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Structural-Petrological Studies of Peridotite and Associated Rocks of the Higashi-akaishi-yama District, Shikoku, Japan

By

Gensei YOSHINO

with 2 Tables, 34 Text-figures, and 4 Plates

ABSTRACT: The Higashi-akaishi-yama peridotite mass lies along the axis of the root-zone of the Besshi recumbent anticline, nearly concordantly with adjacent Sambagawa crystalline schist beds, extending E.-W. for a distance of about 4.5 km or more. It is a large lenticular mass dipping to the north, bounded by the Iratsu amphibole schist on the north and by spotted black schist on the south. The mass is mainly compossed of massive and foliated dunite, accompanied by a small amount of clinopyroxene-bearing peridotite. Clinopyroxenite and eclogite occur as fine streaks, bands and lenticular masses in the upper (northern) part of the peridotite mass. Large masses of amphibolic and pyroxenic rocks also occur, being enclosed in the peridotite mass. No contact effects of higher temperature have been found in crystalline schists around the peridotite mass. Small irregular-shaped masses of eclogite have been locally developed in the Iratsu amphibole schist.

Throughout the massive dunite is developed a continuous *s*-surface clearly defined by the statistical lattice orientation of olivine. The preferred orientation of olivine in the massive dunite must have been developed through the process of recrystallization or neocrystallization of the mineral during the Besshi recumbent folding. Preferred orientation of olivine is less remarkable in the foliated dunite than in the massive one. Foliation of the foliated dunite is defined by closely spaced alternation of serpentine-rich layers and olivine-rich ones. The foliated dunite is believed to have been intensely folded during or after the formation of preferred orientation of olivine.

Clinopyroxenes in both the clinopyroxenite and the eclogite tend to show marked preferred orientation. The fabric axes defined by the orientation of clinopyroxene in both the clinopyroxenite and the eclogite roughly coincide in direction with those defined by the orientation of olivine in the adjacent massive dunite. The preferred orientation of clinopyroxene as well as olivine is believed to have been developed under the same tectonic setting.

CONTENTS

I. Introduction

A large lenticular mass of peridotite, which is mainly composed of dunite, occurs in the Higashi-akaishi-yama (Mt. Higashi-akaishi) district of Ehime Prefecture, Shikoku, Southwest Japan (fig. 1). The mass extends from the east to the west for a distance of about 4.5 km or more. Many geologists have hitherto studied the mass and published their results. On the basis of the study on hand specimens of chromite

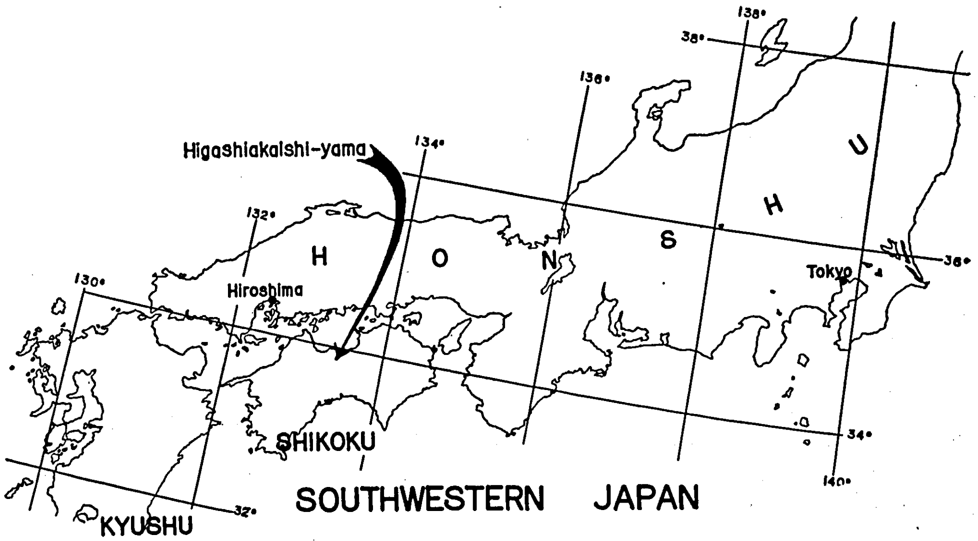

FIG. 1. Map indicating the location of Higashiakaishiyama.

ore of the Akaishi Mine, T. KATÔ (1921) said: "From these observations, it is highly probable that the banded ore was formed by a flowing motion of the crystallizing dunite magma, in which settling of the chromite crystals was going on." Furthermore, he suggested: "...... the granulation along the margins and cracks of the chromite crystals has occurred prior to the crystallization of olivine." K. KINOSHITA (1936) commented on the variability of chemical composition of this mass. Y. HORIKOSHI (1937a, 1937b) described petrographic characters of the peridotite and associated rocks, and inferred that eclogite found in the dunite mass represents a pegmatitic part derived from the dunite magma. Furthermore, he suggested that the crystalline schists enclosing the dunite mass was affected by post-igneous action of the dunite magma. Z. HARADA (1941) reported some chrome minerals, such as kämmererite, uvarovite, and chrome-diopside, from the Akaishi Mine. Y. UCHIDA (1949) concluded from his observation of the occurrence of the chromite ore of the Akaishi Mine that the chromite was crystallized prior to the crystallization of olivine and that after the solidification of dunite the accumulated chromite crystals have been injected into the dunite mass along cleavage plane in the form of banded chromite ore. Recently, T. BANBA (1953) divided the whole Higashi-akaishi-yama peridotite mass into two parts, from the structural and petrological aspects, namely, the Higashi-akaishi-yama peridotite mass and the Hachimaki-yama peridotite mass. As to the Higashi-akaishi-yama peridotite mass, he noted that Cr_2O_3 content of chromite scattered in dunite is less than that of chromite in banded chromite ore. The foregoing is almost the whole of our knowledge about the peridotite and associated rocks of the Higashi-akaishi-yama district. It must be noted that these authors above mentioned seem to agree about the magmatic origin of the peridotite.

Since 1952, the present author has been engaged in the geological as well as structural-petrological studies of the Higashi-akaishi-yama district where peridotite and coarser-grained crystalline schists occur. In this paper the author intends to analyse the structure of the Higashi-akaishi-yama peridotite mass in connection with the structure of the Sambagawa crystalline schists in this district. This paper mainly deals with the result of structural-petrological studies and some considerations on the origin of the peridotite and associated rocks are attempted. Owing to the scarcity of chemical data, petrochemical discussions on the origin of the eclogitic rocks is not included in this paper.

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To the officers of the Akaishi Mine, Meiji Mining Co., Ltd., the Iratsu Office, Sumitomo Forestry Co., Ltd., and the Besshi Mine, Sumitomo Metal Mining Co., Ltd., who made possible his field works in the Higashi-akaishi-yama district, the author is greatly indebted. To the staff of the Institute of Geology and Mineralogy, Faculty of Science, Hiroshima University, the author is grateful for permitting him to use the five-axis universal stage of the Institute.

The knowledge of geological setting of the peridotite mass in the Sambagawa crystalline schist zone is basd on the results of studies on the Besshi Spotted Schist Zone by G. KOJIMA, K. HIDE, and G. YOSHINO.

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II. GEOLOGICAL SETTING

In Shikoku, the Sambagawa crystalline schist zone extends E.-W. with the maximum width of about 25 km at the Besshi-Shirataki district. The crystalline schist system of the Sambagawa zone in Shikoku was divided stratigraphically by G. KOJIMA, K. HIDE, and the present author as follows (G. KOJIMA, 1951a, 1951b; G. KOJIMA, K. HIDE, and G. YOSHINO, 1956):

Group	Sub-group	Formation	Member
Yoshinogawa	Upper	Ôjôin	
	Middle	Minawa	Upper
			Main green schists
			Lower
		Koboke	
	Lower	Kawaguchi	
		Ôboke	
Nishiiya			

In the Besshi-Shirataki district, the crystalline schist zone can be divided petrographically into two sub-zones, namely, the spotted sub-zone and the non-spotted sub-zone. The spotted sub-zone, or the northern terrain, is composed of coarser-grained schists with large porphyroblasts of albitic feldspar, being named the "Besshi Spotted Schist Zone" (K. HIDE, G. YOSHINO, and G. KOJIMA, 1956). The non-spotted sub-zone, or the southern terrain, consists of finer-grained low-grade schists of regional metamorphic type which contain no porphyroblasts of feldspar. The change in metamorphic features accross the boundary zone between these two sub-zones is gradual.

In the spotted sub-zone of the Besshi-Shirataki district develops a large scale recumbent fold (G. KOJIMA, 1951a, 1951b; K. HIDE, 1954), the axial plane of which

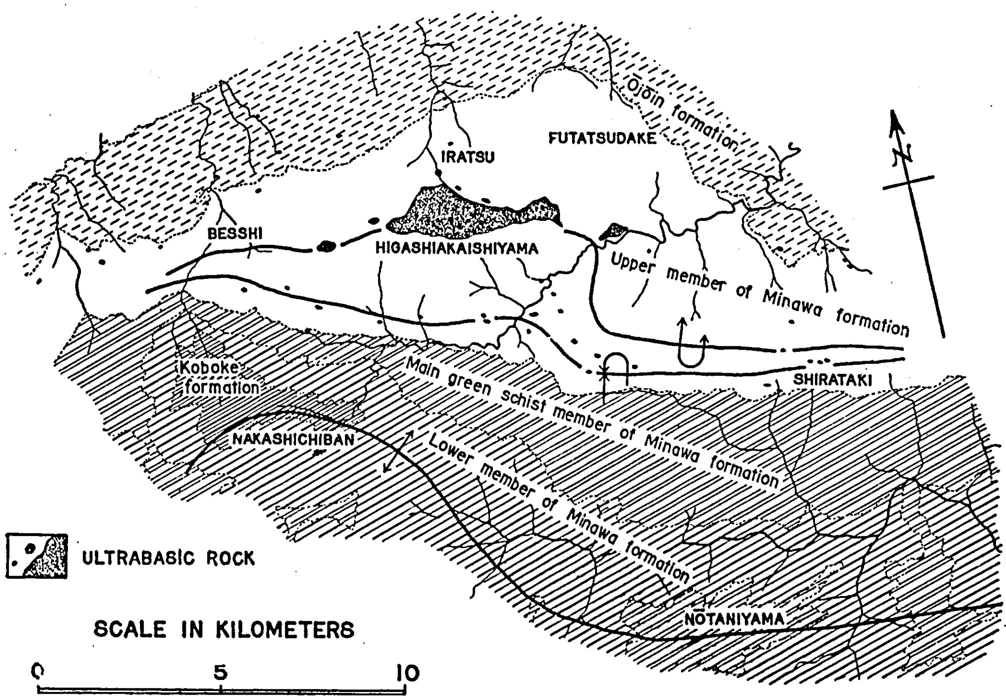


FIG. 2. Geological map of the Besshi-Shirataki district (after K. HIDE, G. YOSHINO, and G. KOJIMA, 1956).

dips to the north. In this paper the fold is called the "Besshi recumbent fold" (K. HIDE, G. YOSHINO, and G. KOJIMA, 1956). In general, the axis of the recumbent anticlinorium extends from the west to the east, plunging eastward at about 10°. Along the northern part of the non-spotted sub-zone occurs an asymmetrical anticline named the "Nakashichiban-Nôtaniyama anticline" (G. KOJIMA, 1951a, 1951b; K. HIDE, 1954). The axis of this anticline also runs from the west to the east, plunging at about 10° to the east. Throughout the spotted sub-zone as well as the non-spotted sub-zone, bedding schistosity commonly develops in the crystalline schists. The lineation on the surface of the bedding schistosity generally coincides in direction with the *B*-axis of regional folding. The boundary zone between these two subzones is named the "Otoji transitional zone" (K. HIDE, G. YOSHINO, and G. KOJIMA, 1956). Features of the Besshi recumbent anticline overturned southward against the northern limb of the Nakashichiban-Nôtaniyama anticline and of the Otoji transitional zone between these two anticlines were illustrated there (fig. 2).

In the Besshi-Shirataki district, the Koboke formation and both the Lower member and the Main green schists member of the Minawa formation occur within the Nakashichiban-Nôtaniyama anticline. The uppermost horizon of the northern limb of this anticline consists of the Main green schists member, the Upper member of the Minawa formation being restricted in the terrain of the Besshi recumbent fold. The Ôjôin formation is exposed occupying the northern part of the recumbent fold zone. From these stratigraphical distribution of schist formations in relation to the geologic structure mentioned above, the Besshi recumbent anticlinorium is believed to be a kind of large scale intraformational fold (K. HIDE, G. YOSHINO, and G. KOJIMA, 1956). The upper member of the Minawa formation is composed of spotted black schist, spotted sandstone schist, spotted siliceous schist, spotted green schist, spotted amphibole schist, and coarser-grained amphibole schist with garnet porphyroblasts.

The upper member of the Minawa formation has been intensely deformed, especially at the inverted limb of the recumbent anticline, and the thickness of each schist beds belonging to the member is not uniform both to the dip side and to the strike side. For instance, the coarser-grained amphibole schist, named by Y. HORIKOSHI (1937a) the "Iratsu amphibole schist", is distributed mainly from Iratsu-Sanrin (Iratsu Forest) to Futatsudake. The schist body consisting mainly of the Iratsu amphibole schist forms the northern limb (normal limb) of the recumbent anticline, and it was so thickened as to form a comparatively large mountain mass of Futatsudake. The mass consisting of the Iratsu amphibole schist and the other spotted amphibole schists shows rapid decrease in thickness both to the east and to the west. K. HIDE pursued the eastern extension of the mass through the zone of bending in strike in the region of the Dôzangawa River towards the Shirataki district, and clarified that the mass becomes thinner towards the inverted limb of the recumbent anticline. Several thin beds of spotted amphibole schist, frequently accompanied by spotted quartz schist, are distributed on the southern side of Higashi-akaishi-yama, or the inverted limb of the recumbent anticline, some of these beds corresponding stratigraphically to the thick beds of the coarser-grained Iratsu amphibole schist and other spotted amphibole schists at the normal limb.

Some geologists reported that the Iratsu amphibole schist has been derived from syntectonic intrusives. Judging from the following facts, however, the present author infers that the coarser-grained Iratsu amphibole schist as well as the spotted amphibole schist or the spotted green schist in the district have been formed as the result of regional metamorphism from basic pyroclastic and effusive rocks related to the geosynclinal submarine volcanism:

1. In the Higashi-akaishi-yama district, the Iratsu amphibole schist is distributed in the east-west direction in concordance with the spotted amphibole schist bed, and becomes gradually thinner towards the west.

2. The Iratsu amphibole schist occurs in association with thin beds of spotted black schist, calcareous schist, and siliceous schist. The proportion of the constituent minerals is not uniform.

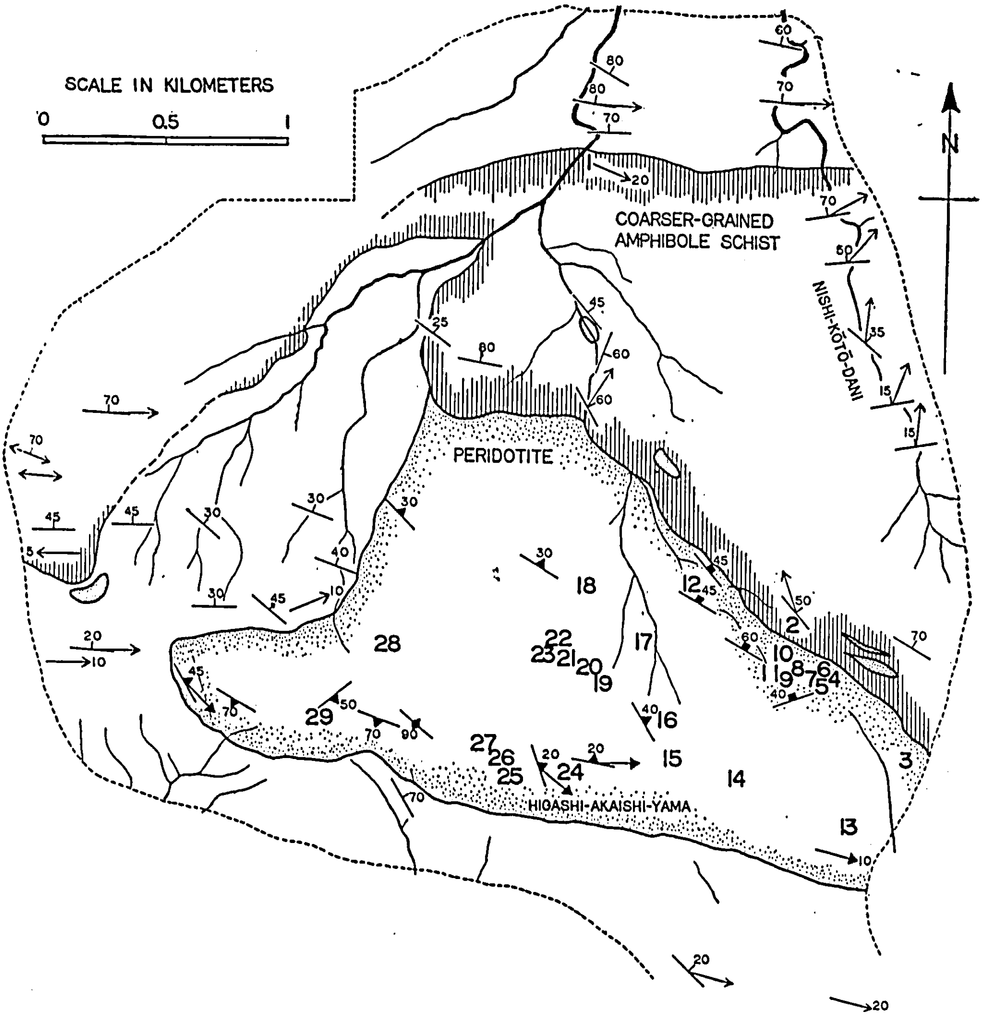
3. Except for garnet, the mineral assemblage of the Iratsu amphibole schist does not differ from that of the spotted amphibole schist. Plagioclase in the former differs little in optical properties from that in the latter.

4. The wastern part of the Iratsu amphibole schist bed does not always consist of coarser-grained rocks. Accordingly, near the Kamikabuto ridge, it becomes difficult to distinguish the Iratsu amphibole schist proper from the adjacent spotted amphibole schist.

In the Besshi-Shirataki district, masses of peridotite and serpentinite are found almost exclusively in the spotted sub-zone. The Higashi-akaishi-yama peridotite mass, which will be considered in this paper, is the largest one of these masses. It lies nearly concordantly with the adjoining crystalline schist beds, and extends from the east to the west for more than 4.5 km. The mass is bounded on the north by the Iratsu amphibole schist and on the south by spotted black schists. It must be noted that the Higashi-akaishi-yama peridotite mass occurs along the axis of the root-zone of the Besshi recumbent anticlinorium.

III. Geology of the Higashi-akaishi-yama District

The Higashi-akaishi-yama district is divided into two parts, *i. e.*, the northern and the southern, by the Higashi-akaishi-yama ridge extending E.–W. Both sides have been deeply incised by valleys. The root-zone of the Besshi recumbent anticlinorium is exposed in this district. The Besshi recumbent fold is composed of the Upper member of the Minawa formation. The geologic structure of the Besshi recumbent anticlinorium was already analysed by G. Kojima, K. Hide, and the present author in the field mainly by pursuing the extension of every key bed of crystalline schists, such as amphibole schist, green schist, and quartz schist (K. Hide, G. Yoshino, and G. Kojima, 1956). The axial plane of the recumbent anticline is overturned to the south, dipping to the north. The greater part of the crystalline schists exposed on



Slip cleavage in dunite-mylonite

Foliation } in foliated dunite
Axis of micro-wrinkles on foliation plane }

Predominant schistosity } in the Sambagawa crystalline schists proper
Lineation by mineral parallelism or axis of micro-wrinkles on schistosity plane }

1-29 Localities of rock specimens to which microfabric diagrams are referred.

Fig. 3. Map showing geological structure of the Higashiakaishiyama district and localities of rock specimens to which microfabric diagrams in this paper are referred. Structural data along Nishi-Kôtô-Dani (Nishi-Kôtô Valley) were copied from the geological map by K. Hide, 1958.

the northern side of the Higashi-akaishi-yama ridge represents the strata of the normal limb (northern limb) of the recumbent anticline, whereas the greater part of the crystalline schists on the southern side forms the inverted limb of the anticline (figs. 2, 3, and plate 43). Table 1 shows the strata distributed in the Higashi-akaishi-yama district.

TABLE 1. CRYSTALLINE SCHIST BEDS DISTRIBUTED IN THE HIGASHI-AKAISHI-YAMA DISTRICT

FORMATION		ROCK ASSOCIATION	THICKNESS (METERS)
The Ôjôin Formation		Spotted sandstone schist and spotted black schist, interbedded with thin beds of spotted green schist and spotted siliceous schist.	1200+
The Upper member of the Minawa formation	Normal limb of the Besshi recumbent anticline	Spotted black schist, interbedded with thin beds of spotted green schist and spotted siliceous schist.	250±
		Spotted green schist, intercalated with thin beds of spotted siliceous schist and spotted black schist.	70∼100
		Spotted siliceous schist, intercalated with thin beds of spotted green schist and spotted black schist.	30∼100
		Spotted amphibole schist and coarser-grained (Iratsu) amphibole schist, intercalated with thin beds of spotted black schist, spotted siliceous schist, and calcareous schist.	300∼1500
	Inverted limb of the Besshi recumbent anticline	Spotted black schist, spotted amphibole schist, and spotted siliceous schist.	?

In the Ôjôin formation, which occupies the northernmost part of the district, the surface of bedding schistosity dips gently to the north. The southernmost (the lowest) horizon of the Ôjôin formation traverses the bottom of a valley near the Iratsu Office, Shikoku Forestry Co. Ltd. Beneath the Ôjôin formation is exposed a bed of spotted black schist, in which is found a marked fold, though on a minor scale, having almost horizontal axial plane. The bed seems to represent a transitional zone between the block of the Besshi recumbent fold and the block of the Ôjôin formation.

On the southern side of the Higashi-akaishi-yama ridge several thin beds of spotted amphibole schist and spotted siliceous schist are distributed. These beds, belonging to the inverted limb of the recumbent anticline, correspond to the beds of the coarser-grained (Iratsu) amphibole schist, spotted amphibole schist, spotted green schist, and spotted siliceous schist of the normal limb of the anticline. The beds of spotted amphibole schist and spotted siliceous schist of the inverted limb are, however, much thinner than the corresponding beds of the normal limb. Contrary to the normal limb the greater part of the inverted limb is occupied by spotted black schist. Grains of constituent minerals of schists tend to become coarser towards the axial zone of the Besshi recumbent anticline.

Besides the commonly developed bedding schistosity, axial-plane schistosity is locally developed in the recumbent fold zone. The linear structure of the crystalline schists is defined by the linear arrangement of prismatic minerals, micro-wrinkles on the surface of the schistosity, and the line of intersection of the bedding schistosity and the axial-plane schistosity. In the Besshi recumbent fold zone, with the exception of the linear structure in and around the swelling part of the Iratsu amphibole schist bed, these types of lineation of the crystalline schists coincide in direction with the axes of minor folds as well as the regional tectonic axis B, and they plunge about 15° in the direction of E.S.E. While in and around the swelling part of the Iratsu amphibole schist bed, the trend and the plunge of the lineations deviate from those of the regional tectonic axis (fig. 3).

The Higashi-akaishi-yama peridotite mass extends E.–W. across the peak of the Higashi-akaishi-yama ridge. It is a north-dipping lenticular mass bounded on the north (the upper side) by the Iratsu amphibole schist of the normal limb of the Besshi recumbent anticline, and on the south (the lower side) by spotted black schist beds mainly belonging to the inverted limb of the anticline. The peridotite mass is regionally concordant with the adjacent crystalline schist beds, but it seems to transgress locally the bedding of the latter. In the crystalline schists around the Higashi-akaishi-yama peridotite mass are exposed numerous minor masses of peridotite and serpentine-rock (figs. 2, 3, and plate 43).

