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Ultramafic Masses in the Eastern Part of the Maizuru Zone and Their Geological Bearings

By

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Abstract

In the eastern part of the Maizuru zone, southwest Japan, ultramafic masses are classified into two types; type I refers to those arranged along the northern side of the Maizuru zone and type II refers to those occurring in the Yakuno complex inside the Maizuru zone. Petrographical differences between the two can be recognized. In type I ultramafic masses, dunite is most dominant accompanying harzburgite, clinopyroxenite, hornblendite and albitite. In type II ultramafic masses, peridotitic rocks are dominant over dunite and characteristic spinels are universally found. Type II ultramafic masses are subdivided into three subtypes; that is H-, W- and G-subtypes. H-subtype is composed of dunite, harzburgite, orthopyroxenite and clinopyroxenite, among which harzburgite is most dominant. W-subtype is composed of dunite, wehrlite, olivine clinopyroxenite and clinopyroxenite, and olivine clinopyroxenite is most dominant in them. G-subtype is composed of hornblende clinopyroxenite and clinopyroxene hornblendite. The modal composition of clinopyroxene and hornblende in G-subtype is variable. The occurrence of each subtype is characteristic. H-subtype occurs at the boundary of the Maizuru zone and the Tanba zone, and W-subtype occurs in the gabbroic rocks of the Yakuno complex but is not transitional to them. G-subtype occurs as a layer in the gabbroic rocks of the Yakuno complex from a centimeter to 5 m thick and is transitional to the latter.

It is suggested that type I ultramafic masses have something to do with the Sangun metamorphism,and type II ultramafic masses have a relation to the gabbroic rocks of the Yakuno complex, of which, H-subtype has a relation to the formation of the zonal arrangement of the Maizuru zone.

I Introduction

In the Inner zone of southwest Japan, the Maizuru zone is a remarkable tectonic zone, characterized by the zonal arrangements of the Yakuno complex (NAKAZAWA, 1961, p.156), of the Permian Maizuru Group and of the Triassic Systems which are distributed sporadically. The Maizuru zone separates the Tanba zone, composed of non-metamorphosed paleozoics, from the Chūgoku zone, which includes the Sangun metamorphic rocks generated by the glaucophane schist metamorphism.

In the eastern part of the Maizuru zone, it has been noticed that ultramafic masses occur in two different geological situations; the one consists of those which are arranged along the northern side of the Maizuru zone from Ōeyama (Kyoto Prefecture) to the Chūgoku mountains, and the other occurring within the Yakuno complex inside the Maizuru zone (NAKAZAWA, SHIKI and SHIMIZU, 1954, p. 98; IGI, 1965). The ultramafic masses in the Yakuno complex are small, but relatively large masses occur in the Ōshima peninsula, Fukui Prefecture, which is situated in the most eastern part of the Maizuru zone. The small ultramafic masses in the Yakuno complex are so far treated as a member of the Yakuno complex (NAKAZAWA et. al., 1954, p. 98; IGI, 1959). But petrographical correlation of the Ōshima mass to the ultramafic masses arranged along the northern side of the Maizuru zone and to minor ultramafic masses in the Yakuno complex has not been clarified yet. HIROKAWA (1957, p. 4) stated that the Ōshima mass intruded into the Yakuno complex at the same age as the ultramafic masses distributed in the Chūgoku mountains. NAKAZAWA (1961, p. 156) suggested that the arrangement of the ultramafic masses from Ōeyama to the Tari district (Chūgoku mountains) intersects the Maizuru zone and that these ultarmafic masses may have intruded later than the Yakuno complex. IGI et. al. (1965) noticed the petrographical differences between the Ōeyama ultramafic mass and the minor ultramafic masses in the Yakuno complex in the Ōeyama district, and he regarded both of these masses as having intruded from the post late-Triassic to the end of the Mesozoic Era.

Petrographical studies on the ultramafic masses in the eastern part of the Maizuru zone have been also published; on the Kōmori, Izushi, Sekinomiya masses by KURODA and SHIMODA (1967), on the Kōmori (Ōeyama) mass by OGURA et. al. (1969) and by KUROKAWA (1970), and on the Ōshima mass by HIRANO (1969). Through these studies, petrographical differences can be recognized between the Ōeyama, Izushi and Sekinomiya masses, which are arranged along the northern side of the Maizuru zone, and the Ōshima mass which is located in the Maizuru zone. The former three masses are composed mainly of dunite, while the Ōshima mass is composed mainly of harzburgite with characteristic spinel in every kind of rocks in the mass. RESEARCH GROUP of PERIDOTITE INTRUSION (1967) paid attention to the difference of the geological situations of these masses, but the petrographical studies on the minor ultramafic masses in the Yakuno complex were not attempted.

On the basis of these studies, the author conceives that in the eastern part of the Maizuru zone, petrographical characteristics of the ultramafic masses are different according to their geological situations; that is the one consists of those arranged along the northern side of the Maizuru zone, and the other consists of those occurring in the Yakuno complex. In this respect, it is expected that the petrographical characteristics of the Ōshima mass must not bear a close resemblance to those arranged along the northern side of the Maizuru zone, but rather to those in the Yakuno complex. Therefore, the occurrence and petrography of the minor ultramafic masses in the Yakuno complex have been examined, and in conclusion, ultramafic masses in the eastern part of the Maizuru zone are classified into two types petrographically. Furthermore, those occurring in the Yakuno complex are shown to be subdivided into three subtypes.

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II Ultramafic Masses in the Yakuno complex inside the Maizuru zone

(A) *Occurrence and petrography*

The occurrence and petrography of the Ōshima and Machinoyama masses, which are situated in the most eastern part of the Maizuru zone are already reported by HIRANO (1969). According to him, these masses are composed of dunite, harzburgite, orthopyroxenite and clinopyroxenite. In this section, the author gives the descriptions of the occurrence and petrography of the ultramafic masses from the Wada district (Fukui Prefecture) to the Takakura district (near Ayabe city, Kyoto Prefecture). The localities of these masses are already shown by SUGI (1925), HIROKAWA et. al. (1957) and IGI et. al. (1961).

(1) The Wada district

In the Wada district, which is situated in western Fukui Prefecture, ultramafic rocks occur at the boundary between the Maizuru zone and the Tanba zone, trending from east-northeast to west-southwest with more than 300 m in width. The Tanba zone is mainly composed of slate, showing monoclinic structure in this district with strike of N70°E to E-W, dipping steeply to the north near the boundary. Ultramafic rocks are suffered from serpentinization more remarkably toward the boundary, and in sheared serpentinite, foliated planes develope which are N50°E in strike, dipping 70° to the north.

