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THE TAKADOMARI SERPENTINITES IN THE KAMUIKOTAN OPHIOLITE BELT, HOKKAIDO, JAPAN

by

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(with 11 text-figures)

Abstract

Within the Kamuikotan Ophiolite Belt, a large serpentinite mass more than 10 × 12 km is observed around Takadomari as a tectonic unit of dismembered ophiolite.

The Takadomari serpentinites show an east-facing layered structure composed primarily of dunite, harzburgite, and olivine-orthopyroxenite layers. More than 120 dykes of microdiorite-microgabbro were found in the serpentinite mass and clearly show an intrusive relation. The serpentinization is characterized by a progressive crystallization of antigorite replacing lizardite and chrysotile serpentines crystallized retrogressively.

The Takadomari mass is regarded as a dismembered ophiolite unit which is situated at the base of the Horokanai ophiolite complex. High pressure and low temperature type metamorphic rocks such as glaucophane schist are considered to be a tectonic unit lifted up by the Takadomari serpentinites.

Introduction

The Takadomari serpentinite mass crops out more than 10 × 12 km near Horokanai and along the westernmost side of the Kamuikotan Ophiolite Belt in Hokkaido (Text-fig. 1).

The serpentinite mass has been regarded as a constituent of the western wing of an anticline, which is composed mainly of metamorphic rocks, greenstones, sedimentary rocks of the Sorachi Group and the Yezo Group, and serpentinites (Igi et al., 1958; Asahina and Komatsu, 1979). However, Katoh (1982) explained that the Horokanai region is characterized by a tectonic complex composed of two separate ultramafic units.

The nature of the Kamuikotan Belt has been discussed and is recognized as a tectonic zone or a tectonic mélange zone (Hunahashi, 1957, 1958; Komatsu et al., 1977; Hashimoto, 1978; Watanabe et al., 1978; Katoh et al., 1979; Watanabe, 1981; Gouchi, 1983; Ishizuka et al., 1983). Moreover, it has been emphasized that some serpentinite masses in the Kamuikotan Belt are probably serpentinite tectonic mélanges (Niida and Katoh, 1978; Katoh et al., 1979; Nakagawa, 1981). Maekawa (1983) asserted that the serpentinite masses in the Biei area originated in a sedimentary mélange (olistostrome). Generally, it seems that the serpentinites in the Kamuikotan Belt underwent a regional metamorphism together with country rocks (Katoh, 1979; Asahina and Komatsu, 1979; Ishizuka, 1980; Imaizumi and Kanehira, 1980; Maekawa, 1983).

Hunahashi (1953), Kizaki (1954), and Saito (1958) reported the geological and petrographical characteristics of the Takadomari serpentinite mass. Hunahashi (1953) believed that the Takadomari mass was serpentinized in varing degrees and its original

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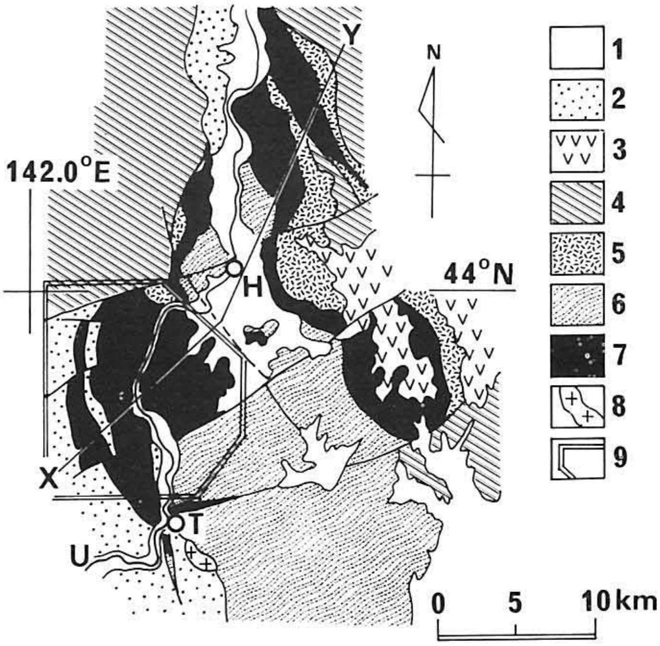
rocks were orthopyroxene peridotites and dunites. Kizaki (1954) divided the serpentinites into three types; massive serpentinite, sheared serpentinite, and serpentinite conglomerate. Futhermore, Kizaki discovered serpentinite sandstones in the middle Miocene Horoshin Formation. Saito (1958) studied the serpentinization of the Takadomari mass, and proposed a process of serpentinization as follows: serpentine replacement after olivine and orthopyroxene, crystallization of flaky antigorite, crystallization of chrysotile.

In this paper, geology and petrology of the Takadomari serpentinite mass and its structural significance are described and the original status of serpentinites and the process of serpentinization will be discussed.

