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Ultrabasic Rocks in the Eastern Part of the Chugoku Zone, Japan*

By

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Introduction

In the eastern part of the Chugoku zone, Japan, many ultrabasic rock masses with various dimensions are intruded into Paleozoic formations and their metamorphosed equivalents. Although these rocks were summarized in a paper by "the Research Group of Peridotite Intrusion" (1967), they have not been described in detail. Generally they occur as the rather large masses in the non-metamorphic or slightly metamorphic terrains, and as rather small masses in the higher grade metamorphic in Tari district ; and they are remarkably serpentinized, and have a little or no relicts of original minerals such as olivine and pyroxene. The purpose of this study is, then, to discuss whether there are differences between these ultrabasic rocks, based chiefly on their chemical characteristics, or not.

This study has been done as one of the investigation subjects by "the Research Group of Peridotite Intrusion". The expense of this study was partly defrayed by the UMP (Upper Mantle Project) of the Science Council of Japan.

Acknowledgments

The authors wish to express their thanks to members of the Research Group of Peridotite Intrusion, who influenced them with kind suggestions. Thanks are also due to Dr. M. HAYASHI, Assistant Professor of Kyushu University, for giving his unpublished data and his kind advices, and to Dr. K. TAKAHASHI for analyses of minor elements by means of JACO Ebert 3.4 m Stigmatic grating spectrograph. Any acknowledgment would be incomplete without expressing deep gratitude to Miss. Yukiko ONODERA for her help in copying figures and manuscript of this paper.

Geologic Setting and Petrography

Distribution of the ultrabasic rocks in the eastern part of the Chugoku zone, "Inner Zone of Southwest Japan", is shown in Figure 1. The representative ultrabasic rock masses in the region are those from Sekinomiya, Wakasa, Katsuyama, Atetsu and Tari districts, as given in Figure 1, and most of them penetrate the non-metamorphosed or slightly metamorphosed Paleozoic sediments, formed by the Sangun regional metamorphism. However, the ultrabasic rocks in the northern

* Read before the 74th Annual Meeting (1967) of the Geological Society of Japan at Nagoya City.

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Fig. 1 Distribution of ultrabasic rocks in the eastern part of the Chugoku zone.

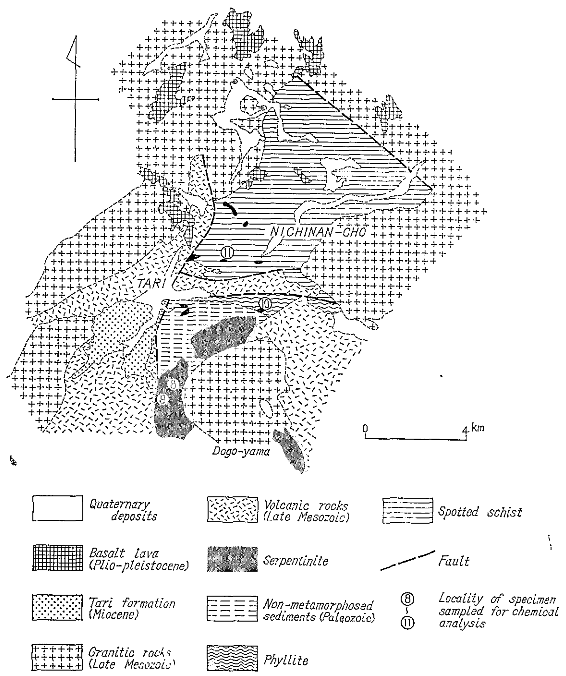

Fig. 2 Geological map of Tari district, Tottori prefecture, after Tottori-ken (1966) and Igi (unpublished).

part of Tari district occur as small masses in albite-spotted schists and phyllitic rocks ; on the other hand, those in the southern part as large masses in non-metamorphosed Paleozoic sediments. The geologic map of this district is given in Figure 2.

According to Research Group of Peridotite Intrusion (1967), the main types of the ultrabasic rocks in the Sangun metamorphic belt, the metamorphic parts of the Chugoku zone, are harzburgite and dunite. In this region described here, the rocks have nearly completely altered into serpentinite with chromitic spinel. However, judging from roughly estimated modal compositions of the relict-minerals such as olivine, orthopyroxene and clinopyroxene, the rock species of the original peridotite are likewise dunite and harzburgite, being accompanied by a small amount of pyroxenite, lherzolite and wehrlite in some cases. The associated dikes are gabbro and microdiorite.