Ultramafic rocks comprise of harzburgite, dunite and olivine orthopyroxenite. In harzburgite, enstatite has fine exsolution lamellae of clinopyroxene in (100) direction. Small amounts of anhedral clinopyroxene are sometimes found interstitially among enstatite and olivine. Brown~dark brown chrome spinel is found universally even in completely serpentinized ones. These petrographical features are closely resemble to those of the Ōshima mass. Optical properties: in harzburgite (05205), olivine (+)2V = 86° and enstatite (+)2V = 78°.

Besides these rocks, the sheet of quartz-carbonate rock occurs in more than 10 m wide in serpentinite. By X-ray diffraction pattern, carbonate is ditected to be magnesite and dolomite. In this rock, dark brown chrome spinel is also found. This rock may be derived from serpentinite. MIYAKAWA (1968) reported simillar rock from the Hida marginal belt.

(2) The Kobi district

Ultramafic rocks occur between gabbroic rocks of the Yakuno complex to the northwest and paleozoic rocks of the Tanba zone to the southeast, with about 300 m in width in the Kobi district, most western Fukui Prefecture. Ultramafic rocks are composed of dunite, harzburgite, olivine clinopyroxenite and clinopyroxenite.

Harzburgite is composed of large grains (up to 3 mm in size) of olivine and enstatite, which has exsolution lamellae of clinopyroxene in (100) direction. Subordinate amount of clinopyroxene is sometimes accompanied. In olivine clinopyroxenite, olivine tends to aggregate making elongated pool. Some clinopyroxenites have cataclastic texture and in them diopside grains are bent or broken, and among such crystals small grains of diopside are found. In such rocks, (001) twinning of diopside sometimes develops. Spinel group minerals always occur in every kind of rocks, and the color of spinels is variable according to rock facies; in harzburgite, it is brownish~greenish brown, in olivine clinopyroxenite greenish brown and in clinopyroxenite it is green. Optical properties: in harzburgite (17063), olivine (+)2V = 88° and enstatite (+)2V = 79°; in olivine clinopyroxenite, olivine (+)2V = 90° (17062) and clinopyroxene (+)2V = 54°~56° (17062), (+)2V = 57°~60° and γ = 1.693 (En_{52} Fs_1 Wo_{47}) (07227). In clinopyroxenite (07226), clinopyroxene (+)2V = 57°~60° and γ = 1.697 (En_{49} Fs_2 Wo_{49}). These clinopyroxenes are very close to diopside in chemical composition.

(3) The Ichishi district

Along the road from Ichishi to Mitsuno, eastern Ayabe city, small ultramafic mass occurs in the Yakuno complex. It is more than 20 m in width and northern half is dunite and southern half is olivine clinopyroxenite. In dunite, rodingite occurs.

Dunite is completely serpentinized and small amount of bastite is found in it. In olivine clinopyroxenite, olivine and clinopyroxene grains tend to aggregate separately each other. In olivine rich portion, serpentinization is remarkable and stained by secondary magnetite. Primary spinel is dark brown in dunite and brownish green in olivine clinopyroxenite. Optical properties: in olivine clinopyroxenite (07146), olivine (−)2V = 89° and clinopyroxene (+)2V = 57°~58°,

γ = 1.697 (En_{49} Fs_3 Wo_{48}).

Besides this mass, in clinopyroxene gabbro of the Yakuno complex, ultramafic part developes (clinopyroxene hornblendite). In this rock, grain size of hornblende and clinopyroxene are variable (up to 4 mm in size) and hornblende is rather interstitial to pyroxene. Magnetite is scarce and spinel is not found. Optical properties: in clinopyroxene hornblendite (07144), clinopyroxene (+)2V = 52° ~54°, γ = 1.703 (En_{48} Fs_9 Wo_{43}) and hornblende (—)2V = 89°, γ = 1.666 which shows pleochroism with X = pale yellow, Y = greenish brown, Z = brown. In gabbro (07143), clinopyroxene (+)2V = 56°~59°.

(4) The east of Ichishi district

At the east of Ichishi, eastern Ayabe city, ultramafic masses occur in gabbroic rocks of the Yakuno complex in about 80 m width. Ultramafic masses comprise three minor bodies (Fig. 1). Gabbroic rocks have distinct banded structure (Pl. 2 No. 2) and banding plane is N60°~70°E and dips almost vertically. Ultramafic rocks and gabbroic rocks are not transitional but separated by sharp boundaries. The boundary plane is almost concordant to the banding plane of gabbro.

Ultramafic masses are composed of dunite, wehrlite, olivine clinopyroxenite and clinopyroxenite. Dunite is completely serpentinized but brownish spinel is abundantly recognized and the arrangement of it is somewhat oriented. In dunite (21227), an aggregate of orthopyroxene is found, the size of which is about 5 cm in diameter. It consists of large crystals of orthopyroxene, up to 5 mm in size, and small amount of clinopyroxene is accompanied interstitially. Olivine clinopyroxenite sometimes carries orthopyroxene. Spinel is greenish brown and olivine shows undulatory extinction. Clinopyroxenite shows cataclastic texture and almost free from spinel and magnetite. Gabbroic rocks comprise diallage and plagioclase, but plagioclase is mostly decomposed. Bastite, probably after orthopyroxene, is sometimes recognized. Optical properties: in olivine clinopyroxenite (21224), olivine (+)2V = 90°, orthopyroxene (+)2V = 90° and clinopyroxene (+)2V = 56°~57°, γ = 1.702 (En_{47} Fs_7 Wo_{46}). In clinopyroxenite (07149), clinopyroxene (+)2V = 54°~55°, γ = 1.710 (En_{41} Fs_{13} Wo_{46}), and in the aggregate of pyroxene in dunite (21227), orthopyroxene (+)2V = 88°~91° and clinopyroxene (+)2V = 55°~56°. In gabbroic rocks, clinopyroxene (+)2V = 53°~55°, γ = 1.709 (En_{43} Fs_{12} Wo_{45}) (21226), and (+)2V = 56°, γ = 1.709 (En_{42} Fs_{12} Wo_{46}) (21229).

