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Petrography of primary peridotites from the Ohsa-yama area, Okayama Prefecture

Toshio NOZAKA and Tsugio SHIBATA

Department of Earth Sciences, Faculty of Science
Okayama University

Ultramafic rocks exposed around Mt. Ohsa (= Ohsa-yama), Okayama Prefecture, designated as "Ohsa-yama ultramafic body" all together, are one of the Alpine-type peridotites in the Sangun metamorphic belt. They are intensely serpentinized and locally suffered contact metamorphism by younger granitic intrusions. In a portion of the Ohsa-yama body where it has not been affected by the contact metamorphism, the constituent minerals, texture and structure of primary ultramafic rocks have been locally preserved. Petrographic studies reveal that the primary ultramafic rocks of the Ohsa-yama body consist dominantly of dunite and harzburgite possessing no obvious layering, and their constituent minerals are similar in composition to those of the Tari-Misaka and Ashidachi ultramafic bodies. These features indicate that unlike the Ochiai-Hokubo body, the Ohsa-yama ultramafic body belongs to the "massive group" of the Arai's (1980) classification.

Keywords : petrography, dunite, harzburgite, massive ultramafic body

I. Introduction

A number of ultramafic bodies occur in the so-called "Sangun metamorphic belt" of high-pressure type in the inner zone of southwestern Japan. Most of them are intensely serpentinized; in addition, they are in many cases thermally metamorphosed by younger granitic rocks (Research Group of Peridotite Intrusion, 1967). Due to intense serpentinization and contact metamorphism, the primary petrologic characters of these ultramafic bodies were generally obscured, but original structure, texture and minerals have been preserved in some portions of individual bodies, hence making it possible to obtain their primary characters (*e.g.*, Igi and Abe, 1969; Arai, 1980).

According to Arai (1980), the ultramafic bodies in the Sangun-Yamaguchi Zone can be classified into two groups on the basis of original structure and rock type; *i.e.*, layered group and massive group. The layered bodies consist of several types of rocks such as lherzolite, dunite, wehrlite, chromitite, websterite and clinopyroxenite. The massive bodies rarely show layered structure, and consist of dunite, harzburgite and chromitite. He contends that the former represents cumulates derived from crystallization of basaltic magma, the latter refractory residues left after partial fusion of primordial peridotites, and both have initially constituted a part of an ophiolite suite.

Compared to other regions in the Sangun belt, ultramafic rocks are exposed most abundantly in the region from northwestern Okayama Prefecture to northeastern Hiroshima Prefecture (Fig. 1). Among the relatively large ultramafic bodies in this region, the Tari-Misaka and Ashidachi bodies belong to the Arai's massive group, and the Ochiai-Hokubo body (also called "Onoro-yama body") belongs to the layered group (Arai, 1980; Hamada, 1982); however, the nature of ultramafic rocks exposed around Mt. Ohsa (= Ohsa-yama*), Okayama Prefecture (designated hereafter as "Ohsa-yama ultramafic body") has not been clearly known. Petrography of some peridotites in the Ohsa-yama body is presented here for the purpose of clarification of its primary petrologic nature.

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* also spelled "Oosa-yama" in other papers.

