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OLIVINE CLINOPYROXENITE IN SERPENTINIZED DUNITE – HARZBURGITE MASSES OF THE KAMUIKOTAN ZONE, HOKKAIDO

by

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(with 6 figures and 2 tables)

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Abstract

Many olivine clinopyroxenite intrusives have been found in the serpentinized dunite–harzburgite–orthopyroxenite masses of the Kamuikotan Zone. The intrusives are composed of wehrlite, olivine clinopyroxenite, and clinopyroxenite. These rocks are mostly composed of diopside($Ca_{46-48}Mg_{47-50}Fe_{4-6}$) and olivine ($Fo_{85-87}$), having typical igneous textures. Ultramafic rocks in the Kamuikotan Zone are not only characterized by the main rock types of dunite–harzburgite, but also by small ones of olivine clinopyroxenite.

Introduction

Large serpentinite masses such as Pinneshiri, Inushibetsu-Takadomari, and Mukawa-Sarugawa, and numerous small masses are distributed along the Kamuikotan Zone (Suzuki, 1952; Bamba, 1957; Hunahashi, 1958). It is noticeable that these serpentinites contain many relict minerals indicating the original rock type of the intrusives. The Research Group of Peridotite Intrusion (1967) mentioned that the main rock types of the ultramafic rocks in the Kamuikotan Zone are dunite–harzburgite and that plagioclase is absent and clinopyroxene is rare in these ultramafic rocks. Accompanying these serpentinite masses are many small dykes of gabbro pegmatite, microdiorite, and leucocratic rocks such as albitite, trondhjemite and rodingite. Hitherto only a few ultramafic rocks carrying clinopyroxene have been reported from the Kamuikotan Zone (Ishibashi, 1939).

Recently, several types of olivine clinopyroxenite have been found in the serpentinized dunite–harzburgite–orthopyroxenite masses of the Kamuikotan Zone. The olivine clinopyroxenites are separate intrusive units from the dunite–harzburgite. Their occurrence and petrography are given in this paper with a discussion of associations of ultramafic rocks in the Kamuikotan Zone.

Occurrence and Rock Descriptions

Twelve localities of olivine clinopyroxenite have been found as in Fig. 1. Without exception, the occurrence of these rocks is restricted to within the serpentinized masses. The contacts of these rocks are not always well exposed, but in some cases the olivine clinopyroxenite clearly shows an intrusive relation to the serpentinized dunite–harzburgite. Most of the rocks occur as small dykes or pipe-like masses ranging from about 1 to 200 m in diameter. They are composed almost entirely of clinopyroxene ($Ca_{46-48}Mg_{47-50}Fe_{4-6}$) and