Besides these, ultramafic layers are developed in gabbroic rocks, as shown in Pl. 2 No. 2. These layers are composed of clinopyroxene and brown hornblende in variable modal composition. Optical properties: clinopyroxene (+)2V = 55°, γ = 1.713 (En_{39} Fs_{15} Wo_{46}) (21228), (+)2V = 55°~56°, γ = 1.698 (En_{49} Fs_5 Wo_{46}) (07147) and (+)2V = 53°~55°, γ = 1.714 (En_{39} Fs_{16} Wo_{45}) (07148). Hornblende (07148)(—)2V = 85°, γ = 1.672 and has X = pale yellowish, Y =

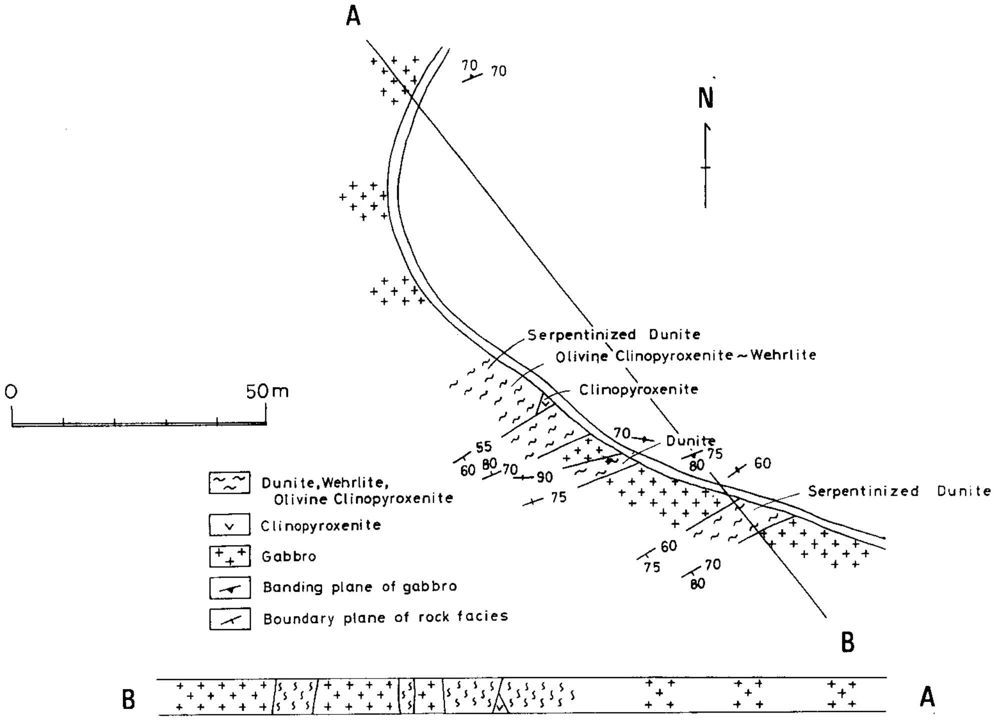

Fig. 1 Occurrence of ultramafic masses in the Yakuno complex at the east of Ichishi district

greenish brown, Z = greenish brown.

(5) The north of Ichishi district

At the north of Ichishi, ultramafic mass occurs in more than 20 m width in gabbroic rocks. The mass is composed of wehrlite and clinopyroxenite. Wehrlite sometimes carries orthopyroxene and considerably stained by secondary magnetite. Spinel is olive green. In clinopyroxenite, bastite after orthopyroxene is found in small amount and almost free from spinels. Optical properties: in wehrlite, olivine $(+)2V = 88°$, clinopyroxene $(+)2V = 54° \sim 55°$ (071412), and (071411) clinopyroxene $(+)2V = 57°$, $\gamma = 1.703$ (En_{46} Fs_7 Wo_{47}) and orthopyroxene $(-)2V = 84° \sim 89°$ and faint pleochroism can be recognized with X = pale yellow, Y = pale yellow, Z = pale reddish. This orthopyroxene is estimated optically to be bronzite. In clinopyroxenite (07143), clinopyroxene $(+)2V = 56°$ and $\gamma = 1.694$ (En_{53} Fs_2 Wo_{45}).

(6) The Sefukuji district

In the Sefukuji district, ultramafic mass occurs in about 10 m width at the boundary of the Yakuno complex and the Tanba zone. Near the boundary, the Tanba zone is composed slaty and basaltic rocks with strike of almost E-W direction, dipping 50°~90° to the north.

Ultramafic mass is composed of dunite, and in dunite, small mass of rodingite occurs. Dunite is completely serpentinized and bastite after orthopyroxene and a lot of brownish chrome spinel is observed.

Besides this, clinopyroxene hornblendite occurs as a layer of about 5 m thick in gabbroic rocks in this district. The clinopyroxene hornblendite is composed of alternation of clinopyroxene-rich layer and hornblendite-rich layer by 5 mm~1 cm as shown in Pl. 2 No. 1. Spinel is not found and magnetite is sometimes recognized. Optical properties: in clinopyroxene hornblendite (05214), clinopyroxene (+)2V = 50°~51°, γ = 1.708 ($En_{44}\,Fs_{13}\,Wo_{43}$) and hornblende (+)2V = =88°, γ = 1.666 and axial colors are X = pale yellow, Y = pale brown, Z = pale brown.

(7) The Takakura district

At Takakura, north-east of Ayabe city, ultramafic mass occurs in the Yakuno complex in more than 200 m width. The petrology of gabbroic rocks and diallagite was previously reported by Sugi (1925).

Ultramafic mass is composed of wehrlite, olivine clinopyroxenite and clinopyroxenite. Orthopyroxene and bastite are sometimes found in these rocks. Spinel is generally found in wehrlite and olivine clinopyroxenite and it is brownish green to olive green, but not found in clinopyroxenite. Optical properties: in wehrlite (0X202), clinopyroxene (+)2V = 50°~57°; in olivine clinopyroxenite (0X205), olivine (+)2V = 90°, orthopyroxene (−)2V = 88°~90° and clinopyroxene (+)2V = 54°~58°, γ = 1.705 ($En_{46}\,Fs_9\,Wo_{45}$~$En_{44}\,Fs_8\,Wo_{48}$). In clinopyroxenite (0X206), clinopyroxene (+)2V = 56°~57°.

(B) *Subdivision of ultramafic masses in the Yakuno complex of the Maizuru zone*

Ultramafic masses in the Yakuno complex can be subdivided into the following three subtypes according to their assemblages of rock facies in each mass.

