

Nambulite, a new lithium- and sodium-bearing manganese silicate from the Funakozawa mine, northeastern Japan

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ABSTRACT

The new mineral, nambulite, is a lithium- and sodium-bearing hydrous manganosilicate discovered at the Funakozawa manganese mine in the Kitakami mountains, northeastern Japan. Coarse prismatic crystals of the mineral occur in the veinlets in the braunite ore. It has vitreous reddish brown color with orange tint; and perfect (001), distinct (100) and (010) cleavages. Mohs' hardness is 6.5. Specific gravity is 3.51 ± 0.01 (meas.) and 3.49 (calc.). Optically it is biaxial positive with refractive indices (Na-light) $\alpha = 1.707$, $\beta = 1.710$, $\gamma = 1.730$ (all ± 0.002); with $2V = 30^\circ \pm 2^\circ$ and $X' \wedge c = 19^\circ$.

Chemical analysis gives: SiO_2 49.23, TiO_2 0.01, Al_2O_3 0.37, Fe_2O_3 0.40, MnO 40.67, MgO 1.32, CaO 0.81, Na_2O 2.49, K_2O 0.04, P_2O_5 0.02, Li_2O 1.55, $\text{H}_2\text{O} + 1.63$, $\text{H}_2\text{O} - 0.26$, CO_2 0.19, total 98.99%. The result yields the formula $\text{Li}_{1.00}(\text{Na}_{0.98}\text{K}_{0.01})(\text{Mn}_{6.95}\text{Mg}_{0.40}\text{Li}_{0.27}\text{Ca}_{0.18}\text{Al}_{0.09}\text{Fe}_{0.06}^{+3})\text{Si}_{10.00}\text{O}_{27.79}(\text{OH})_{2.21}$, which may be written ideally as $\text{LiNaMn}_8\text{Si}_{10}\text{O}_{28}(\text{OH})_2$.

It is triclinic and the crystallographic data are as follows: space group, $P1$ or $P\bar{1}$; $a = 7.621$, $b = 11.761$, $c = 6.731 \text{ \AA}$ (all $\pm 0.003 \text{ \AA}$); $\alpha = 92^\circ 46'$, $\beta = 95^\circ 05'$, $\gamma = 106^\circ 52'$ (all $\pm 3'$); $V = 573.4 \pm 0.3 \text{ \AA}^3$; $Z = 1$. Principal powder lines (d in \AA) with relative intensities and indices are: 7.11(25) ($\bar{1}10$), 6.70(25) (001), 3.56(20) (220), 3.54(35) ($12\bar{1}$), 3.34(40) (131 , 002, 201), 3.17(65) ($\bar{1}02$, 031), 3.14(45) (012), 3.09(55) ($\bar{1}12$), 3.07(60) (221), 3.01(30) ($11\bar{2}$), 2.97(80) ($0\bar{2}2$), 2.96(100) ($\bar{1}\bar{1}2$), 2.92(70) ($\bar{1}40$, 102), 2.71(35) (112 , 220). Infrared spectrum shows strong absorptions at 1040, 935, 890 and 460 cm^{-1} .

Nambulite may be an alkaline analogue of rhodonite.

The mineral name is for Professor Matsuo Nambu of Tohoku University.

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Introduction

Nambulite (pronounced ná-m-bu-lait) has been discovered in veinlets in the braunite orebody of the Funakozawa mine, north-eastern Japan. The first specimen of this mineral was collected by Y. Ôkura, Head of the mine, who asked one of the writers (M. Y.) for its identification. At first, the mineral was considered rhodonite, though its color, reddish brown with orange tint, appeared somewhat peculiar. Subsequent laboratory investigations, however, revealed that the mineral was a new lithium- and sodium-bearing hydrous manganosilicate, or a possible alkaline analogue of rhodonite.

The mineral name is in honor of Professor Matsuo Nambu of the Research Institute of Mineral Dressing and Metallurgy, Tohoku University, who is famed for studies of various manganese minerals including such new minerals as manjiroite, kôzulite and takanelite.

