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Tochilinite in ultrabasic rock from Kurotani, Gifu Prefecture, Central Japan

By

Satoshi MATSUBARA and **Akira KATO**

Department of Geology, National Science Museum, Tokyo

Abstract Tochilinite was found in ultrabasic rock from the Kurotani, Kamitakara-Mura, Gifu Prefecture, Central Japan. It rims magnetite and troilite in association with pyrrhotite and pentlandite. The mean of 10 analyses (and ranges) by EDS are: Fe 40.98 (39.38–42.75), Mg 11.77 (10.87–12.45), Ni 0.51 (0–1.61), S 22.75 (21.54–23.53), Total 76.01 wt.%. The empirical formula is $2\{(Fe_{0.99}Ni_{0.01})S\}\cdot 1.45\{(Mg_{0.94}Fe^{2+}_{0.06})(OH)_2\}$ or $2\{(Fe_{0.88}Ni_{0.91})S\}\cdot 1.67\{(Mg_{0.81}Fe^{2+}_{0.19})(OH)_2\}$ if O and H_2O are added. The obtained X-ray diffractions are all basal, 11.01 (15) (003), 5.448 (100) (006), 3.659 (30) (009).

Introduction

Tochilinite was originally described as a valleriite-type mineral in serpentinite from Voronezh region, USSR (ORGANOVA *et al.*, 1971). In Japan it was uniquely found in a skarn from the Kamaishi mine (MURAMATSU and NAMBU, 1980).

Recently we reported the occurrence of valleriite and haapalaite, Ni analogue of tochilinite, in ultrabasic rock from Kurotani, Kamitakara-Mura, Gifu Prefecture, Japan (MATSUBARA *et al.*, 1991). The subsequent examinations on the materials therefrom revealed the occurrence of tochilinite in association with magnetite, troilite, pyrrhotite and pentlandite. In this paper we consider the chemical composition and genesis of tochilinite.

Occurrence

Kurotani is the name of a steep valley cutting the western slope of Yake-dake volcano, and situated in Kamitakara-Mura, Gifu Prefecture, Central Japan (approximately 36°14′N, 137°35′E). There are small outcrops of ultrabasic rock of dunite origin belonging to the Hida marginal zone, where a small mine produced talc in the 1950's. Although the age of the original dunite is unknown, the present rock suffered from thermal recrystallization due to intrusion of Neogene granite porphyry. The ultrabasic rock is composed mainly of forsterite or forsterite-actinolite in association with talc, brucite, dolomite, magnesite, ludwigite and sulfides. The occurrence and chemical compositions of constituting minerals except tochilinite have been already described (MATSUBARA *et al.*, 1991).

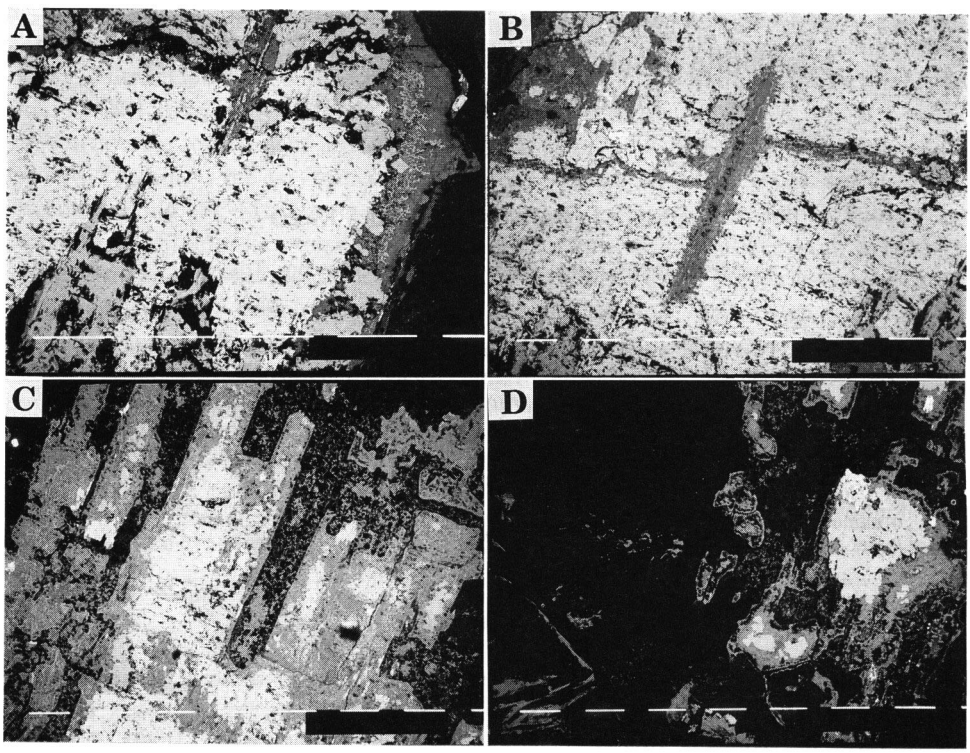

Fig. 1. BEI photographs of tochilinite (dark grey), magnetite (light grey) and troilite (light) in forsterite (black). Bar indicates 0.1 mm.