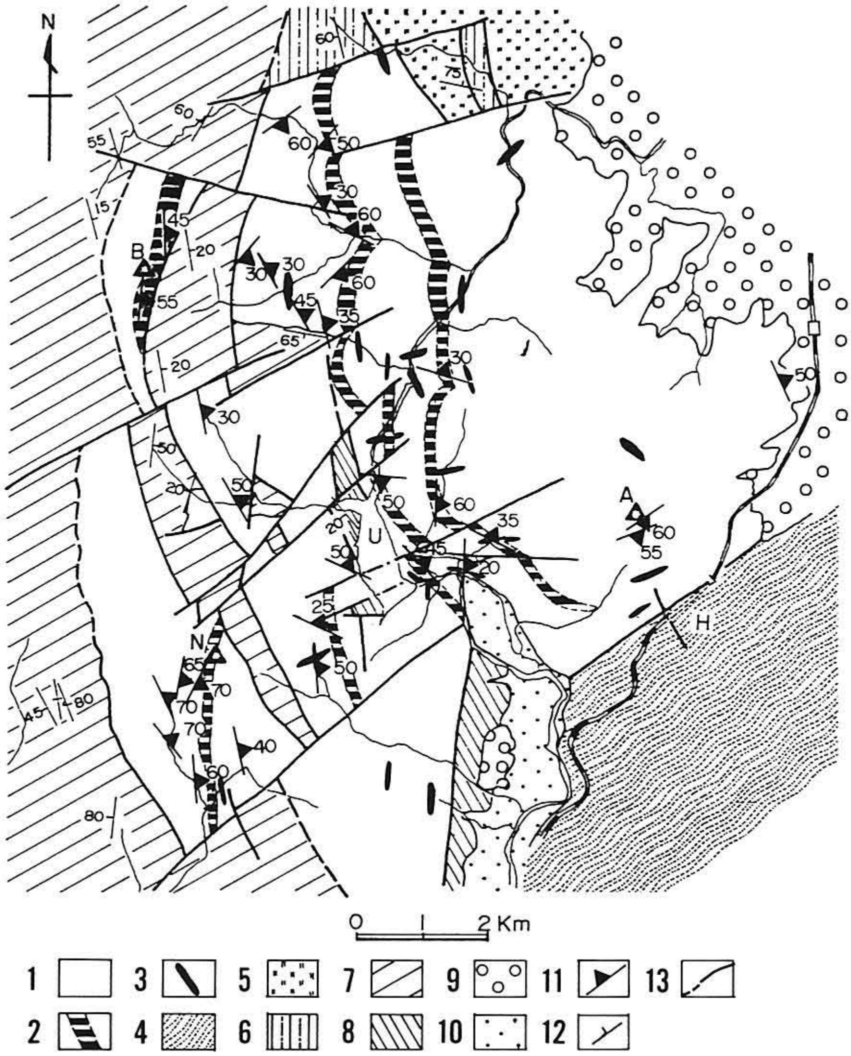
Geology

The Takadomari serpentinite mass extends about 10 km east-west and 12 km north-south (Text-fig. 1). At the southern side the serpentinite mass is in contact with the Kamuikotan metamorphic rocks belonging to the glaucophane schist facies (Banno



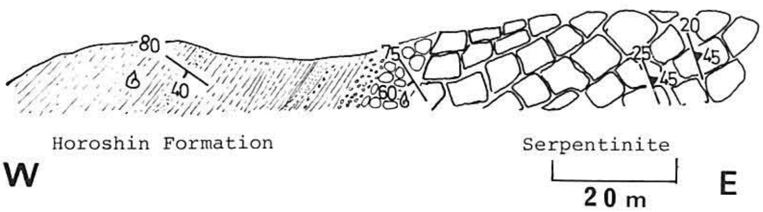
Text-fig. 1 Map showing the geologic outline of the Horokanai ophiolite complex (compiled after Suzuki, 1953, 1957; Hunahashi, 1953; Igi et al., 1958; Asahina and Komatsu, 1979; Igarashi et al., this study).
1 Quaternary sediments. 2 Tertiary sediments. 3 Tertiary volcanic rocks. 4 Cretaceous Yezo Group. 5 Ophiolitic metabasalt, metagabbro, and amphibolite. 6 High-pressure and low-temperature type metamorphic rocks. 7 Serpentinites. 8 Trondjemite. 9 Mapped area. H: Horokanai. T: Takadomari. U: Uryu-gawa River. Line X-Y: see Text-fig. 11

and Hatano, 1963; Shibakusa, 1974). As shown in Text-fig. 2, greenstones and cherts of late Jurassic to early Cretaceous and sandstones and shales of the Cretaceous Yezo Group are observed in the northern area of the serpentinite mass. The Horoshin Formation, composed mainly of sandstone, mudstone, conglomerate, and tuff of Miocene age, is widely distributed along the western border of the mass. The Takikawa Forma-



Text-fig. 2 Geological map of the Takadomari serpentinite mass.
1 harzburgite. 2 dunite. 3 microdiorite-microgabbro. 4 high-pressure and low-temperature type metamorphic rocks. 5 Sorachi Group. 6 Yezo Group. 7 Horoshin Formation. 8 Takikawa Formation. 9 Terrace deposits. 10 Alluvium deposits. 11 primary layering planes. 12 bedding planes. 13 fault. A: Mt. Asabayama. B: Mt. Bozu-yama. N: Mt. Nuppu-bozu-yama. U: Uryu-gawa River.

tion composed of mudstone, sandstone, conglomerate, and tuffaceous sandstone of Pliocene age, occupies narrow areas in the southern half of the mass. Text-fig. 3 shows a sedimentary relationship between the Horoshin Formation and the serpentinites. The massive serpentinite is uncomformably overlain by basal conglomerate of the Horoshin Formation. Sandstones and conglomerates containing a large amount of serpentinite clasts are commonly observed in the formation. It is probable that the Takadomari serpentinites were exposed widely in the Neogene Tertiary Horoshin sedimentary basin.