The ultrabasic rocks occurring as small masses in the northern part of Tari district have wholly been serpentinized without any relicts of the original peridotite, excluding chromian spinels, and are not associated with any gabbroic rocks.

The Sekinomiya mass, the largest in the Chugoku zone, is intruded into the Sangun metamorphic rocks of glaucophanitic facies derived from the Paleozoic sediments (IKEBE and IGI, unpublished), and is covered by Tertiary volcanics and sediments. The mass is mainly composed of serpentinized dunite and harzburgite, in which chromite deposits are sporadically found.

Several masses of Wakasa ultrabasic rocks occur separately in the metamorphic rocks of epidote amphibolite facies and are covered by Tertiary volcanics (MIYAKAWA, 1961 ; Tottori-ken, 1966 ; YAMADA, SAKAMOTO and UEMURA, unpublished). In a certain mass, monomineralic vein of altered clinopyroxene, optical properties of which are not able to be determined, with 2~5 cm in width, is found. Some of serpentinites have been altered into colourless amphibole-bearing rocks formed probably by thermal effect of intrusion of granitic rocks not yet exposed around the serpentinite masses.

In Katsuyama district, the serpentinite masses with medium sizes, derived mainly from dunite and harzburgite, are isolated each other and are intruded into the low grade metamorohic rocks (MITSUNO and OMORI, 1963). Serpentinite from Hokubo-cho contains not only olivine and orthopyroxene but also clinopyroxene as relict-minerals of original peridotite, presumably lherzolite, and is accompanied with altered clinopyroxenite ; that is exceptional in the Chugoku zone.

The serpentinite masses in Atetsu district penetrate the non-metamorphosed Paleozoic sediments, and are injected by dikes of gabbroic rocks. The original peridotites are also probably dunite and harzburgite.

In Tari district, as mentioned above, there are two types of the serpentinite masses, namely small one in the northern part and large one in the southern part.

Table 1 Mineral associations of serpentinites analyzed chemically, from the eastern Chugoku zone. Numbers, 1—11 correspond to specimen numbers in Table 2.

No.	Locality	Relict-mineral / Original rock	Olivine (Fo%)	Ortho-pyroxene	Clino-pyroxene	Spinel	Serpentine mineral	Other (secondary) minerals	Other rock-facies and associated rocks
1	SEKINOMIYA	Harzburgite	X (92)	X		(Chromite) Brown	P, B, V (m. s.)	Chlorite (magnetite)	Talc-carbonate rock Tremolite-bearing serpentinite
2		Dunite	X (92)	(?)		(Chromite) Brown	P, V (B)	Chlorite (Magnetite) Carbonate, talc	Quartz diorite } Quartz albitite } dike, rare
3	WAKASA	Harzburgite	X (91)	(X)		Yellowish brown	V, P, B (m. s.)	Chlorite	Dunite Clinopyroxenite vein
4		(Hornfels of) Peridotite	X (86)		(?)	?	?	Tremolitic amphipole (Magnetite) Chlorite	Gneissic hornblende gabbro } dike ?
5	KATSUYAMA	Lherzolite	X (90)	X	X	Brown Yellowish brown	P, B, V	Chlorite Carbonate (Magnetite)	(Harzburgite) Dunite Clinopyroxenite
6	ATETSU	Dunite	X (95)			Yel. brown (black-rim)	P, V (m. s. & d)	Talc (Magnetite)	
7		Harzburgite	X (92)	(X)		Yel. brown (black-rim)	P, V, B (m. s.)	(Magnetite) Carbonate	Diallage gabbro } Diorite-gabbro } dike
8	TARI (I)	(Dunite)	(X)			Yel. brown (black-rim)	P, V (m. s.)	Talc (Magnetite)	Harzburgite Lherzolite Clinopyroxenite Amphibole-bearing peridotite Amphibole rock
9		Dunite	X, C (?) (96)			Red-brown (black-rim)	P, V (m. s.)	Chlorite (Magnetite) (Anthophyllitic amphibole)	Micro-diorite-gabbro } Diallage gabbro } dike Albitite }
10	TARI (II)	(Peridotite)				Yel. brown (black-rim)	V, P	Chlorite Carbonate (Magnetite)	
11						Red-brown (black-rim)	P, V		

X: Illustrates existence only
C: Cleavable olivine
Fo%: Determined by X-ray powder method (after Yoder & Sahama, 1957)
P: Prismatic
B: Bastitic
V: Vein
(m.s.): Mesh structure
d: Decussate structure

The masses in the southern part are composed of serpentinites derived from dunite and harzburgite, rarely from pyroxenite, judging from their relict minerals. Some of the masses, however, are of anthophyllite- or tremolitic colourless amphibole-bearing serpentinite altered by the thermal effects of the late Mesozoic granitic intrusions. Chromite deposits are also found in the large masses and are now worked at the well-known chrome-mines of Japan, such as the Hirose and Wakamatsu mines.