The mineral and the mineral name have been approved by the Commission on New Minerals and Mineral Names, I. M. A.

Occurrence

Bedded braunite orebodies of the Funakozawa manganese mine (Lat. 40°15'N, Long. 141°37'E) occur in the Mesozoic (probably Jurassic) formation in the northern Kitakami mountains. The formation consists mainly of slate and chert with some volcanic rocks of basaltic compositions. The manganese mineralization is thought to be primarily related to this volcanic activity.

Nambulite occurs in veinlets up to 5 cm thick which cut the braunite orebody in chert. Coarse prismatic crystals up to 8×4×3 mm are found near the center of the veins. Small amount of albite and neotocite are common accesories. Fine-grained rhodochrosite found along the walls of the veins fills the space between nambulite crystals.

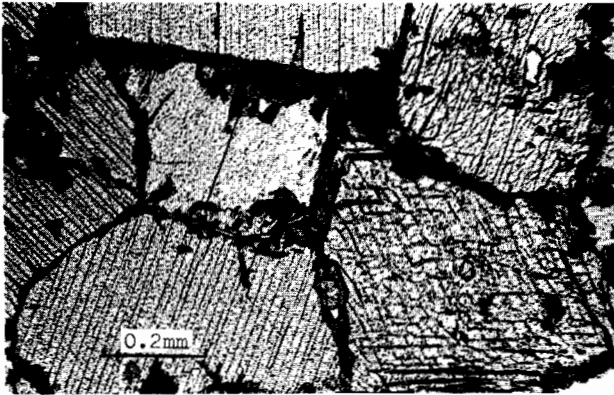


Fig. 1

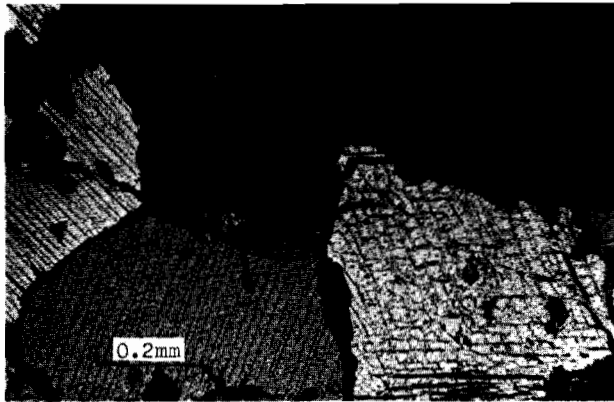


Fig. 2

Fig. 1. Nambulite crystal from the Funakozawa mine (plane light).

Fig. 2. Ditto (crossed nicols).

Physical and optical properties

The crystal of nambulite is prismatic. Its color is reddish brown with orange tint, with vitreous luster. Twinning is infrequent. Cleavages are perfect on (001) and distinct on (100) and (010). Hardness on the Mohs' scale is 6.5. Streak is very pale yellow. Specific gravity measured by Berman balance using carbon tetrachloride is 3.51 ± 0.01 , while it is calculated as 3.49 from the unit cell

data described below.

In thin sections the mineral is transparent with little pleochroism. Refractive indices are measured as $\alpha=1.707\pm 0.002$, $\beta=1.710\pm 0.002$, $\gamma=1.730\pm 0.002$ with the spindle stage, using sodium light. Optical axial angle is $2V(+)=30^\circ\pm 2^\circ$ by the universal stage, with the dispersion being weakly $r>v$. Extinction angle is $X'\wedge c=19^\circ$ on (010).

Chemical composition

Hand specimens which have nambulite crystals on their surface were washed by 6% hydrochloric acid to remove neotocite. The specimens were then broken; and pieces of nambulite crystals were picked up, crushed, and sieved between 100 and 200 meshes. Separation from rhodochrosite was mostly accomplished by Franz Isodynamic separator. However, the purified powdered specimen still contained a small amount of rhodochrosite that exists as filmy coating on the surface of nambulite crystals.