Text-fig. 3 Sketch showing a relationship between the Horoshin Formation and the Takadomari serpentinite. The massive serpentinite is uncomformably overlain by basal conglomerate of the Horoshin Formation.

The Sorachi Group is regarded as the late Jurassic to early Cretaceous as confirmed by recent studies of radiolarian ages (e.g. Kanie et al., 1981; Kito, 1982; Sano et al., 1982). Many fossils of Miocene to Pliocene age were found in the Horoshin and Takikawa Formations at several localities.

Petrography

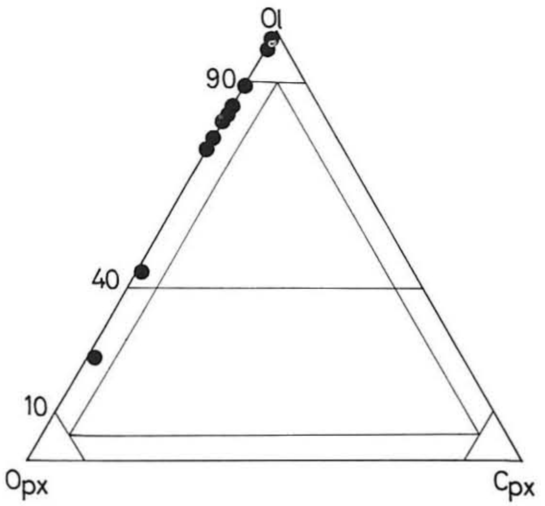
Serpentinite

Serpentinites are classified into the following three types: dark-colored massive serpentinite, lustrous pale green or dark-colored foliated serpentinite, and serpentine clay. Moreover, ophi-carbonate and quartz-magnesite rocks altered from serpentinites are also rarely found. The massive serpentinites are observed widely throughout the Takadomari mass. The foliated serpentinites are distributed along fault zones and sheared zones and in the narrow zones, 1 to 10 m from the margin of microdiorite-microgabbro dykes. The serpentine clays crop out along land-slides and fault planes. The ophi-carbonate rocks are strongly foliated and are restricted within fault zones. The quartz-magnesite rocks are found around Mt. Bozu-yama (Text-fig. 2) and along the Dai-Nuppu River.

All the ultramafic rocks of the Takadomari mass are partially to completely serpentinized. In most cases, however, the original rock types of the massive serpentinite can be recognized in the field because pyroxenes are well preserved as primary crystals and/or pseudomorphs. The massive serpentinite of the Takadomari mass consists mainly of harzburgite, dunite, and olivine-orthopyroxenite. Harzburgite is the most predominant type in the mass. Thick layers of dunite, several 10's to 100 meteres thick, are intercalated in the massive harzburgites as shown in Text-fig. 2. Numerous thin layers of dunite, less than 50 cm thick, are also observed in the harzburgites.

In weakly serpentinized rocks, olivine, orthopyroxene, spinel, and clinopyroxene are found as relict minerals. Olivine shows anhedral, granular, and interlocking texture and is in part replaced by mesh serpentine minerals. Olivine grains range in size from 0.8 to 6.0 mm and average 3.0 mm. In most cases, olivines show wavy extinction and have many kink bands. Orthopyroxene is subhedral to anhedral and ranges in grain size from 5.0 to 6.0 mm. Orthopyroxenes also have many kink bands and sometimes contain many exsolution lamellae of clinopyroxene. Primary clinopyroxene grains are rarely found as interstices showing an irregular form among olivine, spinel, and orthopyroxene grains in the massive serpentinites. The grain size of clinopyroxenes ranges from 0.2 to 1.0 mm. Spinels are observed as accessory minerals showing reddish brown to brown in thin section, generally less than 1 volume % in dunite and harzburgite. In rare cases, spinels attain 3 to 5% in dunite. Some dunites carry thin chromitite layers in which spinels comprise about 50%. Spinels included in olivine crystals are generally euhedral to subhedral. At the grain boundaries between large crystals of olivine and pyroxene, spinels are observed as anhedral crystals. The grain size of spinels varies from 0.1 to 1.5 mm and reaches 4.0 mm in thin layers of chromitite.

Modal compositions of the ultramafic rocks are plotted on the olivine-orthopyroxene-clinopyroxene diagram (Text-fig. 4). In the modal measurement, mesh serpentine pseudomorphs after olivine and bastites after orthopyroxene were counted as primary minerals. As shown in Text-fig. 4 the Takadomari serpentinite mass consists of dunite-harzburgite which belongs to the H-series proposed by R.G.P.I. (1967) and Kuroda and Tazaki (1969). The dunite-harzburgite of the Takadomari mass probably represents an ophiolitic ultramafic tectonite derived from the upper mantle of an ancient oceanic lithosphere.