The mineral association and petrography of the representative ultrabasic rocks analyzed chemically are summarized in Table 1.

Petrochemistry

Eleven specimens of the serpentinized ultrabasic rocks are selected from the representative masses mentioned above, for chemical analysis.

The results are shown in Table 2. Calculated MgO : FeO + Fe_2O_3 × 0.9 ratios varying from 3.9 to 6.9 are also given in it. Two specimens of Nos. 4 and 5 are of amphibole-bearing metamorphosed peridotite and of serpentinized lherzo-

Table 2 Chemical compositions of serpentinites from the eastern Chugoku zone.

Analyst : Kikuo ABE

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	39.59	37.80	33.88	44.31	39.21	37.56	39.32	35.65	35.62	39.22	41.45
TiO_2	0.05	0.06	0.07	0.09	0.10	0.05	0.05	0.05	0.05	0.07	0.07
Al_2O_3	1.64	1.11	0.43	1.62	1.34	0.81	1.00	1.26	0.83	1.13	1.55
Fe_2O_3	4.73	5.53	8.49	3.36	6.24	5.14	4.43	7.31	6.68	7.53	4.92
FeO	2.81	1.81	1.60	5.53	3.02	1.77	1.58	1.07	1.02	1.62	3.21
MnO	0.10	0.11	0.21	0.30	0.22	0.19	0.18	0.11	0.12	0.14	0.09
MgO	38.15	38.57	40.21	33.49	35.71	39.75	38.51	38.32	41.93	35.15	36.02
CaO	0.74	0.49	0.04	5.69	3.30	0.04	0.04	0.02	0.02	0.03	0.06
Na_2O	0.13	0.46	0.12	0.21	0.30	0.20	0.28	0.06	0.01	0.05	0.02
K_2O	0.01	0.03	0.01	0.02	0.02	0.01	0.02	0.05	0.04	0.04	0.05
P_2O_5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01			
$H_2O(+)$	10.39	11.93	13.19	4.49	8.99	12.59	12.95	13.41	11.38	11.54	11.44
$H_2O(-)$	0.90	0.85	0.93	0.23	0.74	0.92	0.90	1.63	1.78	2.41	0.62
Cr_2O_3	0.33	0.39	0.28	0.15	0.36	0.33	0.29	0.61	0.19	0.95	0.50
C	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01				
CO_2	0.31	0.88	0.43	0.01	0.41	0.48	0.32				
Total	99.89	100.05	99.90	99.52	99.97	99.85	99.88	99.56	99.67	99.88	100.00
$\frac{Mgo}{FeO+Fe_2O_3 \times 0.9}$	5.40	5.68	4.33	3.92	4.13	6.21	6.91	5.00	5.96	4.18	4.71

1. Sekinomiya-cho, Yabu-gun, Hyogo Prefecture (U67-8)
2. Sekinomiya-cho, Yabu-gun, Hyogo Prefecture (U57-3)
3. Wakasa-cho, Yazu-gun, Tottori Prefecture (UC-37)
4. Wakasa-cho, Yazu-gun, Tottori Prefecture (UC-35)
5. Hokubo-cho, Jobo-gun, Okayama Prefecture (Y63-114)
6. Niimi-cho, Atetsu-gun, Okayama Prefecture (U66-9)
7. Shingo-cho, Atetsu-gun, Okayama Prefecture (U66-2)
8. Nichinan-cho, Hino-gun, Tottori Prefecture (T60-69)
9. Nichinan-cho, Hino-gun, Tottori Prefecture (Hiro-12)
10. Nichinan-cho, Hino-gun, Tottori Prefecture (T60-168)··· In phyllite
11. Nichinan-cho, Hino-gun, Tottori Prefecture (T60-100)··· In spotted schist

Table 3 Minor elements (ppm) in serpentinites from Tari district by means of JACO Ebert 3.4 m Stigmatic grating spectrograph (second order).
Numbers, 8—11 correspond to those in Table 2.