A: The outline of aggregate of tochilinite-magnetite-troilite corresponds to hexagonal tabular crystal of troilite. Notice two types of magnetite.

B: Troilite with cracks along which magnetite and tochilinite replace.

C: Replaced troilite crystals (parallel to 001) by tochilinite and magnetite.

D: Magnetite rimmed by tochilinite. The gross of aggregates pseudomorphs troilite which occurs as remnants.

Tochilinite is found as thin black coatings along cracks and vicinities of magnetite and troilite aggregates including pyrrhotite and pentlandite involved in dark-colored forsterite-rich portions. It is too small to observe the morphology even under the microscope. Very minute laminated crystals are rarely observed by the SEM. The photographs indicate that the aggregate of tochilinite is about 0.1 mm in width, and those over 0.2 mm in width replacing troillite crystals are often observed (Figs. 1 A, 1 B, 1 C, 1 D). There are two forms of magnetite, one is granular and the other is heavily ragged (Fig. 1 A). The latter appears to be intergrowth with tochilinite replacing troilite directly, whereas the former is explained as replacement for troilite and other sulfides, and the magnetite is successively replaced by tochilinite. The texture observed in BEI photographs, especially Fig. 1 D, accounts for the above relations.

Table 1. The representative chemical analyses of tochilinite from Kurotani

Weight percentages:					
	Fe	Mg	Ni	S	Total
1	39.38	11.56	1.61	23.09	75.64
2	40.62	12.16	0	22.52	75.30
3	41.73	12.34	0	22.89	76.96
4	40.91	11.98	0	23.18	76.07
5	42.53	11.12	0	21.54	75.19
6	40.75	12.32	0.69	23.31	77.07
7	40.23	11.65	0.56	23.31	75.75
8	40.73	12.45	0.62	21.70	75.50
9	40.16	11.23	1.60	23.53	76.52
10	42.75	10.87	0	22.42	76.04
mean	40.98	11.77	0.51	22.75	76.01
Atomic ratio for the mean analytical result (S=2)					
	2.07	1.36	0.02	2	

X-ray powder study

Although the X-ray powder data were obtained by the diffractometer using Co/Fe radiation, only three broad diffraction peaks corresponding to (00*l*) were recognized. These are 11.01 (15) (003), 5.448 (100) (006), and 3.659 (30) (009), probably due to orientation effect, though the cristallinity might be low. When hexagonal cell (HARRIS and VAUGHAN, 1972) is referred to, the calculated *c* is 32.9 (2) Å, which is slightly larger than those from Cyprus (HARRIS and VAUGHNAN, 1972) and the recalculated value from USSR material (ORGANOVA *et al.*, 1971).

Chemical composition

The chemical analyses of the studied material were made by using the Link Systems EDS. In Table 1 are given the representative chemical analyses and the mean. The present tochilinite is characterized by the absence of Al, which is found in haapalaite and valleriite from the same locality (MATSUBARA *et al.*, 1991).

At least two empirical formulae are derived from the mean of analyses. If metal: sulfur is taken as 1: 1, the empirical formula is $2\{(Fe_{0.99}Ni_{0.01})S\}\cdot 1.45\ \{(Mg_{0.94}Fe^{2+}_{0.06})(OH)_2\}$. This requires $O+H_2O=17.50$ wt. %, and then total is 93.51 wt. %. If the ratio of sulfide layer: hydroxide layer is taken as 6: 5, it becomes $2\{(Fe_{0.88}Ni_{0.01})S\}\cdot 1.67\{(Mg_{0.81}Fe^{2+}_{0.19})(OH)_2\}$. This requires $O+H_2O=20.16$ wt. %, and then total is 96.17 wt. %. Since both have low totals, more hydroxide layer may be needed, where a parcial oxidation of Fe^{2+} into Fe^{3+} takes place.

Discussion

As an example of the genesis of tochilinite in serpentinite from Western Australia, aggregate of pentlandite and pyrrhotite replace that of tochilinite, magnetite and magnesite by hydration and carbonation (VAN DE VUSSE and POWELL, 1983). In the present locality most of tochilinite rims magnetite in recrystallized forsterite rock, suggesting that tochilinite was formed by replacement of magnetite during thermal metamorphism. Also a few tochilinite intergrowths with heavily ragged magnetite were produced by reaction between sulfides and Mg-bearing materials.

It is difficult to derive the correct chemical formula of tochilinite without the determination of oxidation state of Fe and of water content. In the present case where metal: sulfur ratio is 1: 1, the ratio of hydroxide layer (1.45/2) is too small. Generally, hydroxide layer/sulfide layer is larger than 1.5/2. The smallest ratio of metal/sulfur was calculated to 0.77 in tochilinite from the Kamaishi mine, Japan (MURAMATSU and NAMBU, 1980). The ratio of the present tochilinite is 0.89 taking hydroxide layer/sulfide layer=1.67/2, which is reasonable, validating above assumption. Consequently, it is concluded that another formula comprising more hydroxide layer than 1.67/2 approximates the real one.

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