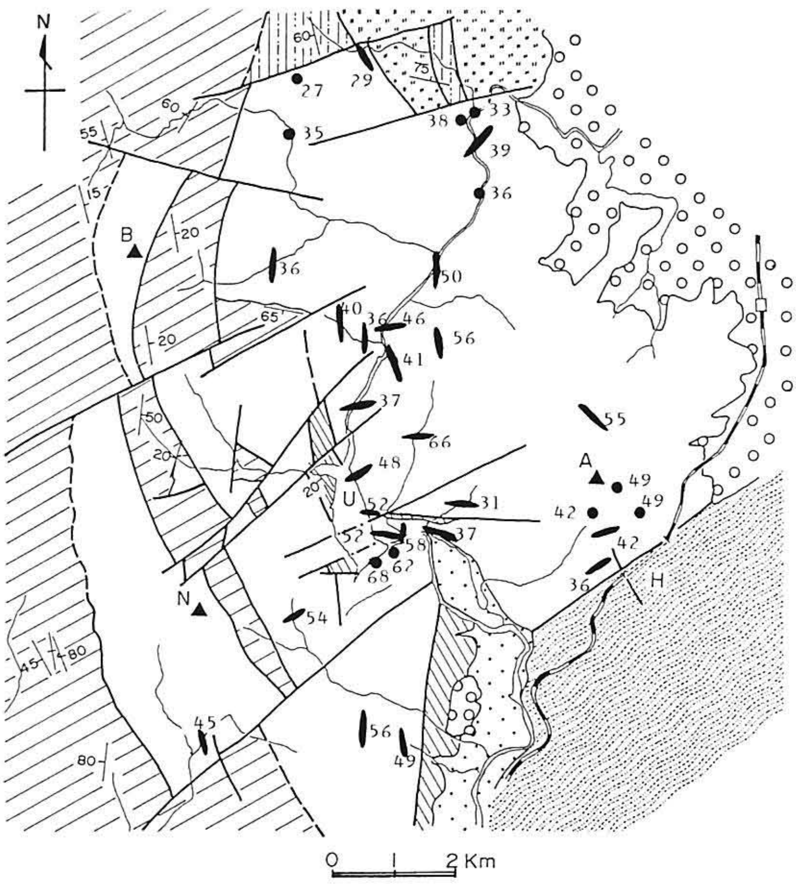
Text-fig. 4 Olivine(Ol) - orthopyroxene(Opx)-clinopyroxene(Cpx) diagram showing primary modal compositions of the Takadomari serpentinite.

Rodingite

White and gray colored rodingites are observed as dyke-like rocks and as tectonic inclusions within strongly sheared and foliated serpentinites. Some microdiorite-microgabbros are metasomatized into rodingite at the periphery of the inclusions. Primary granular to subophitic igneous textures are rarely preserved in some rodingites. Accordingly, most of the rodingites in the Takadomari mass are considered to be derived from the dykes of microdiorite-microgabbro. The rodingites consist mainly of hydrogrossular, diopside, chlorite, zoisite, and pectolite.

Microdiorite-Microgabbro

More than 120 dykes of microdiorite-microgabbro, which have been described as "diorite-gabbro aplite" (Suzuki, 1952) or "microdiorite" (Hunahashi, 1953; Kizaki, 1954), are observed throughout the Takadomari serpentinite mass (Text-fig. 5). The



Text-fig. 5 Map showing color indices of the microdiorite-microgabbro dykes in the Takadomari serpentinite mass. See Text-fig. 2 for legend.

microdiorite-microgabbros generally show fine to medium-grained and equigranular to subophitic textures. Their occurrences are characteristically restricted within the serpentinite mass and they are up to several meters thick in many cases. At the Takadomari dam-site, a peculiar dyke crops out over 120 m wide. Chilled margins made up of fine-grained minerals without glass are conspicuous in the exposure.

The microdiorite-microgabbros consist mainly of plagioclase, hornblende, clinopyroxene, quartz, and Fe-Ti oxide as primary igneous minerals less than 0.2 mm in grain size, showing equigranular to subophitic texture. The color indices of the dyke rocks vary from 27 to 68 as shown in Text-fig. 5. In the northern area of the Takadomari mass the dykes are relatively leucocratic, whereas in the central part more melanocratic and the lithologies vary from diorite to gabbro (Text-fig. 6).