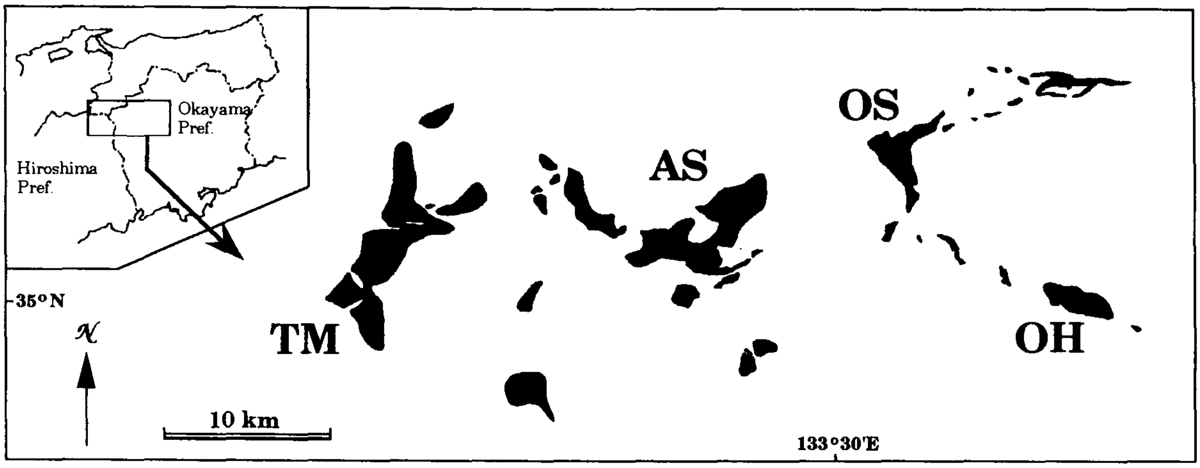

Fig. 1 Distribution of ultramafic rocks in the area of northwestern Okayama and northeastern Hiroshima Prefectures (compiled after Hiroshima Prefecture, 1964; Igi and Sakamoto, 1977; and Mitsuno and Sugita, 1980). Abbreviations for ultramafic bodies: TM, Tari-Msiaka body; AS, Ashidach body, OH, Ochiai-Hokubo body; OS, Ohsa-yama body.

II. Geological Setting

The Sangun metamorphic belt is characterized by glaucophanitic metamorphism (*e.g.*, Hashimoto, 1968). Recent chronological studies reveal that the Sangun metamorphic rocks have a significantly wide range of radiometric ages (Nishimura and Shibata, 1987). On the basis of distribution of crystalline schists that show approximately identical ages, Nishimura (1990) subdivided the glaucophanitic terrane into three regions; *i.e.*, Sangun-Renge Belt (around 300 Ma), Suo Terrane (around 220 Ma) and Chizu Terrane (around 180 Ma). Ophiolitic rocks such as serpentinite and metagabbro occurring in the glaucophanitic terrane are also different in age from one region to another, though they are older than the surrounding crystalline schists in each region. For example, the Ohsa-yama ultramafic body is included in the 180 Ma Chizu Terrane, and a block of basic schist in this body has a K-Ar age of *ca.* 250 Ma (Watanabe *et al.*, 1987). Also, the Tari-Misaka, Ashidachi and Ochiai-Hokubo ultramafic bodies belong to the Chizu Terrane, so that we infer that there exists a close petrogenetic link among these ultramafic bodies.

III. General Geology of the Ohsa-yama Area

The Ohsa-yama ultramafic body is exposed in an area around the summit of Mt. Ohsa, which is *ca.* 3 km wide from north to south and 5 km long from east to west. The exposed body has an unusual, ax-like shape in plane (Fig. 2). Rock outcrops are found sporadically throughout the body. The ultramafic rocks are intensely serpentinized, except for those occurring at the southwestern slope of Mt. Ohsa where the serpentinites have reverted to compact peridotitic rocks due to contact metamorphism by a younger granitic intrusion. Many gabbroic and leucocratic blocks with a few meters in diameter occur in the Ohsa-yama body. These blocks consist of fine-grained gabbro, jadeitite, albitite and rodingite, and have been found only within the ultramafic body. Therefore, they are thought to have been included into or formed within the ultramafic body before its emplacement into the present position in the surrounding schists.

The Ohsa-yama ultramafic body is in fault contact with crystalline schists on the north and east of the body. The crystalline schists are composed dominantly of pelitic and basic rocks with small amounts of intercalated thin beds of psammitic and siliceous rocks. Their schistosity planes trend N-S or NE-SW and dip 30 to 60° NW. On a macroscopic scale, however, these schists form a large fold with its axial plane trending E-W and extending from the Katsuyama through Ohsa-yama to Hokubo areas