In the chemical analysis MnO was determined with Volhard method, Na_2O and K_2O with Lawrence Smith method, Li_2O with atomic absorption spectrometry and flame photometry, and $\text{H}_2\text{O}+$ with Penfield's method, respectively. The results are shown in Table 1. Assuming that all the detected CO_2 is from rhodochrosite, the weight percentages are recalculated after correcting the amount of MnO.

The chemical formula for the mineral calculated on the basis of $\text{O}+(\text{OH})=30$ is

$\text{Li}_{1.00}(\text{Na}_{0.98}\text{K}_{0.01})(\text{Mn}_{6.95}\text{Mg}_{0.40}\text{Li}_{0.27}\text{Ca}_{0.18}\text{Al}_{0.09}\text{Fe}_{0.06}^{+3})\text{Si}_{10.00}\text{O}_{27.79}(\text{OH})_{2.21}$, or it may be idealized to $\text{LiNaMn}_8\text{Si}_{10}\text{O}_{28}(\text{OH})_2$.

Semiquantitative analysis by emission spectrometry revealed the presence of the following minor constituents in ppm unit: Ba, 850; Cr, 100; Zn, 100; and Ag, 1.

Table 1. Chemical composition and atomic ratios of nambulite.

	Weight percentage	Recalculated percentage	Cation ratios	Atomic ratios as O+(OH)=30	
SiO ₂	49.23%	50.12	0.8340	Si	10.00
TiO ₂	0.01	0.01	0.0001	Ti	0.00
Al ₂ O ₃	0.37	0.38	0.0075	Al	0.09
Fe ₂ O ₃	0.40	0.41	0.0051	Fe ⁺³	0.06
MnO	40.67	41.10	0.5794	Mn	6.95
MgO	1.32	1.34	0.0332	Mg	0.40
CaO	0.81	0.82	0.0146	Ca	0.18
Na ₂ O	2.49	2.53	0.0816	Na	0.98
K ₂ O	0.04	0.04	0.0009	K	0.01
P ₂ O ₅	0.02	0.02	0.0003	P	0.00
Li ₂ O	1.55	1.58	0.1058	Li	1.27
H ₂ O+	1.63	1.66	0.1842	H	2.21
H ₂ O-	0.26				
CO ₂	0.19				
Cl	0.0				
SO ₃	0.0				
Total	98.99	100.01			

Analysis by K. MAEDA.

X-ray diffraction study

The cell dimensions of nambulite were first determined from the precession photographs taken in the three directions perpendicular to the *a*, *b* and *c* axes of the crystal. The dimensions were then refined with the powder diffraction data, using two programs: UTRDCL in UNICS (Takeda, 1967) for transformation into the reduced cell, and APPLEMAN by Appleman & Evans, Jr., (1967) for indexing of the reflections and refinement of the cell dimensions. The indexed powder data are presented in Table 2.

The final cell dimensions of nambulite obtained by the present study are as follows:

34 Nambulite, a new lithium- and sodium-bearing manganese silicate

Table 2. X-ray powder data of nambulite.