The Higashi-akaishi-yama peridotite mass consists largely of massive dunite and foliated dunite, with a small amount of clinopyroxene-bearing peridotite. In the massive dunite, any megascopic planar and linear structures can hardly be recognized, whereas the foliated dunite is megascopically characterized by foliated and lineated fabrics. The foliation (or schistosity) of the foliated dunite is defined by the alternation of olivine-rich layers and serpentine-rich layers. Lineation is developed on the surface of the foliation. In the Higashi-akaishi-yama peridotite mass, the massive dunite occurs mostly in the upper part, and the lower part of the mass is occupied mainly by the foliated dunite. The boundary between the massive parts and the foliated parts in the peridotite mass is usually distinct. On the northern side of Higashi-akaishi-yama (Mt. Higashi-akaishi), the foliation plane of the foliated dunite strikes N. 30°∼80° W., and dips 20°∼60° N. E., almost parallel to the northern slope of the mountain. On the southern side of the mountain the foliation plane dips nearly vertical (70° N. ∼ 70° S.). The lineation of the foliated dunite plunges about 15° towards E. S. E., coinciding in direction with the lineation of the spotted black schists distributed on the southern (lower) side of the peridotite mass.

Banded chromite ores are found mainly in the massive dunite, although isolated crystals of chromite are contained as a minor constituent throughout the Higashi-akaishi-yama peridotite mass. Seams and bands of chromite in the massive dunite are arranged subparallel to each other as well as to the tabular shape of the peridotite mass. The chromite bands are not limited in distribution to any specific part of the massive dunite.

In the upper part of the Higashi-akaishi-yama peridotite mass occur several large masses consisting of amphibolic and pyroxenic rocks. Closely spaced subparallel streaks or bands and lenticular masses of clinopyroxenite and eclogite are also found locally. These streaks and bands are subparallel to the tabular shape of the peridotite mass.

Near the upper (northern) margin of the Higashi-akaishi-yama peridotite mass, zones of dunite-mylonite are developed locally.

IV. Rocks of the Higashi-akaishi-yama District

A. Rocks of the Sambagawa Crystalline Schists Proper

1. *Crystalline schists derived from pelitic sediments*

The crystalline schists derived from pelitic sediments have been generally called "black schists" by the geologists who investigated the Sambagawa crystalline schist zone of Central Shikoku.

Occurrence: The Ôjôin formation consists mostly of spotted black schist. In the Upper member of the Minawa formation beds of spotted black schist alternate with beds of spotted siliceous schist, spotted green schist, spotted amphibole schist, and coarser-grained (Iratsu) amphibole schist.

Megascopic features: The schists are black in colour due to the abundance of graphite, and are markedly foliated in general. On the surface of schistosity develops micro-corrugation, the parallelism of which defines the lineation of *b*-type. Porphyroblasts (or Spots) of albitic feldspar are distributed throughout the black schists.

Microscopic features: Spotted black schists in the Ôjôin formation and in the upper part of the normal limb of the Besshi recumbent anticline consist mostly of albite, quartz, muscovite, chlorite, and graphite. A small amount of garnet is frequently found. The average diameter of quartz grains is 0.1 mm, and that of garnet grains is 0.05 mm. The albite porphyroblasts range generally in grain diameter from 0.3 mm to 1.0 mm.

Spotted black schists distributed along the axial zone of the Besshi recumbent anticline are composed mostly of albite, quartz, muscovite, biotite, garnet, and graphite. The average diameter of quartz grains is 0.2 mm, garnet grains are 0.3~1.0 mm, and albite porphyroblasts range from 1.0 mm to 3.0 mm in grain diameter.

2. *Crystalline schists derived from psammitic sediments*

The schists have been generally called "sandstone-schists".

Occurrence: Several thin beds of spotted sandstone-schist alternate with the spotted black schist of the Ôjôin formation. Sandstone-schist is rare in the Upper member of the Minawa formation.

Megascopic features: The colour of the spotted sandstone-schist is gray. The surface of schistosity locally shows faint micro-corrugation. Megascopic planar and linear structures are less conspicuous in the spotted sandstone-schist than in the spotted black schist.

Microscopic features: Sandstone-schists in the Ôjôin formation consist mostly of quartz, albite, muscovite, chlorite, and graphite, with subordinate amounts of titanite, garnet, tourmaline, epidote, and apatite. The average diameter of albite porphyroblasts is 0.5 mm.

3. *Crystalline schists derived from siliceous sediments*

The schists have been generally called "quartz schists" or "siliceous schists".

Occurrence: Several beds of spotted quartz schist occur in the Upper member of the Minawa formation, but it is rare in the Ôjôin formation.

Megascopic features: Quartz schist is generally of light-colour, ranging from white, light gray, pale green, to pink, according to the variation of minor constituents.

Microscopic features: The schist consists mostly of quartz with subordinate amounts of muscovite and albite. Some other minor constituents, such as chlorite, epidote, piedmontite, hematite, garnet, and calcite, frequently occur in special seams. Grains of albite porphyroblasts are 0.5～1.5 mm in diameter.

4. *Crystalline schists derived from calcareous sediments*

Occurrence: Calcareous schists occur in association with the Iratsu amphibole schist.

Megascopic features: In general, the schist is white in colour, but frequently contains pale greenish layers. Fissility is weak, and linear structure is inconspicuous.

Microscopic features: White parts of the rock consist essentially of calcite, and pale greenish layers consist of calcite, zoisite, albite, muscovite, and clinopyroxene. Calcite ranges in grain diameter from 0.3 mm to 1.2 mm.

5. *Crystalline schists derived from basic pyroclastic and effusive rocks of geosynclinal submarine volcanism*

In the Higashi-akaishi-yama district, these schists are found in the zone of the Besshi recumbent fold. They vary in both mineralogical and textural characters. Such variation is supposed to have resulted from the differences in metamorphic conditions as well as in properties of the original rocks. For description the crystalline schists of this district are divided into the following three groups, from the standpoints of mineralogy, texture, and occurrence.

a. Albite-epidote-actinolitic amphibole-chlorite schist containing albite porphyroblasts: In this paper, the schist is called "spotted green schist".
b. Albite-epidote-amphibole schist containing albite porphyroblasts: In this paper, the schist is named "spotted amphibole schist".

c. Coarser-grained albite-epidote-amphibole schist containing garnet porphyroblasts: The rock is called "Iratsu amphibole schist" in this paper.

A few beds of spotted green schist occur in association with spotted quartz schist in the upper part of the normal limb of the Besshi recumbent anticline. The spotted amphibole schist is widely distributed throughout the recumbent fold zone of this district. In the normal limb of the recumbent anticline, the spotted amphibole schist is distributed on the southern (lower) side of the spotted green schist, and the Iratsu amphibole schist is distributed on the southern side of the spotted amphibole schist. The lower margin of the Iratsu amphibole schist comes into contact with the Higashi-akaishi-yama peridotite mass.

a. Spotted green schist

Megascopic features: The schist is green to dark-green in colour, and is usually foliated. On the surface of schistosity micro-corrugation is well developed. The schist is often marked with light-greenish layers rich in epidote. The constituent minerals are commonly fine-grained, and minute porphyroblasts of albitic feldspar are dispersed throughout the rock.

Microscopic features: The schist contains abundant albite, chlorite, epidote, and actinolitic amphibole, with small amounts of titanite and opaque minerals. Calcite, muscovite, and quartz are also frequently found. Garnet is rare. Grains of epidote are 0.1～0.8 mm in diameter. The average grain diameter of albite is 0.3 mm. Grains of albite porphyroblasts range from 0.5 to 1.0 mm in diameter. Needles of amphibole range from 0.2 to 0.5 mm in length.

b. Spotted amphibole schist

Megascopic features: The rock is dark-green in colour, with distinct schistosity defined by the parallel arrangement of constituent minerals. Light-coloured seams and layers rich in epidote are often developed parallel to the schistosity. Albite porphyroblasts occur throughout the rock.

Microscopic features: The schist consists of albite, epidote, and amphibole, with small amounts of titanite and opaque minerals. Muscovite, calcite, and quartz are frequently found. Garnet is rare. Chlorite diminishes with progressive development of amphibole. In the schist of the normal limb of the recumbent anticline, the constituent minerals have the following grain sizes: Epidote ranges from 0.1 to 0.3 mm in longer diameter, amphibole ranges from 0.5 to 1.0 mm in longer diameter, and albite porphyroblasts are 0.5～1.5 mm in diameter. The constituent minerals of the schist in the axial zone of the anticline have the grain sizes as follows: Epidote ranges from 0.5 to 1.5 mm in longer diameter, amphibole ranges from 0.5 to 1.5 mm in longer diameter, and albite porphyroblasts are 2～4 mm in diameter.

c. Iratsu amphibole schist

Megascopic features: The schistosity and lineation of the Iratsu amphibole schist are defined by the parallel arrangement of the constituent minerals, such as amphibole, epidote, and muscovite. The rock is characterized by large porphyroblasts of garnet, which vary in both size and distribution. The maximum diameter of garnet porphyroblast attains 3 cm. The shape of the porphyroblast is usually rounded. Sometimes, large crystals of garnet exhibit a beautiful form of rhombic dodecahedron.

Microscopic features: The rock consists mostly of albite, muscovite, epidote, amphibole, and garnet, with a subordinate amount of rutile. The schist frequently contains a part which consists essentially of garnet, amphibole, and rutile, without albite. Grain sizes of the main constituents are as follows: Amphibole ranges from 0.5 mm to 2.0 mm in longer diameter, epidote ranges from 0.5 mm to 1.0 mm in longer diameter, and the average diameter of albite is 0.1~0.2 mm. The optical properties of the amphibole and the albite are as follows: Amphibole:—the optic axial plane is parallel to (010), the extinction angle ($c \wedge Z$) in (010) varies from 15° to 18°, the optic axial angle (2V) from 67° to 79°, negative, the pleochroism is distinct, with X = colourless to light-yellow or light-greenish-yellow, Y = pale-yellowish-green, Z = colourless to light-greenish-blue. Albite:—the average optic axial angle (2V) is 83°, positive.

6. *Rocks associated with the Iratsu amphibole schist*

The following rocks occur in association with the Iratsu amphibole schist.

a. Schistose amphibole rock
b. Eclogitic rocks

Schistose amphibole rock locally occurs along the lower margin of the Iratsu amphibole schist. Some of the rock masses come in contact with the Higashi-akaishiyama peridotite mass. Clusters or single crystals of clinopyroxene are found locally in the lower part of the Iratsu amphibole schists. Such eclogitic masses measure from several centimeters to several meters in diameter.

a. Schistose amphibole rock

Megascopic features: The rock is generally dark-green, and usually has the schistosity defined by the parallel arrangement of amphibole crystals.

Microscopic features: The rock consists mainly of amphibole, with a little or no clinozoisite. The longer diameter of the amphibole grains ranges from 1.0 to 3.0 mm. The optical properties of the amphibole in a representative specimen are as follows: The optic axial plane is parallel to (010), the extinction angle ($c \wedge Z$) in (010) is about 21°; the optic sign is negative, the optic axial angle (2V) is about 84°; the pleochroism is distinct with X = colourless to light-yellow, Y = pale-yellow to pale-yellowish-green, Z = colourless to pale-bluish-green.

b. Eclogitic rocks

Megascopic features: The rocks are massive or schistose. The presence of light-coloured garnet and pale greenish clinopyroxene is characteristic.

Microscopic features: The rocks consist chiefly of garnet and clinopyroxene, with minor amounts of rutile and titanite. Sometimes, they contain a small amount of amphibole or clinozoisite. Grains of clinopyroxene are not uniform in size, rarely larger than 1.5 mm. The optical properties of the clinopyroxene and the amphibole in a representative specimen are as follows: Clinopyroxene: — the angle $c \wedge Z$ is about 43°, the optic axial angle (2V) is about 64°, positive, and it is colourless in thin section. Amphibole: — the extinction angle ($c \wedge Z$) in (010) is about 18°; the optic sign is negative, the optic axial angle (2V) is about 85°; the pleochroism is distinct, with X = colourless, Y = pale-yellowish-green, Z = pale-bluish-green.

B. Peridotite and Associated Rocks

In contrast with the Horoman peridotite mass of the Hidaka zone, Hokkaido (M. Funahashi and S. Hashimoto, 1951; S. Igi, 1953) or the Miyamori peridotite mass of Kitakami Mountainland, North Honshû (Y. Seki, 1951a, 1951b, 1952), the peridotite masses occurring in the Higashi-akaishi-yama district are comparatively homogeneous in the mineral composition and in the content of olivine. The Higashi-akaishi-yama peridotite mass consists chiefly of dunite. Occurrence of monoclinic pyroxene in this peridotite mass is only local. There are two kinds of monoclinic pyroxene; one is black to gray in colour, and is dispersed in the olivine aggregates, while the other is light-green, and occurs usually as aggregates in the form of streak, band, or lens in the dunite. Black clinopyroxene is occasionally found within the aggregates of the light-green clinopyroxene.

1. *Peridotite*

a. Dunite

The dunite differs in its textural character within the Higashi-akaishi-yama peridotite mass. Roughly speaking, the upper (northern) part of the lenticular peridotite mass is composed mainly of massive dunite, and the lower (southern) part of the mass is occupied mainly by foliated dunite. Thin layers of the foliated dunite are frequently found within the massive dunite, while the massive dunite occurs as thin layers and lenses within the foliated dunite. Boundary between the massive part and the foliated part is distinct. Massive dunite also occurs as small bodies in the Iratsu amphibole schist situated to the north of the Higashi-akaishi-yama peridotite mass, whereas foliated dunite cannot be found in the Iratsu amphibole schist. Below, and almost parallel to, the upper margin of the Higashi-akaishi-yama peridotite mass, zones of dunite-mylonite are developed, locally bordering the peridotite mass. The structure of the dunite-mylonite zone is well disclosed in the Gongen valley. The degree of mylonitization is not uniform throughout the zone. Within the zone, continuous layers of uncrushed massive dunite frequently alternate with layers of mylonitized dunite, and they run roughly parallel to the upper margin of the peridotite mass. The colour of fresh specimens of the dunite is light-green to dark-green.

i. Massive dunite

The rock is massive, megascopic planar or linear structure being uncommon. Subparallel streaks consisting of chromite frequently occur. Besides fresh olivine, the rock usually contains a subordinate amount of chromite and a little blade-shaped serpentine mineral, occasionally associated with some carbonate minerals of calcite group.

In general, the grains of olivine are equidimensional, ranging from 0.05 mm to 3.0 mm in diameter. Distinct (010) cleavage is common. Fine lamellar structure and undulatory extinction band cannot be detected even in large crystals. Optical properties of olivine are almost uniform throughout the massive dunite, the optic sign being commonly positive, and the optic axial angle in the range of 86° to 89°.

Some parts of the massive dunite show weak granulation, where some large grains of olivine display weak undulatory extinction while others are crushed into smaller grains differing in extinction position by a few degrees with one another. In such cases, the grains of olivine range from 0.05 mm to 1.5 mm in diameter.

Fracture cleavage is locally developed within the massive dunite in the Higashi-akaishi-yama peridotite mass, and the closely spaced fracture cleavage traverses the olivine grain resulting in microscopic intragranular parallel cracks. Fibrous serpentine minerals are found along the fracture cleavage. Such fractured olivine grains do not always exhibit undulatory extinction.

ii. Foliated dunite

Megascopically the foliated dunite shows a foliated and lineated fabric. The early-formed foliation (or schistosity) is defined by the alternation of olivine-rich layers and serpentine-rich layers. The surface of the foliation is often folded, and subsequent axial-plane foliation frequently intersects the early-formed foliation. Megascopic linear structure is attributed to the parallelism of micro-corrugation of olivine-rich layers and serpentine-rich layers, to the parallelism of elongated lenticular clusters of olivine, or to the intersection of the early-formed foliation and the later axial-plane foliation. In many cases, these lineations roughly coincide in direction with the regional fold axis of the Besshi recumbent anticline.

A small amount of chromite is contained in the foliated dunite, although streaks and bands of chromite are scarcely found. Grains of olivine are generally equidimensional, ranging from about 0.05 mm to 1.5 mm in diameter, and weakly undulatory extinction is observed in some of the larger grains of olivine. The optical properties of olivine are almost uniform, the optic sign being commonly positive and the optic axial angle in the range of 86° to 89°.

iii. Dunite-mylonite

The dunite-mylonite usually has a distinctly laminated fabric. Parallel set of slip cleavage can be observed, with a few millimeters interval between the individual planes of megascopic cleavage. Under the microscope, closely spaced discontinuous slip cleavage, along which fibrous mineral of serpentine is found, runs subparallel with the megascopic slip plane. Olivine is generally fine-grained, but strained large crystals of olivine are scattered throughout the fine-grained matrix.

b. Clinopyroxene-bearing peridotite

The peridotite consisting of olivine and black monoclinic pyroxene is distributed mainly within the upper (northern) part of the lenticular Higashi-akaishi-yama peridotite mass, although a few masses of such peridotite have been found in the lower part also. In most cases, the clinopyroxene-bearing peridotite occurs as layers. Crystals of the black clinopyroxene are often large, and they are scattered in a olivine aggregates. Sometimes, crystals of black clinopyroxene collected together, that showing the transition from wehrlite, which is clinopyroxene-rich peridotite, to clinopyroxenite, an extreme type, although these rocks occur only locally. In the Gongen valley, layers of wehrlite and clinopyroxenite alternate with layers of dunite-mylonite and massive dunite. The mylonite of the clinopyroxene-bearing peridotite is speckled with uncrushed crystals of olivine and black clinopyroxene.

In addition to the above minerals, the wehrlite commonly contains chromite and fibrous mineral of serpentine. The clinopyroxenite consisting of black clinopyroxene contains frequently small amounts of olivine, chromite, and fibrous mineral of serpentine. In some instances, the clinopyroxenite contains light-green clinopyroxene and light-coloured garnet.

The optical properties of olivine in the clinopyroxene-bearing peridotite are quite identical with those of olivine in the massive dunite. In the peridotite, grains of the black clinopyroxene range from 1.0 mm to 5.0 mm, rarely attaining to 3 cm in longer diameter. The clinopyroxene described here is megascopically black to gray, but colourless in thin section; (110) cleavage is distinct, parting on (100) is well developed; occurrence of (010) parting is frequently but not always found. Sometimes, amphibole is found in the crystal of black clinopyroxene. The optical properties of these minerals in a representative specimen are as follows: Monoclinic pyroxene:—the extinction angle ($c \wedge Z$) is about 42°, the optic sign is positive, the optic axial angle is about 57°. Amphibole:—colourless in thin section, the extinction angle ($c \wedge Z$) is about 24°, the optic sign is positive, the optic axial angle is about 84°.

2. *Chromite bands*

Seams and bands of chromite are frequently developed parallel to the specific direction in the massive dunite mass. Several outcrops of thick banded chromite ore have been known in this district. The distribution of seams and bands of chromite is not limited to any specific part of the massive dunite. Intensive undulations of the seams and bands are rather rare, although small scale folds are locally observed.

Thick chromite band (or banded chromite ore) consists of irregularly alternating black and light-green layers, presenting a marked banded texture. These layers range in thickness from a few millimeters to several centimeters. The black layer is an aggregate of large and small crystals of chromite, the interstices being filled with grains of olivine. The green layer consists essentially of olivine with a small amount of separate crystals of chromite. The chromite grains are not uniform in size and are extremely irregular in shape. The features of the chromite aggregate indicate that crushing has occurred along the borders and cracks of larger crystals of chromite. In thin section, the colour of chromite crystal scattered in the dunite is black, but chromite from the thick chromite band is often dark-brown. Olivine grains which fill up the interstices of chromite grains show no dimensional orientation. Undulating extinction is not always observed in the crystals of olivine.

3. *Serpentine rocks*

The Higashi-akaishi-yama peridotite mass rarely contains rocks consisting essentially of serpentine minerals, except for the marginal zones where serpentinized dunite is found. Under the microscope, mesh texture is common in the serpentinized dunite. Unaltered relics of olivine still remain. The rock is black in hand specimen. Serpentinized dunite also occurs as small masses in the crystalline schists near the Higashi-akaishi-yama peridotite mass.

Green or dark-green serpentine rocks also occur as small masses in the crystalline schists around the Higashi-akaishi-yama peridotite mass. Without exception, such serpentinites are composed entirely of serpentine minerals.

4. *Clinopyroxenite and eclogite*

Light-coloured monoclinic pyroxene occurs very locally and frequently in association with pink garnet, usually as aggregates, in the Higashi-akaishi-yama peridotite mass. The aggregates are found mainly within the upper (northern) part of the lenticular peridotite mass, forming closely spaced parallel streaks, bands and lenticular masses in the peridotite. Such rocks are scarcely found in the foliated dunite in the lower (southern) part of the Higashi-akaishi-yama peridotite mass. The proportion of garnet and clinopyroxene in the aggregates are variable, and there can be found any transition from clinopyroxenite to eclogite. Clinopyroxene-garnet aggregates show sometimes banded structure consisting of clinopyroxene-rich parts and garnet-rich parts. Large crystals of black clinopyroxene are occasionally dispersed in the garnet-clinopyroxene aggregates. In the Gongen valley occurs coarser-grained beautiful eclogite which consists of light-coloured clinopyroxene and pink garnet in nearly equal proportions.

The mode of occurrence of clinopyroxenite and eclogite can be well observed in the Gongen valley where clinopyroxene aggregates and clinopyroxene-garnet aggregates occur as continuous streaks, bands and isolated lenses in massive dunite and in dunite-mylonite. Small lenses containing clusters of pink garnet enclosed by the mantle of clinopyroxene aggregate occur frequently. The direction of lamination of dunite-mylonite is almost parallel to the streaks and bands of both the clinopyroxenite and the eclogite. In most cases, the streaks and bands are closely spaced, extending almost parallel to each other, but the spacing is not always regular. The streaks and bands range from a few millimeters to several centimeters in thickness, but the thickness of each band usually remains constant for a long distance. The streaks and bands are frequently swollen into roundish lenses. The isolated lenses are a few centimeters to several decimeters in thickness and a few centimeters to several meters in length. Numerous isolated lenses of garnet-clinopyroxene aggregates are aligned within the special horizons of sheared layers of dunite-mylonite. In some cases the alternation of parallel layers consisting of aggregates of clinopyroxene and garnet with different mutual proportions in a large lenticular body in the dunite-mylonite is intersected obliquely with the outer surface of this body. From the field evidence of the bands and lenses of garnet-clinopyroxene aggregate and clinopyroxene aggregate it may be inferred that the outer boundary of the bands and lenses in the dunite-mylonite represents the surface of shear movement during the mylonitization of the surrounding dunite.

The microscopic features of the thin bands of garnet-clinopyroxene aggregate in the massive dunite are as follows. In general, the boundary between the band of clinopyroxene-garnet aggregate and the olivine aggregate of massive dunite is distinct, although the boundary surface is not always regular. Olivine along the boundary is fine-grained. Sometimes, the clinopyroxene occurs as separate crystals, scattered in the fine-grained olivine aggregate near the band of clinopyroxene-garnet aggregate. In most cases, chromite seams extending in the olivine aggregate near the eclogite band are bent along the swollen parts of the band. Some of large crystals of garnet occupying the small swelling of thin band occasionally enclose trains of chromite inclusions, the arrangement of which indicates rotation of the garnet in the swelling. Sometimes, the boundary between the large swelling of garnet-clinopyroxene aggregate and the massive dunite tends to be flat and regular, that suggesting the shearing at the boundary between these two parts with differing physical properties.

In the dunite-mylonite, the bands and lenticular masses of clinopyroxenite and eclogite are bordered by thin films of amphibole, which usually shows preferred orientation on the surface of the film. Such amphibole is contained also in the clinopyroxenite and eclogite. Thin layers of amphibole are found frequently along the slip surface of the dunite-mylonite, and sometimes garnet occurs along such amphibole layers. In the dunite-mylonite locally occur small rounded masses of amphibole and garnet. Judging from the occurrence of such amphibole, the amphibole described here seems to have been formed from the clinopyroxene by the later retrogressive metamorphism.