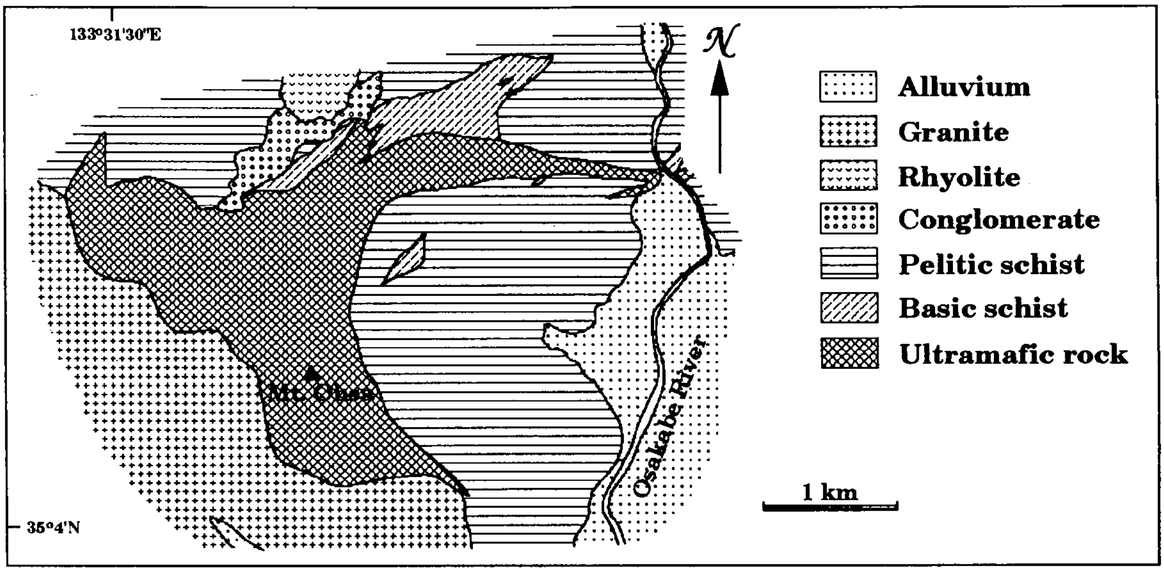

Fig. 2 Geological sketch map of the Ohsa-yama (Mt. Ohsa) area.

(Mitsuno and Sugita, 1980). The Ohsa-yama ultramafic body is situated at the crest of this fold. The unusual shape of the Ohsa-yama body may result from bending associated with the large-scale folding.

Metamorphic minerals composing the crystalline schists adjacent to the Ohsa-yama body include muscovite, chlorite and epidote in pelitic schists, and chlorite, epidote, actinolite, albite, stilpnomelane, muscovite and locally glaucophane in basic schists. A lawsonite-bearing basic schist has also been reported from the Ohsa-yama area (Hashimoto and Igi, 1970). Occurrence of these metamorphic minerals suggests high P/T metamorphism in this area.

The Ohsa-yama body and the surrounding schists are intruded by a biotite granite and hornblende-biotite granite, and overlain by unmetamorphosed conglomerates and rhyolites. These younger igneous and sedimentary rocks are Cretaceous in age (Mitsuno and Sugita, 1980).

IV. Petrography

The Ohsa-yama ultramafic rocks have suffered contact metamorphism by the granitic intrusion. The metamorphic aureole developed from the southwestern margin to middle portion of the Ohsa-yama body along this granitic intrusion (Nozaka, 1987). The minerals formed by the contact metamorphism include orthopyroxene, olivine, talc and tremolite, and the recrystallized Ohsa-yama rocks show distinct, granoblastic or poikiloblastic textures. The ultramafic rocks occurring in the eastern portion of the Ohsa-yama body are not affected by the contact metamorphism. Although these rocks have suffered intense serpentinization, they still locally preserve the original textures and contain olivine, orthopyroxene, clinopyroxene and brown spinel as relict minerals. Any layered structures on both mesoscopic and microscopic scales are not recognized in the Ohsa-yama body.

Olivine, the most abundant relict phase, is equidimensional in shape and a few millimeters in diameter. Pyroxenes have commonly exsolution lamellae; *i.e.*, clinopyroxene lamellae in orthopyroxene, and vice versa. Brown spinel has an equidimensional shape in a serpentine matrix, and a vermicular shape within or in contact with clinopyroxene grains.

The relict minerals are never in direct contact with each other due to replacement by minerals produced during serpentinization. Generally, olivine and orthopyroxene are replaced at their rims and along cleavages by serpentine and fine-grained magnetite, and spinel is fringed with such opaque minerals as ferritchromite and

Table 1 Representative micropobe analyses of relic minerals in the Ohsa-yama ultramafic body.

