= 26 *epfu*; or slightly less if the effect of Mn is taken into account). We have no indication of the possible ordering of Mn and hence Fe²⁺ is written as Fe²⁺ = Fe²⁺ + Mn²⁺ here. The amount of Fe³⁺ in this amphibole (1.36 Fe³⁺ *apfu*, Table 1) is slightly greater than the amount of Fe³⁺ at M(2): 1.28 Fe³⁺ *apfu*, and hence a small amount of Fe³⁺ must occur at M(1) and/or M(3).

The populations of the M(4) and A sites were assigned from the unit formula and are in accord with the refined site-scattering values (Table 6). The resulting

		Site scattering (epfu)			
Site	Site population (apfu)	Refined	Calculated		
<i>T</i> (1)	0.59 AI + 3.41 Si				
T(2)	4 Si				
<i>M</i> (1)	1.80 Fe + 0.20 Mn	51.3(2)	51.8		
<i>M</i> (2)	0.66 Fe ²⁺ + 1.28 Fe ³⁺ + 0.06 Ti	51.2(2)	50.9		
<i>M</i> (3)	0.84 Fe + 0.10 Mn + 0.06 Mg	24.7(1)	25.1		
<i>M</i> (4)	1.83 Na + 0.17 Ca	23.2(2)	23.5		
A	0.68 Na + 0.27 K	12.4(6)	12.6		
O(3)	1.57 (OH) + 0.43 F	15.5	16.4		

TABLE 6. SITE POPULATIONS (apfu) FOR FERRO-FERRI-NYBØITE

site populations were then adjusted to fit the unit formula and the refined site-scattering values equally well, and the final values are given in Table 6.

DISCUSSION

As with other amphiboles with (OH + F) dominant at the O(3) site, octahedrally coordinated trivalent cations in ferro-ferri-nybøite are ordered at the M(2)site. Ferro-ferri-nybøite, ideally NaNa₂(Fe²⁺₃Fe³⁺₂) Si₈O₂₂(OH)₂, is related to endmember nybøite, NaNa₂ (Mg₃Al₂)Si₈O₂₂(OH)₂, by the substitutions Fe²⁺ \rightarrow Mg and Fe³⁺ \rightarrow Al.

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