Analyst : Kiyoshi Takahashi

No.	8	9	10	11
B	35	50	60	20
Ba	<25	<25	<25	<25
Co	45	60	70	65
Cr	1200	4000	6000	3500
Cu	30	40	90	100
Ga	8	12	12	18
Mn	900	800	1100	700
Ni	800	1800	2300	2500
Sc	35	50	60	45
Sr	<25	<25	<25	<25
V	<10	15	<10	20

lite respectively, and both of these rocks have different mineralogical characteristics from other rocks. Two specimens of last numbers, 10 and 11, are of wholly serpentinized rocks with small dimensions from the northern part of Tari district, and they were added for comparison with the rocks of large masses.

Chemical analyses of minor elements of ultrabasic rocks only from Tari district are performed by means of JACO Ebert 3.4 m Stigmatic grating spectrograph (Second order), and the results are shown in Table 3.

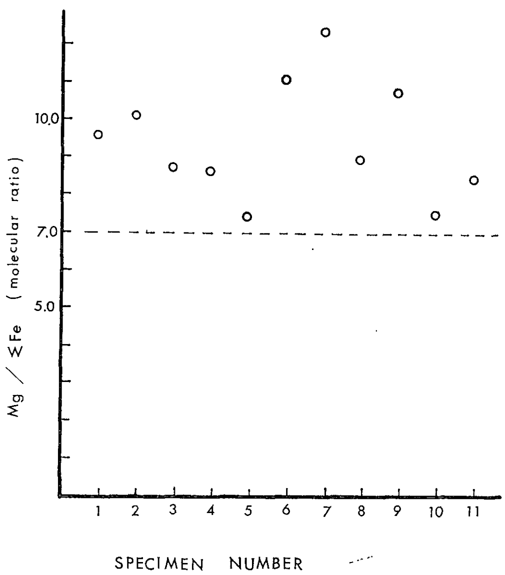

Fig. 3 Diagram showing Mg : $\sum$ Fe ratios (molecular ratio), recalculated from chemical analyses of serpentinites (after HESS, 1938). Specimen numbers correspond to those in Table 2.

Recalculated Mg : ΣFe (molecular ratio) are shown in Figure 3. They are all over 7.0. This fact indicates that these ultrabasic rocks belong to the alpine types (ultramafic magma series) after HESS (1938).

The relations between MgO : total FeO ratio (wt. %) and various oxides are shown in Figure 4. Values of most oxides, excepting those of MgO, decrease or are kept constant with increasing of MgO : total FeO ratio. The tendency which values of some oxides are kept constant, does not precisely correspond with anyone of rock-series, such as lherzolite, wehrlite, etc., of the mafic and ultramafic nodules in basaltic rocks of Hawaii, given by KUNO (1968). It may be of the reason that the ultrabasic rocks described in this paper belong to series of harzburgite and dunite type (Research Group of Peridotite Intrusion, 1967), not yet found in these nodules.