The garnet-bearing clinopyroxenite, including the variety of eclogite, consists of light-green clinopyroxene and pale-pink garnet, usually with small amounts of rutile, chlorite, and amphibole. In general, grains of clinopyroxene in the clinopyroxenite and eclogite are remarkably inequigranular. The grains of clinopyroxene range from 0.05 mm to 1.5 mm in diameter. In the coarser-grained typical eclogite, grains of the clinopyroxene attain to 3.0 mm in diameter. In the crystals of light-green clinopyroxene, (110) cleavage is distinct, and the parting on (100) is common. Optical properties of the clinopyroxene and the amphibole in the clinopyroxenite and in the eclogite are as follows: Clinopyroxene:—the extinction angle ($c \wedge Z$) is 37°~40°; the optic sign is positive; the optic axial angle (2V) varies from 56° to 58°; and colourless in thin section. Amphibole:—the extinction angle ($c \wedge Z$) is 22°~24°; the optic sign is positive; and the optic axial angle (2V) varies from 82° to 84°. The amphibole is green in mass colour, but in thin section almost colourless or weakly pleochroic with Y=pale-yellowish-green, Z=pale-green.

5. *Amphibolic and pyroxenic rocks*

Several masses composed of amphibolic and pyroxenic rocks occur mainly within the upper part of the lenticular Higashi-akaishi-yama peridotite mass, the contact being sharp. The largest exposure of the mass measures about 150 meters or more. Rocks composing these masses are variable in mineral assemblage, and can be divided into three rock types, that is, epidote-amphibole rock, garnet-amphibole rock, and garnet-amphibole-clinopyroxene rock. These rocks are either massive or schistose. In most cases, the schistose varieties also have megascopic linear structure defined by the parallel arrangement of amphibole grains. The rocks mentioned here commonly contain no feldspar.

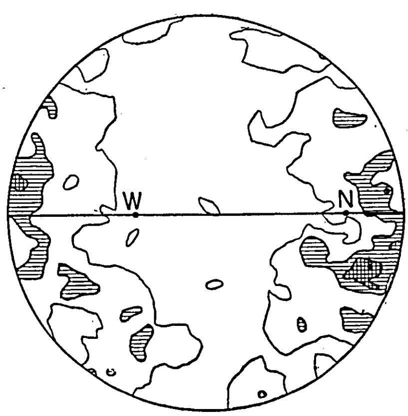
The epidote-amphibole rock is principally composed of green amphibole with subordinate amounts of epidote and chlorite. Frequently, large crystals of epidote are scattered throughout the matrix of amphibole aggregate. The large crystals of epidote are usually elongated along the crystallographic axis b, sometimes attaining to 3 cm in length. Sometimes, clusters of garnet occur sporadically in the epidote amphibole rock. The optical properties of the amphibole and the epidote from a representative specimen are as follows: Amphibole:—the extinction angle ($c \wedge Z$) is about 15°; the optic axial angle (2V) is about 90°; and the pleochroism is weak with X=colourless, Y=Z=pale-green. Epidote:— the optic sign is negative; the optic axial angle (2V) is about 86°; and $c \wedge Z$ is about 3°.

The garnet-amphibole rock consists mainly of garnet and amphibole, with small amounts of chlorite and epidote. The proportion of the above two principal minerals is not constant throughout the rock.

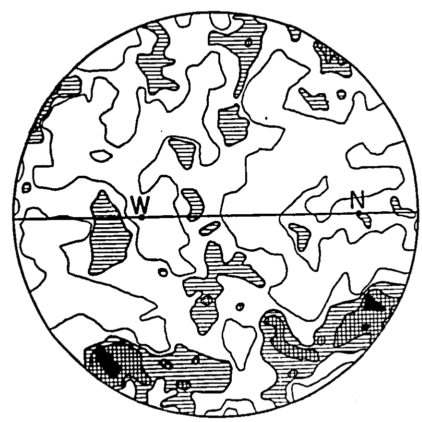
The garnet-amphibole-clinopyroxene rock consists principally of three minerals above named. The proportion of amphibole and clinopyroxene in the rock is not uniform throughout the rock. Pale-green clinopyroxene and pink garnet often become the major constituent, that representing a variety of eclogite. Such eclogite contains usually a little green amphibole. Optical properties of the constituent minerals from a representative specimen of the rock are as follows: Amphibole:—the extinction angle ($c \wedge Z$) is about 16°; the optic sign is positive; the optic axial angle (2V) is about 86°; and in thin section the pleochroism is weak with X=colourless, Y=Z=pale-green. Clinopyroxene:— the extinction angle ($c \wedge Z$) is about 37°; the optic sign is positive; and the optic axial angle (2V) is about 60°.

V. Orientation Patterns of Minerals

The author has carried out microfabric analyses on the preferred orientation of the principal minerals in the Higashi-akaishi-yama peridotite and associated rocks as well as in the Iratsu amphibole schist. For each of the minerals, the orientation of crystal grains was determined by measuring the directions of optic elasticity axes X, Y, and Z of each grain on the oriented thin section. The measurements were plotted after the method of equal-area-projection on the lower hemisphere of Schmidt-net. In most cases, 200 grains were measured for each mineral in a thin section. Then, contoured microfabric diagrams for X-, Y-, and Z-axes of each mineral were made. The microfabric diagrams are shown in figs. 4~33. Megascopic and microscopic characteristics of rock specimens to which these diagrams are referred will be noted briefly in the following pages. N, E, S, and W in the diagrams represent the geographical directions of north, east, south, and west respectively. The interpretation of microfabric patterns will be attempted in the following chapters.



a



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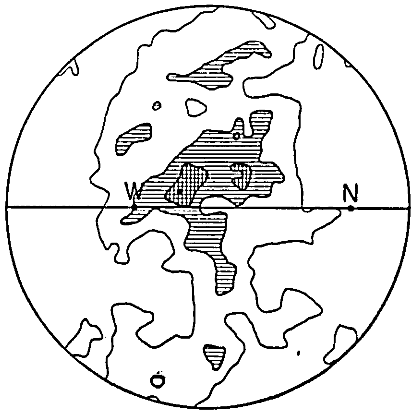


c

Fig. 4. Orientation diagrams for X-, Y-, and Z-axes of 200 amphibole grains in Specimen GY 57 X 28-5.

a. Orientation of X. Contours 1-3-5-7% per 1% area.
b. Orientation of Y. Contours 1-2-3-4% per 1% area.
c. Orientation of Z. Contours 1-3-5-7% per 1% area.

A. ORIENTATION PATTERNS OF AMPHIBOLE AND EPIDOTE IN THE IRATSU AMPHIBOLE SCHIST

Specimen 1: GY 57 X 28-5.

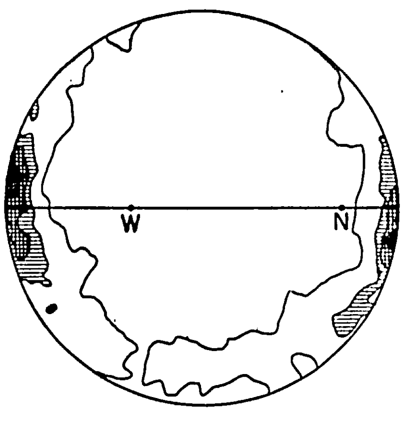
Rock name: Amphibole schist containing garnet porphyroblasts.

Locality: No. 1 in fig. 3.

Banded structure is indistinct. The lineation on the specimen is distinct, plunging at about 20° to S. S. E.

Thin section number: GY 57 X 28-5.

The section was made perpendicular to the geographical horizontal plane. The orientation diagrams for X, Y, and Z, based on the measurements of 200 amphibole grains and 200 epidote grains, are shown in figs. 4 a, 4 b, 4 c, 5 a, 5 b, and 5 c.



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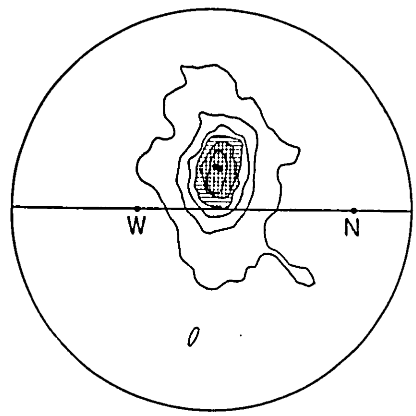

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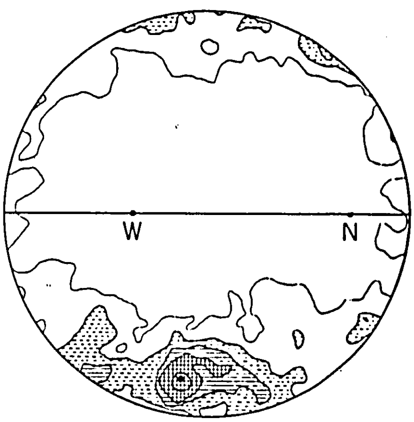


c

FIG. 5. Orientation diagrams for X, Y, and Z of 200 epidote grains is Specimen GY 57 X 28-5.

a. Orientation of X. Contours 1-5-10-15-17 % per 1% area.
b. Orientation of Y. Contours 1-5-10-15-20-25-28% per 1% area.
c. Orientation of Z. Contours 1-3-5-7-10-12 % per 1% area.

Specimen 2: GY 58 VIII 28-1.

Rock name: Amphibole schist containing garnet porphyroblasts.

Locality: No. 2 in fig. 3.

In the rock are developed alternating layers of different mineral proportions, with the strike of N. 40° W. and the dip of 50° N.E. Frequently, the alternating layers are folded on a small scale.

Thin section number: GY 58 VIII 28-1.

The section was made parallel to the geographical horizontal plane. The orientation diagrams for X, Y, and Z, based on the measurements of 200 amphibole grains and 200 epidote grains, are shown in figs. 6a, 6b, 6c, 7a, 7b, and 7c.

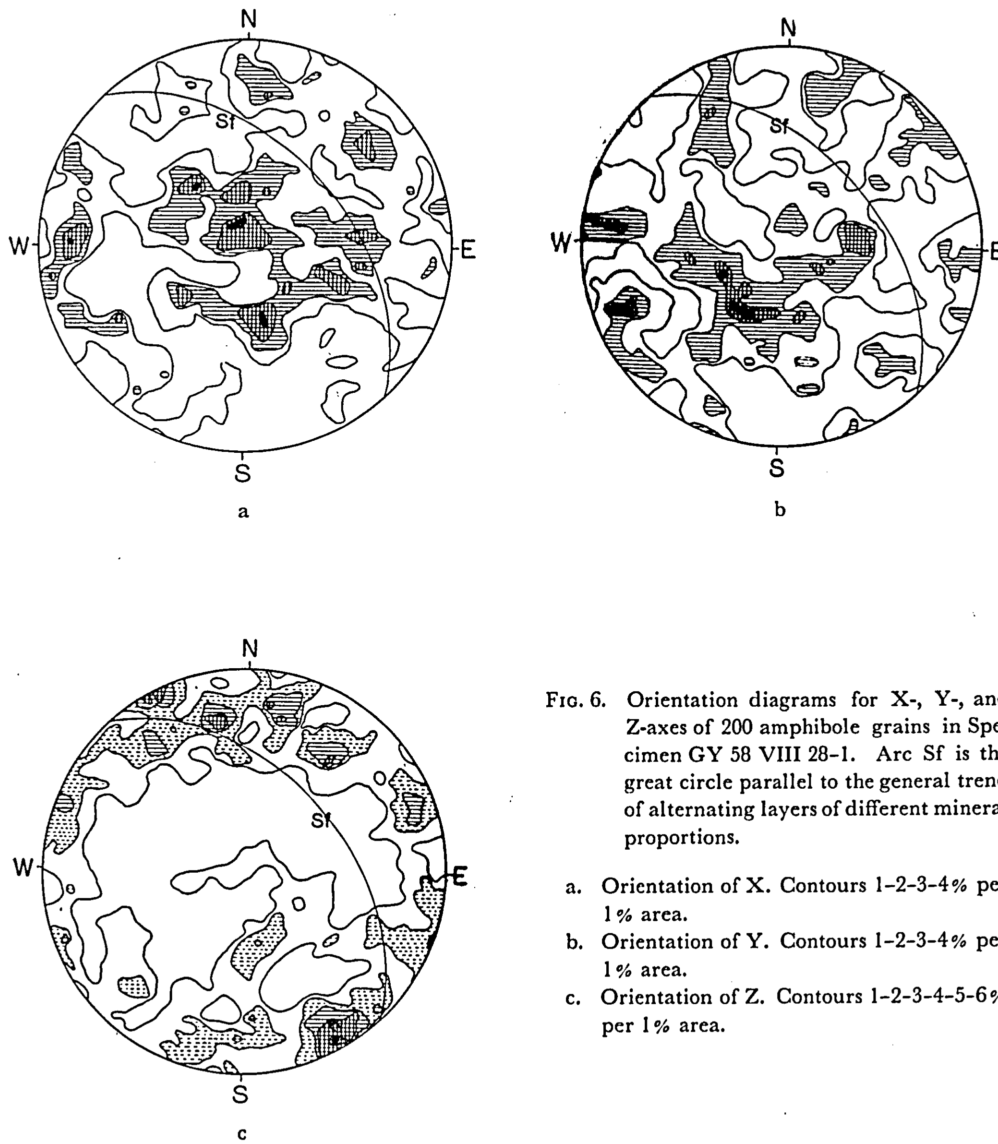
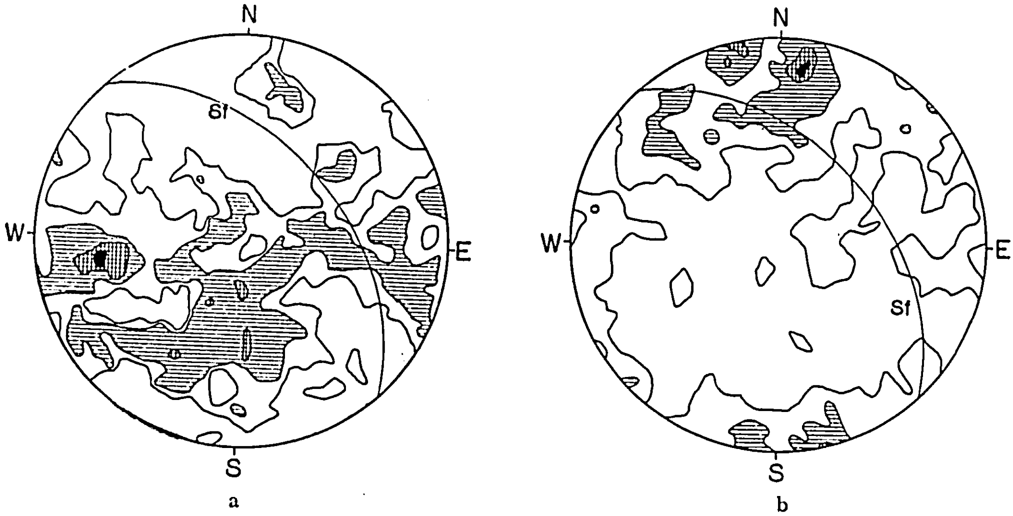


FIG. 6. Orientation diagrams for X-, Y-, and Z-axes of 200 amphibole grains in Specimen GY 58 VIII 28-1. Arc Sf is the great circle parallel to the general trend of alternating layers of different mineral proportions.

a. Orientation of X. Contours 1-2-3-4% per 1% area.
b. Orientation of Y. Contours 1-2-3-4% per 1% area.
c. Orientation of Z. Contours 1-2-3-4-5-6% per 1% area.



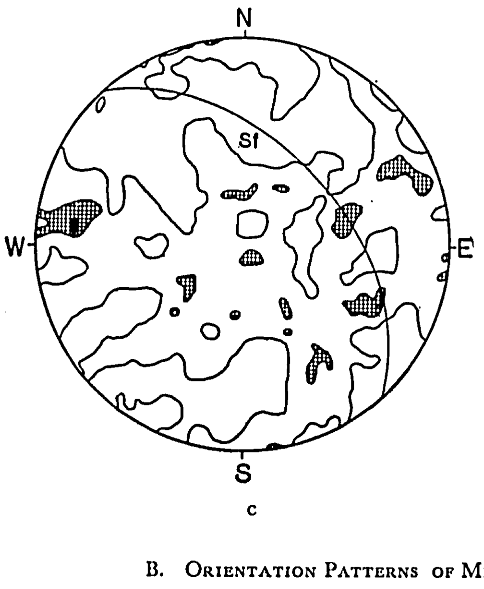


Fig. 7. Orientation diagrams for X, Y, and Z of 200 epidote grains in Specimen GY 58 VIII 28-1. Arc Sf is the great circle parallel to the general trend of alternating layers of different mineral proportions.

a. Orientation of X. Contours 1-2-4-6% per 1% area.
b. Orientation of Y. Contours 1-3-5-7% per 1% area.
c. Orientation of Z. Contours 1-3-5% per 1% area.

B. Orientation Patterns of Minerals in the Higashi-akaishi-yama Peridotite and Associated Eclogitic Rocks

1. *Orientation patterns of olivine in peridotite*

Specimen 3: GY 58 VIII 29-3.

Rock name: Massive dunite with chromite band.

Locality: No. 20 (the Main Adit of the Akaishi Mine) in fig. 3.

At the locality, the rock contains a slightly undulating thick chromite band. The hand specimen consists of the massive dunite and the upper part of the banded chromite ore, as sketched in fig. 8.

Thin section numbers: GY 58 VIII 29-3-A, GY 58 VIII 29-3-B, GY 58 VIII 29-3-C.

Three thin sections (-A, -B, -C), all being perpendicular to the chromite band, were prepared from three parts (A, B, C of fig. 8) of the hand specimen. In parts C, A, and B, olivine grains are equidimensional, showing no lamellar structure.

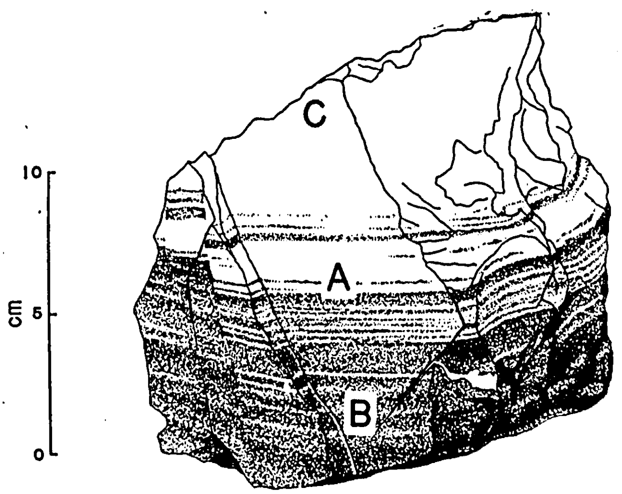


FIG. 8. Sketch showing hand specimen (GY 58 VIII 29-3) of massive dunite, containing banded chromite-ore, from the Main Adit of the Akaishi Mine. Blank portion in the sketch represents massive dunite part composed mainly of olivine-aggregate.

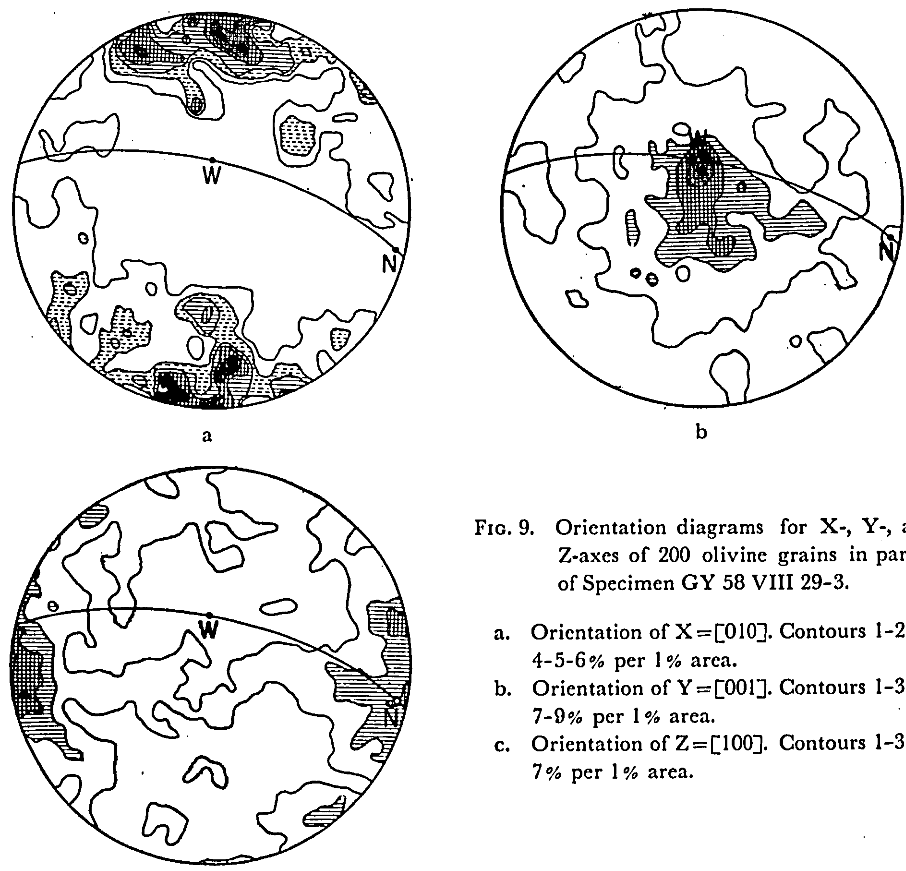
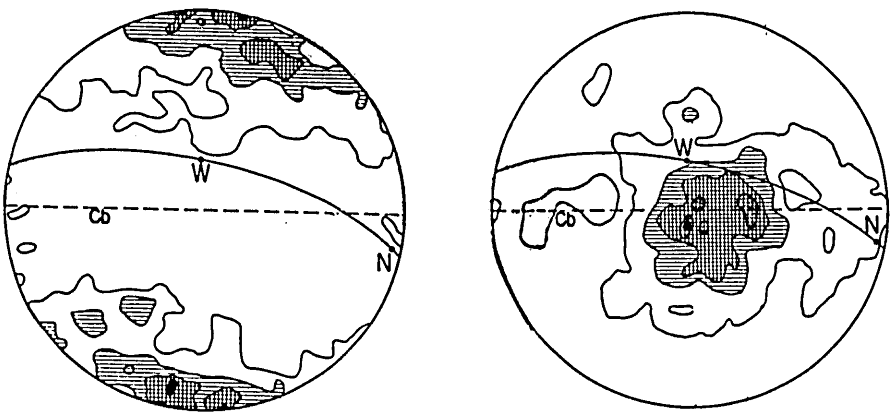


FIG. 9. Orientation diagrams for X-, Y-, and Z-axes of 200 olivine grains in part C of Specimen GY 58 VIII 29-3.

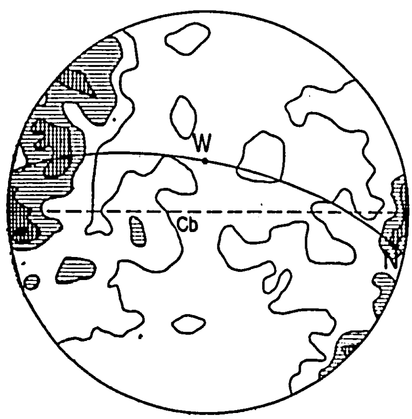
a. Orientation of X=[010]. Contours 1-2-3-4-5-6% per 1% area.
b. Orientation of Y=[001]. Contours 1-3-5-7-9% per 1% area.
c. Orientation of Z=[100]. Contours 1-3-5-7% per 1% area.

In part C, grains of olivine range from 0.05 to 0.7 mm in diameter. Some large grains exhibit undulatory extinction. The orientation diagrams for X-, Y-, and Z-axes of 200 olivine grains in part C are shown in figs. 9a, 9b, and 9c.

In part A, olivine grains range from 0.02 to 0.7 mm in diameter, although grains larger than 0.2 mm are uncommon. Some large grains exhibit undulatory extinction. The orientation diagrams for X-, Y-, and Z-axes of 170 olivine grains in part A are shown in figs. 10a, 10b, and 10c.



a　　　　　　　　b



c

FIG. 10. Orientation diagrams for X-, Y-, and Z-axes of 170 olivine grains in part A of Specimen GY 58 VIII 29-3. Broken line Cb is the plane of chromite band.