Rock type	Harzburgite								Dunite			
Phase	Olivine		Orthopyroxene**		Clinopyroxene		Spinel		Olivine		Spinel	
SiO2	40.80	40.79	55.35	55.42	52.35	53.37	0.03	0.01	40.56	40.53	0.04	0.03
TiO2	-	-	0.04	0.01	0.00	0.01	0.02	0.00	-	-	0.05	0.05
Al2O3	-	-	2.72	2.83	2.78	1.84	27.45	28.46	-	-	28.85	28.55
Cr2O3	-	-	0.80	0.81	1.09	0.82	40.03	40.04	-	-	38.64	38.26
FeO*	8.99	9.03	5.68	5.76	1.94	1.53	21.00	17.80	8.39	8.72	21.94	22.94
MnO	0.10	0.13	0.14	0.16	0.08	0.07	0.42	0.35	0.11	0.11	0.55	0.68
NiO	0.36	0.38	0.08	0.11	0.04	0.04	0.11	0.06	0.44	0.42	0.06	0.07
MgO	50.24	49.98	33.35	33.80	16.43	17.14	10.94	13.01	50.93	50.67	9.58	8.56
CaO	0.00	0.01	1.63	1.07	24.71	25.07	0.02	0.03	0.00	0.03	0.00	0.01
Na2O	-	-	0.00	0.01	0.06	0.04	-	-	-	-	-	-
Total	100.49	100.32	99.79	99.98	99.48	99.93	100.02	99.76	100.43	100.48	99.71	99.15
O	4	4	6	6	6	6	32	32	4	4	32	32
Si	0.992	0.994	1.921	1.917	1.919	1.943	0.007	0.002	0.986	0.986	0.010	0.007
Ti	-	-	0.001	0.000	0.000	0.000	0.004	0.000	-	-	0.009	0.009
Al	-	-	0.111	0.115	0.120	0.079	7.937	8.102	-	-	8.362	8.375
Cr	-	-	0.022	0.022	0.032	0.024	7.765	7.647	-	-	7.513	7.529
Fe	0.183	0.184	0.165	0.167	0.059	0.047	4.309	3.596	0.171	0.177	4.512	4.775
Mn	0.002	0.003	0.004	0.005	0.002	0.002	0.087	0.072	0.002	0.002	0.115	0.143
Ni	0.007	0.007	0.002	0.003	0.001	0.001	0.022	0.012	0.009	0.008	0.012	0.014
Mg	1.822	1.816	1.725	1.743	0.898	0.930	4.001	4.685	1.846	1.838	3.512	3.176
Ca	0.000	0.000	0.061	0.040	0.971	0.978	0.005	0.008	0.000	0.001	0.000	0.003
Na	-	-	0.000	0.001	0.004	0.003	-	-	-	-	-	-
Total	3.006	3.004	4.012	4.013	4.006	4.007	24.137	24.124	3.014	3.012	24.045	24.031
Mg/Mg+Fe	0.909	0.908	0.913	0.913	0.938	0.952	0.481	0.566	0.915	0.912	0.438	0.399
Wo			3.1	2.1	50.4	50.0						
En			88.4	89.4	46.6	47.6						
Fs			8.5	8.6	3.1	2.4						
Al***							0.494	0.504			0.523	0.524
Cr***							0.483	0.476			0.470	0.471
Fe3+***							0.023	0.021			0.007	0.005

*total iron as FeO. **Beam diameter: 30 microns.

***Al-Cr-Fe3+ atomic ratios in spinel. Fe3+ is caluculated from structural formula.

magnetite. In some cases where serpentinization has proceeded completely, serpentine and associated minerals form pseudomorphs after olivine and orthopyroxene, exhibiting mesh and bastite textures. In contrast with olivine and orthopyroxene, clinopyroxene tends to better preserve its original crystal shape. It suggests that clinopyroxene is more resistant to serpentinization than olivine and orthopyroxene.

In spite of its stronger resistance to serpentinization, clinopyroxene occurs less frequently than olivine and orthopyroxene. Spinel is also a relatively resistant phase and in fact it occurs more frequently than the other relict phases, but is only a small amount in all specimens examined. Therefore, clinopyroxene and spinel appear to have been a minor constituent of the primary peridotites. Abundance of the relict minerals and their pseudomorphs indicates that the dominant primary rock types of the Ohsa-yama body have been dunite and harzburgite.

V. Mineral Chemistry

All analyses in this study were carried out by using a JEOL electron probe microanalyzer (Model JXA-733) at Okayama University. The correction procedure was that of Bence and Albee (1968) with alpha factors of Nakamura and Kushiro (1970).