<i>hkl</i>	2θ obs.	<i>d</i> obs. Å	<i>Q</i> calc. $\times 10^4$	<i>Q</i> obs. $\times 10^4$	<i>Q</i> dif. $\times 10^4$	<i>I</i> obs.
$\bar{1}10$	15.64	7.11	197	198	-1	25
001	16.61	6.70	224	223	+1	25
020	19.82	5.62	318	316	+2	10
$\bar{1}01$	21.40	5.21	370	368	+2	15
$\bar{1}\bar{1}1$	23.53	4.75	444	444	0	15
021	27.08	4.13	{ 583 }	585	{ -2 }	10
$\bar{1}21$			{ 583 }		{ -2 }	
$\bar{1}\bar{2}1$			{ 589 }		{ +4 }	
120	28.60	3.92	653	651	+2	10
220	31.56	3.56	788	789	-1	20
121	31.73	3.54	791	798	-7	35
131	33.68	3.34	{ 893 }	896	{ -3 }	40
002			{ 895 }		{ -1 }	
201			{ 896 }		{ 0 }	
012	34.45	3.27	933	936	-3	10
$\bar{1}02$	35.60	3.17	{ 997 }	997	{ 0 }	65
031			{ 1001 }		{ +4 }	
012	35.95	3.14	1016	1018	-2	45
$\bar{1}\bar{1}2$	36.49	3.09	1045	1046	-1	55
221	36.70	3.07	1059	1058	+1	60
201	36.97	3.05	1073	1073	0	10
$11\bar{2}$	37.58	3.01	1107	1107	0	30
022	38.03	2.97	1130	1133	-3	80
$\bar{1}\bar{1}2$	38.15	2.96	1139	1140	-1	100
$\bar{1}40$	38.67	2.92	{ 1170 }	1170	{ 0 }	70
102			{ 1174 }		{ +4 }	
122	40.28	2.81	1263	1265	-2	10
$\bar{1}12$	41.93	2.71	{ 1368 }	1366	{ +2 }	35
220			{ 1369 }		{ +3 }	
221	43.45	2.62	1463	1462	+1	40
222	45.46	2.51	{ 1588 }	1593	{ -5 }	15
320			{ 1593 }		{ 0 }	
$\bar{1}32$	45.80	2.49	1618	1616	+2	30
122	47.30	2.41	1720	1717	+3	10
330	48.08	2.38	1772	1771	+1	5
222	48.16	2.37	1777	1777	0	10
151	51.05	2.246	{ 1977 }	1982	{ -5 }	15
231			{ 1985 }		{ +3 }	
050			{ 1985 }		{ +3 }	
232	51.19	2.241	{ 1987 }	1992	{ -5 }	20
142			{ 1988 }		{ -4 }	
013	51.68	2.221	2032	2027	+5	30
331	52.27	2.198	{ 2067 }	2071	{ -4 }	45
301			{ 2068 }		{ -3 }	
$\bar{1}03$			{ 2072 }		{ +1 }	
051	52.81	2.177	{ 2106 }	2111	{ -5 }	10
340			{ 2110 }		{ -1 }	
132	54.45	2.116	2231	2234	-3	10
042	55.73	2.071	{ 2332 }	2331	{ +1 }	10
242			{ 2333 }		{ +2 }	

142 } 123 } 213 }	56.63	2.041	{ 2392 2410 }	2401	{ -9 +9 }	10
232 } 203 } 261 }	58.01	1.996	{ 2505 2509 }	2509	{ -4 -4 0 }	15
043 } 203 } 400 }	63.23	1.847	{ 2935 3036 3041 }	2933	{ +2 -5 0 }	35
441 } 250 } 233 }	64.52	1.814	{ 3043 3468 3473 }	3041	{ +2 -1 +4 }	5
361 } 243 } 160 }	69.52	1.698	{ 3473 3477 3481 }	3469	{ +4 +4 -3 }	25
352 } 313 } 004 }	69.64	1.695	{ 3485 3560 3562 }	3480	{ +5 -3 -1 }	25
402 } 332 } 152 }	70.59	1.675	{ 3581 3583 3585 }	3563	{ -1 -3 -1 }	20
024 } 420 } 422 }	70.83	1.670	{ 3730 3733 3942 }	3584	{ -1 +1 -2 }	35
421 } 104 } 432 }	72.50	1.637	{ 3946 3947 3949 }	3732	{ -4 0 +1 }	10
224 } 114 } 180 }	74.90	1.592	{ 4011 4179 4184 }	3946	{ +1 +3 -11 }	15
314 } 163 } 372 }	75.75	1.577	{ 4691 4975 4994 }	4022	{ +1 -2 -4 }	5
158 } 323 } 171 }	77.50	1.547	{ 4995 4997 5003 }	4181	{ +3 +3 +3 }	5
214 } 181 } 380 }	83.05	1.460	{ 5004 5004 5036 }	4690	{ +1 -2 -1 }	10
244 } 181 } 380 }	86.15	1.417	{ 5049 5054 }	4977	{ -2 -5 -4 }	5
	86.38	1.414	{ 4997 5003 5004 }	4999	{ -2 +4 +5 }	25
	86.79	1.409	{ 5036 5049 5054 }	5037	{ +5 -1 -3 }	15
	86.94	1.406	{ 5049 5054 }	5052	{ -3 +2 }	15

Instrument: Rigaku Denki's "Geigerflex" X-ray diffractometer.