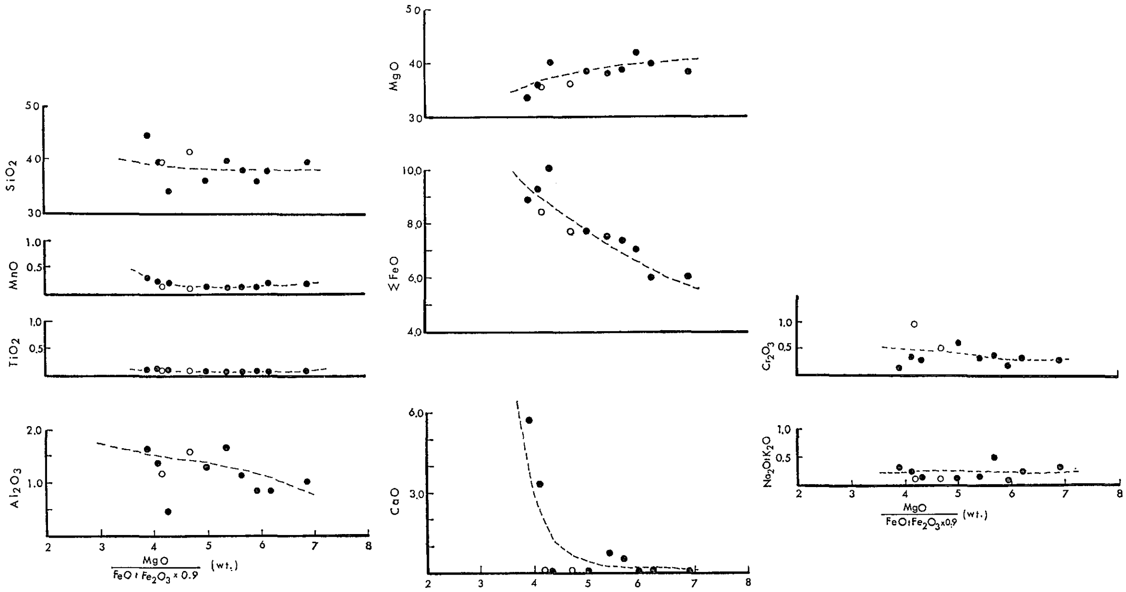

Fig. 4 Variation diagram representing the relations between MgO/total FeO ratio and various oxides. Open circles indicate serpentinites in the spotted schist and phyllite from the northern part of Tari district ; solid circles, from other districts.

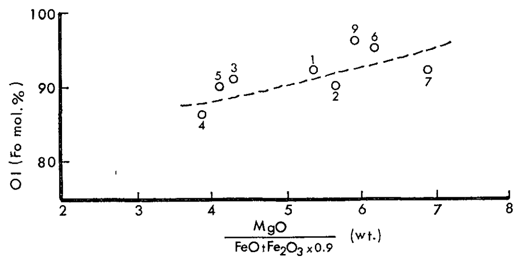

Fig. 5 Relation between MgO/total FeO ratio and forsterite molecular proportion. Numbers for open circles, 1—9, correspond to those in Tables 1 and 2.

Figure 5 represents the relations between MgO : total FeO ratio and Fo-molecular proportion of olivine, determined by X-ray powder method after Yoder and Sahama (1957), from olivine relict-bearing serpentinites, as already given in Table 1. Of these olivines determined here, the "cleavable olivines" (Kuroda and Shimoda, 1967) are not contained.

It is very difficult to interpret the meaning of the interrelation between variations of the minor elements plotted against MgO : total FeO ratio, as shown in Figure 6.

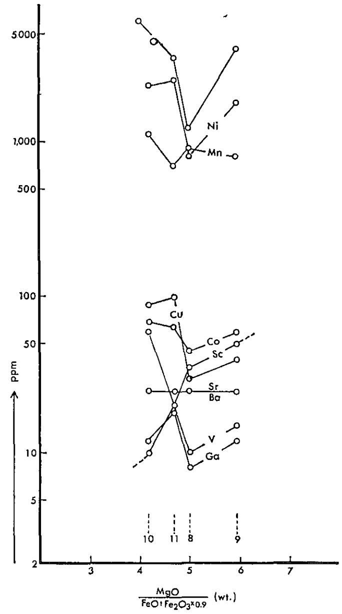

Fig. 6 Relation between MgO/total FeO ratio and minor elements. Specimen numbers, 8—11 correspond to those in Table 3.

MgO — 2 ($FeO+Fe_2O_3$) — 5 CaO diagram, as given in "Ultrabasic rocks in Japan" (1967), is shown in Figure 7. Excepting special cases of Nos. 4 and 5, the points calculated from Table 2, are plotted in the same fields of "Sangun-Maizuru", as given in the paper (Figure 3).

Condition of Serpentinite Emplacement

A triangular diagram representing the relations between enstatite, talc, serpentine and olivine in the system MgO — SiO_2 — H_2O is shown in Figure 8. Ultrabasic rocks analyses from this region, recalculated to molecular percent, are plotted on the diagram. Most of the points plotted are concentrated around the site of the ideal serpentine, excepting special case of No. 4. We cannot see the difference, in this diagram, between serpentines of large masses in slightly or non-metamorphosed rocks and those of small masses in the higher grade metamorphic rocks.