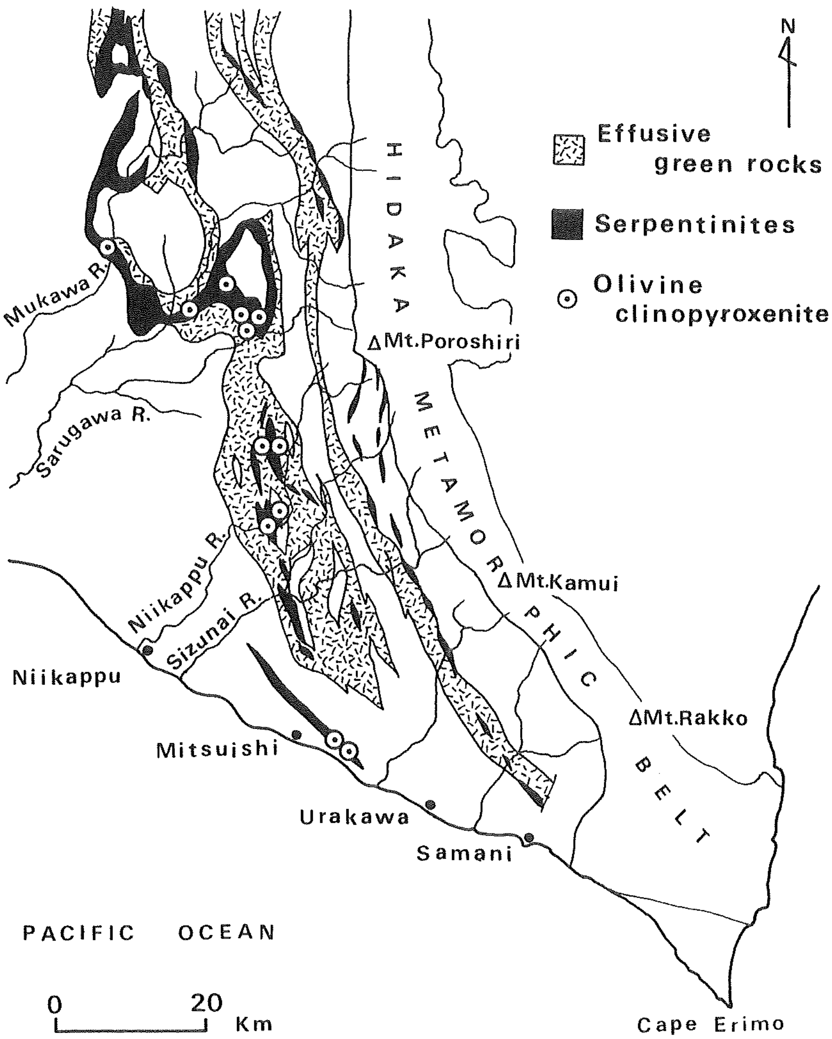


Fig. 1 Localities of olivine clinopyroxenite in serpentinite bodies of the Kamuikotan Zone.

olivine (Fo_{85-87}). The clinopyroxenes are well preserved, but most of the olivines are changed into serpentine minerals.

On the basis of modal composition, the olivine clinopyroxenitic rocks are classified into the following rock types in order of decreasing olivine:

Type 1. wehrlite (rare),
50 – 75% olivine, 25 – 50% clinopyroxene.

Type 2. olivine clinopyroxenite with olivine cumulates (rare),
20 – 50% olivine, 50 – 80% clinopyroxene.

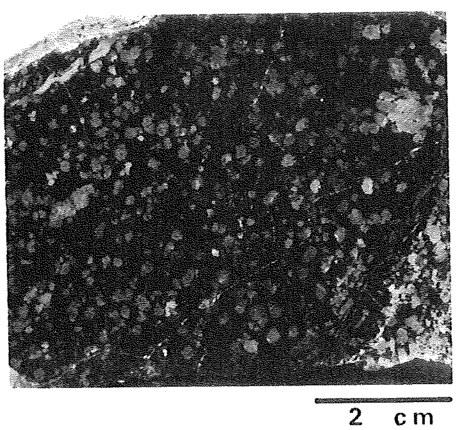
Type 3. olivine clinopyroxenite (most abundant),
10 – 30% olivine, 70 – 90% clinopyroxene.

Type 4. clinopyroxenite (abundant),
0 – 10% olivine, 90 – 100% clinopyroxene.

Wehrlite is a rare type which is associated with the olivine clinopyroxenite masses (Fig. 2). Clinopyroxenes in this type are approximately 1 to 5 mm in grain size. Magmatic flow alternations of wehrlite and clinopyroxenite are commonly observed.

Olivine clinopyroxenite characteristically shows olivine cumulate texture (Fig. 3). Clinopyroxenes in this type occur as large oikocrysts up to about 2 cm in grain size. Cumulus olivines are anhedral grain ranging from 1 to 10 mm in size and entirely enclosed by the intercumulus clinopyroxenes. Sometimes, fresh olivine is preserved in this rock type.

The most predominant type is type 3 olivine clinopyroxenite which constitutes more than about 70% of the masses (Fig. 4). Clinopyroxenes in this type are euhedral to subhedral grains with greenish-yellow colour and 1 to



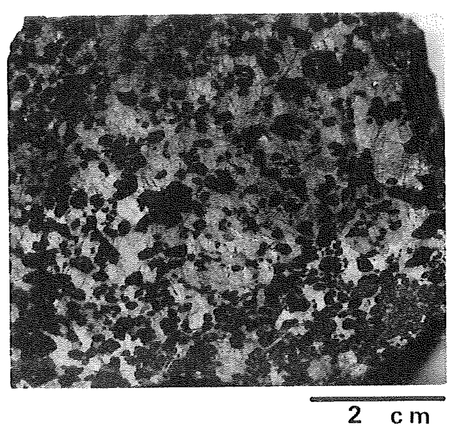
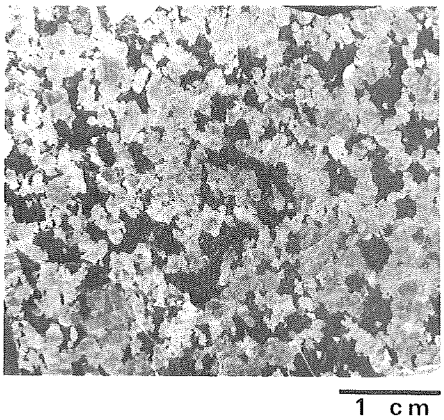


Fig. 2 (Left) Polished sample of wehrlite (type 1) from the olivine clinopyroxenite intrusives at Iwashimizu.