Conditions: Mn filtered Fe radiation ($\lambda=1.9360\text{\AA}$ for $K\alpha_1$) at 30 kV and 10 mA, slits $1^\circ-1^\circ-0.1$ mm, 2θ $0.25^\circ/\text{min.}$, 800 cps., 4 sec., goniometer radius 185 mm.

Computation: By CDC 6600 computer, using APPLEMAN program.

$$\begin{aligned}
 a &= 7.621 \pm 0.003 \text{\AA} & \alpha &= 92^\circ 46' \pm 3' \\
 b &= 11.761 \pm 0.003 & \beta &= 95^\circ 05' \pm 3' \\
 c &= 6.731 \pm 0.003 & \gamma &= 106^\circ 52' \pm 3' \\
 V &= 578.4 \pm 0.3 \text{\AA}^3 & Z &= 1
 \end{aligned}$$

Space group, $P1$ or $P\bar{1}$.*Infrared absorption study*

Infrared absorption spectra of nambulite and rhodonite from Funakozawa are shown in Fig. 3 and Table 3. The spectra for rhodonite and inesite from Broken Hill, Australia (Ryall and Threadgold, 1966) are also given for comparison (Table 3). Ryall and Threadgold (1966) have shown that the number of absorption peaks

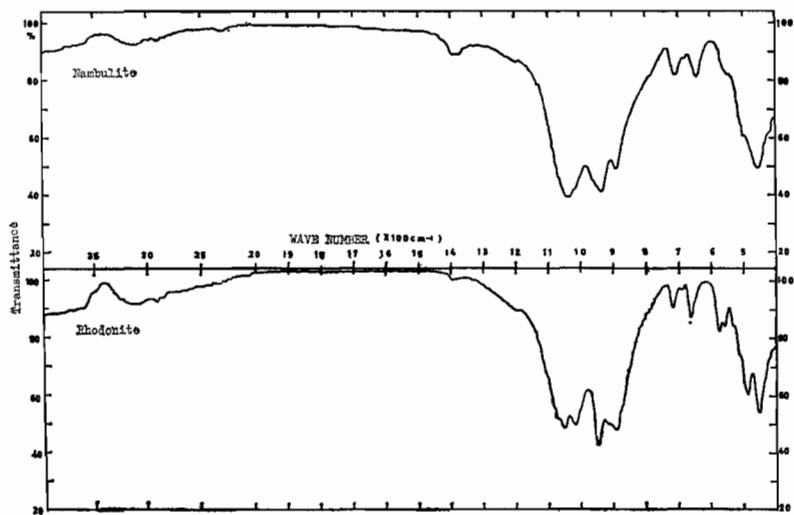


Fig. 3. Infrared absorption spectra of nambulite and rhodonite from the Funakozawa mine.

in the 530 to 775 cm^{-1} region is an indicator of the number of Si-O tetrahedra in the repeat unit of the chains. Comparing to the IR spectrum of rhodonite, the absorption peaks of nambulite are found to be less resolved. However, when the range is extended to 780 cm^{-1} , five peaks are countable at 550 , 640 , 675 , 710 and 780 cm^{-1} , respectively. Thus, it may be assumed that five Si-O tetrahedra

Table 3. Infrared absorption peaks (cm^{-1}) of nambulite, rhodonite and inesite.

