SODA-TREMOLITE-BEARING DUNITE FROM THE HOROKANAI OPHIOLITE IN THE KAMUIKOTAN TECTONIC BELT, HOKKAIDO, JAPAN

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"Soda-tremolite" having an intermediate composition between tremolite and richterite has been newly found in dunites from the Horokanai ophiolite in the Kamuikotan tectonic belt, Hokkaido, and its occurrence is the first report in alpine-type ultramafic rocks. The optical properties and crystal chemical formula of soda-tremolite are as follows; colorless in thin section, $2V_x$ (mean) = 80° , $r < v$ weak, $c \wedge Z = 15^\circ$, $b = Y$, and $(Na_{0.8})(Ca_{1.4}Na_{0.6})(Mg_{4.6}Fe^{2+}_{0.3}Cr_{0.1}Al_{0.1})(Al_{0.2}Si_{7.8})O_{22}(OH)_2$, respectively. The formation of the Horokanai soda-tremolite is probably explained by a local metasomatic process which increased the Na/Al ratio in the host dunite.

INTRODUCTION

So-called soda-tremolite having an intermediate composition between tremolite $Ca_2Mg_5Si_8O_{22}(OH)_2$ and richterite $Na_2CaMg_5Si_8O_{22}(OH)_2$ has been described from metamorphosed limestones at Långban, Sweden (Deer *et al.*, 1963, Table 55), and from kimberlite diatremes at Buell Park, Arizona (Aoki *et al.*, 1972) and at Green Knobs, New Mexico (Smith, 1979). In the course of the petrographical works on the Horokanai ophiolite in the Kamuikotan tectonic belt, in the area about 30 km northwest of the Asahigawa city, Hokkaido, the present author has found dunites that contain soda-tremolite. The following is a petrographical description of the soda-tremolite-bearing dunites along with a brief discussion on the origin of soda-tremolite.

MODE OF OCCURRENCE

The Horokanai ophiolite consists of a close association of ultramafic and mafic rocks, associated with a small amount of radiolarian chert as the uppermost member (Banno *et al.*, 1978; Asahina and Komatsu, 1979; Ishizuka, 1980). The ultramafic rocks are mainly composed of dunite and harzburgite with a minor orthopyroxenite, indicating a common association of alpine-type ultramafic rocks. In particular, the dunite shows two modes of occurrence; one of them, measuring about 500 m thick, underlies the orthopyroxenite, and the other occurs as several interlayers of 1 to 3 m thick within the harzburgites. The latter-type of the dunites contains soda-tremolite. The localities of such dunites are shown in Fig. 1, a geological sketch map.

PETROGRAPHY

The dunites in question are coarse- to medium-grained and massive with granular

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Fig. 1 Geological sketch map of the Horokanai ophiolite showing localities of soda-tremolite-bearing dunites (modified after Ishizuka, 1980). STD-1, -2 and -3 indicate sample Nos. treated in this paper.

texture. Their constituent minerals are olivine and chromite with subordinate amounts of serpentine (less than 10 modal per cent), chlorite, magnetite and soda-tremolite. The modal proportion of olivine to chromite is usually about 9 to 1. The amount of soda-tremolite is extremely small; i.e. only two or three grains were recognized in a thin section. Mineral analyses were performed by means of an electronprobe

microanalyzer, Hitachi Model XMA-5A (Kanazawa University). Supplement EPMA analysis was done using JEOL Model JXA-50A (Hokkaido University).

Olivine is euhedral to subhedral, less than 3 mm across in size, and shows little sign of wavy extinction. Chemically, the olivines except those around chromite grain are mostly homogeneous from a grain to another in regard to X_{Fa} , the mole fraction of fayalite component, being 0.060 to 0.075, whereas those around chromite grain are slightly heterogeneous and have commonly low X_{Fa} ranging from 0.025 to 0.055. On the other hand, there is a negative correlation between the X_{Fa} value and NiO content of olivines, as shown in Fig. 2. Such compositional trend of olivines is close to that formed by igneous crystallization (Sato, 1977), but is the reverse to that from the metamorphosed dunites derived from serpentinites (Kunugiza, 1980). These facts suggest that the olivine essentially retains its primary chemistry, but the low X_{Fa} value of olivine around chromite grain is due to the local Fe-Mg reequilibration with chromite at low temperatures, as proposed by Irvine (1965).

Chromite is euhedral to subhedral, less than 1 mm in diameter, and occasionally poikilitic including olivine with X_{Fa} of 0.035. Chemically, the chromites are nearly

Fig. 2 Variation of NiO content with X_{Fa} for olivines.

homogeneous from a grain to another; Al_2O_3 3.1–3.9 wt.%, Cr_2O_3 65.7–66.5 wt.%, Fe_2O_3 3.2–3.9 wt.%, FeO 17.0–18.2 wt.%, and MgO 9.3–10.5 wt.% (ferric and ferrous iron were calculated from total iron assuming ideal spinel formula). The Fe-Mg partition between olivine-chromite pairs indicates reequilibration at 550–600°C, according to Roeder *et al.* (1979).

Serpentine and chlorite are commonly developed at the grain boundaries and/or along the cracks of olivines, of which the chlorite contains appreciable amounts of Cr_2O_3 , being up to 2.0 wt.%. Magnetite is rare, but present around the margin of chromite.

Soda-tremolite is usually associated with chromite grains; its typical occurrence is shown in Fig. 3. It is commonly stout prismatic, euhedral to subhedral, and less than 3 mm in length. The optical properties are as follows; colorless in thin section, $2V_x$ (mean) = 80° , $r < v$ weak, $c \wedge Z = 15^\circ$, and $b = Y$. The refractive indices were not determined, because of an extremely small amount of it.

