

**MAGNESIOFOITITE, \square (Mg₂Al) Al₆ (Si₆O₁₈) (BO₃)₃ (OH)₄,
A NEW ALKALI-DEFICIENT TOURMALINE**

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ABSTRACT

Magnesiofoitite is a new tourmaline species from an alteration zone in a silicified porphyry developed in completely altered andesitic to dacitic volcanic rocks at Kyonosawa, Mitomi-mura, Higashi-Yamanashi-gun, Yamanashi-ken Prefecture, Honshu, Japan. It occurs as bluish grey individual crystals and felted masses on fracture and void surfaces; individual crystals average ~5 μm wide and 50 μm long, and a few crystals approach 15 μm wide and 1 mm long. It is brittle, $H = 7$, $D_{\text{calc}} = 2.995 \text{ g/cm}^3$. In plane-polarized light, magnesiofoitite is pleochroic, O = grey-blue, E = pale lavender, with moderate absorption, $\omega > \epsilon$; it is uniaxial negative, $\omega = 1.624$, $\epsilon = 1.650$, trigonal, space group $R3m$, in the hexagonal setting, with $a 15.884(4)$, $c 7.178(3) \text{ \AA}$, $V = 1568.0(6) \text{ \AA}^3$, $Z = 3$. The strongest six X-ray-diffraction lines [d in $\text{Å}(I)(hkl)$] are: 3.969(100)(220), 2.567(100)(051), 4.211(90)(211), 2.949(70)(122), 6.366(60)(101), and 3.470(60)(012). A chemical analysis gave (in wt.%), SiO₂ 38.27, Al₂O₃ 40.17, FeO 0.97, MgO 6.15, Na₂O 0.70, B₂O₃ (calc.) 11.09, H₂O (calc.) 3.82, sum = 101.17 wt.%; P, Ti, Ca, Mn, Zn, K and F were not detected. The formula unit, calculated for 6 Si *apfu* (atoms per formula unit) with B = 3.0 *apfu* and OH = 4.0 *apfu*, is $X(\square_{0.79}\text{Na}_{0.21})^Y(\text{Mg}_{1.44}\text{Fe}_{0.13}\text{Al}_{1.42})^Z\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_4$, with the ideal end-member formula $\square(\text{Mg}_2\text{Al})\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_4$, where \square represents a vacancy. Thus magnesiofoitite is an X-site-vacant tourmaline; it is derived from foitite, $\square(\text{Fe}^{2+}_2\text{Al})\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_4$, by the homovalent substitution $^Y\text{Mg} \rightarrow ^Y\text{Fe}^{2+}$, and from dravite, $\text{NaMg}_3\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_4$, by the heterovalent substitution $X\square + ^Y\text{Al} \rightarrow ^X\text{Na} + ^Y\text{Mg}$. The new species and name were approved by the CNMMN of the IMA.

Keywords: magnesiofoitite, tourmaline, new mineral species, Kyonosawa, Honshu, Japan.

SOMMAIRE

Nous décrivons ici la magnésiofoïtite, espèce de tourmaline nouvellement homologuée, provenant d'une zone d'altération dans un porphyre silicifié développé aux dépens de roches volcaniques andésitiques et dacitiques à Kyonosawa, Mitomi-mura, Higashi-Yamanashi-gun, préfecture de Yamanashi-ken, île de Honshu, au Japon. Les cristaux individuels gris bleuâtre et les amas feutrés tapissent les parois de fissures et de cavités; chaque cristal a une largeur moyenne d'environ 5 μm et une longueur de 50 μm , quoique quelques individus atteignent une largeur de 15 μm et une longueur de 1 mm. Il s'agit d'un minéral cassant, d'une dureté de 7, dont la densité calculée est 2.995 g/cm^3 . En lumière polarisée, la magnésiofoïtite est pléochroïque, O = gris-bleu, E = lavande pâle, avec absorption moyenne, $\omega > \epsilon$; elle est uniaxe négative, $\omega = 1.624$, $\epsilon = 1.650$, trigonale, groupe spatial $R3m$, en référence à une convention hexagonale, avec $a 15.884(4)$, $c 7.178(3) \text{ \AA}$, $V = 1568.0(6) \text{ \AA}^3$, $Z = 3$. Les six raies les plus