Sample	PRIMARY MINERALS						METAMORPHIC MINERALS					(vein)	
No.	Pl	Ho	Cpx	Qz	Fe-Ti	Ap	Ac	Cz	Sph	Chl	Ser	Pre±Qz	Pec
825-1	●	●		●	●		●	●		●	●		
807-6	●	●			●		●	●	●	●	●		
831-4A	●	●					●	●	●	●	●		
1018-6	●	●			●		●	●	●	●			
1018-11	●	●			●	●	●	●	●				
808-8	●		●		●		●				●		
822-20	●	●			●		●	●	●	●	●		
910-5	●	●					●	●	●	●	●		
920-2	●	●					●	●	●		●		●
924-10	●	●	●	●			●		●				
926-13	●	●		?			●	●	●		●	●	●
910-8B	●	●		●			●	●	●	●	●		
925-5M	●	●		●			●	●	●		●		
927-11	●	●	●	●			●				●		
823-5	●	●			●		●	●		●	●		

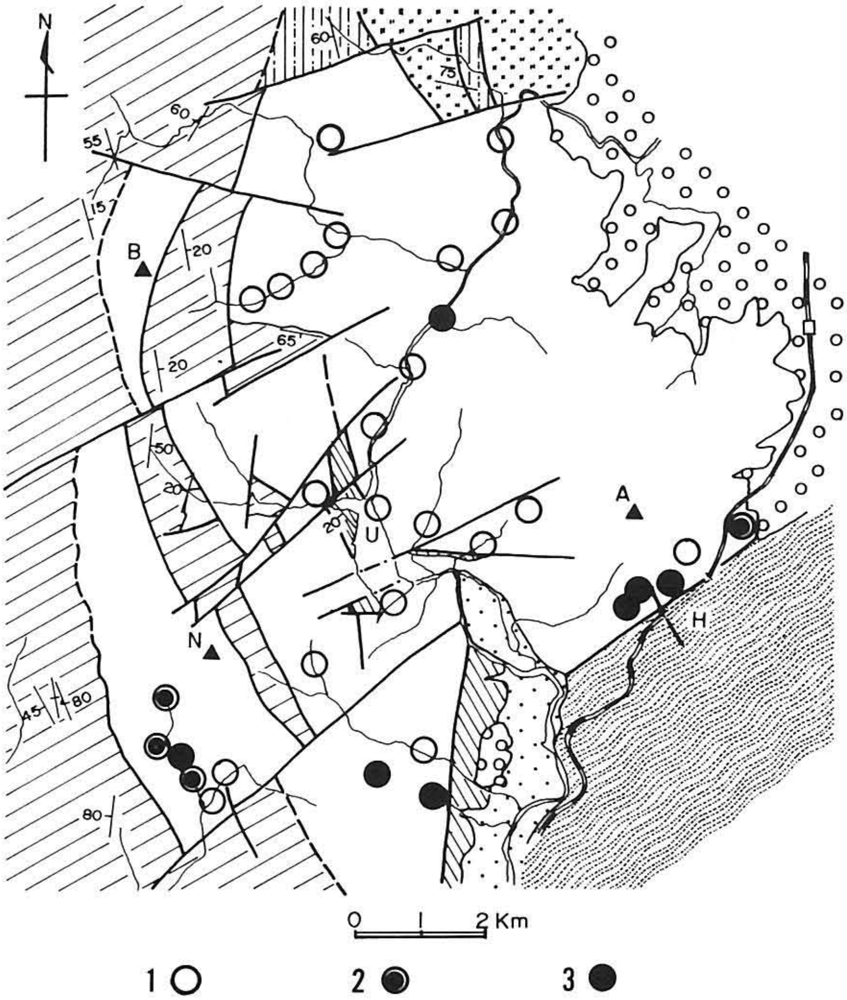
Pl: plagioclase Ho: hornblende Cpx: clinopyroxene Qz: quartz Fe-Ti: Fe-Ti oxide
Ap: apatite Ac: actinolite Cz: clinozoisite Sph: sphene Chl: chlorite
Ser: sericite Pre: prehnite Pec: pectolite

Text-fig. 6 Mineral assemblages of the microdiorite-microgabbro dykes in the Takadomari serpentinite mass.

Some metamorphic minerals such as albite, epidote-clinozoisite, zoisite, actinolite, chlorite, prehnite, white mica, and pectolite, are found in the microdiorite-microgabbro. Paragenesis of such minerals indicates that the dykes were subjected to low grade greenschist facies metamorphism after their intrusions.