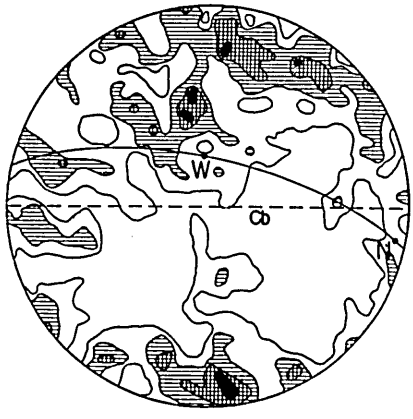
a. Orientation of X=[010]. Contours 1-3-5-7% per 1% area.
b. Orientation of Y=[001]. Contours 1-3-5-7-8% per 1% area.
c. Orientation of Z=[100]. Contours 1-3-5-7% per 1% area.

In part B, the olivine grains filling interstices between chromite grains are smaller than 0.2 mm in diameter. The orientation diagrams for X-, Y-, and Z-axes of 200 olivine grains in part B are shown in figs. 11a, 11b, and 11c.

Specimen 4: GY 58 VIII 20-2.

Rock name: Massive dunite.

Locality: No. 19 (the Main Adit of the Akaishi Mine) in fig. 3, about 2 meters east of No. 20 along the same horizon parallel to the chromite band.



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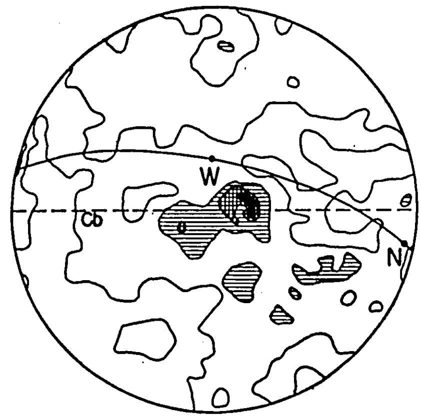

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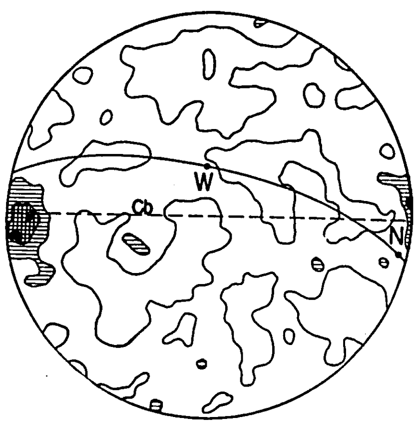

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FIG. 11. Orientation diagrams for X-, Y-, and Z-axes of 200 olivine grains in part B of Specimen GY 58 VIII 29-3. Broken line Cb is the plane of chromite band.

a. Orientation of X=[010]. Contours 1-2-3-4% per 1% area.
b. Orientation of Y=[001]. Contours 1-3-5-6% per 1% aera.
c. Orientation of Z=[100]. Contours 1-3-5-6% per 1% area.

Thin section number: GY 58 VIII 20-2.

The section was made parallel to the geographical horizontal plane. In the rock, large grains ot olivine are set in an fine-grained aggregate of the same mineral. Lamellar structure is absent in these olivine grains. Some large grains exhibit undulatory extinction. Small grains range from 0.05 to 0.3 mm in diameter, and large grains range in diameter from 0.5 to 1.5 mm. The orientation diagrams for X, Y, and Z of 200 olivine grains are shown in figs. 12a, 12b, and 12c.

Specimen 5: GY 58 VIII 20-4.

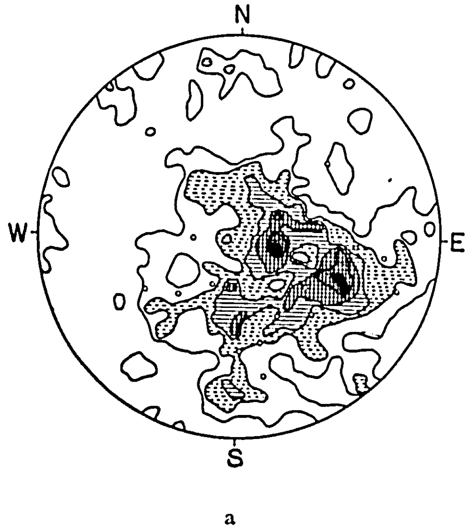
Rock name: Massive dunite.

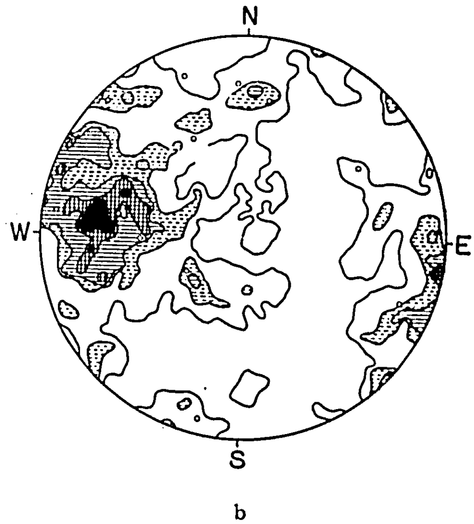
Locality: No. 23 (the Main Adit of the Akaishi Mine) in fig. 3, about 130 meters west of locality 20.

The rock is massive, with subparallel chromite seams.

Thin section number: GY 58 VIII 20-4.

The section was made parallel to the geographical horizontal plane. The rock consists almost entirely of equidimensional grains of olivine which range from 0.1 to 1.0 mm in diameter. In the olivine grains, lamellar structure is absent and undulatory extinction is not observed (plate 41, fig. 1). The orientation diagrams for X, Y, and Z of 200 large grains of olivine are shown in figs. 13a, 13b, and 13c.





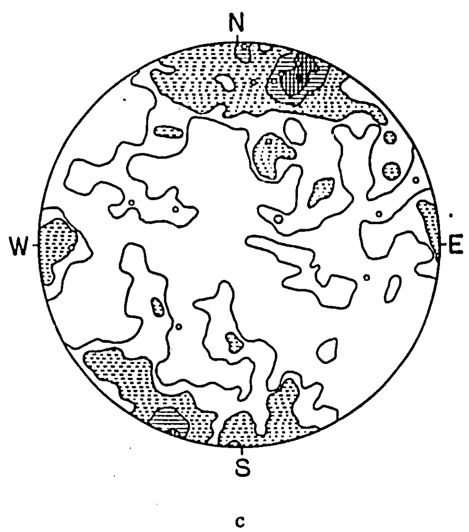
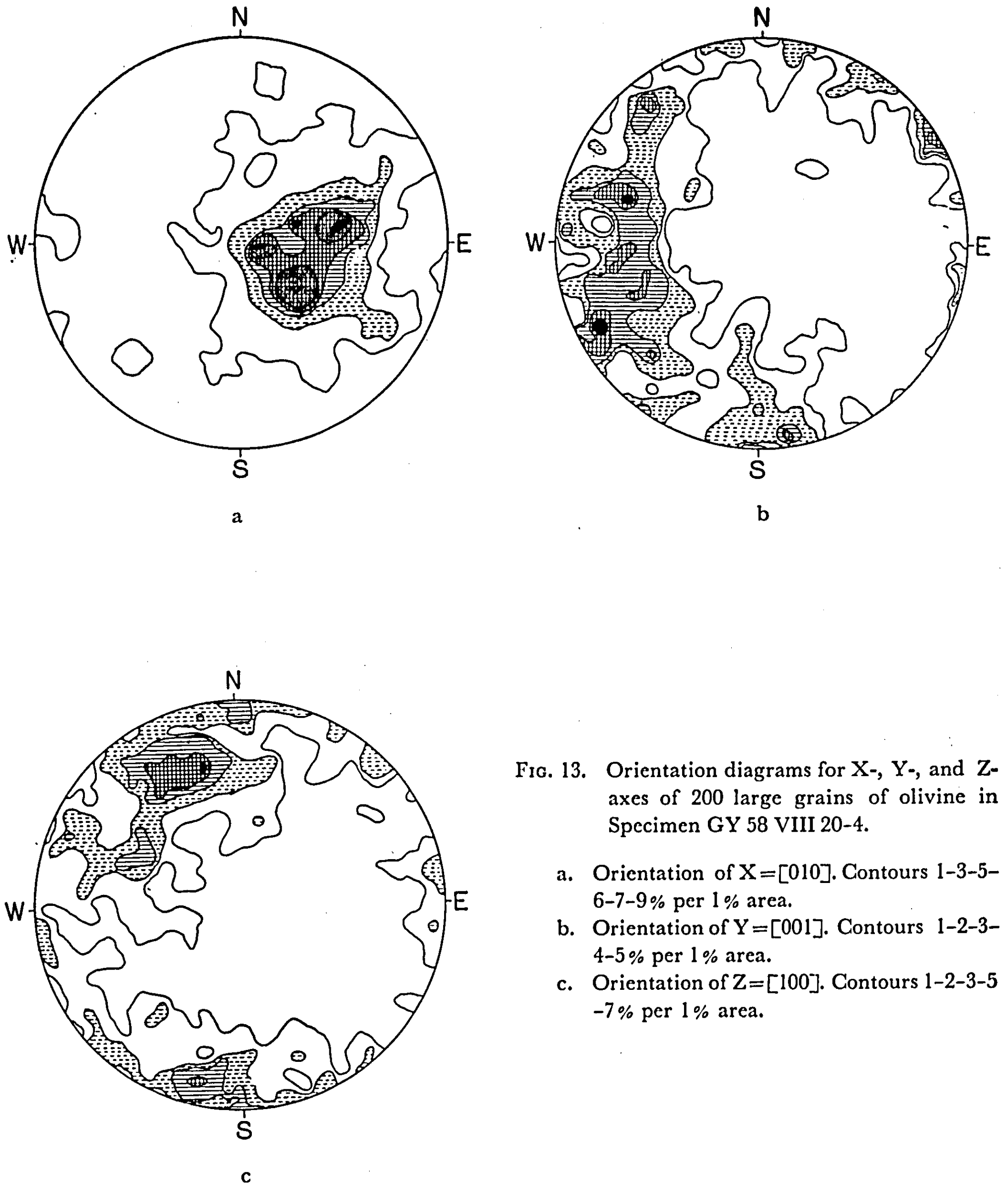


FIG. 12. Orientation diagrams for X, Y, and Z of 200 olivine grains in Specimen GY 58 VIII 20-2. No selection of grains was made. Open circles show the orientations of markedly large grains.

a. Orientation of X=[010]. Contours 1-2-3-4-5-6% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4-5% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-4-6-8% per 1% area.

Specimen 6: GY 57 X 22-3.
Rock name: Massive dunite.
Locality: No. 17 in fig. 3, about 250 meters east of the Motoyama cableway station of the Akaishi Mine. The rock at the locality has subparallel cracks which dip steeply to the north.
Thin section number: GY 57 X 22-3.

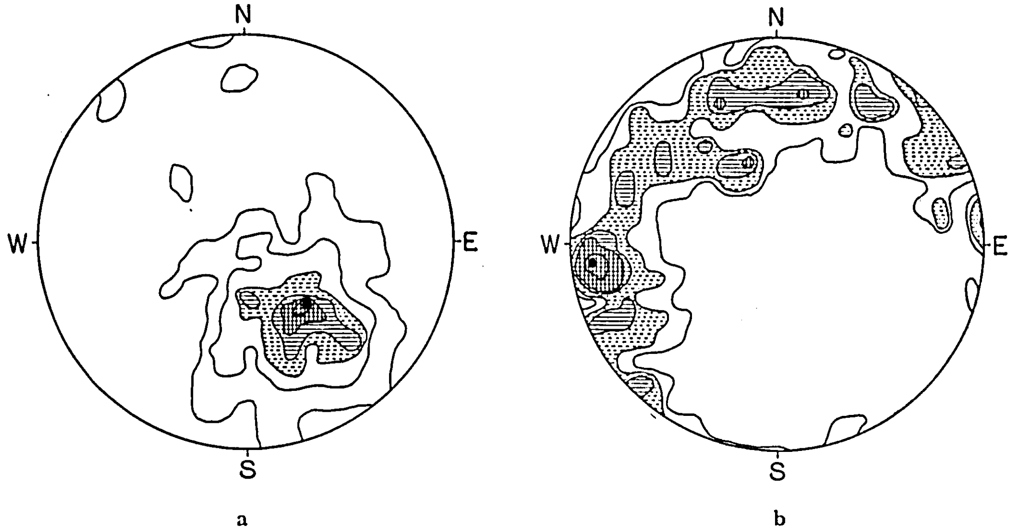
The thin section was made parallel to the geographical horizontal plane. The rock consists of equidimensional grains of olivine which attain to 1.5 mm in maximum diameter. In the olivine grains are developed microscopic intragranular parallel cracks. The orientation diagrams for X, Y, and Z of 200 large grains of olivine are shown in figs. 14a, 14b, and 14c.



a b c

FIG. 13. Orientation diagrams for X-, Y-, and Z-axes of 200 large grains of olivine in Specimen GY 58 VIII 20-4.

a. Orientation of X=[010]. Contours 1-3-5-6-7-9% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4-5% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-5-7% per 1% area.



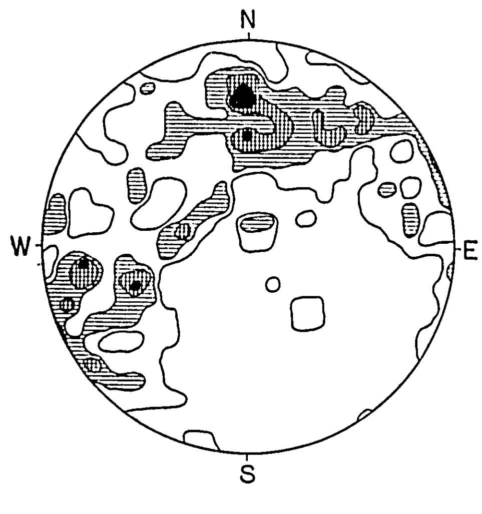


FIG. 14. Orientation diagrams for X, Y, and Z of 200 large grains of olivine in Specimen GY 57 X 22-3.

a. Orientation of X=[010]. Contours 1-3-5-7-9-11-13% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4-6-8% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-4% per 1% area.

Specimen 7: GY 58 VIII 21-4.

Rock name: Massive dunite with chromite band.

Locality: No. 14 (the 6th Adit of the Akaishi Mine) in fig. 3.

The rock at the locality contains a straight chromite band with the strike of N. 65° W. and the dip of about 50° N.E. The hand specimen consists of the massive dunite and the upper part of the banded chromite ore. The sketch of the hand specimen is shown in fig. 15.

Thin section numbers: GY 58 VIII 21-4-P, GY 58 VIII 21-4-Q, GY 58 VIII 21-4-R.

Three thin sections (-P, -Q, -R) were prepared from three parts (P, Q, R of fig. 15) of the hand specimen. Sections GY 58 VIII 21-4-Q and GY 58 VIII 21-4-R were made perpendicular to the chromite band. The

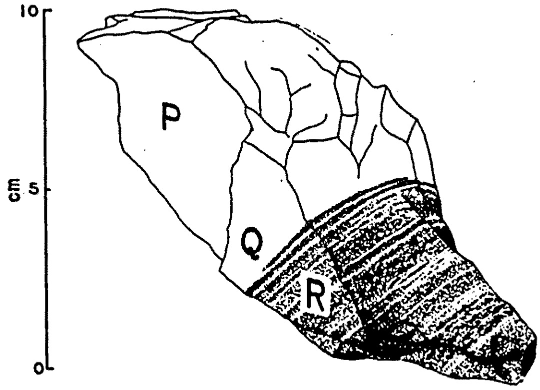


FIG. 15. Sketch showing hand specimen (GY 58 VIII 21-4) of massive dunite, containing banded chromite-ore, from the 6th Adit of the Akaishi Mine. Blank portion in the sketch represents massive dunite part consisting mainly of olivine-aggregate.

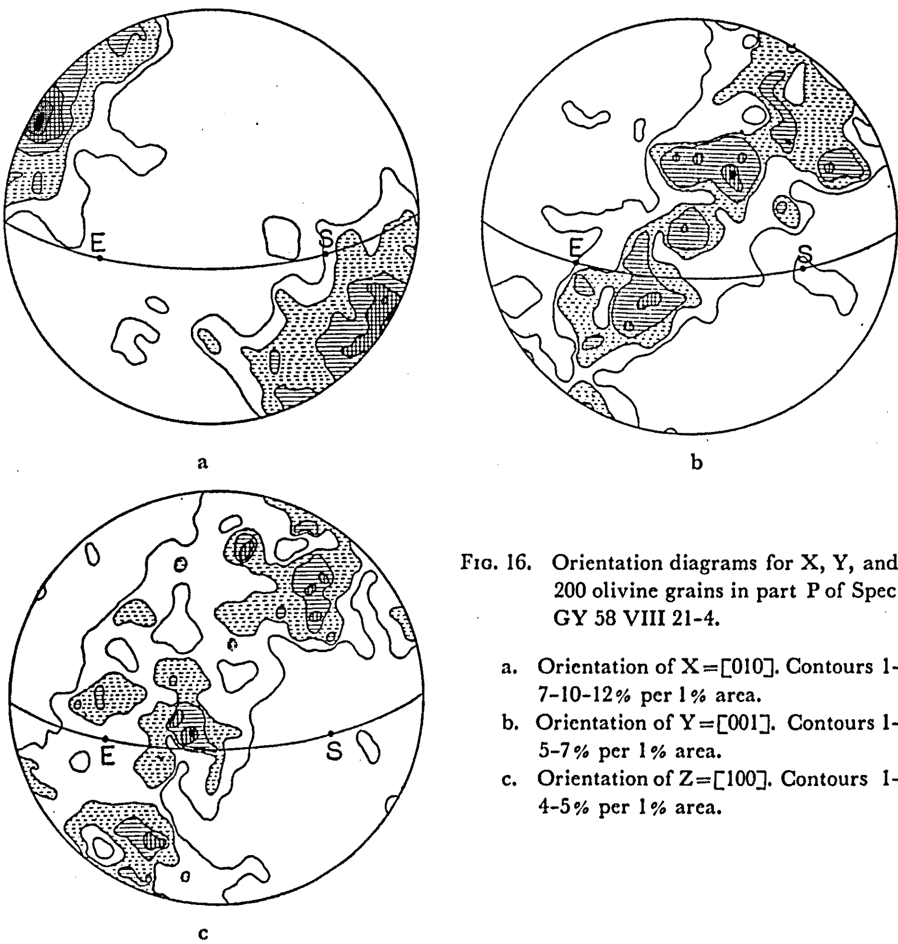


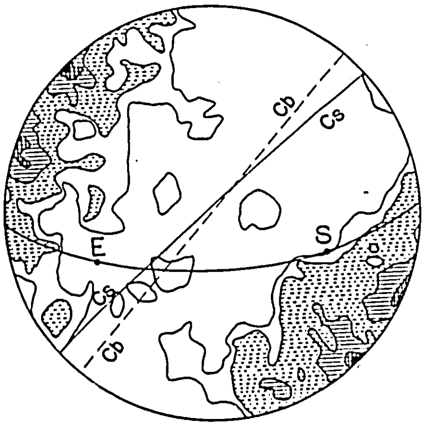
FIG. 16. Orientation diagrams for X, Y, and Z of 200 olivine grains in part P of Specimen GY 58 VIII 21-4.

a. Orientation of X=[010]. Contours 1-2-4-7-10-12% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-5-7% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-4-5% per 1% area.

direction of section GY 58 VIII 21-4-P slightly differs from that of section GY 58 VIII 21-4-Q. In parts P, Q, and R, olivine grains are equidimensional. In these olivine grains, lamellar structure is not found and undulatory extinction is rarely observed.

In part P, grains of olivine range from 0.2 to 1.0 mm in diameter. The orientation diagrams for X-, Y-, and Z-axes of 200 olivine grains in part P are shown in figs. 16a, 16b, and 16c.

In part Q, grains of olivine range from 0.2 to 1.0 mm in diameter. The orientation diagrams for X-, Y-, and Z-axes of 200 olivine grains in part Q are shown in figs 17a, 17b, and 17c.



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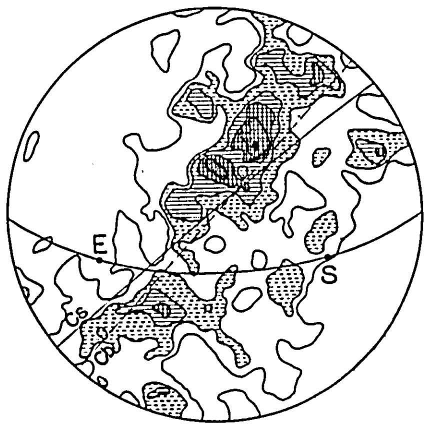

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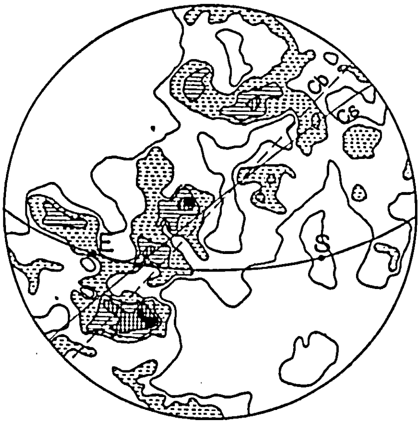
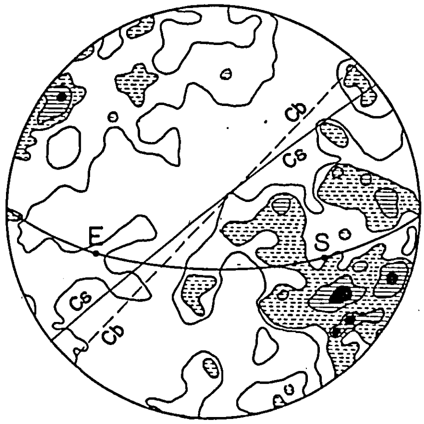


c

Fig. 17. Orientation diagrams for X-, Y-, and Z-axes of 200 olivine grains in part Q of Specimen GY 58 VIII 21-4. Broken line Cb represents the plane of chiomite band, arc Cs represents the plane of alternating component layers in the chromite band.

a. Orientation of X=[010]. Contours 1-2-4-6-7% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4-5-6% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-4-5% per 1% area.

In part R, olivine grains filling interstices between chromite grains are smaller than 0.3 mm in diameter (plate 41, fig. 2). The orientation diagrams for X-, Y-, and Z-axes of 180 olivine grains in part R are shown in figs. 18a, 18b, and 18c.



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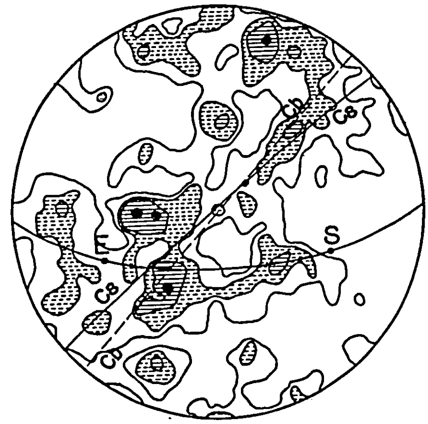

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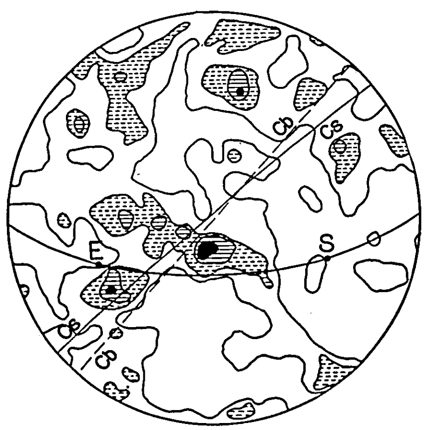

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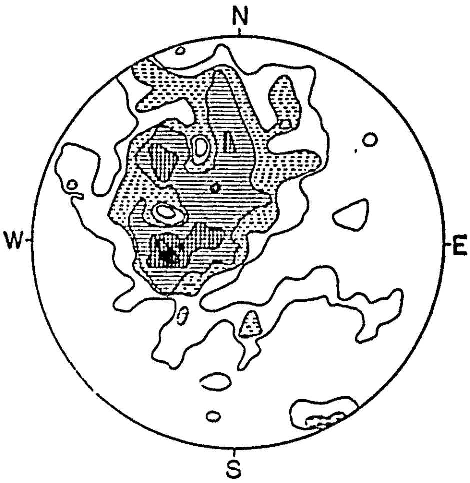
FIG. 18. Orientation diagrams for X, Y, and Z of 180 olivine grains in part R of Specimen GY 58 VIII 21-4. Broken line Cb is the plane of chromite band, arc Cs is the plane of alternating component layers in the chromite band.

a. Orientation of X=[010]. Contours 1-2-3-4% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-4% per 1% area.