Fig. 3 (Right) Polished sample of type 2 olivine clinopyroxenite composed of cumulus olivine (black) and intercumulus clinopyroxene (grey).



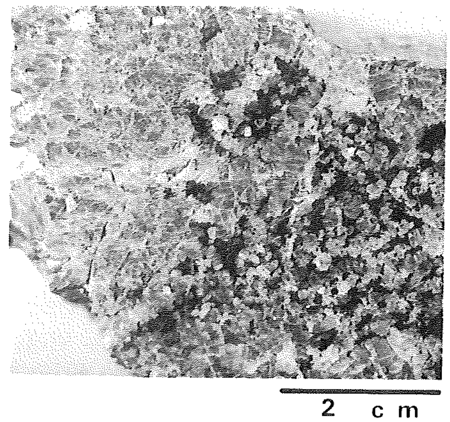


Fig. 4 (Left) Polished sample of type 3 olivine clinopyroxenite which is the most predominant type in the olivine clinopyroxenite intrusives.

Fig. 5 (Right) Polished sample of clinopyroxenite (type 4) (left) and type 3 olivine clinopyroxenite (right), showing a gradation into each other.

5 mm in size. Some clinopyroxenes show undulatory strain banding. Olivines occur as an intercumulate.

Clinopyroxenite is also abundant type and generally grades into the olivine clinopyroxenite (Fig. 5). Clinopyroxenes are commonly euhedral to subhedral grains ranging from 5 to 30 mm in size. Large crystals of clinopyroxene, more than 10 cm in diameter, are occasionally found.

No concentric zoning of these rock types is observed in the field. They are distributed rather irregularly and commonly show gradation into each other. At some good exposures flow layering can be observed.

The following evidence may suggest a magmatic intrusion for the olivine clinopyroxenite: (1) Olivine clinopyroxenite exposed at Iwashimizu shows a primary igneous texture which is composed of cumulus olivine and intercumulus clinopyroxene. (2) Some olivine clinopyroxenites have flow laminae formed by modal variation of clinopyroxene and olivine. (3) Olivine clinopyroxenites near the Niikappu dam and Mitsuishi occur as clear-cut dykes in serpentinized dunite–harzburgite masses.

Diopside veins are rarely found in chromite ores of the Sarugawa serpentinite body (Bamba, personal communication). The veins most probably segregated from the olivine clinopyroxenitic magma at the latest stage of crystallization.

Table 1 EPMA analyses and structural formulae for clinopyroxenes from the olivine clinopyroxenite intrusives.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	53.61	53.99	53.97	54.46	53.61	53.64	53.02	53.31	52.97	54.59	54.29	54.27	54.27	53.68
TiO_2	0.16	0.06	0.18	0.00	0.00	0.16	0.11	0.04	0.08	0.05	0.06	0.04	0.06	0.06
Al_2O_3	2.15	2.04	2.12	0.93	1.39	2.12	2.09	2.07	2.03	1.38	1.02	1.55	1.87	1.77
FeO*	3.69	3.74	3.75	2.33	3.07	3.38	3.43	3.63	3.72	2.83	2.96	3.14	3.18	3.33
MnO	0.13	0.13	0.15	0.08	0.10	0.09	0.11	0.14	0.15	0.11	0.19	0.11	0.08	0.05
MgO	17.12	17.01	17.09	17.99	17.34	17.06	16.93	17.14	17.14	17.70	17.30	17.61	17.03	17.29
CaO	22.54	23.25	22.83	23.49	23.91	22.68	23.41	23.06	22.82	23.27	24.65	23.96	23.97	24.02
Na_2O	0.15	0.13	0.14	0.18	0.06	0.24	0.11	0.10	0.13	0.11	0.02	0.11	0.14	0.12
K_2O	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Total	99.55	100.35	100.24	99.47	99.49	99.37	99.21	99.50	99.05	100.04	100.39	100.79	100.60	100.32
Numbers of cátions on the basis of 6 oxygens														
Si	1.958	1.959	1.959	1.984	1.964	1.961	1.949	1.953	1.952	1.978	1.971	1.960	1.963	1.951
Al^{IV}	0.042	0.041	0.041	0.016	0.036	0.039	0.051	0.047	0.048	0.022	0.029	0.040	0.037	0.049
Al^{VI}	0.051	0.047	0.051	0.024	0.023	0.053	0.039	0.042	0.039	0.038	0.015	0.027	0.044	0.027
Ti	0.004	0.002	0.005	0.000	0.000	0.004	0.003	0.001	0.002	0.002	0.002	0.001	0.002	0.002
Fe**	0.113	0.114	0.114	0.071	0.094	0.103	0.105	0.111	0.114	0.086	0.090	0.095	0.096	0.102
Mn	0.004	0.004	0.005	0.002	0.003	0.003	0.003	0.004	0.005	0.003	0.003	0.003	0.003	0.002
Mg	0.932	0.920	0.924	0.977	0.946	0.930	0.927	0.935	0.940	0.956	0.936	0.948	0.918	0.937
Ca	0.882	0.904	0.888	0.917	0.938	0.888	0.922	0.905	0.900	0.903	0.959	0.927	0.929	0.936
Na	0.010	0.009	0.010	0.013	0.004	0.017	0.008	0.007	0.009	0.008	0.002	0.008	0.010	0.009
K	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.996	4.000	3.998	4.005	4.008	3.998	4.007	4.005	4.009	3.996	4.007	4.009	4.002	4.015
Fe	5.9	5.9	6.0	3.6	4.8	5.5	5.4	5.8	5.9	4.5	4.6	4.9	5.0	5.2
Mg	48.3	47.5	48.0	49.7	47.8	48.3	47.4	47.9	48.1	49.1	47.1	48.1	47.2	47.5
Ca	45.8	46.6	46.0	46.7	47.4	46.2	47.2	46.3	46.0	46.4	48.3	47.0	47.8	47.3
sample	7680708	7680708	7680708	7680708	7680902	7680902	7680902	7680706	7680706	7680702	7680702	7680702	7680702	7680702
rock type	1	1	1	2	2	2	3	3	3	4	4	4	4	4