1. H-subtype : dunite-harzburgite-orthopyroxenite-clinopyroxenite
   Harzburgite is most dominant.
2. W-subtype : dunite-wehrlite-olivine clinopyroxenite-clinopyroxenite
   Small amount of orthopyroxene is sometimes observed.
   Olivine clinopyroxenite is most dominant.
3. G-subtype : hornblende clinopyroxenite-clinopyroxene hornblendite
   Modal composition of clinopyroxene and hornblende

Table 1 Rock facies assemblage of each mass and color of spinel

	Rock facies	color of spinel
H-subtype: Machinoyama*	Dunite	brown
	Harzburgite	brown
	Orthopyroxenite	
	Clinopyroxenite	
Ōshima*	Dunite	brown
	Harzburgite	brown
	Orthopyroxenite	
	Clinopyroxenite	
Wada	Dunite	brown
	Harzburgite	brown
	Olivine Orthopyroxenite	brown
	Quartz Carbonate Rock	brown
Kobi	Harzburgite	brown～greenish brown
	Olivine Clinopyroxenite	greenish brown～yellowish green
	Clinopyroxenite	green
Sefukuji	Harzburgite	brown
W-subtype: Ichishi	Dunite	brown
	Olivine Clinopyroxenite	brownish green
East of Ichishi	Dunite	greenish brown
	Wehrlite	greenish brown
	Olivine Clinopyroxenite	greenish brown
	Clinopyroxenite	absent
North of Ichishi	Wehrlite	olive green
	Olivine Clinopyroxenite	olive green
	Clinopyroxenite	absent
Takakura	Wehrlite	greenish brown～olive green
	Olivine Clinopyroxenite	brownish green～olive green
	Clinopyroxenite	absent
G-subtype: East of Ichishi	Hornblende Clinopyroxenite	absent
Sefukuji	Clinopyroxene Hornblendite	absent

* after HIRANO (1969)

is variable.

In terms of this subdivision, rock facies assemblages of each mass and the color of spinel of each rock facies are summerized in Table 1.

It must be noticed that the occurrence of each subtype is characteristic in relation to the Maizuru zone, especially to the gabbroic rocks. H-subtype occurs at the boundary of the Maizuru zone and the Tanba zone, as relatively large mass in the most eastern part of the Maizuru zone. W-subtype occurs in the gabbroic rocks of the Yakuno complex and the contact plane with them is sharp and not transitional to them as well observed at the east of Ichishi district. (as shown in Fig. 1) G-subtype occurs as a layer in the gabbroic rocks of the Yakuno complex from a centimeter to 5 m thick and transitional to them.

(C) *Some petrographical differences among the three subtypes of the ultramafic masses in the Yakuno complex*

1. Chemical composition

Cr_2O_3, FeO and Fe_2O_3 contents of the whole rock are shown in Table 2, and the modal compositions of these rocks are also shown in Table 3. It is notable that Cr_2O_3 contents in G-subtype are distinctly low as compared with other two subtypes. In H-subtype and W-subtype, Cr_2O_3 content is higher in dunite, harzburgite and orthopyroxenite than in wehrlite and olivine-clinopyroxenite. Color of spinel roughly reflected the Cr_2O_3 content of the whole rock; from brownish through brownish green to olive green as Cr_2O_3 content decreases. In G-subtype, which is low in Cr_2O_3 content, spinel is not found and only magnetite occurs.

FeO content is higher in G-subtype, but in H- and W-subtypes it is rather

Table 2 Cr_2O_3, Fe_2O_3, FeO and total FeO content of type II ultramafic rocks and color of spinel

		Cr_2O_3	FeO	Fe_2O_3	total FeO**	spinel
H-subtype:	Dunite (Ōshima, 90517)*	0.67	5.25	3.89	8.75	brown
	Harzburgite (Ōshima, 53004)*	0.55	5.02	2.62	7.38	brown
	Harzburgite (Machinoyama, 52313)*	0.68	3.92	3.39	6.97	brown
	Orthopyroxenite (Ōshima, 101104)*	0.57	4.50	1.76	6.08	
	Olivine Clinopyroxenite (Kobi, 07227)	0.37	3.06	1.60	4.51	greenish brown
W-subtype:	Wehrlite (north of Ichishi, 071412)	0.12	3.54	7.17	10.06	olive green
	Olivine Clinopyroxenite (Ichishi, 07146)	0.31	4.00	4.44	8.00	brownish green
	Olivine Clinopyroxenite (Takakura, 0X205)	0.48	4.53	2.87	7.14	brownish green
G-subtype:	Hornblende Clinopyroxenite (east of Ichishi, 07147)	0.013	6.42	1.10	7.42	absent
	Clinopyroxene Hornblendite (Sefukuji, 05124)	0.049	9.33	0.53	9.81	absent

* after Hirano (1969)

** total FeO = $FeO+0.9Fe_2O_3$

constant. Fe_2O_3 contents are sometimes considerably high owing to the formation of the secondary magnetite. It must be noticed that total FeO (FeO+0.9 Fe_2O_3) in W-subtype is not so high as in the ultramafic rocks in the Mikabu zone, where wehrlitic rocks are also dominant. (TAZAKI, 1966)

2. Composition of clinopyroxene

Compositions of clinopyroxene determined by immersion method are

Table 3 Modal compositions of type II ultramafic rocks (refer to Table 2)

	Olivine	cPx	oPx	Hornblende	Spinel	Magnetite	Serpentine
H-subtype:							
Harzburgite (Wada, 05205)	42	1	10	—	1	3	43
Olivine Clinopyroxenite (07227)	4	85	—	—	tr	—	11
W-subtype:							
Wehrlite (071412)	12	22	1	—	1	14	50
Olivine Clinopyroxenite (07146)	1	55	—	—	tr	18	26
Olivine Clinopyroxenite (0X205)	11	68	13	—	1	—	—
G-subtype:							
Hornblende Clinopyroxenite (07147)	—	78	—	6	—	1	15
Clinopyroxene Hornblendite (05124)	—	29	—	70	—	1	—

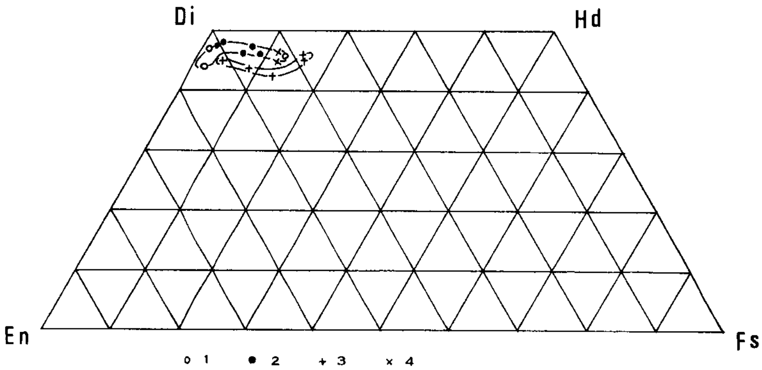

Fig. 2 Compositions of clinopyroxene
1. in clinopyroxenite (H- and W-subtypes)
2. in olivine clinopyroxenite and wehrlite (H- and W-subtypes)
3. in G-subtypes
4. in gabbroic rocks of the Yakuno complex

shown in Fig. 2.