Serpentinization

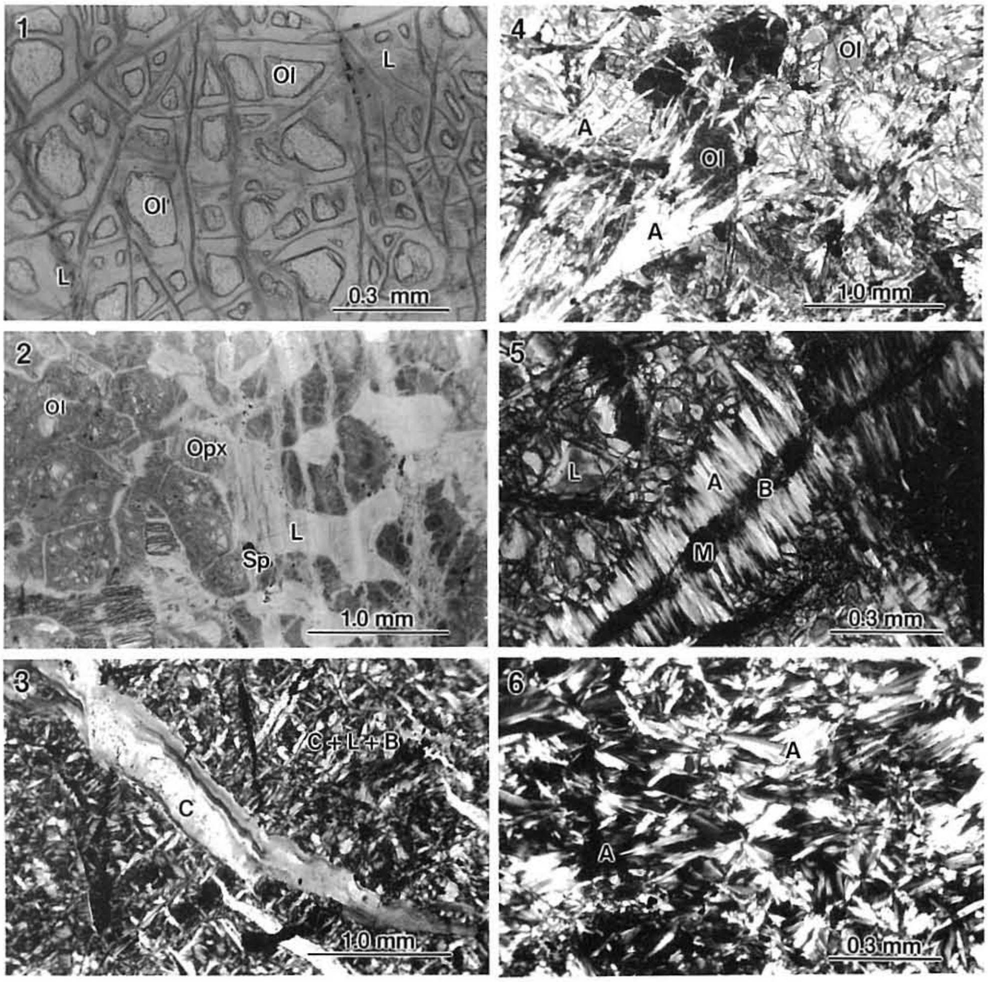
Serpentine minerals are widely observed throughout the Takadomari mass. Text-fig. 7 shows the distribution of the typical serpentine assemblages of chrysotile + lizar-



Text-fig. 7 Map showing distribution of serpentine minerals.
1 chrysotile + lizardite. 2 chrysotile + lizardite + antigorite. 3 antigorite + chrysotile. See Text-fig. 2 for legend.

dite, chrysotile + lizardite + antigorite, and antigorite + chrysotile. Brucite and magnetite are commonly observed in the Takadomari Serpentinites. Antigorite is characteristically predominant in the southern part of the mass.

The following gradational change of serpentine crystallization is microscopically observed in the serpentinite (Text-fig. 8). (1) Initially, platy and fibrous serpentines of chrysotile + lizardite, brucite and magnetite were formed in the interestices of olivine meshes. (2) Fine-grained serpentine aggregations with magnetite crystallized along the center of the serpentinite (1). Primary spinel changed into magnetite and chlorite along cracks and at the rim. (3) The mesh olivine was converted to platy lizardite at the



Text-fig. 8 Photomicrographs of thin sections of the Takadomari serpentinites.
Ol: olivine. Opx: orthopyroxene. Sp: spinel. L: lizardite. C: chrysotile. A: antigorite. B: brucite. M: magnetite.
1 Mesh olivines replaced by platy crystals of lizardite. Open nicol. Sample No. 9249.
2 Primary orthopyroxene partly altered into lizardite. Open nicol. Sample No. 8244.
3 Monomineralic chrysotile veins across a mesh texture formed by lizardite, chrysotile, and brucite. Crossed nicols. Sample No. 8212.
4 Antigorites in the serpentinized dunite No. 10193. Crossed nicols.
5 Flaky aggregation vein composed of antigorite and brucite. Chrysotile-lizardite-brucite shows a mesh texture. Crossed nicols. Sample No. 8309D.
6 Antigorite crystals showing a bladed-mat texture. Crossed nicols. Sample No. 9267.

periphery. Olivine + serpentine shows a typical mesh texture. (4) Primary grains of orthopyroxene were partly altered into lizardite. (5) Monomineralic chrysotile veins cutting the mesh texture were formed. Orthopyroxenes, olivines, and spinels remained as relict minerals at that stage, while clinopyroxene was wholly preserved. (6) Finally, primary minerals were completely replaced by serpentines, brucite, and magnetite, nevertheless mesh textures and bastites are well observed.

In the southern area of the Takadomari mass, (7) monomineralic flaky antigorite and antigorite + brucite partly replaced the serpentinites (1) to (6). (8) Antigorite crystals completely replaced the lizardite and chrysotile. Such a serpentinite shows a bladed-mat texture (Maltman, 1978) composed mainly of antigorite ± brucite + magnetite. Increasing degree of serpentinization can be completely traced from (1) to (6) and also from (7) to (8).

