

Marsturite, $Mn_3CaNaHSi_5O_{15}$, a new mineral of the nambulite group from Franklin, New Jersey

DONALD R. PEACOR

*Department of Geology and Mineralogy, The University of Michigan
Ann Arbor, Michigan 48109*

PETE J. DUNN

*Department of Mineral Sciences, Smithsonian Institution
Washington, D.C. 20560*

AND B. DARKO STURMAN

*Department of Mineralogy and Geology, Royal Ontario Museum
Toronto, Ontario, Canada*

Abstract

Marsturite, $Mn_3CaNaHSi_5O_{15}$, occurs as white prismatic crystals on rhodonite and manganaxinite from Franklin, New Jersey. It is triclinic, space group $P1$ or $P\bar{1}$, with $a = 7.70(1)$, $b = 12.03(3)$, $c = 6.78(1)A$, $\alpha = 85.26(35)$, $\beta = 94.10(26)$ and $\gamma = 111.04(12)^\circ$, $Z = 2$. Marsturite is isostructural with nambulite. Optical data are: $\alpha = 1.686(2)$, $\beta = 1.691(1)$, $\gamma = 1.708(1)$, biaxial (+), $2V = 60^\circ$. The most intense reflections in the powder pattern are: 3.18(40), 2.999(80), 2.916(90), 2.725(100), 1.441(40).

Introduction

Prismatic crystals having a unique appearance and coating manganaxinite and rhodonite in a specimen from Franklin, N. J., were first observed by one of us (P.D.) on a specimen in the collection of Mr. Neal Yedlin. Mr. Yedlin subsequently generously donated this specimen to the National Museum of Natural History. Qualitative electron microprobe analyses then indicated that these crystals are an unusual Mn,Ca,Na silicate. They were therefore subjected to a detailed study using quantitative electron microprobe and X-ray diffraction techniques, confirming that they are crystals of a new mineral with the ideal formula $Mn_3CaNaHSi_5O_{15}$, and isostructural with nambulite.

We take pleasure in naming this new species marsturite in honor of Marion Stuart (Mrs. E. Hadley Stuart, Jr.) of Bellevue, Idaho. Mrs. Stuart has given generous support to the preservation of natural history specimens, most notably in connection with the Maricopa Brea fossil recovery project south of Bakersfield, California, and the La Brea tar-pit fossil recovery program in Los Angeles. In addition, she

has made substantial contributions to the development of the mineral collections and the new E. Hadley Stuart, Jr. Gem and Mineral Hall of the Los Angeles County Museum of Natural History.

The mineral name is derived from the first three letters of her given name and surname. Both the mineral and the name were approved by the Commission on New Minerals and Mineral Names, IMA, prior to publication. The holotype and only specimen is preserved in the mineral collection of the National Museum of Natural History, Smithsonian Institution, under catalog #127923.

Occurrence

Marsturite is found on only one specimen measuring 1 cm³. The type locality is Franklin, Sussex County, New Jersey. The original label did not state any precise part of the Franklin–Sterling Hill mineral deposit, and the date of collection is not known. However, the mineral assemblage is representative of the manganaxinite known to have come from the mine at Franklin.

Marsturite occurs as white to very light pink, eu-

hedral, prismatic crystals up to 0.5 mm in size, implanted for the most part on yellow manganaxinite. The mineral is associated with rhodonite, willemite, and abundant manganaxinite. The sequence of formation is as follows: manganaxinite containing euhedral colorless willemite, followed by rhodonite, followed by marsturite. The complete sequence was noted on only one part of the specimen, and an incomplete sequence, with most of the marsturite deposited on manganaxinite, is predominant. Hence, marsturite is found coating willemite, rhodonite, and manganaxinite and is the last mineral to form. Marsturite is implanted on only one side of the specimen in a manner suggesting gravity-controlled deposition or growth from a solution flowing in a preferred direction relative to the specimen. For the most part, marsturite occurs as an incrustation of small crystals with their direction of elongation normal to the surface of the host manganaxinite. No epitaxy between the associated minerals and marsturite was noted.

Physical properties

Marsturite is transparent to translucent and white to light pink in color. The density was measured as 3.46 using heavy-liquid techniques, as compared to a calculated value of 3.465. There are two imperfect pinacoidal cleavages, {100} and {001}. Marsturite does not fluoresce in either short or long wavelength ultraviolet radiation. The Mohs' hardness is approximately 6.