Specimen 8: GY 58 VIII 21-1.
Rock name: Massive dunite.
Locality: No. 26 in fig. 3.
Thin section number: GY 58 VIII 21-1.

The thin section was made parallel to the geographical horizontal plane. The rock consists almost exclusively of olivine. The grains are equidimensional, ranging in diameter from 0.05 to 1.0 mm, and rarely attaining as large as 1.5 mm. In these grains lamellar structure is absent and undulatory extinction is not observed (plate 41, fig. 3). Two sets of orientation diagrams of X-, Y-, and Z-axes of olivine grains were prepared; those obtained from the measurements of 200 large grains are shown in figs. 19a, 19b, and 19c, and those of 200 small grains in the same section are shown in figs. 20a, 20b, and 20c.



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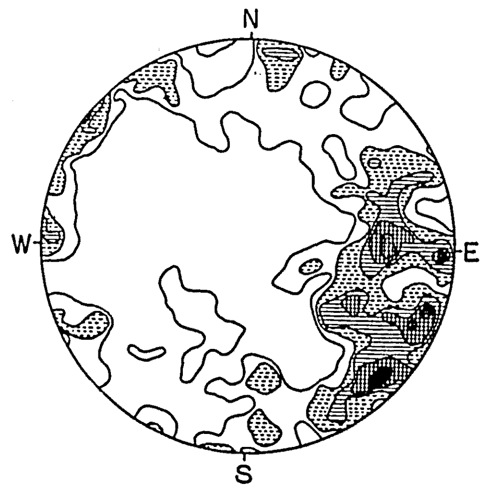

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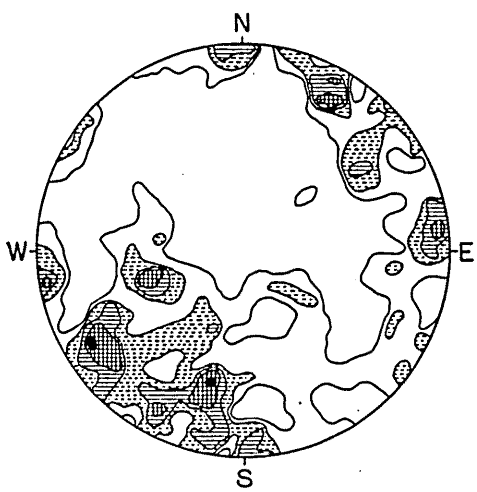


c

Fig. 19. Orientation diagrams for X-, Y-, and Z-axes of 200 large grains of olivine in Specimen GY 58 VIII 21-1.

a. Orientation of X=[010]. Contours 1-2-3-5-7-8% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4-5-6% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-4-5% per 1% area.

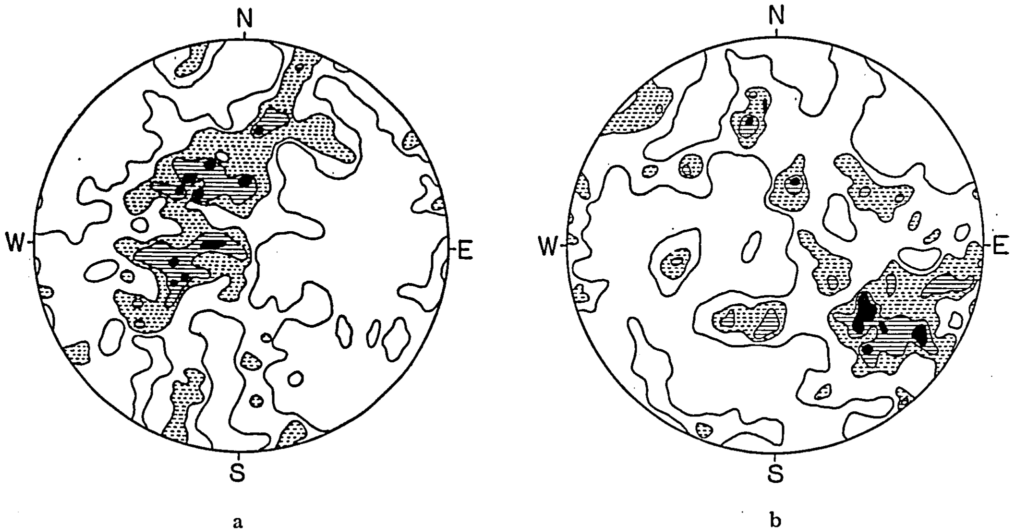
Specimen 9: GY 58 X 9-1.

Rock name: Massive dunite.

Locality: No. 28 in fig. 3.

Thin section number: GY 58 X 9-1.

The thin section was made parallel to the geographical horizontal plane. The rock consists almost



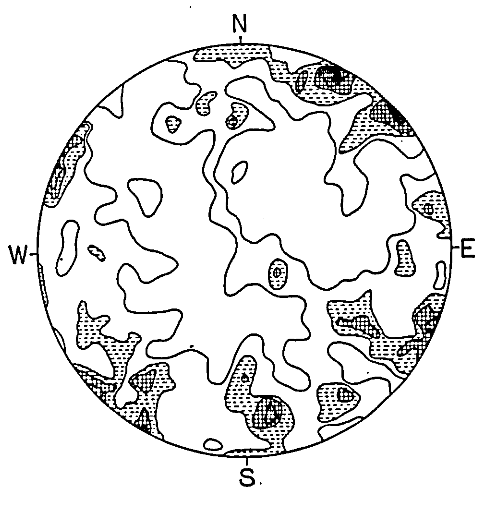
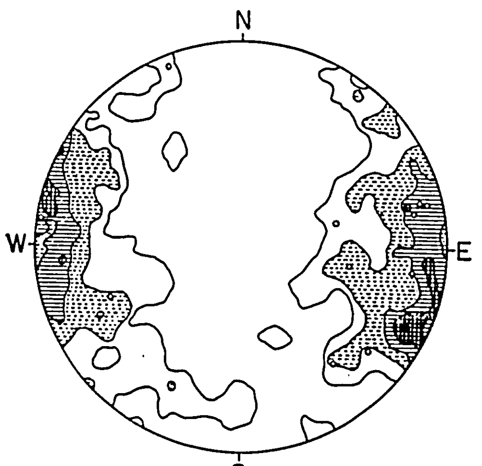


FIG. 20. Orientation diagrams for X-, Y-, and Z-axes of 200 small grains of olivine in Specimen GY 58 VIII 21-1.

a. Orientation of X=[010]. Contours 1-2-3-4% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-4-5% per 1% area.

exclusively of equidimensional grains of olivine which range in diameter from 0.05 to 3.0 mm. The olivine grains rarely exhibit undulatory extinction and lack in lamellar structure (plate 41, fig. 4). The orientation diagrams for X, Y, and Z of 200 large grains of olivine are shown in figs. 21 a, 21 b, and 21 c.

Specimen 10: GY 58 X 7-3.



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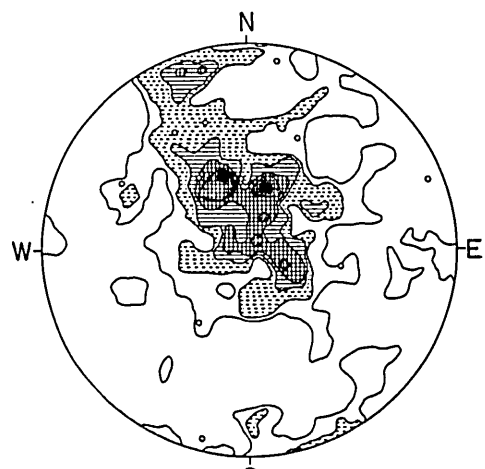

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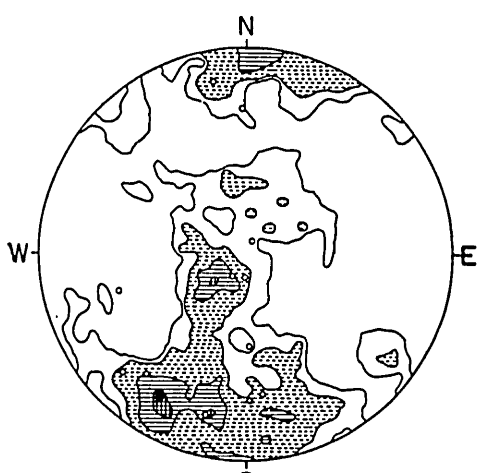


c

FIG. 21. Orientation diagrams for X, Y, and Z of 200 large grains of olivine in Specimen GY 58 X 9-1. Measurements were made on grains larger than 0.3 mm. Open circles show the orientations of markedly large grains of olivine.

a. Orientation of X=[010]. Contours 1-2-4-6-8 % per 1 % area.
b. Orientation of Y=[001]. Contours 1-2-3-4-5-6% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-4-6-8% per 1% area.

Rock name: Massive dunite.
Locality: No. 29 in fig. 3.
Thin section number: GY 58 X 7-3.

The thin section was made parallel to the geographical horizontal plane. Olivine grains in the rock are equidimensional, ranging in diameter from 0.1 to 3.0 mm. The grains rarely show undulatory extinction and lack in lamellar structure. The orientation diagrams for X, Y, and Z of 200 olivine grains are shown in figs. 22a, 22b, and 22c.

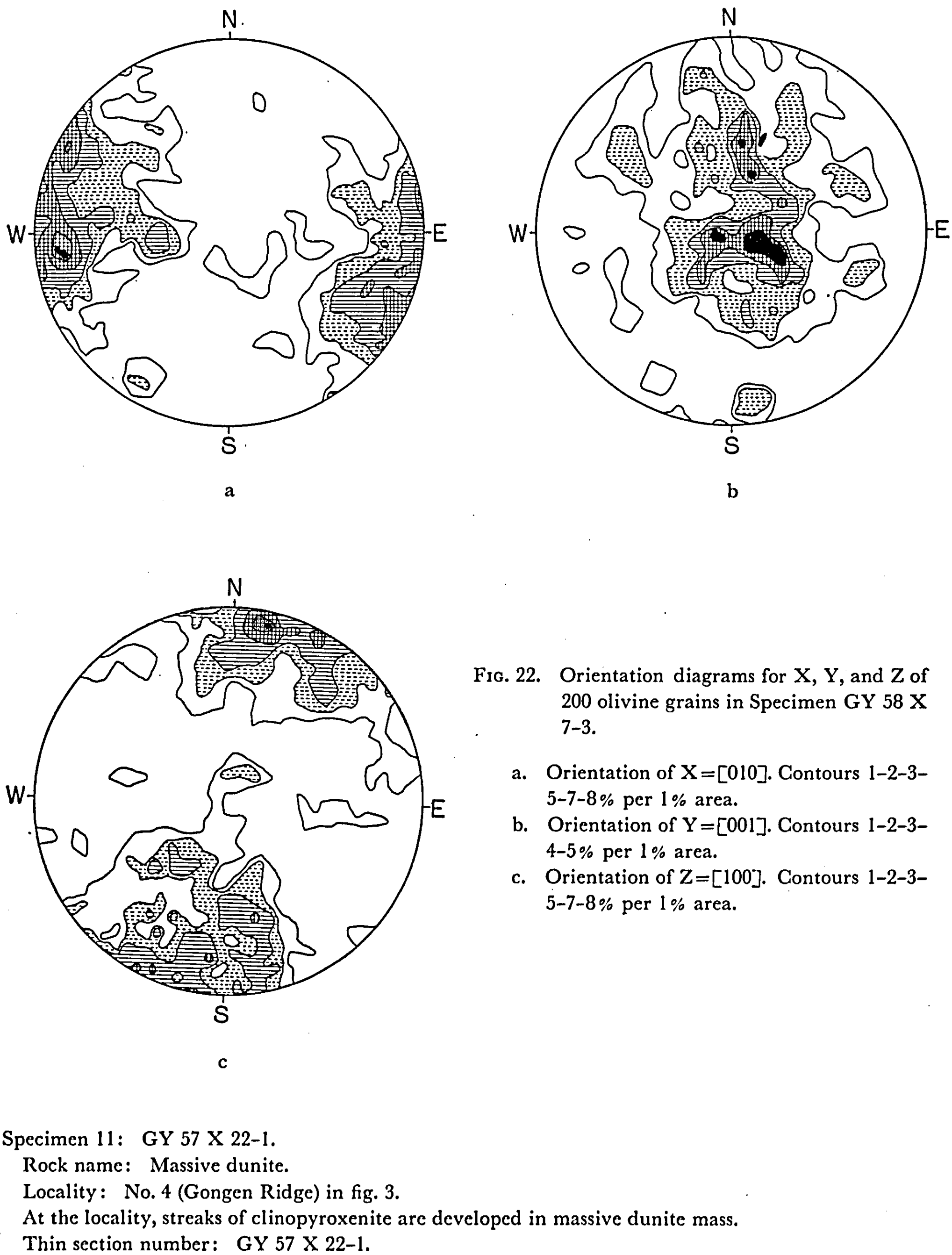
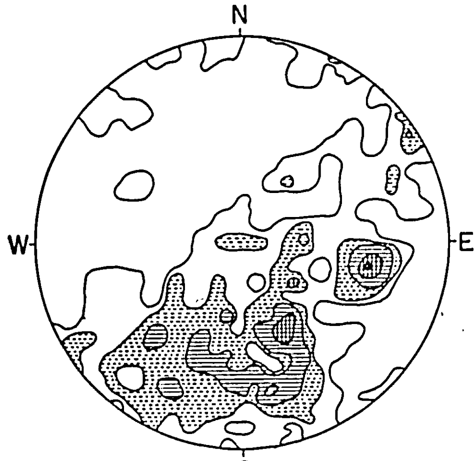


FIG. 22. Orientation diagrams for X, Y, and Z of 200 olivine grains in Specimen GY 58 X 7-3.

a. Orientation of X=[010]. Contours 1-2-3-5-7-8% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4-5% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-5-7-8% per 1% area.

Specimen 11: GY 57 X 22-1.
Rock name: Massive dunite.
Locality: No. 4 (Gongen Ridge) in fig. 3.
At the locality, streaks of clinopyroxenite are developed in massive dunite mass.
Thin section number: GY 57 X 22-1.

The thin section was made parallel to the geographical horizontal plane. Olivine grains in the rock are equidimensional, ranging from 0.2 to 1.0 mm in diameter. Lamellar structure of olivine is absent. Undulatory extinction is observed in some large grains. The orientation diagrams for X, Y, and Z of 200 olivine grains are shown in figs 23a, 23b, and 23c.



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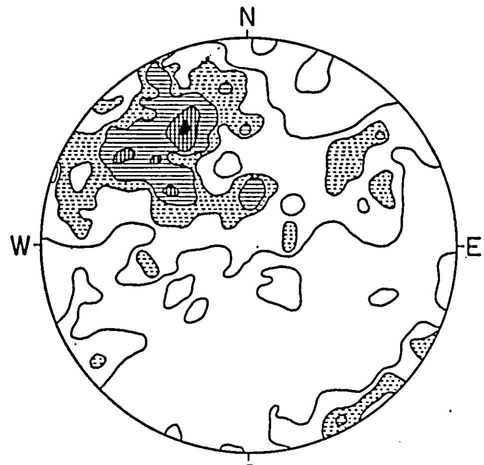

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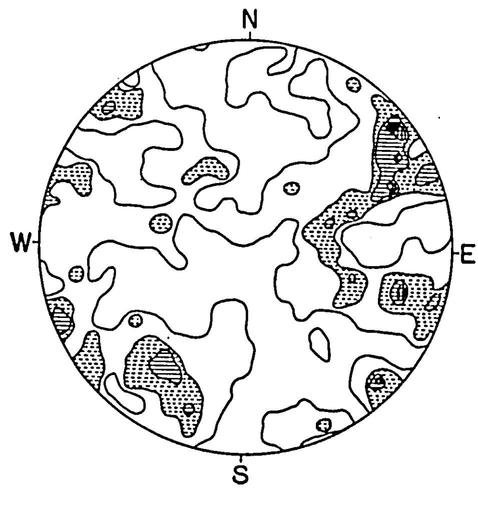


c

FIG. 23. Orientation diagrams for X, Y, and Z of 200 olivine grains in Specimen GY 57 X 22-1.

a. Orientation of X=[010]. Contours 1-2-3-5-7% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-5-7% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-4-5% per 1% area.

Specimen 12: GY 57 X 26-2.
Rock name: Massive dunite.
Locality: No. 6 in fig. 3.

At the locality, streaks and bands of clinopyroxenite and eclogite are developed in massive dunite mass, with the strike of N. 40° E. and the dip of 40° N.W.

Thin section number: GY 57 X 26-2.

The rock consists of equidimensional grains of olivine which rarely show undulatory extinction and lack in lamellar structure. The grains range in diameter from 0.1 to 1.5 mm. The orientation diagrams for X, Y, and Z of 200 large grains of olivine are shown in figs. 24a, 24b, 24c, and 24d.

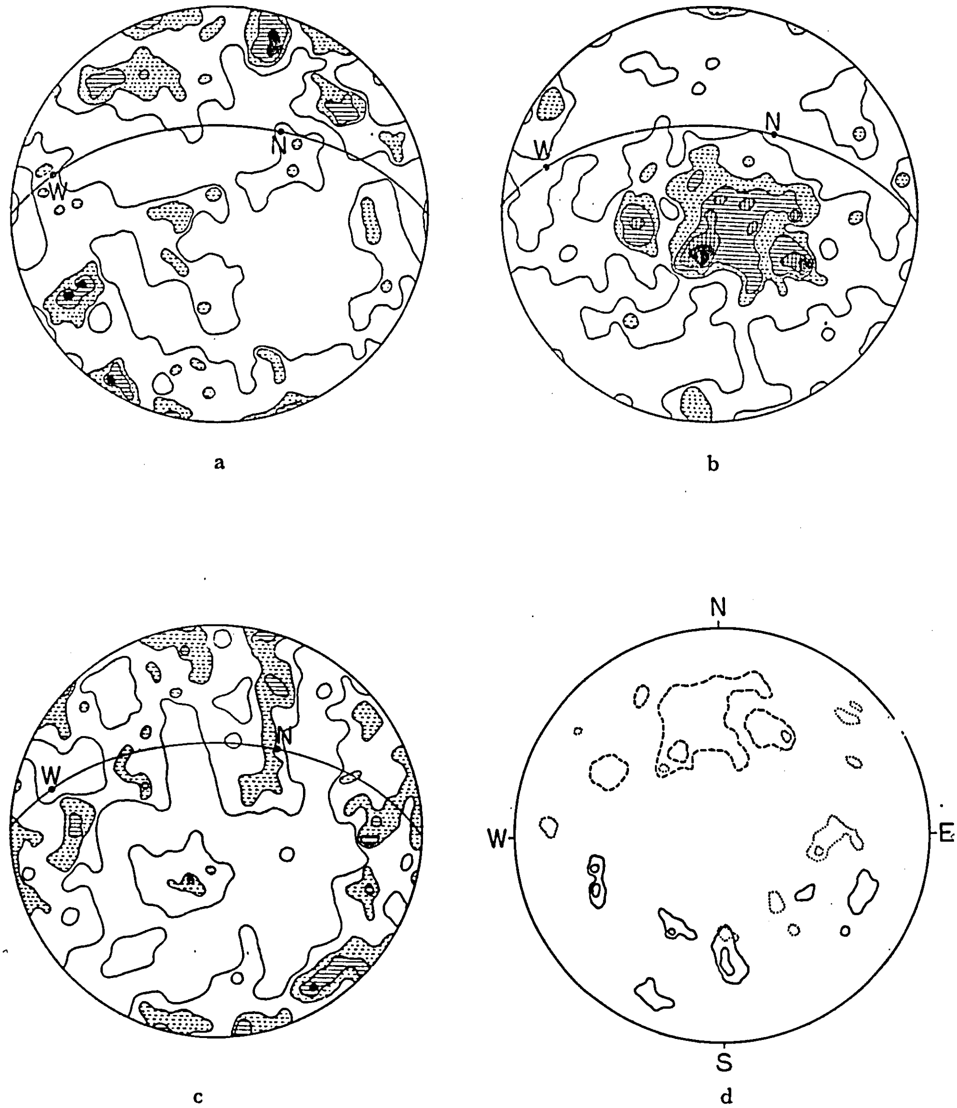


FIG. 24. Orientation diagrams for X, Y, and Z of 200 large grains of olivine in Specimen GY 57 X 26-2.

a. Orientation of X=[010]. Contours 1-2-3-4% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4-5% per 1% area.
c, Orientation of Z=[100]. Contours 1-2-3-4% per 1% area.
d. Collective diagram of X, Y, and Z. The geographical horizontal plane is parallel to the page. Contours: X, 3-4% (full lines); Y, 3-5% (broken lines); Z, 3-4% (dotted lines).

Specimen 13: GY 57 X 23-4.

Rock name: Foliated dunite.

Locality: No. 24 (the summit of the Mt. Higashi-akaishi) in fig. 3.

In the rock, foliation predominates and lineation is indistinct. At the locality, slightly undulating foliation is observed. The foliation of the hand specimen has the strike of N. 60° W. and the dip of 25°~30° N.

Thin section number: GY 57 X 23-4.

The thin section was made perpendicular to both the foliation plane and the geographical horizontal plane. The rock consists of olivine-rich layers and serpentine-rich ones (plate 42, fig. 1). Olivine grains in the rock are equidimensional, ranging from 0.1 to 1.0 mm in diameter. Lamellar structure is not observed. Some large grains show undulatory extinction. The orientation diagrams for X-, Y-, and Z-axes of 200 large grains of olivine are shown in figs. 25a, 25b, and 25c.

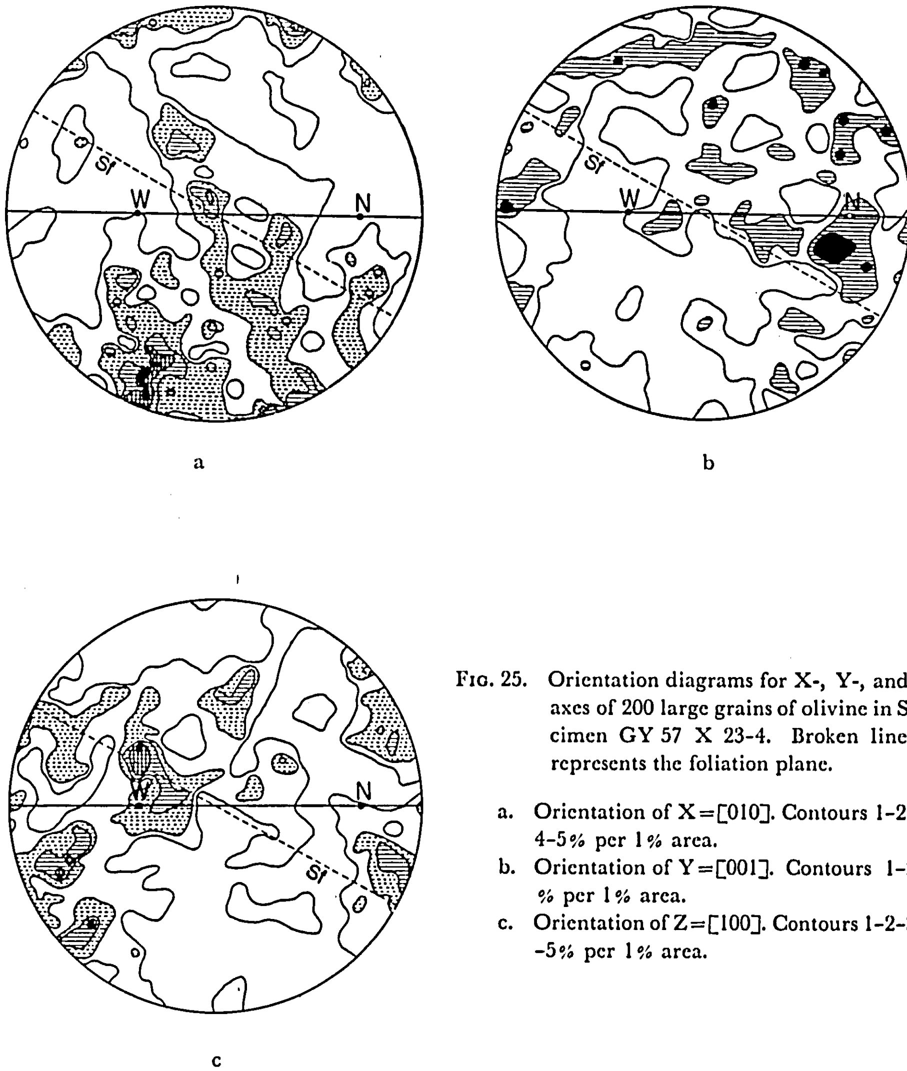


FIG. 25. Orientation diagrams for X-, Y-, and Z-axes of 200 large grains of olivine in Specimen GY 57 X 23-4. Broken line Sf represents the foliation plane.

a. Orientation of X=[010]. Contours 1-2-3-4-5% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3 % per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-4 -5% per 1% area.