It is well known that antigorite is common in relatively higher grade metamorphic terrains (e.g. Hess et al., 1952; Page, 1967; Hayashi, 1968; Maltman, 1978). Evans (1977) suggested that lizardite/chrysotile serpentinite belongs to the zeolite to pumpellyite facies and that brucite-antigorite serpentinite belongs to the blueschist to low grade greenschist facies. It is supported from experimental and thermodynamic investigations that antigorite is stable at higher temperature than lizardite and chrysotile (e.g. Iishi and Saito, 1973; Evans et al., 1976). Progressive reaction of chrysotile → antigorite + brucite is considered to take place at about 300°C (Evans et al., 1976).

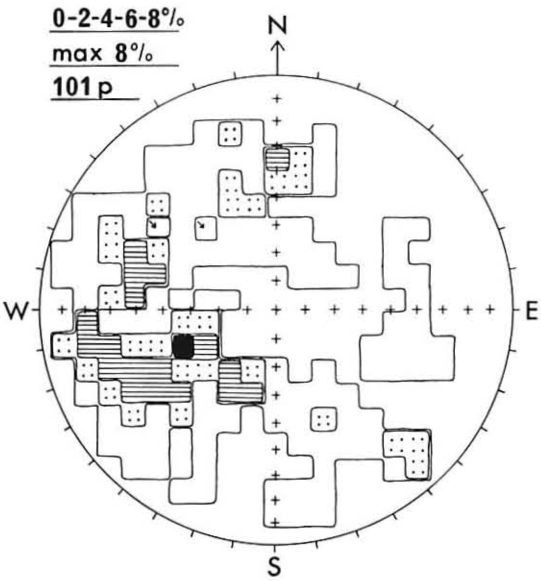
In the case of the Takadomari serpentinite mass, the mesh texture of chrysotile-lizardite serpentinites becomes destroyed as a result of flaky antigorite growth in the southern area, as mentioned above (Text-fig. 8). This implies that the Takadomari serpentinite mass suffered from retrogressive metamorphism at relatively low temperature (less than 300°C). Subsequently, the Takadomari serpentinites were progressively metamorphosed into the greenschist to blueschist facies toward the southern border of the mass.

Structure

Primary Layering

Primary layering of the Takadomari serpentinites is well observed, though the rocks are altered to serpentinite in varying degrees. The following three structural factors can be used to recognize the primary layering in the serpentinites. One is a layering plane compositionally divided into dunite and harzburgite, and/or olivine-orthopyroxenite. Thin compositional layers less than several 10's of cm thick are considerably useful for the recognition. The second factor is a mineral layering of orthopyroxenes. Aggregations of large porphyroclastic grains of orthopyroxene form thin mineral layers ranging from 0.5 to 5.0 cm. In the other cases, layered arrangements of spinel crystals are rarely observed in dunite.

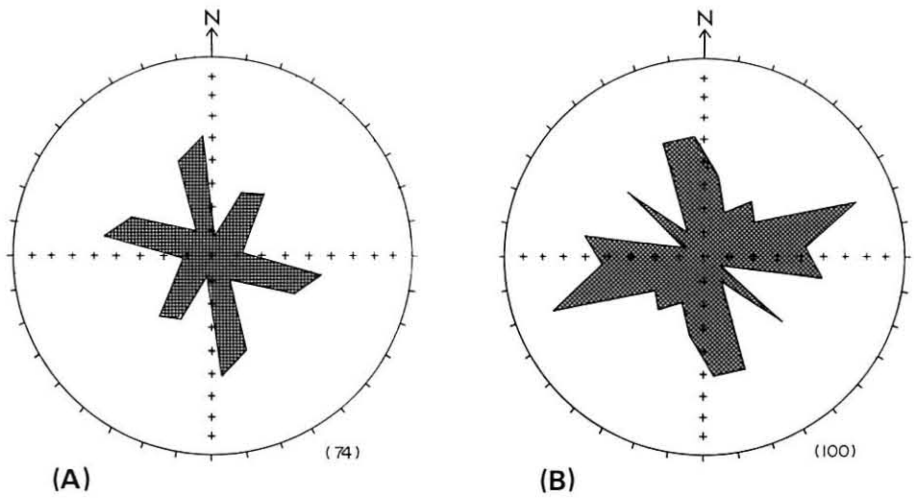
As shown in the π-pole diagram (Text-fig. 9), the primary layering of the Takadomari serpentinite mass is megascopically characterized by a monoclinal structure striking roughly NNW-SSE with a moderate dip to east. Though the structure is disturbed near the border of the mass, the primary internal structure is regarded as rather uniform one.



Text-fig. 9 π-pole diagram showing a monoclinal structure formed by primary compositional layers of dunite, harzburgite, and orthopyroxenite.

Structure of the Takadomari Serpentinite Mass

Structure of the Horoshin Formation on the western side of the serpentinite mass is generally monoclinal one dipping moderately to the west, and is overturned near the boundary with the Takadomari serpentinites. The boundary fault displays an east-facing thrust fault, as shown in Text-fig. 2.



Text-fig. 10 Rose-diagrams showing preferred directions of joints in the massive serpentinites (A) and intrusive directions of microdiorite-microgabbro dykes (B).