Two samples from the Ohsa-yama body were selected for chemical analysis of constituent minerals; one is dunite containing olivine and brown spinel (sample no. 03141083) and the other is harzburgite containing olivine, orthopyroxene, clinopyroxene and brown spinel (sample no. 02231183). Their representative analyses are listed in Table 1.

1. Olivine

Olivine crystals in both the dunite and harzburgite are homogeneous in composition within individual grains and from grain to grain; *e.g.*, the *Fo* contents are restricted from 90.8 to 91.0 in the harzburgite sample, and from 91.2 to 91.5 in the dunite with the exception of a small grain (*Fo* 92.6) that is included in a larger ferritchromite grain. NiO contents in olivines from the Ohsa-yama body are plotted against *Fo* contents in Fig. 3 along with ranges of olivine compositions from peridotites in the neighboring ultramafic bodies reported by Arai (1980) and Hamada (1982). All the plotted points of the Ohsa-yama olivine compositions are entirely included in the compositional area for the Tari-Misaka and Ashidachi olivines.

2. Orthopyroxene

Orthopyroxene grains examined have invariably many thin exsolution lamellae of clinopyroxene. The orthopyroxene analyses obtained by a focused, narrow electron beam of 1 μm or so in diameter show considerably disper-

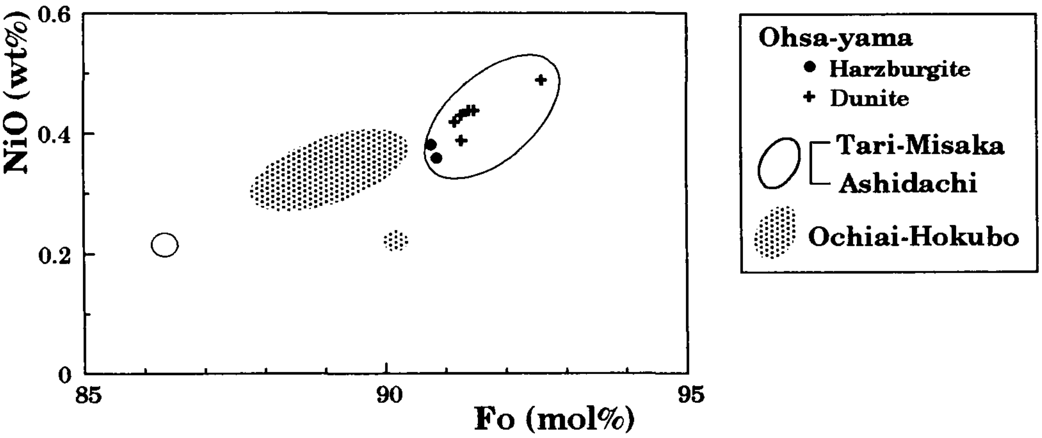

Fig. 3 Correlation between Fo and NiO contents of olivine in harzburgite and dunite from the Ohsa-yama ultramafic body. Compositional areas for olivines in peridotites from the Tari-Misaka and Ashidachi bodies (data from Arai, 1980), and from the Ochiai-Hokubo body (data from Hamada, 1982) are also shown for comparison.