Specimen 14: GY 57 X 23-1.

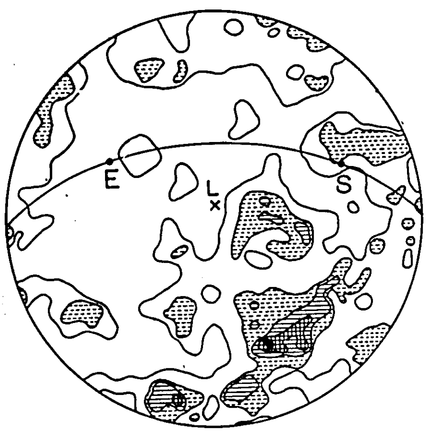
Rock name: Foliated dunite.

Locality: No. 27 in fig. 3.

The rock has distinct lineation due to the parallelism of elongated ellipsoidal clusters of olivine. The lineation on the hand specimen plunges at 25°, S. 50° E.

Thin section number: GY 57 X 23-1.

The thin section was made roughly perpendicular to the lineation. The rock consists of many clusters of olivine. The olivine grains are equidimensional, ranging in diameter from 0.1 to 1.0 mm, and attaining rarely as large as 1.5 mm. Lamellar structure is absent. Some large grains exhibit undulatory extinction. The orientation diagrams for X-, Y-, and Z-axes of 200 large grains of olivine are shown in figs. 26a, 26b, and 26c.



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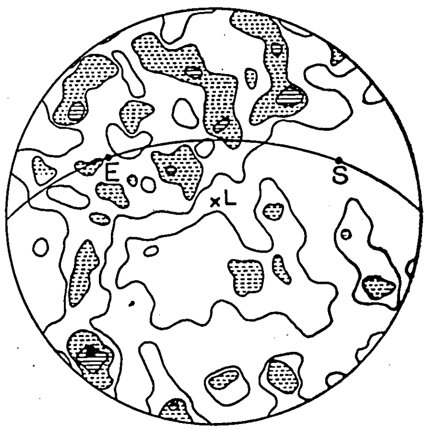
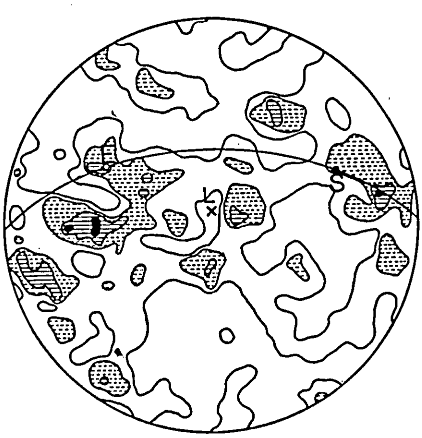


b



c

FIG. 26. Orientation diagrams for X-, Y-, and Z-axes of 200 large grains of olivine in specimen GY 57 X 23-1. L represents the trend of lineation.

a. Orientation of X=[010]. Contours 1-2-3-4-5% per 1% area.
b. Orientation of Y=[001]. Contours 1-2-3-4% per 1% area.
c. Orientation of Z=[100]. Contours 1-2-3-4% per 1% area.

Specimen 15: GY 58 VIII 27-2-B.

Rock name: Mylonite of clinopyroxene-bearing peridotite.

Locality: No. 12 in fig. 3.

The rock has a laminated fabric. Slip cleavage has the strike of N. 60° W. and the dip of 45° N.E. In the specimen large crystals of black clinopyroxene occur sporadically.

Thin section number: GY 58 VIII 27-2-B.

The thin section was made parallel to the geographical horizontal plane. Less-crushed grains of olivine and clinopyroxene are set in a granulated matrix consisting of olivine and clinopyroxene smaller than 0.1 mm in diameter. The porphyroclasts of olivine range from 0.3 to 1.0 mm in diameter. In these olivine grains, lamellar structure is not found and undulatory extinction is rarely observed. The orientation diagrams for X-, Y-, and Z-axes of 200 large grains of olivine are shown in figs. 27a, 27b, and 27c.

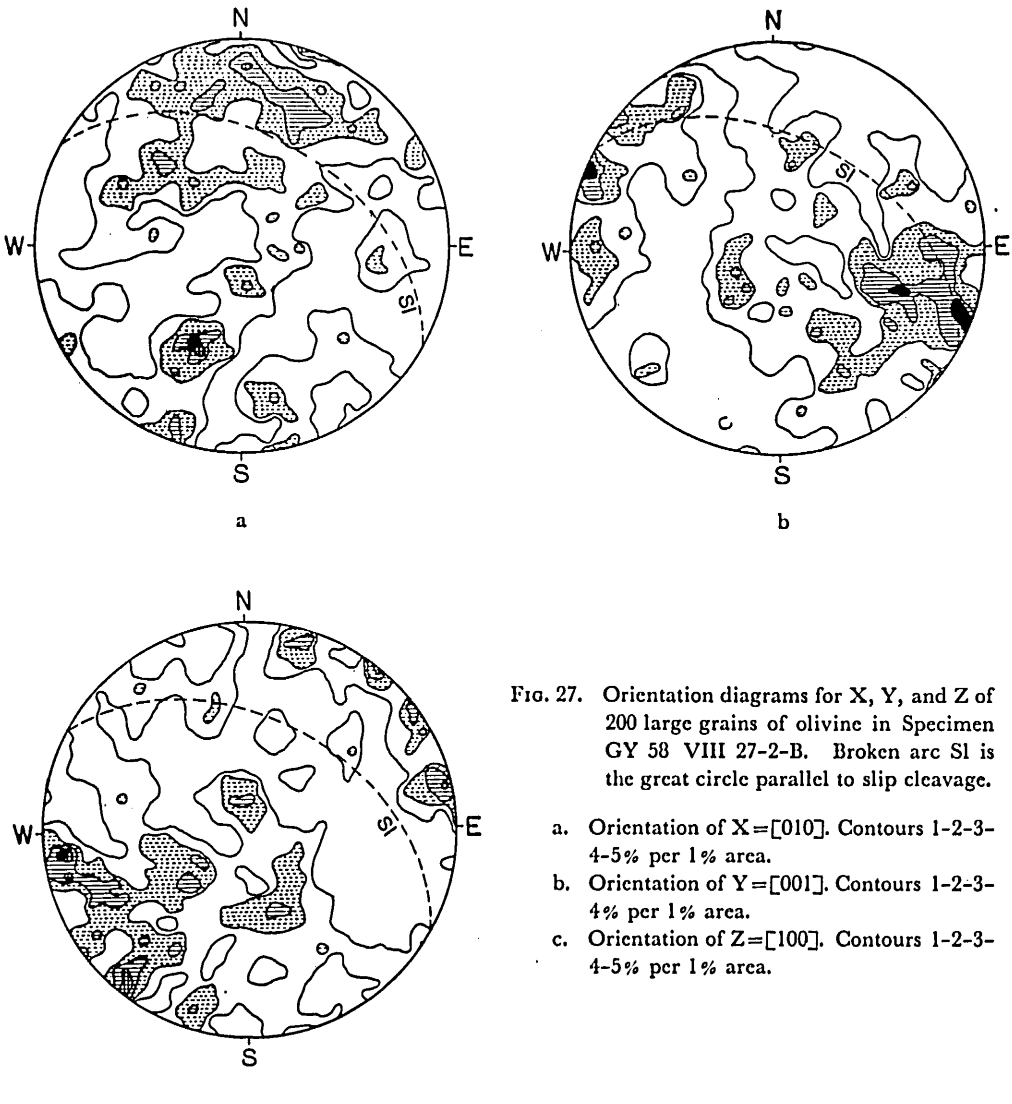


FIG. 27. Orientation diagrams for X, Y, and Z of 200 large grains of olivine in Specimen GY 58 VIII 27-2-B. Broken arc Sl is the great circle parallel to slip cleavage.

a. Orientation of X=[010]. Contours 1-2-3-4-5% per 1% area.

b. Orientation of Y=[001]. Contours 1-2-3-4% per 1% area.

c. Orientation of Z=[100]. Contours 1-2-3-4-5% per 1% area.

2. *Orientation patterns of clinopyroxene in peridotite*

Specimen 16: GY 59 VIII 18-5.

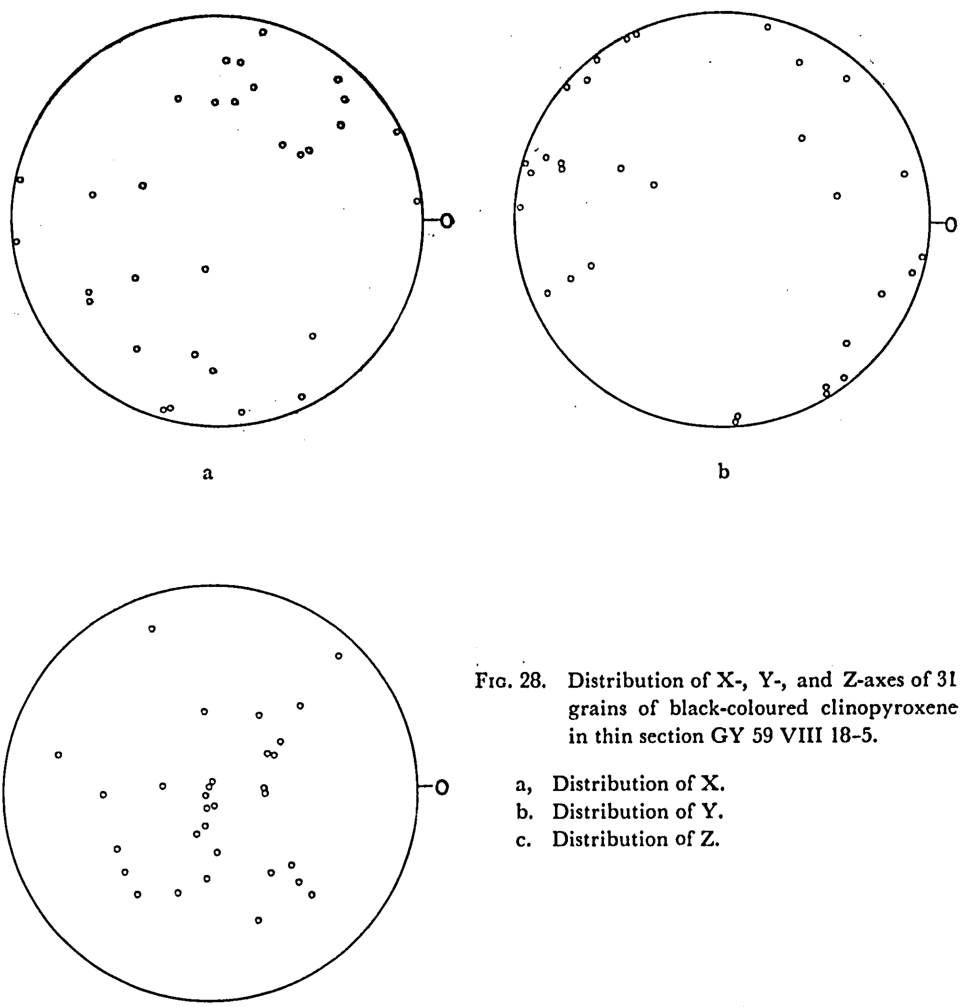
Rock name: Clinopyroxene-bearing peridotite.

Locality: No. 9 in fig. 3.

Throughout the specimen large grains of black clinopyroxene are scattered.

Thin section number: GY 59 VIII 18-5.

The rock consists mostly of black clinopyroxene and olivine, with small amounts of green clinopyroxene, garnet, and opaque mineral. Serpentine and amphibole are also contained a little. The grain diameter of black clinopyroxene is 2 to 3 mm on the average, attaining to 5.0 mm in maximum (plate 42, fig. 2). The distribution of X-, Y-, and Z-axes of 31 grains of black clinopyroxene are shown in figs. 28a, 28b, and 28c.



a b c

Fig. 28. Distribution of X-, Y-, and Z-axes of 31 grains of black-coloured clinopyroxene in thin section GY 59 VIII 18-5.

a, Distribution of X.
b. Distribution of Y.
c. Distribution of Z.

3. *Orientation patterns of clinopyroxene in eclogitic rocks*

Specimen 17: GY 58 VIII 26-3.

Rock name: Massive dunite with eclogite streaks.

Locality: No. 8 in fig. 3.

In the specimen eclogite streaks, 1 to 5 mm thick with the interval of 1 to 10 mm, run subparallel to chromite seams, which have the strike of N. 80° W. and the dip of 65° N. (fig. 29). Along the streaks are developed rounded swellings.

Thin section number: GY 58 VIII 26-3.

The thin section was made parallel to the geographical horizontal plane. Grains of clinopyroxene in the eclogite streaks range from 0.05 to 0.7 mm in diameter (plate 42, fig. 3). Orientation diagrams for X, Y, and Z of 150 clinopyroxene grains in the eclogite streaks are shown in figs. 30a, 30b, and 30c.

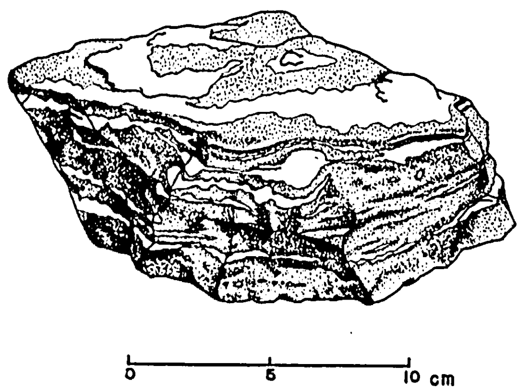
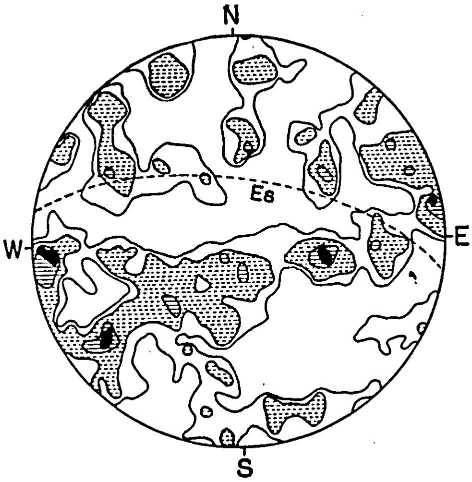
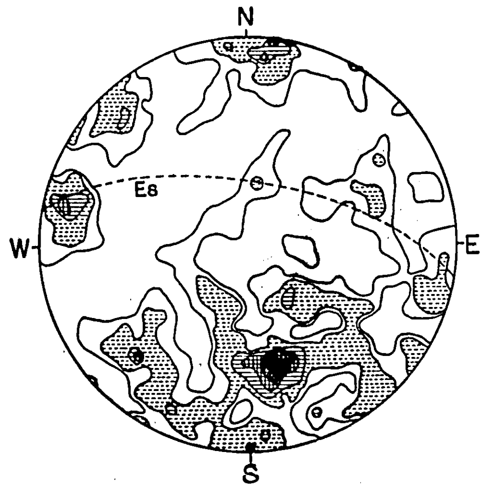


FIG. 29. Sketch showing hand specimen GY 58 VIII 26-3. Chromite-seams in massive dunite part are omitted. Stippled: massive dunite, blank: eclogite.



a



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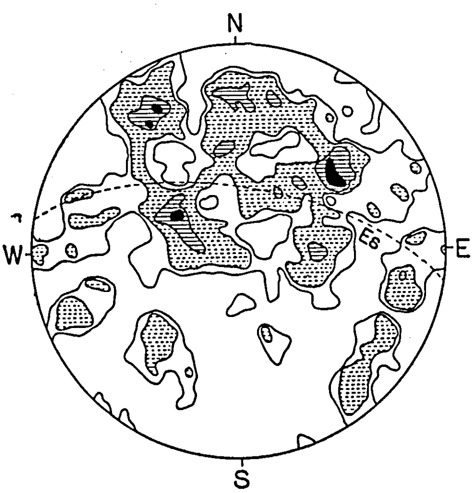


c

FIG. 30. Orientation diagrams for X-, Y-, and Z-axes of 150 clinopyroxene grains in the eclogite-streaks of Specimen GY 58 VIII 26-3. Broken line Es represents the plane parallel to eclogite-streaks.

a. Orientation of X. Contours 1-2-3-4% per 1% area.
b. Orientation of Y. Contours 1-2-3-4-5-6% per 1% area.
c. Orientation of Z. Contours 1-2-3-4% per 1% area.

Specimen 18: GY 57 X 24-3.
Rock name: Eclogite.
Locality: No. 5 in fig. 3.
The rock occurs as a band having a thickness of about 3 cm in massive dunite. The band has the strike of N. 60° E. and the dip of 35° N.W.
Thin section number: GY 57 X 24-3.
The thin section was made perpendicular to the band. The grains of clinopyroxene in the specimen range from 0.1 to 0.7 mm. Orientation diagrams for X-, Y-, and Z-axes of 200 clinopyroxene grains are shown in figs. 31 a, 31 b, 31c, and 31 d.

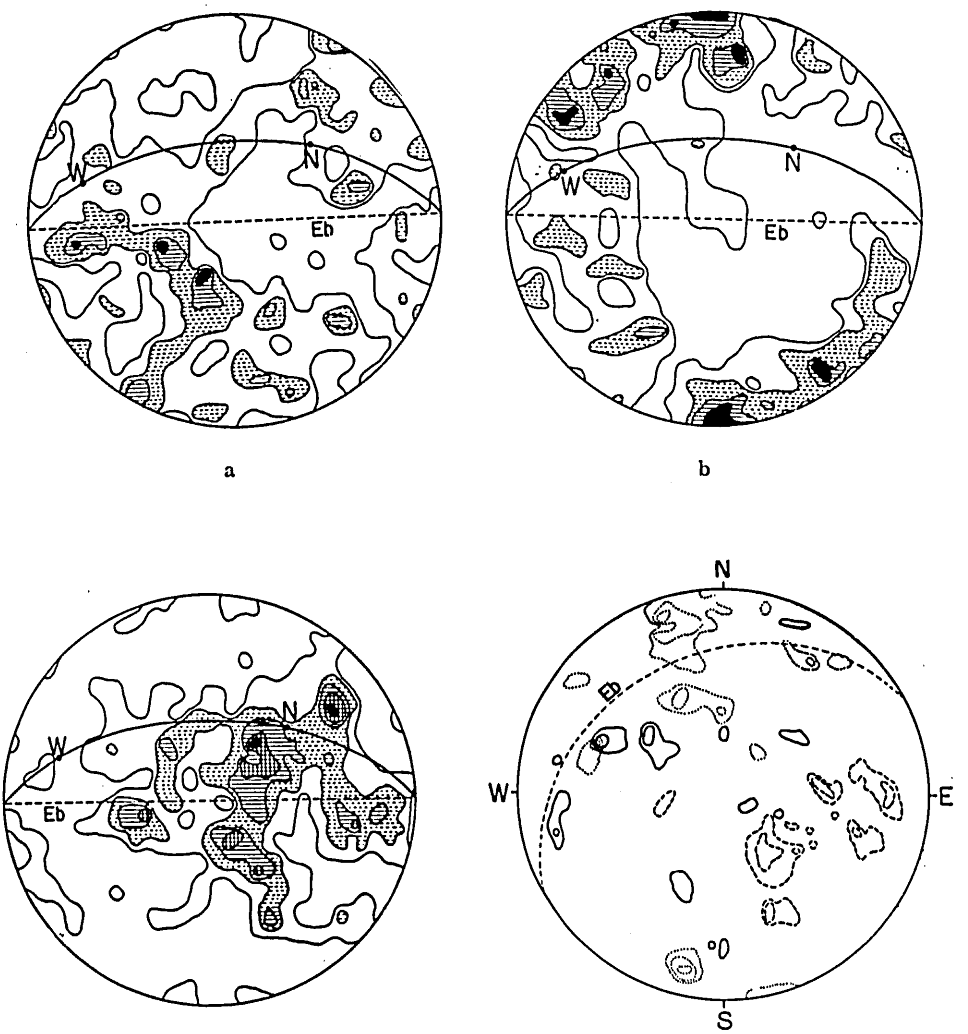


FIG. 31. Orientation diagrams for X-, Y-, and Z-axes of 200 clinopyroxene grains in Specimen GY 57 X 24-3. Broken line Eb represents the plane of eclogite band.

a. Orientation of X. Contours 1-2-3-4% per 1% area.
b. Orientation of Y. Contours 1-2-3-4% per 1% area.
c. Orientation of Z. Contours 1-2-3-4-5% per 1% area.
d. Collective diagram of X, Y, and Z. The geographical horizontal plane is shown parallel to the page. Contours: X, 3-4% (full lines); Y, 3-4% (broken lines); Z, 3-4-5% (dotted lines).

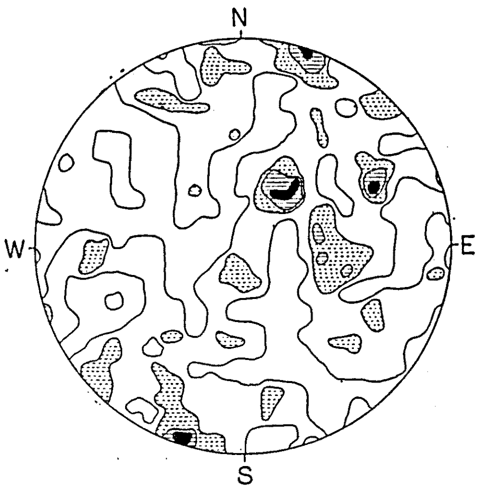
Specimen 19: GY 58 VIII 26-5.
Rock name: Eclogite.

Locality: No. 7 in fig. 3.

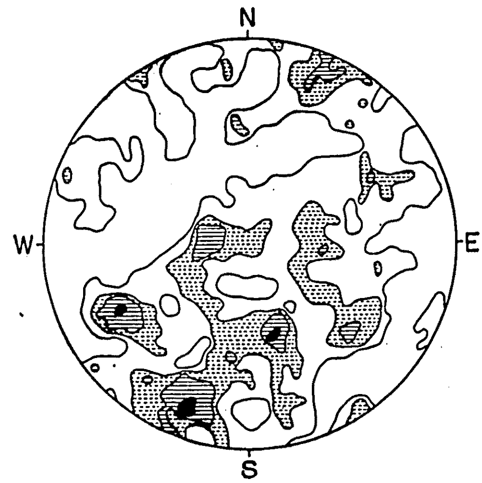
The rock occurs as an isolated large lenticular body in dunite-mylonite. It contains alternating layers of garnet and clinopyroxene of different relative proportions.

Thin section number: GY 58 VIII 26-5.

The thin section parallel to the geographical horizontal plane was prepared. The grains of clinopyroxene in the specimen range from 0.2 to 1.5 mm in diameter (plate 42, fig. 4). The orientation diagrams for X-, Y-, and Z-axes of 200 clinopyroxene grains are shown in figs. 32a, 32b, and 32c.



a



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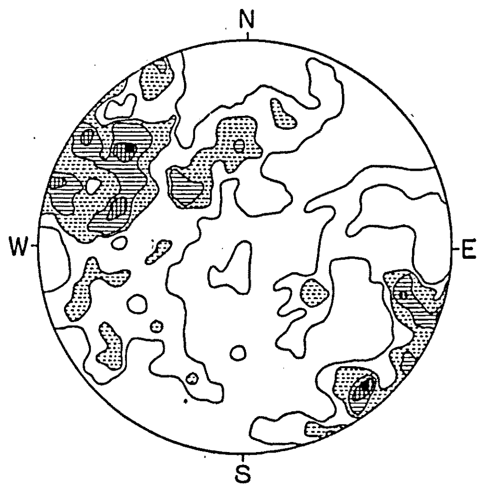


c

Fig. 32. Orientation diagrams for X-, Y-, and Z-axes of 200 clinopyroxene grains in Specimen GY 58 VIII 26-5.

a. Orientation of X. Contours 1-2-3-4% per 1% area.
b. Orientation of Y. Contours 1-2-3-4% per 1% area.
c. Orientation of Z. Contours 1-2-3-4-5% per 1% area.