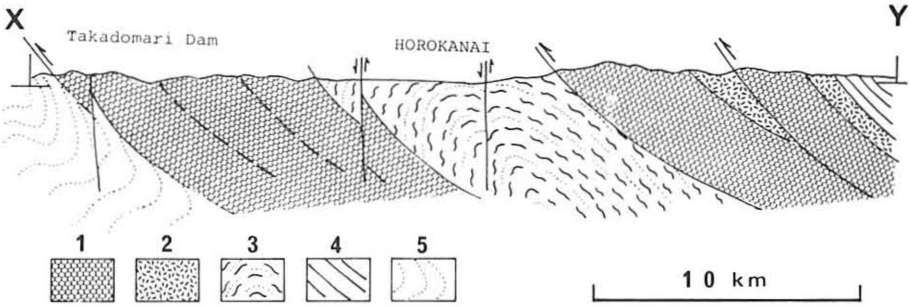
Rose-diagram (Text-fig. 10A) shows a preferred orientation of jointing planes in the serpentinite mass. NNW-SSE joint system, which is one of the most conspicuous directions, coincides with the direction of the boundary fault plane. Accordingly, it is considered that the NNW-SSE jointing were formed during the emplacement of the Takadomari mass. Intrusive planes of the microdiorite-microgabbro dykes are also concentrated in a NNW-SSE direction (Text-fig. 10B). No relationship between the joint system and the direction of microdiorite-microgabbro dykes has been clearly observed in the other directions. The NNW-SSE preferred direction of the microdiorite-microgabbro is consistent with the NNW-SSE trend of primary layering in the serpentinites. However, it is not clear how the microdiorite-microgabbro intrusives relate originally to the layering.

Geologic Structure in the Horokanai Area

Several structural units of ophiolite crop out in the Horokanai area as mentioned previously along the SW-NE section (Line X-Y in Text-fig. 1) a clear arrangement of serpentinites is recognized. The Takadomari serpentinite mass is situated at the southwestern margin of this area and shows an east-facing layered structure. High pressure and low temperature type metamorphic rocks are widely distributed around Horokanai. To the northeastern area of Horokanai two coupling units of ophiolite are exposed. Ishizuka (1980) proposed a westward obduction model for the tectonic emplacement of the Inushibetsu serpentinites. The first suggestion of anticlinal structure observed around the Horokanai basin was given by Igi et al. (1958). Shibakusa (1974) subsequently showed an anticlinal structure for the metamorphic rocks in the Horokanai basin. The above explanation of the anticlinal structure has been supported by Asahina and Komatsu (1979) and Ishizuka (1980), and the Takadomari serpentinites have been recognized as a western wing of the anticline. The high pressure and low temperature metamorphic rocks have been regarded as a basement overlain by the ophiolite sequences.

On the contrary, Text-fig. 11 shows that the metamorphic rocks are considered to be a tectonic unit lifted up by the serpentinites and thrust up to the surface. This is supported by the east-facing layered structure of the Takadomari serpentinites that is underlying the metamorphic complex.

Serpentinite masses are sporadically distributed along the western border of the Kamuikotan Belt closely accociated with the high-pressure and low-temperature type metamorphic rocks. Such a geologic relation is also known in the area around the Kamuikotan Gorge. It is probable that the Takadomari serpentinites were coupled tectonically with the metamorphic rocks in a deeper environment under the Cretaceous arc-trench gap basin (Okada, 1980), which was situated above the westward subducting slab in Cretaceous time (Komatsu et al., 1981; Kiminami and Kontani, 1983; Niida et al., 1984; Kimura and Hoyanagi, 1983). The emplacement of the Takadomari serpentinite mass together with the metamorphic complex should be explained in a late Cretaceous to Tertiary tectonic model of Hokkaido.



Text-fig. 11 Geologic section showing a tectonic situation of the Takadomari serpentinite mass as a dismembered unit in the Horokanai ophiolite complex. Location of the section: Line X-Y in Text-fig. 1.
1: Serpentinite. 2: Metabasalt, metagabbro, and amphibolite. 3: High-pressure and low-temperature type metamorphic rocks. 4: Cretaceous Yezo Group. 5: Tertiary.

Conclusions

(1) The Takadomari serpentinite mass situated at the western border zone of the Kamuikotan Ophiolite Belt crops out over approximately 10 × 12 km. The serpentinites are divided into massive serpentinite, foliated serpentinite, and serpentine clay.

(2) The Takadomari mass consists primarily of dunite, harzburgite, and olivine-orthopyroxenite layers. More than 120 dykes of microdiorite-microgabbro are observed in the serpentinites. Some rodingites derived chiefly from microdiorite-microgabbro are observed in strongly foliated serpentinites.

(3) The Takadomari serpentinites are characterized by lizardite-chrysotile assemblage, whereas the serpentinites are replaced by antigorite in southern part. This means that the mass probably suffered from retrogressive metamorphism at relatively low temperature. Subsequently, the Takadomari serpentinites were progressively metamorphosed into the greenschist to blueschist facies toward the southern border of the mass.

(4) Primary layering observed in the massive serpentinites shows a monoclinal structure with east-facing. The Takadomari mass is regarded as a dismembered ophiolite unit in the Horokanai area. High pressure and low temperature type metamorphic rocks of Horokanai area are considered to be a tectonic unit lifted up by the Takadomari serpentinites.

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