Clinopyroxene of G-subtype occupies distinctly different position from those in H-subtype and W-subtype. In the G-subtype, clinopyroxene is calcium poor as compared with clinopyroxene in H-subtype and W-subtype.

3. Composition of orthopyroxene

The difference of chemical composition of orthopyroxene in H-subtype and W-subtype can be presumed by the mesurement of the optic axial angle. The optic axial angle of orthopyroxene in H-subtype is positive and 78°~79°. It represents enstatite in composition. While, in W-subtype optic axial angle of orthopyroxene, which occurs in wehrlite and olivine clinopyroxenite in small amount, is negative and 84°~90°. Some of them show pleochroism. It represents bronzite in composition.

III Two types of ultramafic masses in the eastern part of the Maizuru zone

(A) *Petrographical characteristics of ultramafic masses arranged along the northern side of the Maizuru zone*

Along the northern side of the Maizuru zone, large ultramafic masses occur; the Ōeyama (Kōmori), Izushi, Sekinomiya and Wakasa masses from east to west. The Sekinomiya mass is the largest of these, being about 16 km long from east to west. The Ōeyama mass is the next, being about 11 km long from east-northeast to west-southwest.

1. The Ōeyama (Kōmori) mass

The Ōeyama mass is situated north of Fukuchiyama city and contacts Cretaceous granite to the north and the Shimomidani Formation (middle Permian) to the south, both by faults. The mass is composed mainly of dunite, accompany-

Table 4 Volume ratio of each rock facies in the Ōeyama (Kōmori) mass

Rock facies	volume (Km^3)	volume ratio (%)
Dunite	26.24	81.8
Clinopyroxenite	4.58	14.2
Hornblendite	0.16	0.5
Gabbro-Diabase	1.12	3.5
Total	32.10	100.0

ing clinopyroxenite, harzburgite, hornblendite, diabase, gabbro and albitite. Volume ratio of these rock facies in the mass is shown in Table 4. (KUROKAWA, 1970, p. 66) Thus, it must be noticed that dunite is the most dominant rock facies and occupies more than 80% of the whole mass. Clinopyroxenite is the next dominant rock facies and peridotite is negligible in the computation of volume ratio.

2. The Izushi mass

The Izushi mass is situated in the town of Tantō, northeastern Hyōgo prefecture, and surrounded by Cretaceous granite. According to KURODA *et al.* (1967), the mass is composed of dunite.

3. The Sekinomiya mass

The Sekinomiya mass is situated in the towns of Sekinomiya and Ōya, northern Hyōgo prefecture. The mass contacts the Yakuno complex, the Maizuru Group and the Sangun metamorphic rocks (HASHIMOTO & IGI, 1970) at the southern part of the mass. According to Research Group of Peridotite Intrusion (1967), the mass is composed mainly of dunite, with considerable amount of harzburgite. A small amount of gabbro and albitite are also found.

4. The Wakasa mass

The Wakasa mass is situated in the town of Wakasa, southeastern Tottori prefecture. The mass intrudes concordantly into the Sangun metamorphic rocks. (MIYAKAWA, 1961, p. 551) The mass is composed mainly of serpentinized dunite with harzburgite. Hornblendite, gabbro and a clinopyroxenite vein are also reported. (MIYAKAWA, 1961, p. 551; RESEARCH GROUP of PERIDOTITE INTRUSION, 1967; IGI and ABE, 1969)

(B) *Petrographical differences between two types of ultramafic masses in the eastern part of the Maizuru zone*

In the eastern part of the Maizuru zone, ultramafic masses occur in two different geological situations. The one consists of those arranged along the northern side of the Maizuru zone, and the other of those occurring in the Yakuno complex inside the Maizuru zone.

Comparing the petrographical characteristics of these ultramafic masses occurring in two different geological situations, the following petrographical differences can be recognized.

1. Main rock facies

In all of the Ōeyama, Izushi, Sekinomiya and Wakasa masses, dunite is the most dominant rock facies and harzburgite is subordinate. In the Ōeyama mass, considerable amount of clinopyroxenite occurs, and is more abundant than harzburgite. Wehrlite is very scarce in these masses.

On the other hand, in the ultramafic masses in the Yakuno complex, peridotite and pyroxenite (harzburgite, wehrlite, olivine clinopyroxenite and clinopyroxenite)