Band Assignment	1. Nambulite	2. Rhodonite	3. Rhodonite	4. Inesite
(M-O) stretching } (Si-O) bending }	420 sh, vw	450 s	458 s	450 s
	460 s	490 s	495 s	462 sh, w
	500 sh, w	510 sh, w	514 sh, w	475 sh, w
(Si-O-Si) stretching	550 sh, w	530 sh, w	530 sh, w	495 w
	640 m	555 m	559 m	549 m
	675 w	575 m	579 m	611 m
	710 m	660 m	667 m	663 m
	780 sh, vw	690 w	694 m.	727 m
(Si-O) stretching		715 m	720 m	773 m
	890 s	870 sh, w	870 sh, w	937 vs
	935 s	890 s	895 s	999 s
	1010 sh, w	910 sh, w	915 sh, w	1050 s
	1040 vs	950 vs	950 vs	1087 s
		1020 s	1025 s	
		1050 s	1058 s	
		1080 sh, w	1075 sh, w	
		1190 wb		
		1390 vw		
(OH) bending and stretching			1628 w	1640 s
			3420 w	3250 sh, w
				3420 s
			3620 m	

Band intensity: vs-very strong; s-strong; m-medium; w-weak; vw-very weak; sh-shoulder on a stronger band; wb-weak and broad.

Specimens 1. and 2. are from Funakozawa (this paper), 3. and 4. are from Broken Hill, Australia (RYALL and THREADGOLD, 1966).

form a unit of the chain in the nambulite structure. A broad peak at 1390 cm^{-1} may correspond to the OH bending which is characteristic in pectolite (Ryall and Threadgold, 1966).

Discussion

The chemical composition of nambulite is compared with those of some manganese silicate minerals (Table 4). Nambulite is characteristic in that it has Li and Na as the major components, and is

poor in Ca. Hydrorhodonite is most similar to nambulite in composition. A formula of hydrorhodonite may be written as $(\text{Li}, \text{Ca})\text{MgMn}_3\text{Si}_5\text{O}_{14}(\text{OH})\cdot 4\text{H}_2\text{O}$, using the chemical data by Engström (1875). The formula shows that hydrorhodonite contains magnesium as a major constituent and four molecules of water. The two minerals are, therefore, basically different with each other.

The X-ray powder data (Table 5) show that nambulite is very similar to rhodonite and pyroxmangite, but the patterns of nambulite can be distinguished from those of rhodonite and pyroxmangite by the more lines observed in the range of 2.9 to 3.2Å.

The cell dimensions of the related minerals listed in Table 5 are compared with each other (Table 6). Since no data are available for serandite, the data for pectolite are shown in the table as a substitute. The cell dimensions of the original data were transformed into the reduced ones for the convenience of comparison, employing UNICS UTRDCL program (Takeda, 1967). The cell dimensions of nambulite, rhodonite and manganbabingtonite resemble each other, but are different from those of pyroxmangite, pectolite (serandite) and inesite.

Though the crystal structure of nambulite has not been established yet, the IR absorption study suggests that the structure contains five Si-O tetrahedra as a structural unit of the chain. Rhodonite and babingtonite are known to have five Si-O tetrahedra in their chains; while pyroxmangite and pectolite have seven and three tetrahedra, respectively (Liebau, 1959). Therefore, the crystal structure of nambulite is considered to have more similarity to those of rhodonite and/or babingtonite.

Conclusion

Based on the chemical and structural data, nambulite may be considered as an alkaline analogue of rhodonite, in which Li and Na seem to substitute Ca. As has been shown by Peacor and

Table 4. Chemical compositions and physical properties of nambulite and other manganese silicates.