Specimen 20: GY 54 X 25-A.

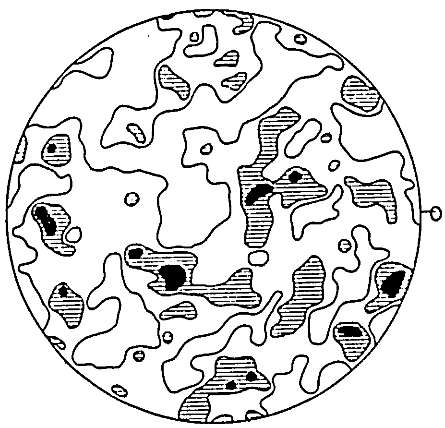
Rock name: Eclogite.

Locality: A boulder at No. 11 in fig. 3.

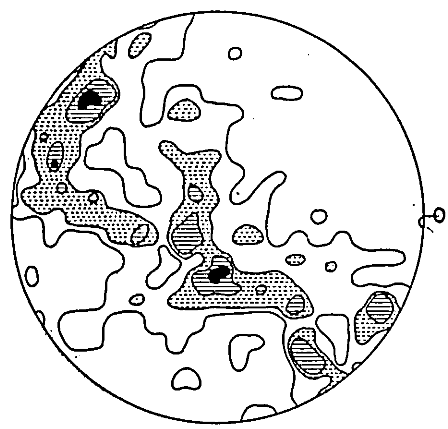
Throughout the specimen, the relative proportion of garnet and clinopyroxene is quite uniform. This is a much more equigranular and homogeneous rock than specimen GY 58 VIII 26-5.

Thin section number: GY 54 X 25-A.

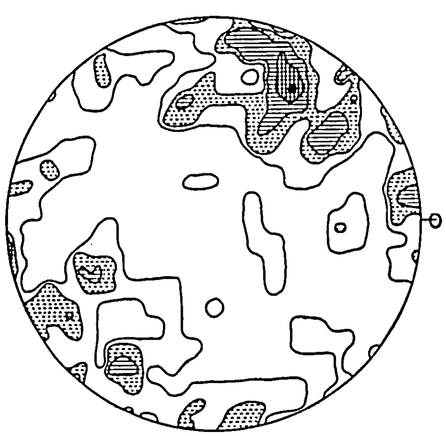
The grains of clinopyroxene in the specimen are 0.2~1.0 mm. The orientation diagrams for X-, Y-, and Z-axes of 200 clinopyroxene grains are shown in figs. 33a, 33b, and 33c.



a



b



c

Fig. 33. Orientation diagrams for X-, Y-, and Z-axes of 200 clinopyroxene grains in thin section GY 54 X 25-A.

a. Orientation of X. Contours 1-2-3% per 1 % area.

b. Orientation of Y. Contours 1-2-3-4% per 1% area.

c. Orientation of Z. Contours 1-2-3-5-8% per 1% area.

VI. Properties of Mineral Orientation

A. Orientation of Amphibole and Epidote in the Iratsu Amphibole Schist

Amphibole and epidote in the Iratsu amphibole schist commonly show remarkable preferred orientation. The amphibole tends to be arranged with the crystallographic axis c parallel to the fabric axis *b*, and the epidote tends to be oriented with the crystallographic axis b parallel to the fabric axis *b*. Further details of mineral orientation in the Iratsu amphibole schist will be given in a separate paper.

B. Mineral Orientation in the Higashi-akaishi-yama Peridotite and Associated Rocks

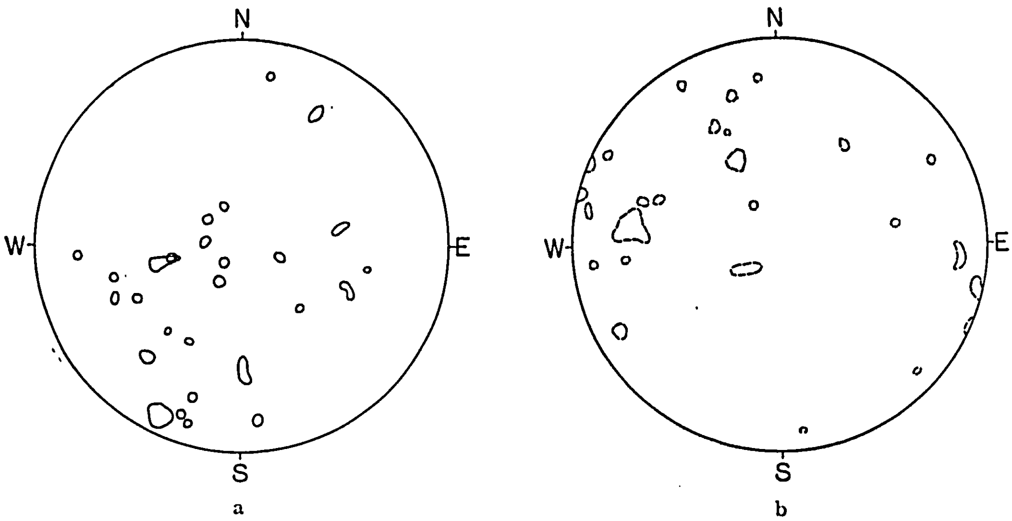
1. *Orientation of olivine*

By examining the equal-area-projection of optic elasticity axes of olivine crystals in the peridotite, the following facts are noticed.

The olivine in the massive dunite commonly shows marked preferred orientation. The Y-axis and the Z-axis of olivine show the tendency to be dispersed in a great circle, and the pole of the great-circle-girdle for Y is almost parallel with that for Z, although the band within which Z is distributed is broader than the band for Y. Within each of the girdles one or more separate maxima commonly occur. The girdle for Y or Z is sometimes incomplete. In most cases, one or more maxima of X occur in one diagram, lying near the pole of the great-circle-girdle for Y. There can be found a tendency for X to spread along one or more great circles which pass through near the pole to great circle girdle for Y or Z. As described in the preceding pages, grains of olivine in the massive dunite are generally equidimensional, irrespective of the grain size. Therefore, the preferred orientation of the olivine is not the type of dimensional orientation, but that of lattice orientation.

In order to examine whether there are any differences in orientation between large grains and small ones of olivine in the massive dunite, two sets of orientation diagrams were prepared for olivine grains of different size in the same thin section of inequigranular massive dunite (figs. 19a, 19b, 19c, 20a, 20b, and 20c). In figs. 12a, 12b, 12c, 21a, 21b, and 21c, the orientation of markedly large grains of olivine is represented by open circles. In general, the degree of preferred orientation is higher in the large grains than in the small grains in the same thin section. Although there are some differences in pattern between their distributions, the pattern for the large grains essentially coincides, with respect to the position of maximum concentration for X, Y, and Z, with that for the small grains in the same thin section.

In the massive dunite mass seams and bands of chromite are often encountered to be developed subparallel to one another. As described in the preceding pages, the thick chromite band consists of an irregular alternation of black and light-green layers. These layers run mostly parallel to the outline of the thick chromite bands, but in some cases they intersect the outline of the thick band at low angles (fig. 15). As shown in figs. 9a, 9b, 9c, 10a, 10b, 10c, 11a, 11b, 11c, 16a, 16b, 16c, 17a, 17b, 17c, 18a, 18b, and 18c, olivine grains in and near the chromite band, no matter whether the grains occur within or outside the chromite band, tend to show essentially identical patterns of preferred orientation, although the degree of preferred orientation of olivine is lower within the chromite band than outside it. The surface represented by the girdles for Y and Z in orientation diagrams for olivine grains in and near the chromite band seems to be roughly parallel to the chromite band. Strictly speaking, however, these girdles are not always parallel either to the chromite band or to the alternating component layers, even when the chromite band extends straight (figs. 17b, 17c, 18b, and 18c).



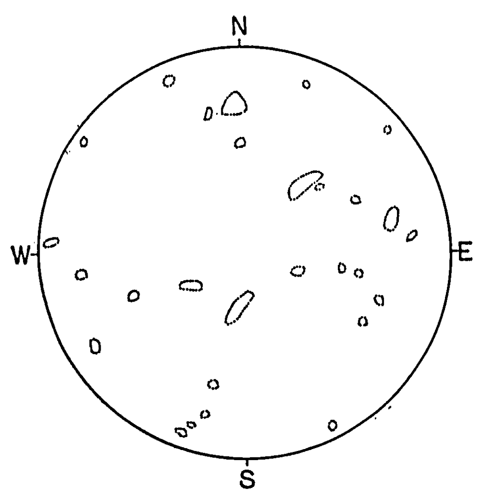


Fig. 34. Collective diagrams with respect to the main maxima for X, Y, and Z of olivine grains from 17 selected specimens of massive dunite.

a. Distribution of main maxima for X.
b. Distribution of main maxima for Y.
c. Distribution of main maxima for Z.

Judging from the fabric diagrams for GY 58 VIII 29-3-C (figs. 9a, 9b, 9c), GY 58 VIII 29-3-A (figs. 10a, 10b, 10c), GY 58 VIII 29-3-B (figs. 11a, 11b, 11c), GY 58 VIII 20-2 (figs. 12a, 12b, 12c), and GY 58 VIII 20–4 (figs. 13a, 13b, 13c), the pattern of preferred orientation of olivine in the massive dunite shows practically identical feature over a distance of about 100 m near the Main Adit of the Akaishi Mine. In order to examine the homogeneity of olivine orientation in the massive dunite body around the Akaishi Mine, collective diagrams with respect to the main maxima for X, Y, and Z of olivine grains were prepared (figs. 34a, 34b, and 34c) from 17 selected specimens. The localities of the selected specimens are shown in table 2.

TABLE 2. LOCALITIES OF 17 ROCK SPECIMENS

SPECIMEN	LOCALITY (LOCATION IN FIG. 3)	SPECIMEN	LOCALITY (LOCATION IN FIG. 3)
GY 58 VIII 19-5	3	GY 57 X 22-3	17
GY 57 X 22-1	4	GY 57 X 25-4	18
GY 57 X 26-2	6	GY 58 VIII 20-2	19
GY 57 X 24-2	10	GY 58 VIII 20-3	21
GY 58 VIII 27-2-A	12	GY 57 X 27-1	22
GY 58 VIII 19-7	13	GY 58 VIII 20-4	23
GY 58 VIII 21-4-P	14	GY 58 X 7-1	25
GY 58 VIII 21-3	15	GY 58 VIII 21-1	26
GY 57 X 25-2	16		

From these collective diagrams one may find a tendency for the main maxima of X, Y, and Z to be concentrated. The optic elasticity axes X, Y, and Z of olivine are equivalent respectively to the crystallographic axes b, c, and a. The distribution of main maxima for X, Y, and Z in the collective diagrams suggests that the olivine grains in the massive dunite body tend to be oriented with the (010) plane roughly parallel to the direction of bedding schistosity surface of the crystalline schists distributed on the northern (upper) side of the Higashi-akaishi-yama peridotite mass, and further that with the crystallographic axis c roughly parallel to the fabric axis *b* of the crystalline schists. Now, it becomes clear that, in the massive dunite, the statistical *s*-surface, which is parallel to the girdle for [001] and normal to the maximum concentration for [010], and the statistical fabric axis *b*, which is parallel to the maximum concentration for [001], are defined by the lattice orientation of olivine.

In the massive dunite body, fracture cleavage is locally developed, traversing the interlocking fabric of olivine aggregates. In most cases, the preferred orientation of olivine has not been affected at all by the development of closely spaced fracture cleavage (figs. 14a, 14b, and 14c).

In general, the degree of preferred orientation of olivine is lower in the foliated dunite than in the massive dunite. In the foliated dunite, the lattice orientation of olivine is not always congruous with the megascopical planar and linear fabrics (figs.

25a, 25b, 25c, 26a, 26b, and 26c).

The orientation pattern of olivine in the mylonite suggests that preferred orientation of olivine has been disturbed during the mylonitization (figs. 27a, 27b, and 27c).

2. *Orientation of clinopyroxene*

Crystals of black clinopyroxene are scattered throughout the matrix of olivine aggregate; therefore, it is difficult to determine the degree of preferred orientation for black clinopyroxene in a thin section. In the point diagrams for the optic elasticity axes of the clinopyroxene, these axes seem to be somewhat concentrated (figs. 28a, 28b, and 28c). In figs. 28b and 28c, Y-axes are distributed along the primitive circle of the projection, while Z-axes are concentrated within the central area of the projection. For each of these diagrams, the plane parallel to the page is perpendicular to the maximum concentration for [001] of olivine in the adjoining massive dunite. These diagrams suggest that the crystals of black clinopyroxene tend to be oriented with the crystallographic axis c parallel to the direction of maximum concentration for [001] of olivine in the adjoining massive dunite.

The streaks and bands of clinopyroxenite and eclogite seem to be oriented parallel to the north-dipping statistical *s*-surface in the peridotite. Light-coloured clinopyroxene in these rocks usually shows preferred orientation. The orientation diagrams for the optic elasticity axes of the light-coloured clinopyroxene in the streaks and bands of these rocks show a distinct tendency for the Y-axes to be dispersed along a great circle and for the Z-axes to be concentrated within an area defined by a small circle. The great-circle-girdle for Y-axes is apt to be oriented perpendicular or subperpendicular to the streak or the band. Within the girdle for Y-axes, chief maxima occur near the pole of the streak or the band. Several maxima for Z-axes usually occur around the pole of the great-circle-girdle for Y-axes. The girdle for Y-axes of the clinopyroxene in the streaks and bands is commonly perpendicular to the concentration of [001] of olivine in the adjoining massive dunite (figs. 24d and 31d). These orientation diagrams denote that the grains of light-coloured clinopyroxene in the streaks and bands of clinopyroxenite and eclogite tend to be oriented with the (010) plane mainly parallel to the streaks or the bands, and with the crystallographic axis c parallel to the direction of maximum concentration for [001] of olivine in the adjoining massive dunite. The clinopyroxene in the large mass of coarser-grained beautiful eclogite also shows similar preferred orientation.

VII. General Considerations

In this section, problems on the origin of the Higashi-akaishi-yama peridotite and associated rocks will be considered. Many of the problems are closely related to the origin of the Besshi spotted schist zone. In recent years knowledge about the crystalline schists in the Besshi spotted schist zone has been advanced chiefly through the studies by G. Kojima, K. Hide and G. Yoshino (G. Kojima, 1951a, 1951b, 1951c, 1953; G. Kojima, K. Hide, and G. Yoshino, 1956; G. Kojima and K. Hide, 1957,

1958; K. HIDE, 1954; K. HIDE, G. YOSHINO, and G. KOJIMA, 1956; G. YOSHINO and G. KOJIMA, 1953).

A. PERIDOTITE

When was the present olivine orientation developed? — Recently, M. H. BATTEY (1960) showed that there is a definite relationship between the fold-axes, the olivine-orientation, and the joint pattern of the peridotite, from Dun Mountain, Nelson, New Zealand, and he discussed the date of emplacement of the peridotite.

The Higashi-akaishi-yama peridotite mass is comparatively homogeneous both in mineral composition and in chemical composition of olivine. The degree of preferred orientation of olivine is higher in the massive dunite than in the foliated dunite. Therefore, it is natural to consider, in the beginning, when the olivine of the massive dunite was oriented. As described in the preceding pages, the lattice orientation of olivine in the massive dunite mass determines a statistical *s*-surface which is parallel to the bedding-schistosity surface of the crystalline schists distributed to the north of the Higashi-akaishi-yama peridotite body, and the statistical fabric axis *b* parallel to the *b*-lineation in the same crystalline schists. These facts suggest that the preferred orientation of lattice type was developed in the olivine of the massive dunite during the Besshi recumbent folding.

The olivine grains in and near the chromite band, no matter whether they occur within or outside the band, tend to show uniform orientation pattern. Seams or bands of chromite in the massive dunite mass extend roughly parallel to the statistical *s*-surface defined by the lattice orientation of olivine. Strictly speaking, however, even where the chromite band extends straight, the plane of the banding is not always parallel to the statistical *s*-surface. Judging from these facts, it is unconceivable that the chromite seams or bands were formed through a process such as differentiation of chromite when the olivine orientation was developed. On the other hand, although examples are few, in such a case as the chromite bands have been formed along slip cleavage of solid dunite mass after olivine grains were almost entirely oriented, the olivine fabric suggesting granulation can be found within or outside the chromite band. Now, it is inferred that most of the chromite seams or bands were formed prior to the development of olivine orientation.

Near the upper margin of the lenticular Higashi-akaishi-yama peridotite body, zones of dunite-mylonite are found, accompanied with streaks and bands of clinopyroxenite and eclogite. The slip cleavage of the dunite-mylonite is roughly parallel to the upper margin of the peridotite body, and also parallel to the streaks and bands of clinopyroxenite and eclogite. These facts suggest that dislocation took place in a later phase near the upper margin of the Higashi-akaishi-yama peridotite body, and that the movement has been facilitated by the banded character of this part consisting of dunite, clinopyroxenite, and eclogite.

In discussing the evolution of dunite fabric, it is important to pay attention to the structural features of the foliated dunite. The lower part of the lenticular Higashi-akaishi-yama peridotite body consists mainly of the foliated dunite. The foliated dunite has megascopically foliated and lineated fabrics, the lineation being roughly coincident in trend and plunge with the *b*-lineation of the spotted black schist on the southern side of the Higashi-akaishi-yama peridotite body. In the megascopic feature of fold, the foliated dunite bears a resemblance to the spotted black schist. These facts suggest that the folding of the foliated dunite occurred in connection with the folding of the spotted black schist distributed along the axial zone of the Besshi recumbent anticline, and that the foliated dunite differed little in competency from the spotted black schist during the folding. Although the degree of preferred orientation of olivine is lower in the foliated dunite than in the massive dunite, the preferred orientation of lattice type can be detected for the olivine in the former. The pattern of preferred orientation of olivine in the foliated dunite is not always conformable to the megascopically foliated and lineated fabrics. The chemical composition of olivine is nearly uniform throughout the Higashi-akaishi-yama peridotite mass, and the grain size of the mineral in the foliated dunite differs little from that in the massive dunite. Furthermore, there are no evidences to verify that a large-scale displacement occurred along the boundary surface between the massive dunite and the foliated dunite, the boundary being generally planar and regular. From these facts, it is inferred that both the massive dunite and the foliated dunite had passed through the same tectonic history before the folding of the foliated dunite began. Indeed, it seems that the degree of preferred orientation of olivine in the foliated dunite has been lowered by the development of small-scale folding. In the foliated dunite are found folds of small- and large-scale. The axial-plane foliation frequently intersects the early-formed foliation where the latter is intensely folded. Nevertheless, in the foliated dunite are seldom found any features which would suggest extreme granulation. If the foliation of the foliated dunite originated from fracture cleavage of discontinuous nature in a rigid mass, the *s*-plane of this type could not be folded plastically after such deformation characterized by rupture occurred, but the foliated dunite should retain traces of extreme granulation. Hence, the foliated fabric of the dunite may be a relict of an initially anisotropic fabric which has been emphasized by the folding movement.

After the consideration above mentioned the author reaches the following conclusion which explains the history of evolution of the dunite.

1) A serpentineous body existed before the crystallization of olivine began. The crystallization of olivine began in the serpentineous body under stress condition. Olivine grains were developed, oriented after the lattice direction of the crystal, in place of the serpentine mineral.

2) While the upper part of the Higashi-akaishi-yama ultramafic mass was converted into the massive dunite consisting mostly of olivine showing the preferred orientation of lattice type, the lower part still carried more serpentine mineral than in the upper part. These two parts with different characters may have been separated by a relatively distinct boundary.

3) After the upper part had become rigid owing to the crystallization of olivine, the lower part containing more serpentine has been folded in connection with the deformation of the spotted black schist on the southern side of the Higashi-akaishi-yama peridotite mass. In this phase the upper part failed to be folded because of the rigid nature of the massive dunite.

What is the origin of the Higashi-akaishi-yama peridotite? — The problem of the origin of dunite has been discussed comprehensively by F. J. TURNER and J. VERHOOGEN (1951).

C. S. ROSS, M. D. FOSTER, and A. T. MYERS (1954) say, referring mainly to the papers of N. L. BOWEN (1928), H. H. HESS (1939), F. J. TURNER (1942), and N. L. BOWEN and O. F. TUTTLE (1949): "These diverse approaches to the problem of the origin of dunite and related rocks seem to present convincing evidence that the rocks were formed by the intrusion of a largely crystalline mushlike material, and that this material was made up essentially of olivine. The relations also indicate that the peridotite substratum is the most probable source of so unusual a material".

H. H. HESS (1955) states briefly on a debate between field geologists and laboratory investigators concerning how ultramafic rocks are emplaced: "For most of this century a magnificent argument has gone on between field geologists who have worked on the peridotites of alpine mountains and laboratory investigators of their chemistry (particularly BOWEN). The former stoutly maintains that the evidence indicates that they were intruded in a fluid state, as magmas; and the latter equally forcefully has proved to his own satisfaction that such magmas are not possible. The writer casts his vote with the field geologist and believes that the field evidence takes precedence. Probably there is some factor or constituent missing in the laboratory investigations".

In the Besshi-Shirataki district, peridotite and serpentinite are distributed almost exclusively in the spotted sub-zone, and larger masses are found along the axis of the root-zone of the Besshi recumbent anticline. Among them, the Higashi-akaishi-yama peridotite mass is the largest, lenticular in form, inserted concordantly with the surrounding schist beds. G. KOJIMA (1953) regarded the Higashi-akaishi-yama peridotite mass as a syntectonic intrusive mass, and G. KOJIMA and K. HIDE (1957) pointed out that the mass occurs as a large tectonic inclusion. Recently D. B. MACKENZIE (1960) clarified the existence of high-temperature contact aureole around an alpine-type peridotite in Northern Venezuela, but no special evidence suggests the effect of high-temperature contact metamorphism in the crystalline schists around the Higashi-akaishi-yama peridotite body. In spite of the study of D. B. MACKENZIE, it has been widely believed that high-temperature contact aureoles are absent for alpine-type peridotite mass. When the Higashi-akaishi-yama ultramafic mass was emplaced into the present position, the temperature of the intruded mass was believed to have been so low that it has failed to convert the adjoining crystalline schists to high-temperature metamorphic rocks. The massive dunite is characterized by the presence of seams or bands of chromite, although they are not confined to any specific part of the mass. Such seams and bands are also found in small masses of massive dunite in the Iratsu amphibole schist bed. The parallel arrangement of the chromite seams and bands seems to have resulted from the flow of the ultramafic masses during intrusion. Granting that the Higashi-akaishi-yama peridotite mass was intruded in a crystalline state into the present position, the mass must have been fairly ductile during its intrusion.

How were oriented the olivine grains? —After detailed study of the fabric of olivine grains in rocks, F. J. TURNER (1942) has explained systematically the process of alignment of olivine grains in peridotite. H. W. FAIRBAIRN (1949) cited TURNER's interpretation in the discussion of the development of olivine orientation. F. J. TURNER (1942) and H. W. FAIRBAIRN (1949) have interpreted the dimensional orientation of olivine in banded olivine-rocks as having been brought about by the effect of semisolid flow. R. N. BROTHERS (1959) has noted such dimensional orientation of olivine phenocrysts in some basic lavas from dykes. Undulatory extinction band and fine lamellar structure in olivine grains have been interpreted by F. J. TURNER (1942) and H. W. FAIRBAIRN (1949) as due to solid flow, and these features in dunites have been reported from New Zealand and elsewhere (e.g., F. J. TURNER, 1942; C. E. TILLEY, 1947; J. LADURNER, 1954). Recently, experiments on deformation of peridotite have been performed by D. T. GRIGGS, F. J. TURNER, and H. C. HEARD (1960), but the mechanism of deformation of olivine have not been clarified.