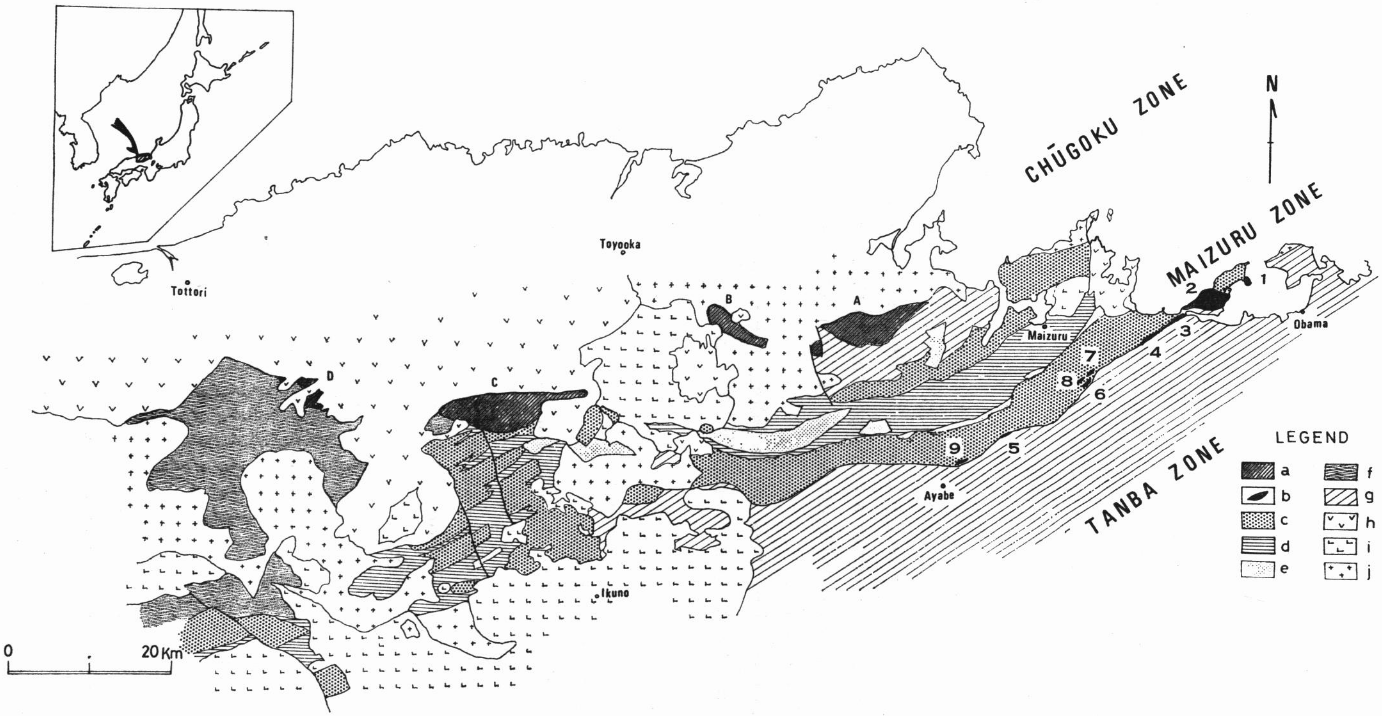

Fig. 3 Distribution of ultramafic masses in the eastern part of the Maizuru zone (a: type I ultramafic masses; A. Ōeyama (Kōmori) B. Izushi C. Sekinomiya D. Wakasa b: type II ultramafic masses; 1. Machinoyama 2. Ōshima 3. Wada 4. Kobi 5. Sefukuji 6. Ichishi 7. east of Ichishi 8. north of Ichishi 9. Takakura c: Yakuno complex (gabbro, diabase and granitic rocks) d: Maizuru Group e: Triassic Systems f: Sangun metamorphic rocks g: Permian Systems outside the Maizuru zone h: Tertiary and Quartanary (mainly volcanic rocks) i: late Mesozoic volcanics j: Cretaceous granite) [compiled from Hyōgo Prefecture (1961), Tottori Prefecture (1966), Hirokawa et. al. (1957, 1963), Igi et. al. (1961, 1965) and Nakazawa (1961).]

are more dominant than dunite. In H-subtype, harzburgite is dominant over dunite and orthopyroxenite is sometimes found, while it is not found in those masses arranged along the northern side of the Maizuru zone. In W-subtype, olivine clinopyroxenite is the most dominant and the series of rock facies of W-subtype (that is dunite-wehrlite-olivine clinopyroxenite-clinopyroxenite) cannot be recognized in the series of the rock facies in the masses arranged along the northern side of the Maizuru zone. The rock series of H-subtype and W-subtype represent Harzburgite series and Wehrlite series by KURODA and TAZAKI (1969, p. 99) respectively. G-subtype is exclusively composed of hornblende clinopyroxenite and clinopyroxene hornblendite and no dunitic rocks are accompanied.

2. Accompanied rocks

The ultramafic masses arranged along the northern side of the Maizuru zone accompany small amounts of gabbroic rocks only inside the mass, and around the mass gabbroic rocks cannot be recognized. While those in the Yakuno complex, a vast amount (probably more than a centiple magnitude of the ultramafic masses) of gabbroic rocks of the Yakuno complex is recognized. G-subtype is itself one rock facies of gabbroic rocks.

Albitite is accompanied in those masses along the northern side of the Maizuru zone, and in those in the Yakuno complex such rocks are not found.

3. Spinel

In those in the Yakuno complex, characteristic subhedral, semitransparent spinel is found. In dunite and harzburgite, it is brownish chrome spinel (picotite), and in wehrlite and olivine clinopyroxenite, it is greenish brown~brownish green and in clinopyroxenite it is green (hercynite).

In those along the northern side of the Maizuru zone, such a spinel is not found and chromite and magnetite can be found. Chromite is often enclosed by a magnetite rim. In the hornblendite of the Ōeyama mass, magnetite with ilmenite exolution is recognized.

4. Cleavable olivine

From the Ōeyama, Izushi, Sekinomiya and Wakasa masses, KURODA et. al. (1967) reported the occurrence of cleavable olivine which has a characteristic parting parallel to (100), (010) and (001). (Pl.2 No. 3) This characteristic olivine is not found in the Yakuno complex.

5. Bronzite

In W-subtype of the ultramafic masses in the Yakuno complex, bronzite ($(-)\ 2V = 84^\circ \sim 90^\circ$) is sometimes found. Some of which shows pleochroism. Such a bronzite is not found in the northern masses.

Thus, it can be concluded that petrographical differences are recognized between the ultramafic masses occurring in the two different geological situations.

Therefore, the following two types of ultramafic masses can be distinguished in the eastern part of the Maizuru zone.

Type I...Ultramafic masses arranged along the northern side of the Maizuru zone

Type II...Ultramafic masses occurring in the Yakuno complex (subdivided into H-subtype, W-subtype and G-subtype)

(B) *Some geological bearings of ultramafic masses in the eastern part of the Maizuru zone*

In the eastern part of the Maizuru zone, it must be noticed that the occurrence of ultramafic masses is characteristic in the three different geotectonic provinces of the Inner zone of southwest Japan. In the Chūgoku zone, where the Sangun metamorphic rocks are distributed, type I ultramafic masses occur. In the Maizuru zone, where a large amount of gabbroic rocks is distributed, type II ultramafic masses occur, and in the Tanba zone, which is composed of non-metamorphic paleozoics, an ultramafic mass is not found. As for type II ultramafic masses, W-subtype occurs in the gabbroic rocks and H-subtype occurs at the boundary between the Maizuru zone and the Tanba zone.

In these respects, it may be suggested that type I ultramafic masses have something to do with the Sangun metamorphism, W-subtype of type II ultramafic masses is related to the gabbroic rocks in the Maizuru zone and H-subtype of type II ultramafic masses is related to the formation of the zonal arrangement of the Maizuru zone. In this point, attention must be paid to the fact that H-subtype of ultramafic masses is dominant in the most eastern part of the Maizuru zone, as shown by the presence of the Ōshima and Machinoyama masses, where the zonal structure of the Maizuru zone developes most remarkably.

It is also noteworthy that the occurrence of type I ultramafic masses is generally restricted near the Maizuru zone, which suggests some genetical relationship between the two.

To correlate the Sangun metamorphic belt and the Maizuru zone with the Hida marginal belt or with the Jōetsu metamorphic belt (HAYAMA et. al. 1969), which have similar geological situations in the inner side of Japan, special attention must be paid to the nature of ultramafic rocks as stated above.