	1.	2.	3.	4	5.	6.	7.
SiO ₂	49.23%	46.70	44.07	47.33	51.85	48.72	45.48
TiO ₂	0.01	0.01		tr	0.15		
Al ₂ O ₃	0.37	0.15		0.21	0.56		0.19
Fe ₂ O ₃	0.40	0.47		3.69	12.26		
FeO			1.04	12.50	4.52	1.33	3.03
MnO	40.67	45.87	30.83	29.22	7.91	28.99	33.24
MgO	1.32	1.54	6.98	3.92	0.60		0.23
CaO	0.81	4.57	3.60	2.21	19.00	10.42	8.73
Na ₂ O	2.49	0.01	0.39		0.25	7.38	0.30
K ₂ O	0.04	0.01			0.09		0.18
P ₂ O ₅	0.02				F 0.1		
Li ₂ O	1.55		1.23		Cl 0.06	etc.	
CO ₂	0.19				0.13	0.69	
H ₂ O+	1.63	0.18	} 11.84	0.54	1.95	} 2.67	6.63
H ₂ O-	0.26	0.11		0.23	0.26		2.10
Total	98.99	99.62	99.98	99.85	99.69	100.20	100.11
Color	reddish brown	pink	reddish brown	dark-grey		pink	orange-red-brown
α	1.707	1.724		1.746	1.716	1.660	1.6178
β	1.710	1.728			1.730	1.664	1.6384
γ	1.730	1.736		1.763	1.746	1.688	1.6519
$\gamma-\alpha$	0.023	0.012		0.017	0.030	0.028	0.0341
2V	+30°	+80°		+40°	+78~82°	+36°	-77°
G	3.51	3.62	2.70	3.56	3.452	3.215	3.033

1. Nambulite from the Funakozawa mine, northeastern Japan (this paper). Analysed by K. MAEDA.
2. Rhodonite from the Funakozawa mine (this paper). Analysed by K. MAEDA.
3. Hydrorhodonite from Långban, Sweden (ENGSTRÖM, 1875).
4. Pyroxmangite from Iwaizumi, northeastern Japan (OMORI & HASEGAWA, 1955).
5. Manganbabingtonite from eastern Sayan, USSR. (VINOGRADOVA *et al.*, 1966). Pleochroic with X=green, Y=faint rose, nearly colorless, Z=rose-brown.
6. Serandite from Rouma, Guinea (LACROIX, 1931. Abstract in *Amer. Miner.*, 16 (1931), 344 and 40 (1955), 1029).
7. Inesite from the New Broken Hill Consolidated mine, Australia (RYALL & THREADGOLD, 1968).

Table 5. X-ray powder data of nambulite and some manganese silicates.

1.			2.			3.		4a.		4b.		5.		6.	
<i>hkl</i>	<i>d</i> (Å)	<i>I</i>	<i>hkl</i>	<i>d</i> (Å)	<i>I</i>	<i>d</i> (Å)	<i>I</i>	<i>d</i> (Å)	<i>I</i>	<i>d</i> (Å)	<i>I</i>	<i>d</i> (Å)	<i>I</i>	<i>d</i> (Å)	<i>I</i>
												7.55	ms	9.16	10
$\bar{1}10$	7.11	25	$\bar{1}10$	7.14	25	6.94	3			6.90	52				
001	6.70	25	001	6.70	5	6.67	5			6.67	100	6.75	ms	6.69	1
														6.54	4
														6.15	0.5
020	5.62	10													
$\bar{1}01$	5.21	15										5.24	mw	5.09	4
$\bar{1}\bar{1}1$	4.75	15	$\bar{1}\bar{1}1, 101$	4.78	5	4.73	16			4.72	7			4.59	5
														4.44	0.5
														4.27	3
$\left. \begin{matrix} 021, \bar{1}21 \\ \bar{1}21 \end{matrix} \right\}$	4.13	10	$\bar{1}21$	4.14	2					4.08	7			4.10	1
														4.01	5
														3.89	1
120	3.92	10	030, $\bar{1}30$	3.82	2	3.71	2			3.716	10	3.77	ms	3.79	1
$\bar{2}20$	3.56	20	$\bar{2}20$	3.56	100	3.56	10							3.62	1
$\bar{1}2\bar{1}$	3.54	35												3.55	1
						3.47	8	3.442	8	3.453	67				
$\left. \begin{matrix} \bar{1}31, 002 \\ 20\bar{1} \end{matrix} \right\}$	3.34	40	$\left. \begin{matrix} \bar{1}31, 002 \\ \bar{1}21 \end{matrix} \right\}$	3.34	10			3.320	1	3.330	36	3.38	mw		

42 Nambulite, a new lithium- and sodium-bearing manganese silicate

Table 6. Comparison of reduced-cell dimensions of nambulite and some manganese silicates.