The optical properties are as follows: biaxial (+), $2V = 60^\circ(1)$ (meas), $2V = 57.4^\circ$ (calc); $r > v$ very weak; $\alpha = 1.686(2)$, $\beta = 1.691(1)$, $\gamma = 1.708(1)$. Refractive indices were measured using sodium light. The coordinates of the principal vibration directions,

Table 2. Powder X-ray diffraction data as obtained using a 114.6 mm diameter Gandolphi camera, N.B.S. Si internal standard, $CuK\alpha$ radiation, Ni filter, intensities visually estimated. The sample used was polycrystalline.

d(obs)	d(calc)	hkl	I/I ₀	d(obs)	d(calc)	hkl	I/I ₀
7.21	7.18	100	20	2.453	2.457	132	20
6.79	6.76	001	20		2.453	221	
4.81	4.81	101	5		2.451	241	
3.57	3.59	200	5		2.450	321	
3.36	3.38	002	10				
	3.36	031		2.258	2.258	340	10
	3.35	221		2.219	2.224	042	30
	3.34	121			2.223	230	
					2.207	113	
3.18	3.19	031	40	2.118	2.122	251	20
	3.18	012			2.121	103	
	3.17	122			2.117	231	
3.11	3.12	221	30		2.115	322	
	3.11	201					
	3.11	210		2.086	2.089	051	20
	3.11	102			2.088	312	
					2.085	341	
2.999	3.005	102	80	1.714			5
	3.000	122		1.695			30
	2.995	140		1.650			10
2.916	2.916	130	90	1.603			10
2.725	2.728	240	100				
2.640	2.649	131	20	1.555			5
	2.646	041		1.441			40
				1.416			5
2.534	2.533	041	20	1.395			5
	2.531	310					

as determined using a single crystal which was also studied by X-ray and optical goniometer techniques, are X: $\phi = -40^\circ$, $\rho = 11^\circ$; Y: $\phi = 63^\circ$, $\rho = 88^\circ$; Z: $\phi = 153^\circ$, $\rho = 79^\circ$. The extinction angles are: $b\Delta Z' = 4^\circ$ for crystals lying on {001} and $b\Delta Z' = 15^\circ$ for crystals lying on {100}.

Table 1. Electron microprobe analyses of marsturite

	1	2	3	Avg.	Cations/5 Si
SiO ₂	48.95%	48.57%	49.30	48.94%	5.00
FeO	0.22	0.25	0.23	0.24	.02
MgO	0.10	0.12	0.12	0.12	.02
CaO	12.56	12.32	12.5	12.46	1.36 5.17
Na ₂ O	3.99	4.11	4.13	4.08	.81
MnO	33.96	34.32	34.21	34.16	2.96
Total	99.78	99.69	100.49		

- Standards: manganite for Mn, hornblende for all other elements.
- Standards: wollastonite for Si, Ca; manganite for Mn; hornblende for Fe, Mg, Na.
- Standards: An(80) glass for Si, Ca, Na; manganite for Mn; hornblende for Fe, Mg.

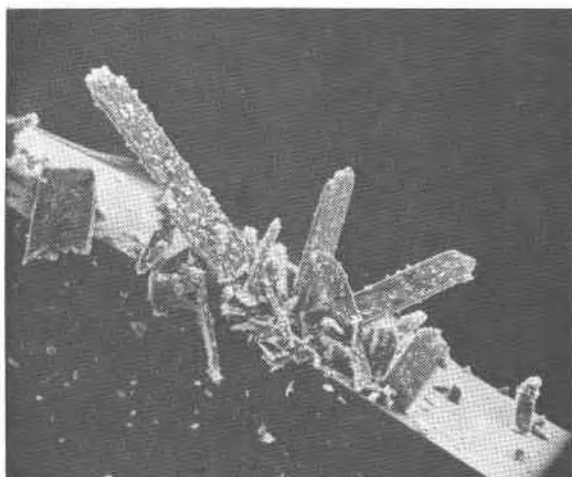


Fig. 1. Scanning electron microscope image (180x) of marsturite crystals.

Chemical analysis

Marsturite was chemically analysed with an ARL-SEMQ electron microprobe utilizing an operating voltage of 15 kV and a beam current of 0.15 μ A. There was insufficient material for a spectrographic analysis, but no elements with atomic number less than nine were detected with a wavelength-dispersive microprobe scan at 20 kV. The mineral was imbedded in epoxy and was analysed in polished thin section. Unprepared crystals were also run in the same batch of analyses as a control on possible alteration during the sample preparation procedures. No differences were noted between the prepared and unprepared crystals. The standards used for the analyses are given, together with the resultant analyses, in Table 1. The data were corrected for absorption, backscatter, fluorescence, and background using standard Bence-Albee correction factors.

Marsturite is homogeneous; no zonal concentrations of any of the cations were observed on step-scans at 10 micron intervals. The associated rhodonite immediately adjacent to marsturite is essentially sodium-free with less than 0.20 percent Na_2O .