IV Conclusion

Ultramafic masses in the eastern part of the Maizuru zone, southwest Japan, are classified into two types. Type I ultramafic masses are large, sometimes attain 16 km in length, and are arranged along the northern side of the Maizuru zone. These masses, in which dunite is the most doninant rock facies, are associated no or little gabbroic rock. Type II ultramafic masses are small, except the Ōshima mass, and they occur in the Yakuno complex. In these masses, peridotite and pyroxenite are dominant over dunite and characteristic spinels are found. Type II ultramafic masses are associated with a large amount of gabbroic rocks of the Yakuno complex. Type II is subdivided into three subtypes; H-, W- and G-subtypes. H-subtype is composed of dunite, harzburgite, orthopyroxenite and clinopyroxenite, of which harzburgite is most dominant, and occurs at the boundary between the Maizuru zone and the Tanba zone. W-subtype is of dunite, wehrlite, olivine clinopyroxenite and clinopyroxenite, of which olivine clinopyroxenite is most dominant. Orthopyroxene is sometimes found in these rocks. W-subtype occurs in the gabbroic rocks of the Yakuno complex but separated from the latter by sharp boundaries. G-subtype is composed of hornblende clinopyroxenite and clinopyroxene hornblendite and occurs as a layer in the gabbroic rocks of the Yakuno complex and transitional to the latter. G-subtype is low in Cr_2O_3 and high in FeO as compared with H- and W-subtypes. Chemical composition of clinopyroxene in G-subtype is also different from other two groups (Fig. 2). Total FeO content of W-subtype is not so high as that of the ultramafic rocks in the Mikabu zone, where wehrlitic rocks are also dominant.

From the view point of ultramafic rocks, the three distinct geotectonic provinces in the Inner zone of southwest Japan have different characteristics respectively. In the Chūgoku zone, including the Sangun metamorphic belt, type I ultramafic masses occur. In the Maizuru zone, where a large amount of gabbroic rocks is distributed, type II ultramafic masses occur, and in the Tanba zone, which is composed of non-metamorphic paleozoics, ultramafic mass is not found.

Type I ultramafic masses may have something to do with the Sangun metamorphism. It may also be pointed out that the occurrence of these ultramafic masses are generally restricted near the Maizuru zone. On the other hand, as for type II ultramafic masses, W-subtype is related to the gabbroic rocks of the Maizuru zone and H-subtype of type II ultramafic masses may be related to the formation of the zonal structure of the Maizuru zone.

In the correlation of the Sangun metamorphic belt and the Maizuru zone with the Hida marginal belt and the Jōetsu metamorphic belt, the characteristics of the ultramafic rocks should also be taken into consideration.

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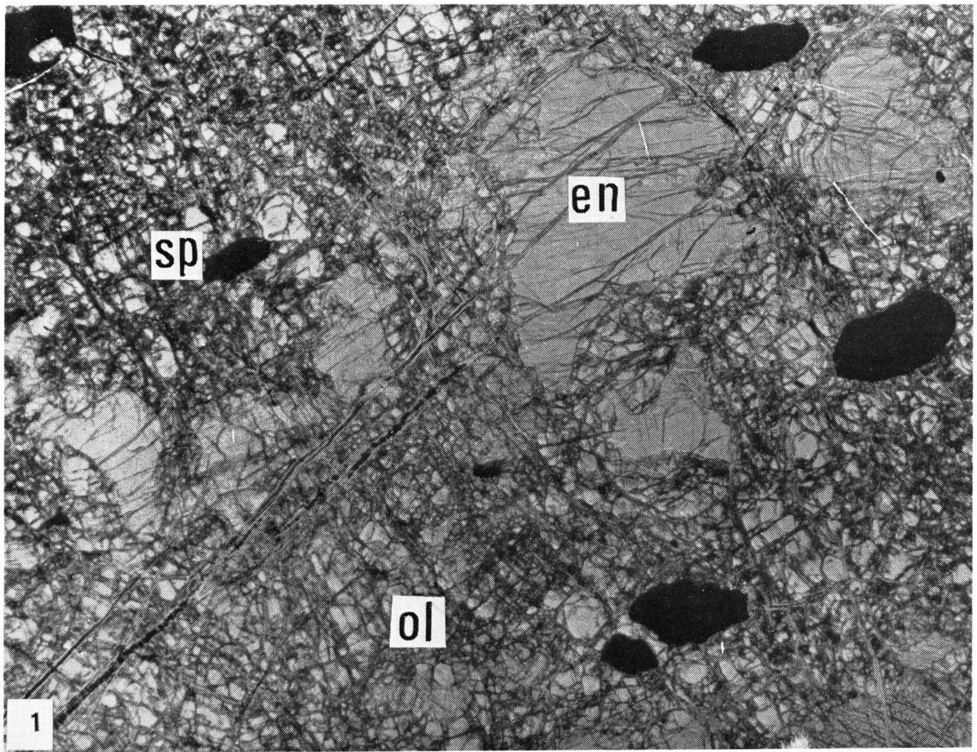
* in Japanese with English abstract