	1.	2.	3.	4.	5.	6.
<i>a</i>	7.621	7.708	7.557	6.88	7.04	8.927
<i>b</i>	11.761	11.86	15.99	11.80	7.99	9.245
<i>c</i> (Å)	6.731	6.710	6.671	6.77	7.02	8.842
α	92°46'	92°39'	94.5°	90°30'	95°17'	96°51'
β	95°05'	93°54'	94.3°	93°30'	90°03'	95°26'
γ	106°52'	104°35'	91.9°	104°54'	102°28'	85°38'
Matrices*	$\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$	$\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$	$\begin{vmatrix} 0 & -1 & 0 \\ 0 & 1 & 1 \\ -1 & 0 & 0 \end{vmatrix}$	$\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$	$\begin{vmatrix} 0 & -1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & -1 \end{vmatrix}$	$\begin{vmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ -1 & 0 & -1 \end{vmatrix}$

* Matrices for transformation of the original data.

1. Nambulite from Funakozawa.
2. Rhodonite from Funakozawa.
3. Pyroxmangite (LIEBAU, 1959).
4. Manganbashingtonite (VINOGRADOVA *et al.*, 1966).
5. Pectolite (BUERGER, 1956).
6. Inesite (RYALL & THREADGOLD, 1968).

Niizeki (1963), Ca in rhodonite preferentially occupies one among five cation sites.

In case of nambulite, Li and/or Na may occupy the position of Ca. However, as the ionic radii of Li and Na are too different one another (Li⁺¹, 0.68; Na⁺¹, 0.97Å) to form a solid solution and the established examples of Li-Na solid solution in minerals are not known, it would be reasonable to assume that the structural positions of Li and Na in nambulite are different. Therefore, the ideal formula for the mineral is considered to be LiNaMn₈Si₁₀O₂₈(OH)₂.

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REFERENCES

- BUERGER, M.J. (1956). *Zeits. Krist.*, **108**, 248.
ENGSTRÖM, N. (1875). *Geol. Fören. Stockholm Förh.*, **2**, 468.
LACROIX, A. (1931). *Compt. Rend. Acad. Sci. Paris*, **192**, 187.
LIEBAU, F. (1959a). *Acta Cryst.*, **12**, 177.
LIEBAU, F. & HILMER, W. (1959b). *Acta Cryst.*, **12**, 182.
MOMOI, H. (1965). *Journ. Min. Soc. Jap.*, **7**, 363 (Abstract in Japanese).
NAMBU, M., TANIDA, K. & KITAMURA, T. (1969). *Bull. Rs. Inst. Min. Dress. Met.*, **25**, 117 (in Japanese).
OMORI, K. & HASEGAWA, S. (1955). *Journ. Jap. Asso. Petro. Econ. Geol.*, **39**, 92 (in Japanese).
PEACOR, D.R. & NIIZEKI, N. (1963). *Zeits. Krist.*, **119**, 98.
RYALL, W.R. & THREADGOLD, I.M. (1966). *Amer. Miner.*, **51**, 754.
RYALL, W.R. & THREADGOLD, I.M. (1968). *Amer. Miner.*, **53**, 1614.
SCHALLER, W.T. (1955). *Amer. Miner.*, **40**, 1022.
TAKASU, S. (1955). *Miner. Journ.*, **1**, 242.
TAKEDA, H. (1967). in *Universal Crystallographic Computation Program System (UNICS)*, ed. by T. Sakurai, **1**, p. 20, Tokyo: Cryst. Soc. Japan.
VINogradova, R.A., SYCHKOVA, V.A. & KABALOV, Yu. K. (1966). *Dokl. Akad. Nauk. SSSR*, **169**, 434 (in Russian).

44 Nambulite, a new lithium- and sodium-bearing manganese silicate

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