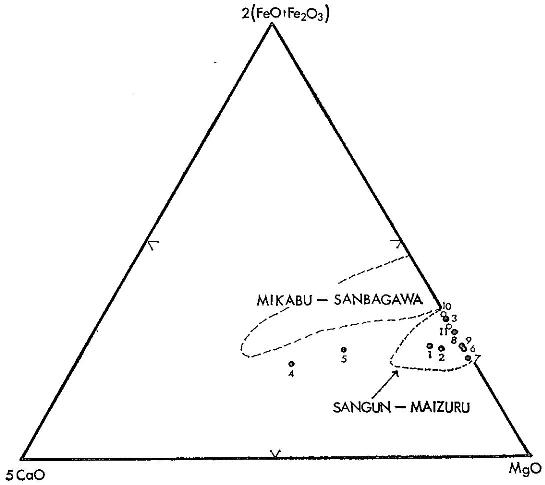

Fig. 7 $MgO-2(FeO+Fe_2O_3)-5CaO$ diagram on serpentinites, after Research Group of Peridotite Intrusion (1967). Specimen numbers for plotted points, 1—11 correspond to those in Table 2.

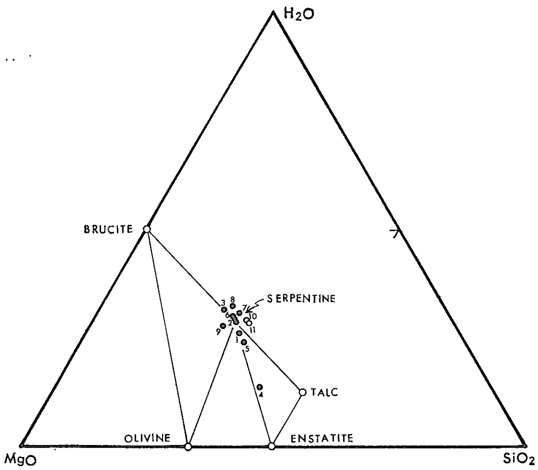

Fig. 8 Triangular diagram representing the relation between enstatite, talc, serpentine and olivine in the system $MgO-SiO_2-H_2O$ from chemical compositions of serpentinized ultrabasic rocks.
Specimen numbers for plotted points, 1—12 corrrespond to those in Table 2.

According to MIYASHIRO (1966), serpentinite in non-glaucophanitic metamorphic terrains tends to be higher in the $FeO : Fe_2O_3$ ratio than those in glaucophanitic metamorphic terrains ; and the latter in turn tends to be higher in the same ratio than those in non-metamorphic terrains. Figure 9 is the same diagram as given in MIYASHIRO's paper, representing the relation of FeO and Fe_2O_3 contents (wt. %) of serpentinites from this region. The plotted points are disseminated on the field, drawed by present authors, which roughly coincide with those of rocks from glaucophanitic or non-metamorphic terrains after MIYASHIRO, around or under magnetite line, denoting Fe_3O_4.

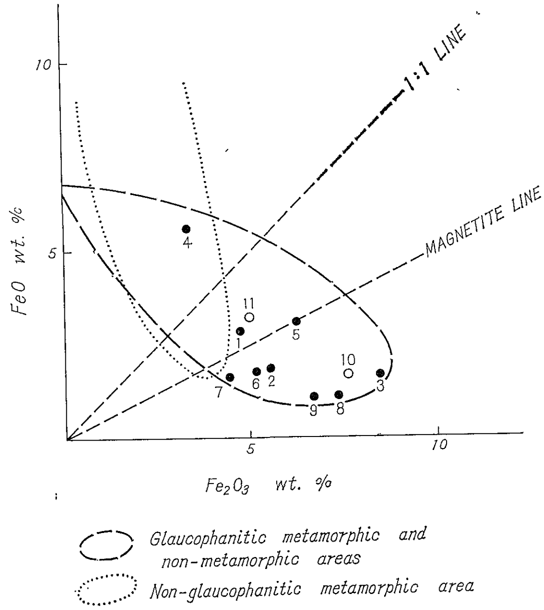

Fig. 9 Relation between FeO and Fe_2O_3 contents (wt. %) of serpentinite, after MIYASHIRO (1966). Specimen numbers for plotted points, 1—12 correspond to those in Table 2.