* FeO = total iron expressed as FeO ** Fe = Fe^{+2}

Table 2 EPMA analyses and structural formulae for olivines from the olivine clinopyroxenite intrusives.

	1	2	3	4	5	6
SiO_2	40.12	40.55	40.46	39.81	40.16	39.75
TiO_2	0.01	0.01	0.00	0.00	0.00	0.00
Al_2O_3	0.00	0.01	0.00	0.00	0.00	0.01
FeO*	12.59	12.63	12.62	13.45	13.53	13.93
MnO	0.15	0.18	0.22	0.19	0.21	0.21
MgO	47.59	47.27	47.19	46.16	46.31	46.70
CaO	0.03	0.03	0.04	0.04	0.02	0.02
Na_2O	0.00	0.00	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.49	100.68	100.53	99.65	100.23	100.62
Numbers of cations on the basis of 4 oxygens						
Si	0.991	0.999	0.999	0.996	0.999	0.988
Al	0.000	0.001	0.000	0.000	0.000	0.001
Ti	0.000	0.000	0.000	0.000	0.000	0.000
Fe**	0.259	0.260	0.261	0.281	0.281	0.290
Mn	0.003	0.004	0.005	0.004	0.005	0.005
Mg	1.753	1.736	1.736	1.721	1.716	1.729
Ca	0.001	0.001	0.001	0.001	0.001	0.001
Na	0.000	0.000	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.007	3.001	3.002	3.003	3.002	3.014
M***	86.9	86.8	86.7	85.8	85.7	85.5
sample	7680902	7680902	7680902	7680901	7680901	7680901
rock type	2	2	2	2	2	2

* FeO = total iron expressed as FeO
** Fe = Fe^{+2}
*** M = 100 Mg / Mg+Fe+Mn

Minerals

Fourteen grains of clinopyroxene and six grains of olivine were analyzed by a fully automatic electron probe microanalyzer (JEOL; JXA-5A) at the Geological Survey of Japan. Operating conditions were 15 kv accelerating potential and about 0.04 μA specimen current. The electron beam diameter was kept at about 5 microns. The data were corrected by the method of Bence and Albee (1968). Calculations for correction and structural formula were carried out by using the computer programs developed by Okumura and Soya (1975).