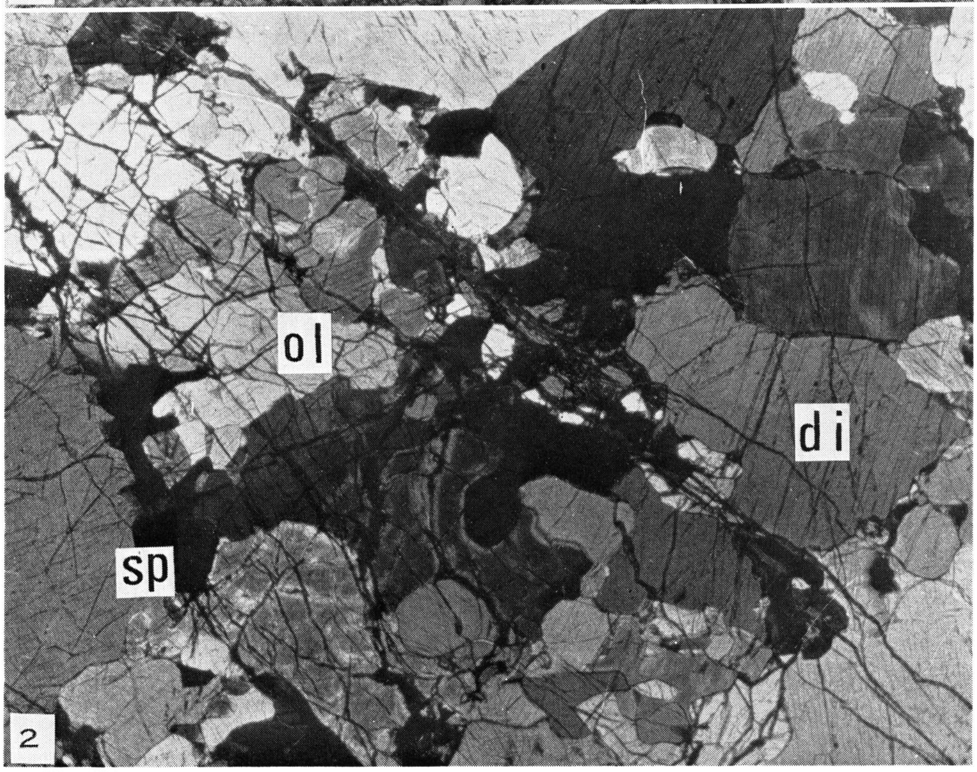
** in Japanese

Explanation of Plates

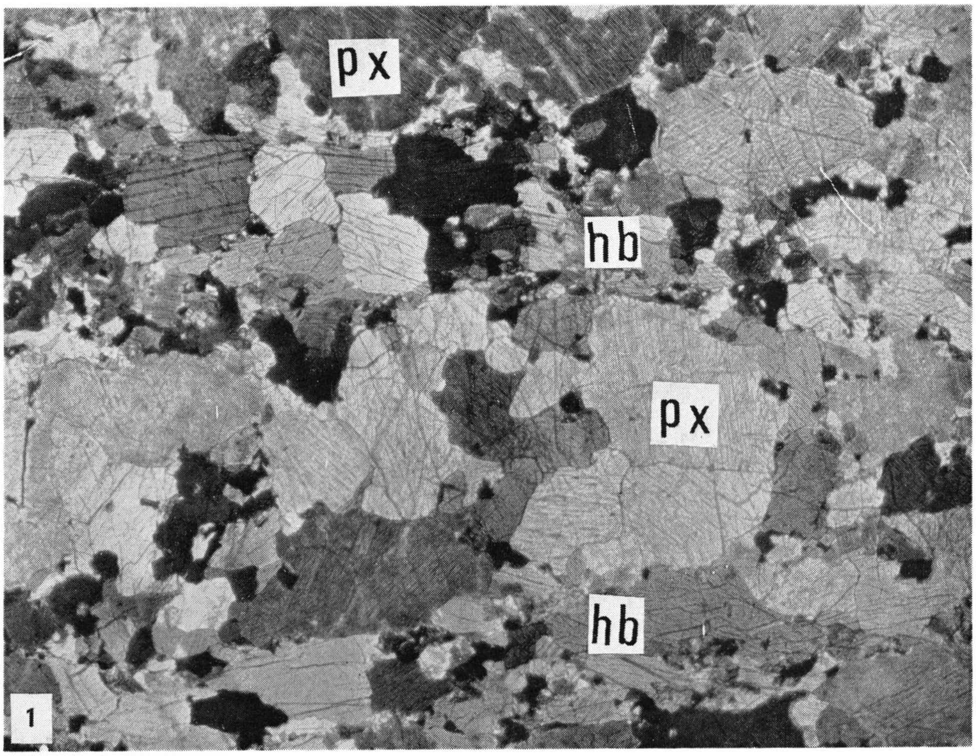
Plate 1
1. Harzburgite of H-subtype (Kobi, 17063) × 20, open nicol; ol: olivine en: enstatite sp: spinel (brown)
2. Olivine Clinopyroxenite of W-subtype (Takakura, 0X205) × 50 crossed nicols; ol: olivine di: diopside sp: spinel (greenish brown)

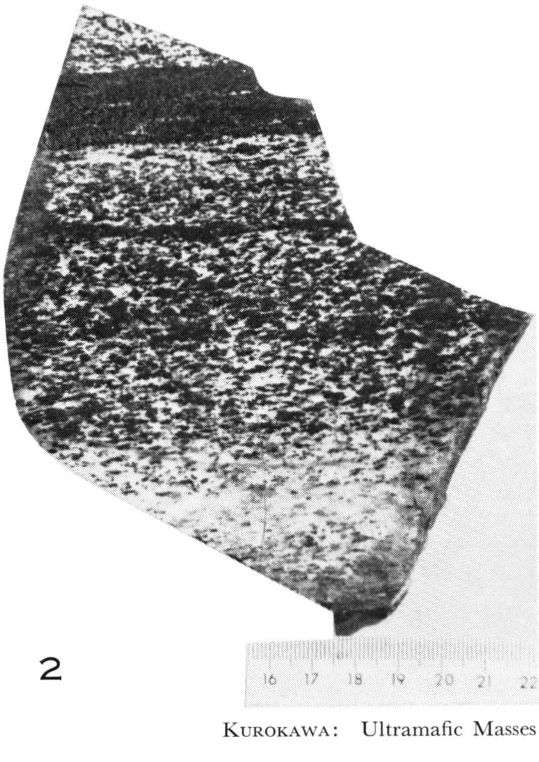
Plate 2
1. Clinopyroxene Hornblendite of G-subtype (Sefukuji, 05214) × 20 crossed nicols; px: clinopyroxene hb: hornblende Note the alternation of clinopyroxene-rich layer and hornblende-rich layer.
2. Banded Gabbro of the Yakuno complex (east of Ichishi, 21228) Scale is shown in cm. Note the alternation of ultramafic, melanocratic and leucocratic layers.
3. Dunite of type I ultramafic mass (Nakanochaya, the Ōeyama mass, 58092) × 20 crossed nicols; ol: olivine Note olivine with well-developed partings in (100), (010) and (001). (cleavable olivine)

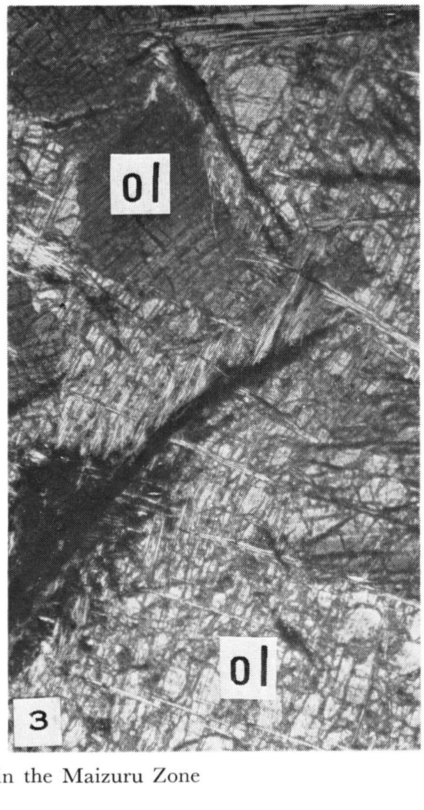




KUROKAWA: Ultramafic Masses in the Maizuru Zone







KUROKAWA: Ultramafic Masses in the Maizuru Zone