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intenses du spectre de diffraction [d en Å(I)(hkl)] sont: 3.969(100)(220), 2.567(100)(051), 4.211(90)(211), 2.949(70)(122), 6.366(60)(101), et 3.470(60)(012). Une analyse chimique a donné (% poids), SiO₂ 38.27, Al₂O₃ 40.17, FeO 0.97, MgO 6.15, Na₂O 0.70, B₂O₃ (calc.) 11.09, H₂O (calc.) 3.82, total = 101.17%; P, Ti, Ca, Mn, Zn, K et F n'ont pas été décelés. L'unité formulaire, sur une base de six atomes de Si, avec la proportion de bore fixée à 3.0 atomes, et 4.0 groupes OH par unité formulaire, serait $X(\square_{0.79}Na_{0.21})^Y(Mg_{1.44}Fe_{0.13}Al_{1.42})^ZAl_6(Si_6O_{18})(BO_3)_3(OH)_4$; la formule idéale est $\square(Mg_2Al)Al_6(Si_6O_{18})(BO_3)_3(OH)_4$, le symbole \square représentant une lacune. La magnésiofoïtite est donc une tourmaline à site X vacant. On peut la dériver de la foïtite, $\square(Fe^{2+}Al)Al_6(Si_6O_{18})(BO_3)_3(OH)_4$, par la substitution homovalente $^Y Mg \rightarrow ^Y Fe^{2+}$, et de la dravite, $NaMg_3Al_6(Si_6O_{18})(BO_3)_3(OH)_4$, par la substitution hétérovalente $^X \square + ^Y Al \rightarrow ^X Na + ^Y Mg$. La nouvelle espèce et son nom ont l'approbation de la Commission des Nouveaux Minéraux et des Noms de Minéraux de l'IMA.

(Traduit par la Rédaction)

Mots-clés: magnésiofoïtite, tourmaline, nouvelle espèce minérale, Kyonosawa, Honshu, Japon.

INTRODUCTION

The general formula of the tourmaline-group minerals may be written as $X Y_3 Z_6 (T_6O_{18}) (BO_3)_3 V_3 W$, where $X = Na, K, Ca, \square$ (vacancy); $Y = Mg, Fe^{2+}, Mn^{2+}, Al, Fe^{3+}, Mn^{3+}, Li$; $Z = Al, Fe^{3+}, Cr^{3+}, Mg$; $V = OH, O$; $W = OH, F, O$ (Hawthorne & Henry 1999), and there is extensive solid-solution among these minerals. Hawthorne & Henry (1999) divided the tourmalines into three principal groups on the basis of the occupancy of the X site: $X = Ca$: calcic tourmalines; $X = Na, K$: alkali tourmalines; $X = \square$: X -site-vacant tourmalines. The X -site-vacant tourmalines have emerged recently as relatively common in a variety of environments (Foit *et al.* 1989, MacDonald *et al.* 1993, Matsubara *et al.* 1994, Pezzotta *et al.* 1996, Orlandi & Pezzotta 1996, Aurisicchio & Pezzotta 1997, Lyckberg & Hawthorne 1997, Selway *et al.* 1998, 1999, Aurisicchio *et al.* 1999, Taylor *et al.* 1997, Dutrow & Henry 1997, Jiang *et al.* 1997), although these compositions had been recorded previously (Rosenberg & Foit 1979). MacDonald *et al.* (1993) initially described the occurrence of foitite, ideally $\square(Fe^{+}Al)Al_6(Si_6O_{18})(BO_3)_3(OH)_4$.

The name magnésiofoïtite reflects its composition; it is the Mg analogue of foitite. Type material is deposited at the Canadian Museum of Nature (catalogue number CMNMN 81566) and the Royal Ontario Museum (M47672). The new mineral and mineral name have been approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association.

OCCURRENCE

The Kyonosawa area, Mitomi-mura, Higashi-Yamanashi-gun, Yamanashi-ken Prefecture, Honshu, is located about 100 km west of Tokyo, Japan (Fig. 1). There are dark-colored andesitic tuff breccia and volcanic breccia of Pliocene age (Miura *et al.* 1984), so heterogeneous that bedding is not observed and sorting is very poor. The rocks contain rounded to angular fragments, up to 1 m in size, of shale, andesite and granite. Along the Okusenjo-Sekisuiji shear zone, which extends NNE approximately 18 km and is 100 m wide,

there are acidic hot springs (*e.g.*, the pH is 1.7 at Kimpusen hot spring), fumaroles and acid-alteration areas (Shimizu & Tsunoda 1987). The Kyonosawa area is situated along the shear zone where there is strong acid hydrothermal alteration, producing dumortierite, alunite, pyrophyllite, kaolinite, magnésiofoïtite, topaz, zunyite, pyrite and rutile.

The rocks containing magnésiofoïtite or associated with it are highly altered and andesitic to dacitic. They are goethite-stained holocrystalline altered porphyritic rocks composed of quartz phenocrysts and quartz-rich groundmass, disseminated light grey to medium grey spots and stringers of magnésiofoïtite, dumortierite and white spots of kaolinite; the maximum dimension of the stringers is a few centimeters.