Representative chemical analyses of soda-tremolites in the Horokanai dunites

are listed in Table 1. The crystal chemical formula is approximately as follows; $(\text{Na}_{0.6})(\text{Ca}_{1.4}\text{Na}_{0.6})(\text{Mg}_{4.6}\text{Fe}^{2+}_{0.2}\text{Cr}_{0.1}\text{Al}_{0.1})(\text{Al}_{0.2}\text{Si}_{7.8})\text{O}_{22}(\text{OH})_2$. The compositional variation as illustrated in Fig. 4 is mainly

Table 1 Representative soda-tremolite analyses in the Horokanai dunites.

Sample No.	STD-1	STD-2	STD-3
SiO_2	57.45	57.43	57.93
TiO_2	0.01	0.01	0.01
Al_2O_3	1.77	1.47	1.58
Cr_2O_3	0.77	1.20	0.51
FeO^*	1.38	1.40	1.50
MnO	0.05	0.06	0.05
MgO	22.71	22.09	22.87
CaO	9.92	9.81	9.89
Na_2O	4.52	4.64	4.23
K_2O	0.05	0.02	0.03
Total	98.63	98.13	98.60
O=23.0			
Si	7.816	7.859	7.866
Ti	0.001	0.001	0.001
Al	0.284	0.237	0.253
Cr	0.083	0.130	0.055
Fe*	0.157	0.160	0.170
Mn	0.006	0.007	0.006
Mg	4.606	4.507	4.630
Ca	1.446	1.438	1.439
Na	1.192	1.231	1.114
K	0.009	0.003	0.005

FeO* means total iron as FeO.

Fig. 3 Photomicrograph showing occurrence of soda-tremolite. Abbreviations: Ol, olivine; Na-Tr, "soda-tremolite"; Ser, serpentine; Chr, chromite.

Fig. 4 Ca-Na plot for soda-tremolites (O = 23.0) in the Horokanai dunites, along with those in the Långban metamorphosed limestones (Deer *et al.*, 1963, Table 55), and in kimberlite diatremes of the Buell Park (Aoki *et al.*, 1972) and the Green Knobs (Smith, 1979). Abbreviations: Tr-Tsch, tremolite-tschermakite; Ed-Pa, edenite-pargasite; Rich, richterite; Gl, glaucophane.

due to the extensive substitution of *Ca for NaNa in $*\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2\text{--Na}_2\text{CaMg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$ solid solution series. Such substitution is also recognized in the soda-tremolites occurring in metamorphosed limestones and kimberlites (Fig. 4).

DISCUSSION

Soda-tremolite has been described from metamorphosed limestones and kimberlites, but this paper is the first report of its occurrence in alpine-type ultramafic rocks.

Aoki *et al.* (1972) suggested that soda-tremolite was a primary phase in kimberlitic magma formed under upper mantle conditions. Hariya and Terada (1973) showed by high-pressure synthetic experiments that tremolite₅₀-richterite₅₀ solid solution has an extremely wide stability field, being stable up to 700°C at 40 kbars and up to 900°C at 34 kbars.

If the soda-tremolite of the Horokanai body was an igneous phase, the host dunite should have been in equilibrium with kimberlitic magma, because this amphibole has never been known as an igneous phase in any igneous rocks except kimberlites. The Horokanai body, composed mainly of dunite and harzburgite, was in equilibrium with tholeiitic magma but not with kimberlitic magma (Ishizuka, in prep.). It is geologically unnatural to consider that only a part of the dunites coexisted with kimberlitic magma while the majority of the body coexisted with tholeiitic magma. Therefore, it is unlikely that the soda-tremolite of the Horokanai body was formed as an igneous phase.

The second possibility for the origin of the Horokanai soda-tremolite is a subsolidus reaction in closed-system. As no sodium-bearing minerals occur in the dunites of the

Horokanai body, we cannot specify the source of sodium. In the Horokanai body, clinopyroxene is extremely rare, occurring only in the orthopyroxenite and gabbroic bands, both of which are rare rock-types. Amphibole except soda-tremolite is absent in the body. For these reasons, the present author thinks it improbable to produce the soda-tremolite by a closed-system subsolidus reaction in ultrabasic compositions. The remaining possibility is a local metasomatic process which increased the Na/Al ratio in the host dunite, even though the source of sodium and the process of metasomatism still remain unsolved.

In this connection, it may be noted that the local metasomatic process seems to have operated in another dunite-harzburgite body of the Kamuikotan tectonic belt, as was described by Nagata (1980, and oral communication) on the Iwanai-dake body. In the Iwanai-dake body, however, metasomatism gave rise to formation of monticellite, perovskite, and ferri-pargasite, and the elements added to the host rock are also different from the Horokanai body, but in any case, both bodies have common features, that is, the sodium-rich amphibole was formed and the basicity of the body increased by metasomatism.

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北海道・神居古潭構造帯・幌加内オフィオライトに産する
ソーダ・トレモラ閃石を含むダナイト

石 塚 英 男

北海道・神居古潭構造帯・幌加内オフィオライトから、アルプス型超苦鉄質岩類としては初めての、ソーダ・トレモラ閃石を含んだダナイトが見出された。ソーダ・トレモラ閃石の光学的性質は、鏡下で無色、 $2V_x$ (平均) = 80° , $r < v$ 弱い, $c \wedge Z = 15^\circ$, $b = Y$ である。また、その化学組成は、 $(Na_{0.6})(Ca_{1.4}Na_{0.6})(Mg_{4.6}Fe^{2+}_{0.2}Cr_{0.1}Al_{0.1})(Al_{0.2}Si_{7.8})O_{22}(OH)_2$ である。この角閃石の形成については、ダナイト中の Na/Al 比を増加させるような局所的交代作用が考えられる。

地 名
Iwanai-dake 岩内岳