In the Higashi-akaishi-yama peridotite mass, olivine grains both in the massive dunite and in the foliated dunite rarely show undulatory extinction, and the lamellar structure can not be found even in olivine grains of the mylonitized dunite. In the massive dunite, although the olivine grains show no dimensional orientation, they present remarkable preferred orientation after the space-lattice of the crystal, *i.e.*, the grains are oriented with the plane (010) parallel to the statistical *s*-surface and with the crystallographic c-axis roughly parallel to the statistical fabric axis *b*. Such petrofabric features of olivine with equidimensional form cannot be explained simply either by semisolid flow during intrusion of a magma, or by intragranular gliding accompanied with external rotation of grains during deformation of an almost completely crystalline magma. The fact that the statistical *s*-surface is developed continuously throughout the massive dunite body indicates that the stress plan involved in the development of olivine orientation was uniform throughout the ultramafic mass during the process of crystallization. Such uniform stress plan is believed to have been maintained within the ultramafic mass in relation to the initially anisotropic fabric character such as stratification or foliation. Considering that no megascopic fabrics such as foliation or lineation can not be found in the massive dunite, the above-mentioned anisotropic fabrics must have inherited from the heterogeneity prior to the olivine crystallization, e. g., the presence of serpentine-rich layer. From the facts above enumerated, the Higashi-akaishi-yama massive dunite is believed to consist largely of recrystallized or neocrystallized olivine. The recrystallization or neocrystallization under stress condition, synchronous with the Besshi recumbent folding, must have been responsible to the development of the olivine orientation.

N. L. Bowen and O. F. Tuttle (1949) studied experimentally the system MgO-SiO_2-H_2O, and revealed that the maximum temperature for the existence of pure magnesian serpentine is approximately 500°C. and that forsterite in contact with water vapor remains stable down to about 430°C. It has been stated in the above discussions that the Higashi-akaishi-yama ultramafic mass may have been composed largely of olivine and serpentine mineral at the time of the orientated recrystallization of olivine. As it is conceivable that, when an ultramafic intrusive mass consisting of forsterite and magnesian serpentine contains sufficient water vapor, the water vapor is capable of removing SiO_2 from the magnesian serpentine, the serpentine in the intrusive mass will diminish in amount at temperatures below 500°C. Therefore, at the temperature level of about 430°C. to 500°C., recrystallization or neocrystallization of olivine may proceed in such ultramafic intrusive mass containing sufficient water vapor. Even at temperatures below 430°C., however, it is also possible to suppose that recrystallization or neocrystallization of olivine proceeds in the magnesian serpentine-forsterite-mass under such a condition as an open system in which water vapor can escape outward from the space of metamorphism.

B. Eclogitic Rocks

P. Eskola (1939) has enumerated four principal modes of occurrence of eclogites. The mode of occurrence of eclogitic rocks in the Higashi-akaishi-yama district can be classified into the following three types:

1. Irregular-shaped masses occurring in the Iratsu amphibole schist.
2. Irregular-shaped large masses enclosed in the Higashi-akaishi-yama peridotite mass.
3. Streaks, bands, and lenticular masses, enclosed in the Higashi-akaishi-yama peridotite mass.

Eclogitic rock masses occurring in the Iratsu amphibole schist:—Eclogitic rock masses of various size are found in the southern (lower in appearance) part of the Iratsu amphibole schist bed. The textural and mineralogical characters of both the eclogitic rock masses and the adjacent amphibole schist seem to indicate that the eclogitic rocks have been formed locally during the formation of the Iratsu amphibole schist.

Eclogitic rocks occurring as irregular-shaped large rock-masses enclosed in the Higashi-akaishi-yama peridotite mass:—Large masses consisting of amphibolic and pyroxenic rocks are found within the relatively upper (northern) part of the peridotite mass. Far from the upper margin of the peridotite mass, such masses become scarce towards the interior. Amphibolic rocks occur also in the Iratsu amphibole schist. The masses of amphibolic and pyroxenic rocks may represent large inclusions of the Iratsu amphibole schist. If this interpretation is correct, it seems probable that the condition of formation of the eclogitic rocks associated with the amphibolic rock in the Higashi-akaishi-yama peridotite mass may have been similar to that controlling the formation of the eclogitic rock masses in the Iratsu amphibole schist.

Streaks, bands, and lenticular masses of eclogite enclosed in the Higashi-akaishi-yama peridotite mass:—They occur mainly within the upper (northern) part of the peridotite mass. The streaks and bands extend almost parallel to the statistical *s*-surface of the surrounding massive dunite, showing frequent swelling. Isolated lenticular masses of eclogite also tend to be arranged roughly parallel to the statistical *s*-surface. The clinopyroxene in the eclogite commonly shows a remarkable preferred orientation, the grains being oriented with the crystallographic axis c roughly parallel to the direction of maximum concentration for Y=[001] of olivine in the surrounding massive dunite. It is a noticeable fact that the massive dunite of the part where the streaks, bands and lenticular masses of eclogite are developed somewhat differs in the pattern of preferred orientation of olivine from the massive dunite distributed in the other part. In the orientation diagrams for the massive dunite near these streaks, bands, and lenticular masses, there can be found a tendency that X=[010] of olivine is dispersed along a great circle and Y=[001] of the mineral is concentrated near the pole of the great-circle-girdle for X (fig. 24d). These facts seem to indicate that both the clinopyroxene orientation in the eclogite and the olivine orientation in the massive dunite have been developed under the same tectonic setting, although whether the eclogitic rocks had existed in the Higashi-akaishi-yama ultramafic mass prior to the development of the clinopyroxene orientation has not been decided. Megascopic and microscopic features of the fine streaks of eclogite, however, suggest that the formation of the eclogite streaks was synchronous with the oriented crystallization of light-coloured clinopyroxene in the ultramafic mass. At moderate temperatures of metamorphism (W. S. FYFE and F. J. TURNER, 1958, p. 154), as assigned above to the Higashi-akaishi-yama ultramafic mass, such assemblage as eclogite may have been formed in the water-deficient region (H. S. YODER, Jr., 1952, 1955; W. S. FYFE and F. J. TURNER, 1958; F. J. TURNER, 1958). Comparatively dry environment may have been created locally in the Higashi-akaishi-yama ultramafic mass during the oriented crystallization of olivine.

Recently, the physical condition of the eclogite facies was discussed by W. S. FYFE and F. J. TURNER (1958), and F. J. TURNER (1958). In addition to petrofabric data as presented in this paper, systematically prepared chemical data will be required for thorough discussion on the genesis of the eclogitic rocks in the Higashi-akaishi-yama district. With regard to this problem, the fact that all of these eclogitic rocks occur only within a specific zone near the boundary between the Iratsu amphibole schist and the Higashi-akaishi-yama peridotite mass seems to be suggestive.

Literatures

BANBA, T. (1953): The Higashi Akaishi-yama dunite mass in Shikoku (Studies on spinels associated with the ultra-mafic rocks, II). (in Japanese) *Jour. Geol. Soc. Japan*, vol. 59, pp. 473-445.

BATTEY, M. H. (1960): The relationship between preferred orientation of olivine in dunite and the tectonic environment. *Amer. Jour. Sci.*, vol. 258, pp, 716-727.

BOWEN, N. L. (1928): *The evolution of the igneous rocks*. Princeton Univ. Press, 334 p.

BOWEN, N. L., and TUTTLE, O. F. (1949): The system MgO-SiO_2-H_2O. *Geol. Soc. America Bull.*, vol. 60, pp. 439-460.

BROTHERS, R. N. (1959): Flow orientation of olivine. *Amer. Jour. Sci.*, vol. 257, pp. 574-584.

ESKOLA, P. (1939): Die metamorphen Gesteine. pp. 263-407 in BARTH, T. F. W., CORRENS, C. W., and ESKOLA, P., *Die Entstehung der Gesteine*, Springer, Berlin, 442 p.

FAIRBAIRN, H. W. (1949): *Structural petrology of deformed rocks*. Cambridge, Mass., Addison and Wesley Publishing Co., 334 p.

FUNAHASHI, M., and HASHIMOTO, S. (1951): Geology of the Hidaka zone, Hokkaido. (in Japanese) *Monograph Assoc. for Geol. Collaboration*, no. 6.

FYFE, W. S., and TURNER, F. J. (1958): Correlation of metamorphic facies with experimental data. pp. 149-185 in FYFE, W. S., TURNER, F. J., and VERHOOGEN, J., *Metamorphic reactions and metamorphic facies*, Geol. Soc. America Mem. 73, 259 p.

GRIGGS, D. T., TURNER, F. J., and HEARD, H. C. (1960): Deformation of rocks at 500° to 800°C. pp. 39-104 in GRIGGS, David and HANDIN, J., *Rock deformation*, Geol. Soc. America Mem. 79, 382 p.

HARADA, Z. (1943): On the chrome minerals of Japan (II). (in Japanese) *Jour. Japan. Assoc. Mineral., Petrol., Economic Geol.*, vol. 29, pp. 12-23.

HESS, H. H. (1939): Island arcs, gravity anormalies, and serpentinite intrusions. *17th Internat. Geol. Cong. Moscow*, 1937, Rept., vol. 2, pp. 263-283 (Cited in ROSS, C, S., FOSTER, M. D., and MYERS, A. T., 1954).

HESS, H. H. (1955): Serpentine, orogeny, and epeirogeny. pp. 391-408 in POLDERVAART, Arie, Editor, *Crust of the Earth*, Geol. Soc. America Special Paper 62, 762 p.

HIDE, K. (1954): Geological structure of the Shirataki mining district, Kôchi Prefecture. (in Japanese) *Jour. Sci. Hiroshima Univ.*, (4), pp. 47-83.

HIDE, K., YOSHINO, G., and KOJIMA, G. (1956): Preliminary report on the geologic structure of the Besshi spotted schist zone. (in Japanese) *Jour. Geol. Soc. Japan*, vol. 62, pp. 574-584.

HORIKOSHI, Y. (1937a): [Rocks and geology of the Besshi district, Ehime Prefecture]. (in Japanese) *Jour. Geol. Soc. Japan*, vol. 44, pp. 121-140.

HORIKOSHI, Y. (1937b): [On the eclogite in the vicinity of Higashi-Akaishi-Yama in the province of Iyo]. (in Japanese) *Jour. Geol. Soc. Japan*, vol. 44, pp. 141-144.

IGI, S. (1953): Petrographical studies on the peridotite in the Horoman region at the southern end of the Hidaka mountain range, Hokkaido. (in Japanese) *Jour. Geol. Soc. Japan*, vol. 59, pp. 111-121.

KATÔ, T. (1921): Notes on the banded chromite ore from the Akaishi mine in the province of Iyo, Japan. *Jour. Geol. Soc. Japan*, vol. 28, pp. 13-18.

KINOSHITA, K. (1936): Dunite from Akaishi chromite mine, Ehime prefecture. (in Japanese) *Jour. Soc. Japan. Mineral. (Our Minerals)*, vol. 5, pp. 414-417.

KOJIMA, G. (1951a): Über das "Feld der Metamorphose" der Sanbagawa Kristallinen Schiefer—besonders in Bezug auf Bildung des Kristallinen Schiefergebietes in Zentral-Sikoku. *Jour. Sci. Hiroshima Univ.*, Ser. C, vol. 1, no. 1, pp. 1-18.

KOJIMA, G. (1951b): Stratigraphy and geological structure of the crystalline schist region in Central Shikoku. (in Japanese) *Jour. Geol. Soc. Japan*, vol. 57, pp. 177-190.

KOJIMA, G. (1951c): Some subjects on the Sambagawa matamorphism. (in Japanese) *Jour. Assoc. for Geol. Collaboration Japan (Earth Sci.)*, vol. 6, pp. 63-71.

KOJIMA, G. (1953): Contribution to the knowledge of mutual relations between three metamorphic zones of Chûgoku and Shikoku, South-Western Japan, with special reference to the metamorphic and structural features of each metamorphic zone. *Jour. Sci., Hiroshima Univ.*, Ser. C, vol. 1, no. 3, pp. 17-46.

KOJIMA, G., HIDE, K., YOSHINO, G. (1956): The stratigraphical position of Kieslager in the Sambagawa crystalline schist zone in Shikoku. (in Japanese) *Jour. Geol. Soc. Japan*, vol. 62, pp. 39-45.

KOJIMA, G., and HIDE, K. (1957): On new occurrence of aegirine augite-amphibole-quartz-schists in the Sambagawa crystalline schists of the Besshi-Shrataki district, with special reference to the preferred orientation of aegirine augite and amphibole. *Jour. Sci., Hiroshima Univ.*, Ser. C, vol. 2, pp. 1-20.

KOJIMA, G., and HIDE, K. (1958): Kinematic interpretation of the quartz fabric of triclinic tectonites from Besshi, Central Shikoku, Japan. *Jour. Sci., Hiroshima Univ.*, Ser. C, vol. 2, pp. 195-226.

LADURNER, J. (1954): Das Verhalten des Olivines als Gefügekorn in einigen Olivingesteinen. *Tschermaks Miner. u. Petrog. Mitt.* B. 5, H. 1-2, pp. 21-36.

MACKENZIE, D. B. (1960): High-temperature alpine-type peridotite from Venezuela. *Geol. Soc. America Bull.*, vol. 71, pp. 303-318.

ROSS, C. S., FOSTER, M. D., and MYERS, A. T. (1954): Origin of dunites and of Olivine-rich inclusions in basaltic rocks. *Amer. Mineral.*, vol. 39, pp. 693-737.

SEKI, Y. (1951a): Metamorphism of ultrabasic rocks caused by intrusion of granodiorite in Miyamori district, Iwate prefecture. (in Japanese) *Jour. Geol. Soc. Japan*, vol. 57, pp. 35-43.

SEKI, Y. (1951b): On the composition-quantity relations of olivine in igneous rocks. (in Japanese) *Jour. Geol. Soc. Japan*, vol. 57, pp. 485-498.

SEKI, Y. (1952): The studies on Miyamori ultrabasic mass, Iwate prefecture, N-E Japan (no. 4). (in Japanese) *Jour. Geol. Soc. Japan*, vol. 58, pp. 505-516.

TILLEY, C. E. (1947): The dunite-mylonites of St. Paul's rock (Atlantic). *Amer. Jour. Sci.*, vol. 245, pp. 483-491.

TURNER, F. J. (1942): Preferred orientation of olivine crystals in peridotites. *Roy. Soc. New Zealand Trans.*, vol. 72, pp. 280-300 (Cited in FAIRBAIRN, H. W., 1949).

TURNER, F, J., and VERHOOGEN, J. (1951): *Igneous and metamorphic petrology*. New York, McGraw-Hill Book Co., 602 p.

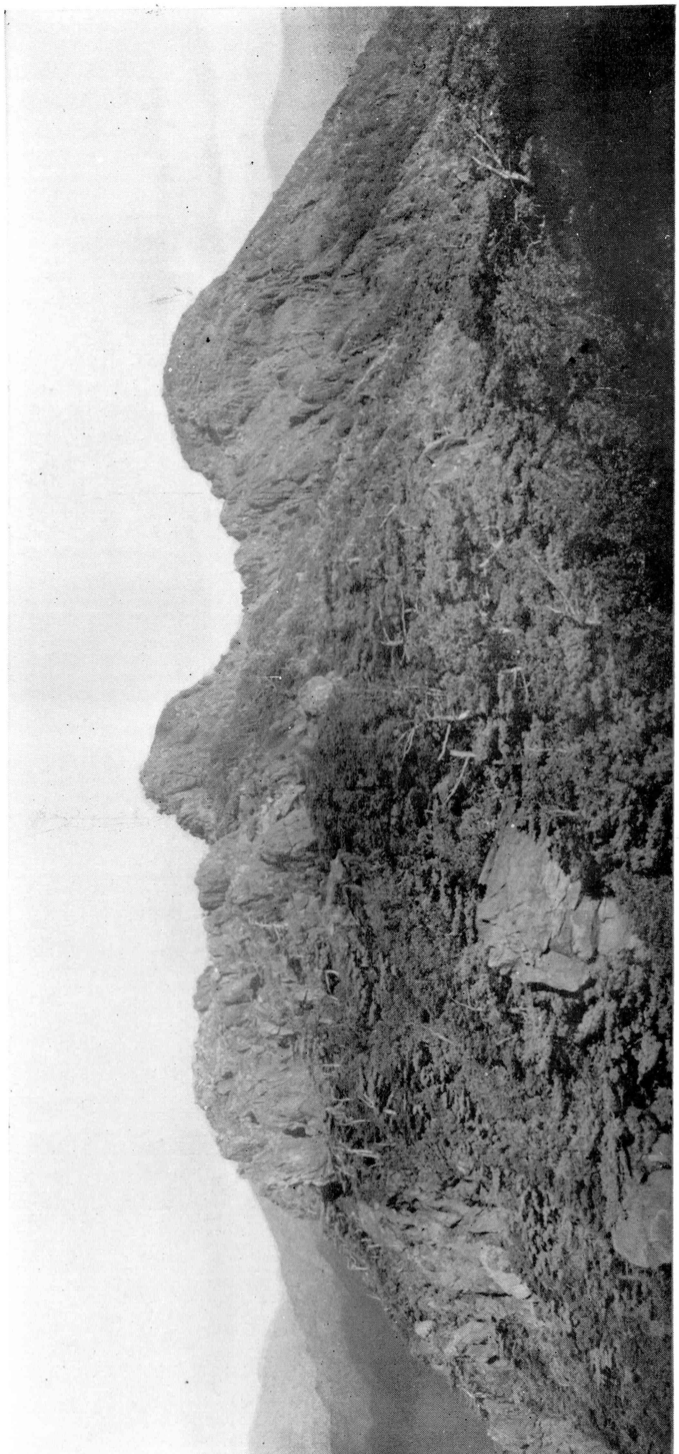
TURNER, F. J. (1958): Mineral assemblages of individual metamorphic facies. pp. 199-239 in FYFE, W. S., TURNER, F. J., and VERHOOGEN, J., *Metamorphic reactions and metamorphic facies*, Geol. Soc. America Mem. 73, 259 p.

UCHIDA, Y. (1949): On the banded chromite deposits. (in Japanese) *Jour. Japan. Assoc. Mineral., petrol., Economic Geol.*, vol. 33, pp. 45-50.

YODER, H. S. Jr., (1952): The MgO-Al_2O_3-SiO_2-H_2O system and the related metamorphic facies. *Amer. Jour. Sci., Bowen Volume*, pp. 569-627.

YODER, H. S. Jr. (1955): Role of water in metamorphism. pp. 505-523 in POLDERVAART, Arie, Editor, *Crust of the Earth*, Geol. Soc. America Special Paper 62, 762 p.

YOSHINO, G., and KOJIMA, G. (1953): Geological structure of the Ehime mining district, Ehime prefecture. (in Japanese) *Jour. Geol. Soc. Japan*, vol. 59, pp. 424-434.



Western Ridge of Higashi-akaishi-yama

View from west (from Locality 29 in fig. 3), showing foliated dunite distributed on the western part of Higashiakaishiyama. (Photo by G. Yoshino)

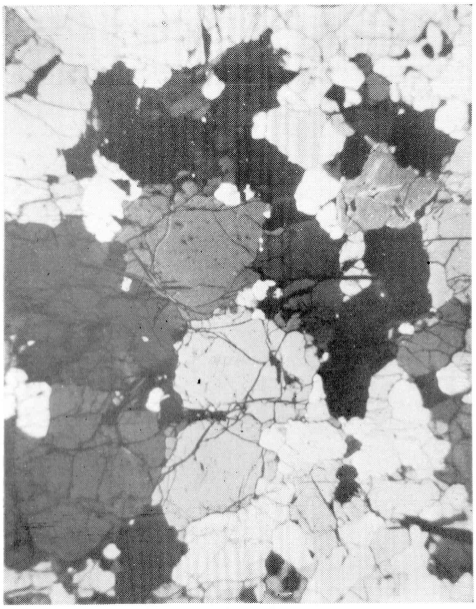
Explanation of Plate XLI

Fig. 1. Photomicrograph of massive dunite. Thin Section No. GY 58 VIII 20-4; nicols crossed.

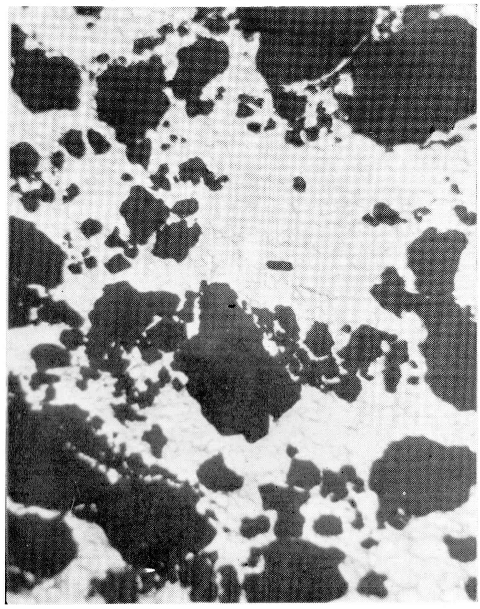
Fig. 2. Photomicrograph of chromite-band. Thin Section No. GY 58 VIII 21-4-R; lower nicol only.

Fig. 3. Photomicrograph of massive dunite. Thin Section No. GY 58 VIII 21-1; nicols crossed.

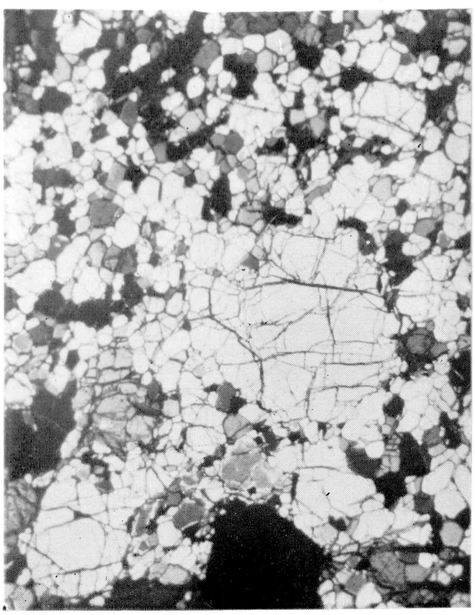
Fig. 4. Photomicrograph of massive dunite. Thin Section No. GY 58 X 9-1; nicols crossed.



1 mm Fig. 1



1 mm Fig. 2



1 mm Fig. 3

1 mm Fig. 4

Explanation of Plate XLII

Fig. 1. Photomicrograph of foliated dunite. Thin Section No. GY 57 X 23-4; nicols crossed.

Fig. 2. Photomicrograph of clinopyroxene-bearing peridotite. Thin Section No. GY 58 VIII 18-5; nicols crossed. Note large crystal of dark coloured clinopyroxene.

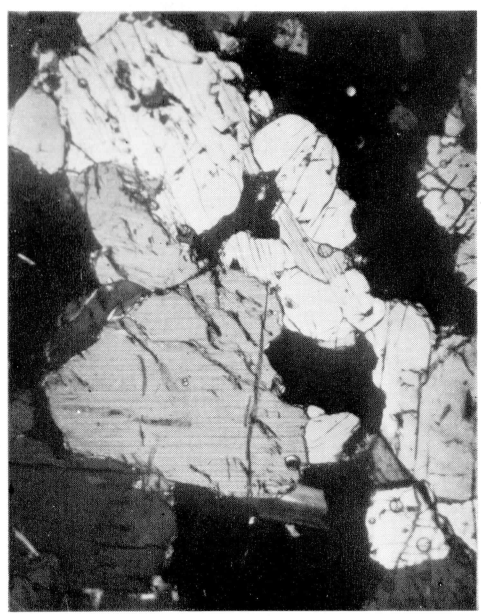
Fig. 3. Photomicrograph of massive dunite containing eclogite-streaks. Thin Section No. GY 58 VIII 26-3; nicols crossed. Upper half illustrates olivine-chromite aggregate; lower half illustrates clinopyroxene-garnet aggregate.

Fig. 4. Photomicrograph of eclogite. Thin Section No. GY 58 VIII 26-5; nicols crossed.

1 mm Fig. 1

1 mm Fig. 2

1 mm Fig. 3



1 mm Fig. 4

GEOLOGICAL MAP OF THE HIGASHI-AKAISHI-YAMA DISTRICT, SHIKOKU, JAPAN

BY G. YOSHINO