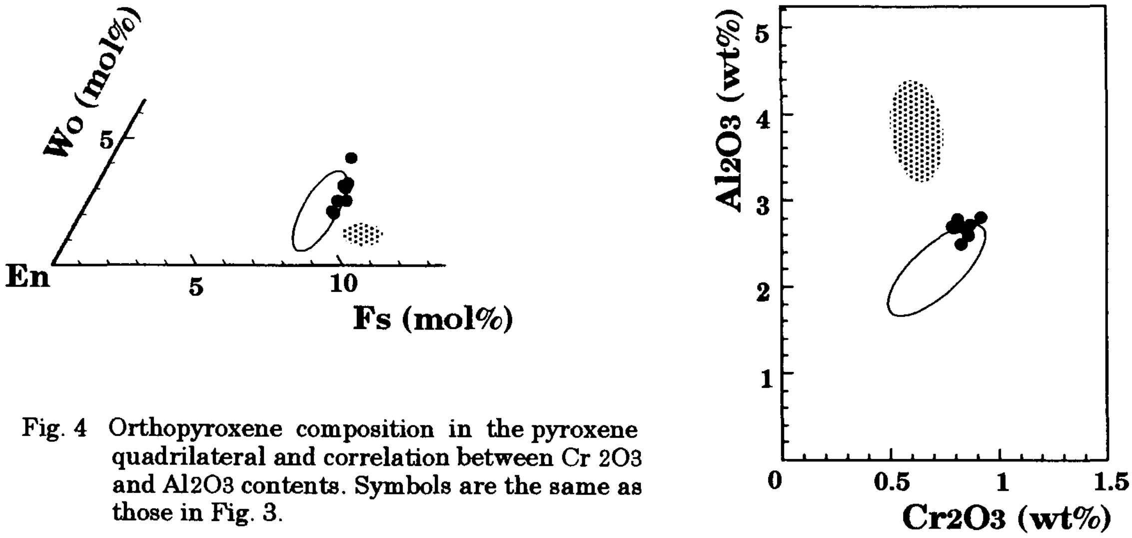

Fig. 4 Orthopyroxene composition in the pyroxene quadrilateral and correlation between Cr 2O3 and Al2O3 contents. Symbols are the same as those in Fig. 3.

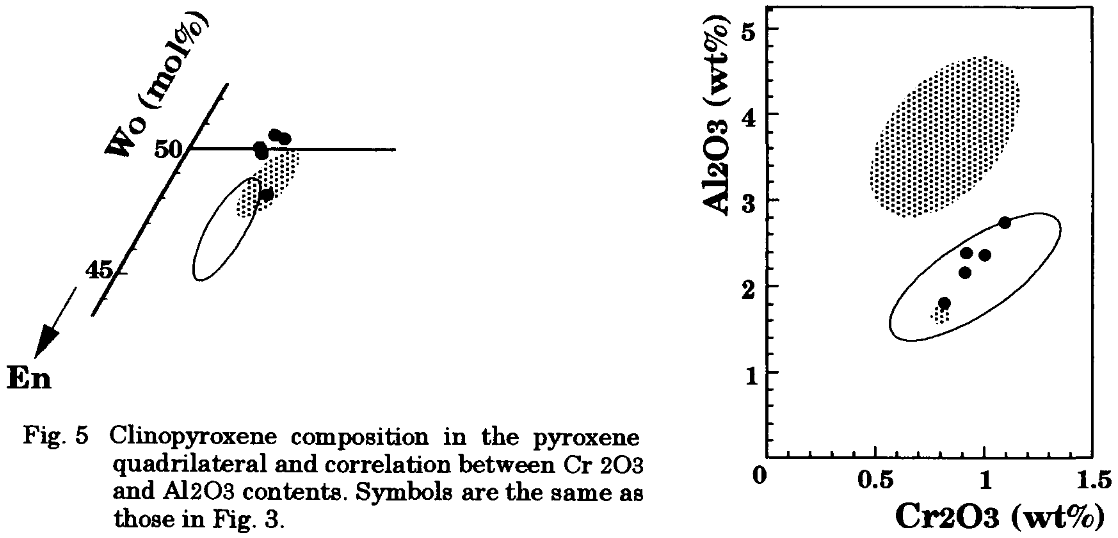

Fig. 5 Clinopyroxene composition in the pyroxene quadrilateral and correlation between Cr 2O3 and Al2O3 contents. Symbols are the same as those in Fig. 3.

sive values of Ca content within each grain, even if no heterogeneity was detected by back-scattered electron images. It is inferred from this fact that the effect of clinopyroxene lamellae adjacent to or beneath the analyzed points was not avoided completely. Hence all quantitative analyses of orthopyroxene were carried out by means of a broad beam of 30 μm in diameter. The results so obtained for the harzburgite sample are shown in Table 1 and Fig. 4. Although the Ohsa-yama orthopyroxenes appear to be rich in *Wo* component owing partly to the analytical procedure, they are rather similar in composition to those in the Tari-Misaka and Ashidachi harzburgites than the Ochiai-Hokubo peridotites.