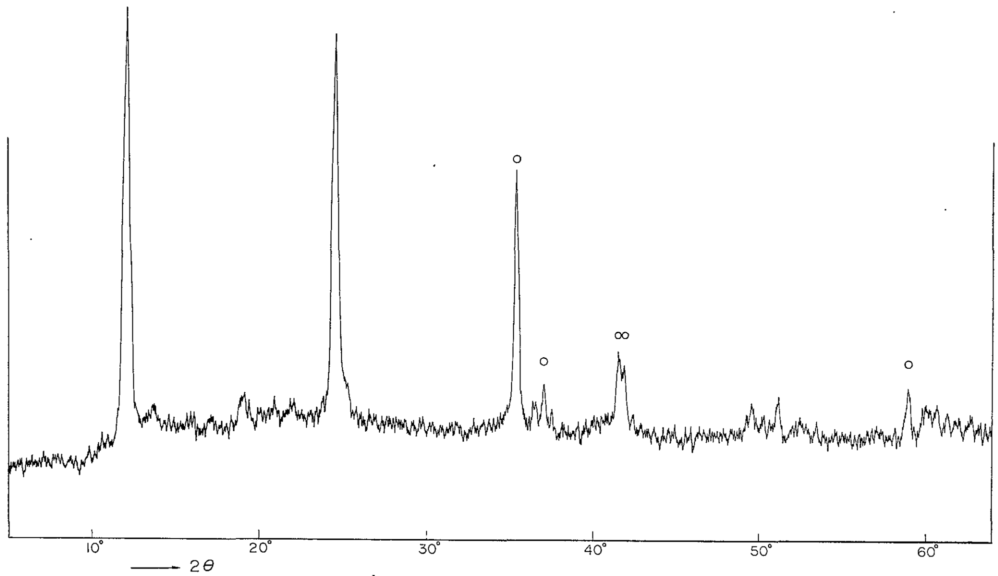

Fig. 10 X-ray powder chart of serpentine mineral of serpentinite (T60-100) in spotted schist from Tari district (2θCuKα).
Peaks marked with open circles fairly consistent with the characteristic (hkl) reflections on antigorite from Kōchi city, after Hayashi's unpublished research (by kindly personal communication) based on Whittaker and Zussman (1956 & 1958).

Besides, according to COLEMAN (1966), who studied the New Zealand ultramafic rocks, X-ray studies of serpentine minerals reveal that ortho- and clinochrysotile predominate in the highly sheared serpentinites and lizardite is more common to the massive serpentinites ; antigorite is the stable serpentine polymorph in the regionally metamorphosed serpentinites within Alpine schist or in restricted areas of high stress in the Great Ultramafic Belts. HAYASHI (1968) also states that lizardite serpentinite is formed under the condition of higher oxygen pressure than antigorite serpentinite, namely when FeO : Fe_2O_3 ratio is lower, lizardite serpentine crystallizes ; when FeO : Fe_2O_3 ratio is higher, antigorite serpentine.

Only one specimen of serpentine mineral of serpentinite (T60—100) in spotted schist from Tari district has been prepared for experiment of X-ray diffraction. The X-ray diffractogram is shown in Figure 10. And the serpentine mineral is identified as antigorite. This fact suggests that serpentinite in the spotted schist might have emplaced during regional metamorphism and have been formed under the condition which oxygen pressure was not so higher.

Conclusion

Most of the serpentinized ultrabasic rocks from the eastern part of the Chugoku zone may originally be dunite and harzburgite, judging from their relict minerals. However, it is very regrettable that the differences between the small mass in higher grade metamorphosed rocks and the larger one in low grade or non-metamorphosed Paleozoic sediments are not able to be pointed out, petrologically or mineralogically, and also petrochemically, because of their strong serpentinization.

The research on the condition of serpentinite emplacement and serpentinization, based on oxygen pressure or serpentine polymorph, has not been done enough…….

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要旨

中国帯には，大小さまざまな超塩基性岩類が分布している。これらいずれの岩体も蛇紋岩化がいちじるしいが，わずかな残晶から，大体 dunite と harzburgite を原岩とすることが推定される。ここでは，大小両岩の相異を検討してみようと試みたが，それは残晶の大部分が変質しているので，岩石の化学組成のみによった。その結果は，特殊な例をのぞくと両者はほとんど差異がなく，MgO/$\sum$FeO (wt%) も，3.9～6.9の範囲内にある。ここでも若干検討はしたが，今後は，FeO/Fe_2O_3 の関係，蛇紋岩化の程度あるいは serpentine mineral の polymorph などにより，その生成の地質条件を検討してみる必要がある。

地名

Atetsu……………………阿哲
Hokubo……………………北房
Katsuyama…………………勝山
Nichinan……………………日南
Niimi………………………新見
Sekinomiya…………………関宮
Shingo……………………新郷
Tari…………………………多里
Wakasa……………………若桜