Under the microscope, the magnésiofoïtite-bearing rock consists of rather coarse-grained equigranular

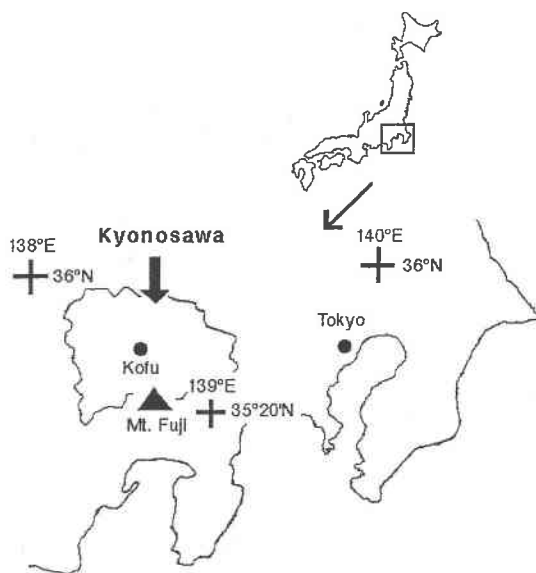


FIG. 1. Location map for the magnésiofoïtite occurrence in the Kyonosawa area, Japan.

groundmass (grain size ~0.05 mm) and phenocrysts of quartz (grain size 0.5 to 1.0 mm). Equigranular aggregates form a mosaic texture, and phenocrysts occur both as isolated grains and as aggregates. A few grains have a hexagonal outline against felty aggregates of magnesiofoitite. Minute needles of magnesiofoitite form radial aggregates up to a millimeter across, or felty aggregates of similar dimensions composed of irregularly oriented extremely fine needles. Some larger prisms in the radial aggregates are deeper grey-green owing to Fe contents up to 4.48 wt.% FeO. In many radial aggregates, pyrite grains occur at the core. Some felted aggregates of magnesiofoitite involve minute clusters of rutile crystals, which are absent in the radial aggregates; these dusty-looking aggregates of rutile occur along boundaries between magnesiofoitite and quartz.

PHYSICAL AND OPTICAL PROPERTIES

Magnesiofoitite is pale bluish grey and occurs as felted masses of fibrous crystals with a matte surface; individual crystals average ~5 μm wide and 50 μm long, with the largest approaching 15 μm wide and 1 mm long. It is brittle, with a Mohs hardness of ~7, and has no cleavage; the calculated density is 2.995 g/cm³.

In transmitted light, magnesiofoitite is dichroic, O = grey-blue, E = pale lavender, with moderate absorption, $\omega > \varepsilon$. It is uniaxial negative, with indices of refraction $\omega = 1.624$, $\varepsilon = 1.650$, measured with gel-filtered Na light ($\lambda = 589.9$ nm).

CHEMICAL COMPOSITION

Magnesiofoitite was analyzed with a Cameca SX-50 electron microprobe operating in wavelength-disper-

sion mode with the following conditions: excitation voltage 15 kV, beam current 20 nA, peak count-time 20 s, and background time 10 s. The following standards and crystals were used for $K\alpha$ X-ray lines: Si: diopside, PET; Al: kyanite, TAP; Fe: fayalite, LiF; Mg: forsterite, TAP; Na: albite, TAP; in addition, P, Ti, Ca, Mn, Zn, K and F were sought but not detected. Data reduction was done using the PAP procedure of Pouchou & Pichoir (1985). The unit formula was calculated on the basis of 6 Si *apfu* (atoms per formula unit) assuming B = 3 *apfu* and OH = 4 *apfu*. The chemical composition and unit formula are given in Table 1. There is some variation in FeO and MgO contents along the length of the fibers. Good-quality analyses were difficult to impossible to obtain with fibers this small in cross section.

CRYSTALLOGRAPHY

The powder-diffraction pattern was recorded on a Gandolfi camera with $\text{CuK}\alpha$ X-radiation; the magnesiofoitite crystals are intimately intergrown with small black spheres of hematite, and it is difficult to get a pure sample. Cell dimensions were refined using the program CELREF (Appleman & Evans 1973); the indexed powder-pattern and refined cell-dimensions are given in Table 2. The systematic absences are compatible with the space group $R3m$ that is observed for all other tourmaline species. The crystals are fibrous and zoned, and a good refinement of the crystal structure of magnesiofoitite is not possible with this material; rather than present a low-quality refinement, we prefer to wait for better material to surface. By analogy with the crystal structure of foitite, the site populations are straightforward to assign from the unit formula.