Crystallography

Single crystals of marsturite were studied using standard Weissenberg and precession techniques, which showed that it is triclinic with space group $P1$ or $P\bar{1}$. The lattice parameters obtained from single-crystal data were refined using Gandolfi camera data obtained with Si as an internal standard, resulting in the values: $a = 7.70(1)$, $b = 12.03(3)$, $c = 6.78(1)\text{\AA}$, $\alpha = 85.26(35)$, $\beta = 94.10(26)$, $\gamma = 111.04(12)^\circ$. The indexed powder diffraction data are listed in Table 2.

The morphology of the crystals is quite simple (Fig. 1). The crystals are elongated parallel to b with pinacoids $\{100\}$ and $\{001\}$, with $\{001\}$ the more prominent of the two. The tips of the crystals are terminated with a rough imperfectly-defined face which approximates to the pinacoid $\{010\}$. The luster of the crystal faces is frosty, making them appear sub-translucent. There are striations on $\{001\}$ parallel to $\{100\}$.

Crystal chemistry

Calculations of the unit-cell contents yield the following results for cations: $\text{Mn}_{5.86}\text{Ca}_{2.70}\text{Na}_{1.60}\text{Fe}_{0.04}\text{Mg}_{0.04}\text{Si}_{9.91}$; the ratio of Si to the sum of all other cations is 0.97, or nearly one. There is a direct correspondence of both these results and unit-cell parameters to the equivalent parameters of nambulite, $\text{LiNaMn}_8\text{Si}_{10}\text{O}_{28}(\text{OH})_2$ (Yoshii *et al.*, 1972), $\text{LiMn}_4\text{HSi}_5\text{O}_{15}$ (Murakami *et al.*, 1977), and a number of other synthetic Li-hydro-pyroxenoids (Ito, 1972), which are all isostructural. The data show that marsturite is isostructural with these phases.

The crystal structures of nambulite (Narita *et al.*, 1975) and $\text{LiMn}_4\text{HSi}_5\text{O}_{15}$ (Murakami *et al.*, 1977) have been determined. They are based on *fünferketten* chains similar to those in rhodonite and with other cations distributed on 5 equipoints, each of rank 2. The cell contents of marsturite were therefore normalized to 5 Si per unit cell, yielding the results listed in Table 1. On the basis of an isostructural relation between marsturite and the other phases including nambulite, the ideal end-member formula becomes $\text{Mn}_3\text{CaNaHSi}_5\text{O}_{15}$.

Reasonable predictions can be made for marsturite of the distributions of the cations over the five available sites. In the nambulite and $\text{LiMn}_4\text{HSi}_5\text{O}_{15}$ structures the M1, M2, and M3 sites are octahedrally coordinated and occupied by Mn. The 2.93 (per 5 Si) Mn atoms must occupy these sites in marsturite. The M4 site in nambulite is occupied by Ca, and by Mn in $\text{LiMn}_4\text{HSi}_5\text{O}_{15}$, with an irregular coordination polyhedron of seven oxygen atoms (average M4-O distance = 2.38Å). The Ca of marsturite must be largely ordered in that site, although there is excess Ca over the two Ca per cell required for this site. The coordination polyhedra about M1, M2, and M3 are very similar to those for M1, M2, and M3 of rhodonite (Peacor and Niizeki, 1963), and M5 of rhodonite is similar to M4. Peacor and Niizeki showed that $\text{Mn}_4\text{CaSi}_5\text{O}_{15}$ is a limiting composition for rhodonite in terms of Ca, and that hypothesis has been largely verified. Note that Ito (1972) synthesized the phase $\text{Mn}_3\text{CaLiHSi}_5\text{O}_{15}$, clearly the Li analogue of marsturite, and this composition represented the maximum Ca content for his synthetic phases which are isostructural with nambulite. The Na of marsturite must occupy the M5 site in the equivalent nambulite structure, taking the place of Li. There is a deficiency of Na relative to that required to fill that site, possibly compensated by some of the Ca which is in excess relative to the M4 site.

References

- Ito, J. (1972) Synthesis and crystal chemistry of Li-hydro-pyroxenoids. *Mineral. J. (Japan)*, 7, 45-65.
- Murakami, T., Y. Takeuchi and T. Tagai (1977) Lithium-hydro-rhodonite. *Acta Crystallogr.*, B33, 919-921.
- Narita, H., K. Koto and N. Morimoto (1975) The crystal structure of nambulite $(\text{Li,Na})\text{Mn}_4\text{Si}_5\text{O}_{14}(\text{OH})$. *Acta Crystallogr.*, B31, 2422-2426.
- Peacor, D. R. and N. Niizeki (1963) The redetermination and refinement of the crystal structure of rhodonite, $(\text{Mn,Ca})\text{SiO}_3$. *Z. Kristallogr.*, 119, 98-116.
- Yoshii, M., Y. Aoki and K. Maeda (1972) Nambulite, a new lithium- and sodium-bearing manganese silicate from the Funakozowa mine, northeastern Japan. *Mineral. J. (Japan)*, 7, 29-77.