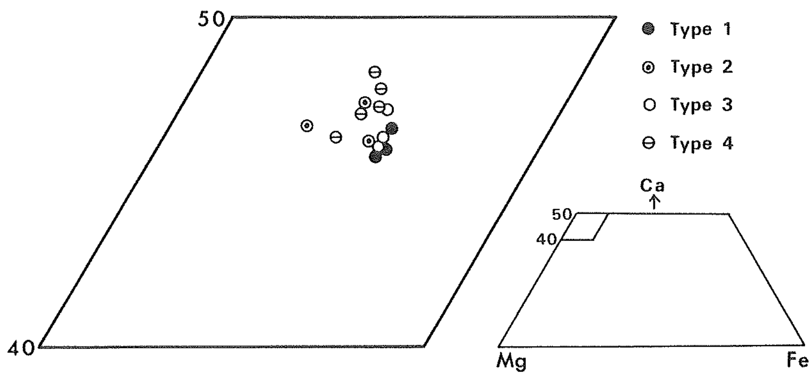


Fig. 6 Chemical composition of clinopyroxenes in each rock type of the olivine clinopyroxenite intrusives.

Clinopyroxenes: EPMA analyses of clinopyroxene from the olivine clinopyroxenite masses are listed in Table 1. As shown in Fig. 6, these analyses are plotted in the diopside region and show small composition ranges; $Ca_{46.2}Mg_{47.9}Fe_{5.9}$ from wehrlite (type 1), $Ca_{46.8}Mg_{48.6}Fe_{4.6}$ from olivine clinopyroxenite (type 2), $Ca_{46.5}Mg_{47.8}Fe_{5.7}$ from olivine clinopyroxenite (type 3), and $Ca_{47.4}Mg_{47.8}Fe_{4.8}$ from clinopyroxenite (type 4). These diopsides have similar composition to those from the "Alpine-type" peridotites, whereas their composition is slightly richer in magnesia than those from some zoned ultramafic complexes, e.g. Duke Island (Irvine, 1974). The diopsides from the olivine clinopyroxenite have a low content of Al_2O_3 (0.9–2.2 wt %) and are also low in TiO_2, up to 0.2 wt %, and Na_2O, 0.1–0.2 wt %.
Olivines: EPMA analyses of olivine from the type 2 olivine clinopyroxenite are listed in Table 2. The olivines have small composition ranges in 100Mg / Mg+Fe+Mn ratio (85.5–86.9), which are apparently lower than those from the host serpentinized dunite–harzburgite (89.8–92.9 after Tazaki et al., 1975).

Discussion

Along the Kamuikotan Zone many olivine clinopyroxenite intrusives, which are mainly composed of wehrlite, olivine clinopyroxenite, and clinopyroxenite, occur in serpentinized dunite–harzburgite–orthopyroxenite bodies, showing a separate intrusive unit. The occurrence of the intrusives suggests that the olivine clinopyroxenites were formed by crystallization of olivine clinopyroxenitic magma which intruded into the host dunite–harzburgite at a deeper level than that of serpentinization.

The "Alpine-type" ultramafic rocks can be classified into three series, i.e. H – series (dunite–harzburgite–orthopyroxenite), L–series (dunite–lherzolite–plagioclase lherzolite), and W–series (dunite–wehrlite–clinopyroxenite), and those in one metamorphic zone are characterized by the occurrence of only one of the three series (Research Group of Peridotite Intrusion, 1967; Kuroda and Tazaki, 1969). It has been regarded that the ultramafic rocks in the Kamuikotan Zone are the H–series (Research Group of Peridotite Intrusion, 1967; Komatsu, 1973). Occurrence of the olivine clinopyroxenite intrusives, however, indicate that the ultramafic rocks in this zone are not only characterized by the H– series as main rock types, but also small intrusives of olivine clinopyroxenite (W– series).

Olivine clinopyroxenite generally occurs associated with wehrlite intrusions, e.g. those in the Mikabu Zone, Japan (Tazaki, 1966; Research Group of Peridotite Intrusion, 1967) and in the zoned ultramafic complexes of Union Bay (Ruckmick and Noble, 1959) and Duke Island (Irvine, 1974). Small intrusive bodies of olivine clinopyroxenite occurring in dunite–harzburgite have also been reported in the maizuru Zone, Japan (Kurokawa, 1970). The chemical compositions of olivines from the olivine clinopyroxenite of the Kamuikotan Zone are generally lower in forsterite content than those from the H–and L–series of the "Alpine-type" peridotites, whereas the compositions are similar to those from W– series of the "Alpine-type" peridotites and the zoned ultramafic complexes. Al_2O_3 contents in diopside from the Kamuikotan olivine clinopyroxenites are also lower than those from H– and L–series. Accordingly, constituent minerals in the olivine clinopyroxenite of the Kamuikotan Zone are similar to those from the W–series of the "Alpine-type" peridotites and the zoned ultramafic complexes rather than the H– and L–series. It is necessary to investigate the origin of both ultramafic rock associations of the H– and W–series in the Kamuikotan Zone.

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