RELATION OF MAGNESIOFOITITE TO OTHER TOURMALINE SPECIES

The composition of magnesiofoitite (Table 1) may be generalized to the end-member composition \square (Mg_2Al) Al_6 (Si_6O_{18}) (BO_3)₃ (OH)₄, the third member

TABLE 1. CHEMICAL COMPOSITION* AND FORMULA UNIT** OF MAGNESIOFOITITE

SiO ₂ wt. %	38.27	Si apfu	6.00
Al ₂ O ₃	40.17		
FeO	0.97	Al	6.00
MgO	6.15		
Na ₂ O	0.70	Al	1.42
B ₂ O ₃	(11.09)	Mg	1.44
H ₂ O	(3.82)	Fe	0.13
Sum	101.17	ΣY	2.99
		Na	0.21
		\square	0.79
		B	3
		OH	4

* P, Ti, Ca, Mn, Zn, K, F not detected;
** based on 6.0 Si with B = 3 apfu, OH = 4 apfu

TABLE 2. X-RAY POWDER-DIFFRACTION DATA FOR MAGNESIOFOITITE

l_{obs}	d_{obs} (Å)	d_{calc} (Å)	hkl	l_{obs}	d_{obs} (Å)	d_{calc} (Å)	hkl
6	6.366	6.364	1 0 1	4	1.913	1.913	3 4 2
3	4.984	4.966	0 2 1	1	1.777	1.775	3 3 3
1	4.602	4.585	3 0 0	2	1.657	1.655	6 0 3
9	4.211	4.211	2 1 1	2	1.638	1.636	2 7 1
10	3.969	3.971	2 2 0	3	1.587	1.588	5 5 0
6	3.470	3.473	0 1 2	2	1.503	1.503	0 5 4
1	3.374	3.369	1 3 1	2	1.405	1.405	2 0 5
7	2.949	2.954	1 2 2	1	1.350	1.351	10 0 1
10	2.567	2.569	0 5 1	1	1.323	1.324	6 6 0
2	2.341	2.336	5 1 1	1	1.305	1.306	10 1 0
5	2.037	2.035	1 5 2	2	1.273	1.271	8 2 3

$a = 15.884(4)$, $c = 7.178(3)$ Å, $V = 1568.0(6)$ Å³

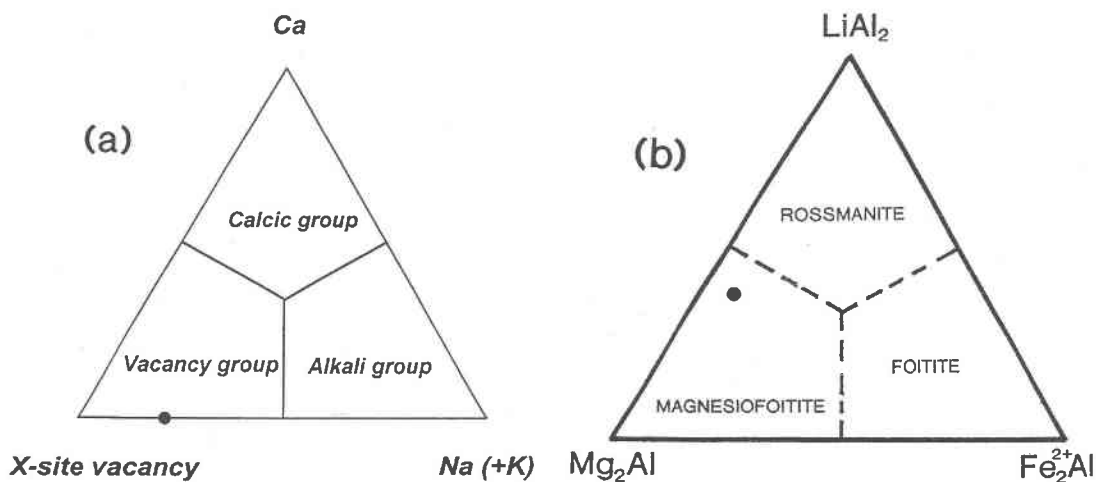


FIG. 2. Graphical representation of the chemical composition of magnesiofoitite (black circle): (a) X-site content, showing the three principal groups of tourmaline; (b) Y-site content in the system magnesiofoitite – foitite – rossmanite.

of the X-site-vacant tourmalines (Hawthorne & Henry 1999). The main division of the tourmalines into the three principal groups is shown in Figure 2a, together with the composition of magnesiofoitite given in Table 1. The three X-site-vacant tourmalines are distinguished among themselves on the basis of their Y-site occupancies (Fig. 2b). In particular, magnesiofoitite is the Mg analogue of foitite.

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