3. Clinopyroxene

Analyses of clinopyroxene were carried out by a focused, narrow electron beam, because the exsolution lamellae in this phase are not so abundant as in orthopyroxene. Figure 5 shows that the clinopyroxenes from the Ohsa-yama body possess a chromian diopsidic composition. Their Al and Cr contents are almost the same as those of the Tari-Misaka and Ashidachi bodies, but their *Wo* contents are slightly higher than those of the Tari-Misaka and Ashidachi bodies as well as the Ochiai-Hokubo body. This compositional difference may be accounted for by difference in equilibration temperature among the ultramafic bodies, but such a possibility cannot be examined further because precise composition of orthopy-

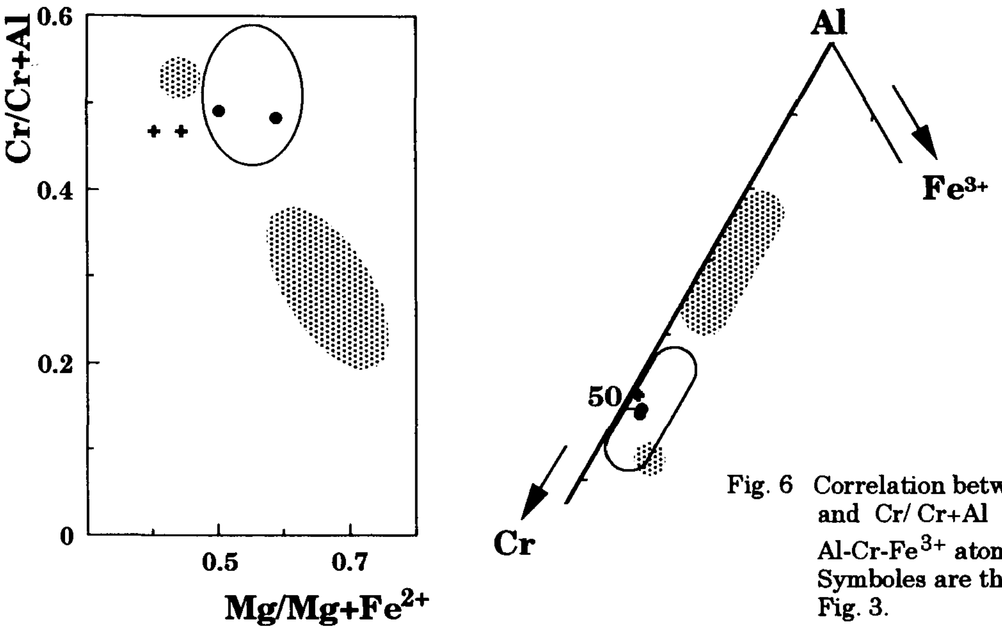

Fig. 6 Correlation between Mg/Mg+Fe^{2+} and Cr/ Cr+Al atomic ratios and Al-Cr-Fe^{3+} atomic ratios of spinel. Symboles are the same as those in Fig. 3.

roxene coexisting with clinopyroxene in the Ohsa-yama body is not known, as mentioned above.

4. Spinel

The analyzed grains of brown spinel exhibit an equidimensional shape in the dunite and a vermicular shape in the harzburgite. The spinel grains in the dunite have been replaced or mantled by opaque minerals thicker than those in the harzburgite. Both the spinels possess almost identical Cr/Cr+Al ratios as shown in Fig. 6. The spinel compositions are plotted nearly halfway between the Al and Cr apices in the Al-Cr-Fe^{3+} triangular diagram, and fall within the composition ranges of spinel from the Tari-Misaka and Ashidachi bodies. Also, the Ohsa-yama spinels vary significantly in Mg/Mg+Fe^{2+} atomic ratio, depending on the type of rock in which they occur. They are more magnesian in the harzburgite than in the dunite (Fig. 6). This may be simply due to the difference in primary spinel composition between the harzburgite and dunite, or otherwise it may reflect the difference in the degree of replacement of spinels by the secondary opaque minerals (Nozaka, 1987).

VI. Conclusions

Observations of the ultramafic rocks in the field and under the microscope, and chemical analyses of the relict minerals derived from primary peridotites have revealed the following; 1) mesoscopic and microscopic layerings do not or rarely exist, 2) the primary peridotites consist mainly of olivine, or of olivine and orthopyroxene with accessory clinopyroxene and spinel; in other words, the dominant rock types are dunite and harzburgite, and 3) the constituent minerals are rather similar in composition to those of the Tari-Misaka and Ashidachi bodies than the Ochiai-Hokubo body. From these facts it is concluded that the Ohsa-yama ultramafic body belongs to the massive group of the Arai's (1980) classification.

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