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THE LAYERED BASIC COMPLEX OF MT. POROSHIRI, HOKKAIDO, JAPAN.

by

Sumio Miyashita and Seiji Hashimoto

(with 16 Figures, 1 Table and 9 Plates)

(Contribution from the Department of Geology and Mineralogy,
Faculty of Science, Hokkaido University, No. 1381)

Introduction

The Mt. Poroshiri is situated in the northern part of Hidaka Metamorphic Belt, Hokkaido, Japan (Fig. 1), which consists of a linear arrangement of various metamorphic and plutonic rocks (Hashimoto, 1958, this volume; Hunahashi, 1957: Minato et. al., 1965). Hashimoto (this volume) has divided the Metamorphic Belt into the Western, Axial and Eastern Zones. In the northern part of the Metamorphic Belt, the Western Zone, which is composed of amphibolite and metagabbro, is some 70 Km in length and ranges from 1–4 Km in width and is thrust against non-metamorphosed sediments of the Hidaka Super Group along the Western Boundary Thrust. Mt. Poroshiri is located in the central area of the Western Zone.

Mt. Poroshiri is a layered gabbroic complex and is a large fault bounded tectonic block that has suffered partial metamorphism. The dominant structural feature of the complex is well developed rhythmic layering which has resulted from crystal setting. Therefore the layered sequence is considered to be representative of primary rocks which had largely consolidated before their uplift during the orogenesis of the Hidaka Metamorphic Belt.

The present work describes the field relations and petrography of the layered rocks. A more detailed discussion on the mineralogy and chemisty will be given in another paper.

Geologic Setting

The exposed layered complex at Mt. Poroshiri is some 5 Km in length along a N-S trend and 2 Km in width. The complex is bounded by thrusts and faults as shown in Fig. 1 and is surrounded by metagabbro and amphibolite.

The Mt. Poroshiri Layered Complex is composed of various unmetamorphosed rocks and their metamorphosed equivalents. Anorthosite, troctolite, olivine gabbro and peridotite occur as primary unmetamorphosed

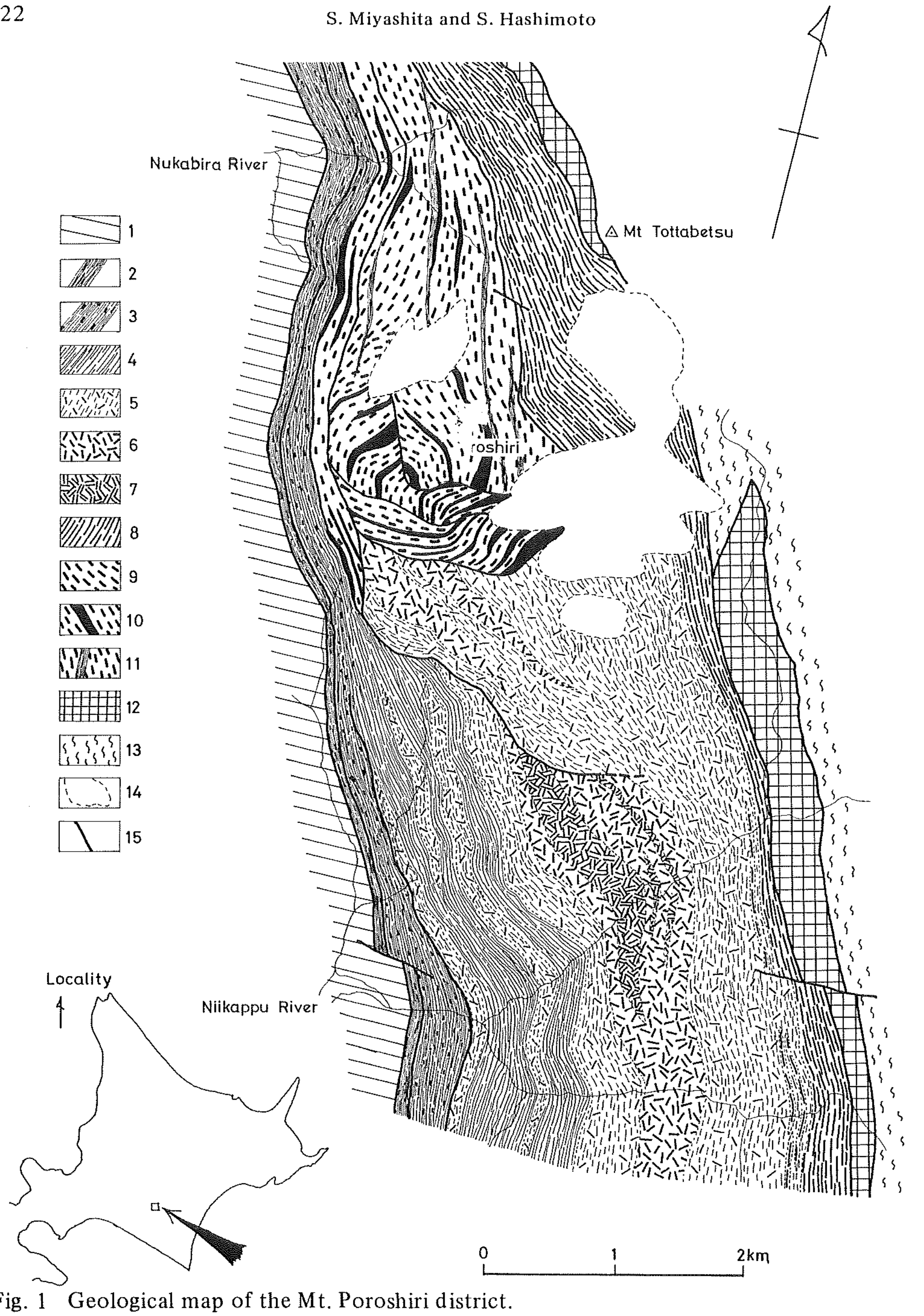

Fig. 1 Geological map of the Mt. Poroshiri district.
1. Hidaka Super Group, 2. Green schist, 3. Epidote amphibolite, 4.Amphibolite, 5. Plagioclase-blastoporphyritic amphibolite, 6. Meta gabbro I, 7. Meta gabbro II, 8. Green-hornblende amphibolite, 9. Meta-layered gabbro (Poroshiri Complex), 10. Meta-layered gabbro (olivine-rich part), 11. Pale green-amphibole schist, 12. Dunite, 13. Biotite gneiss, 14. Morainic deposites, 15. Thrust and fault.

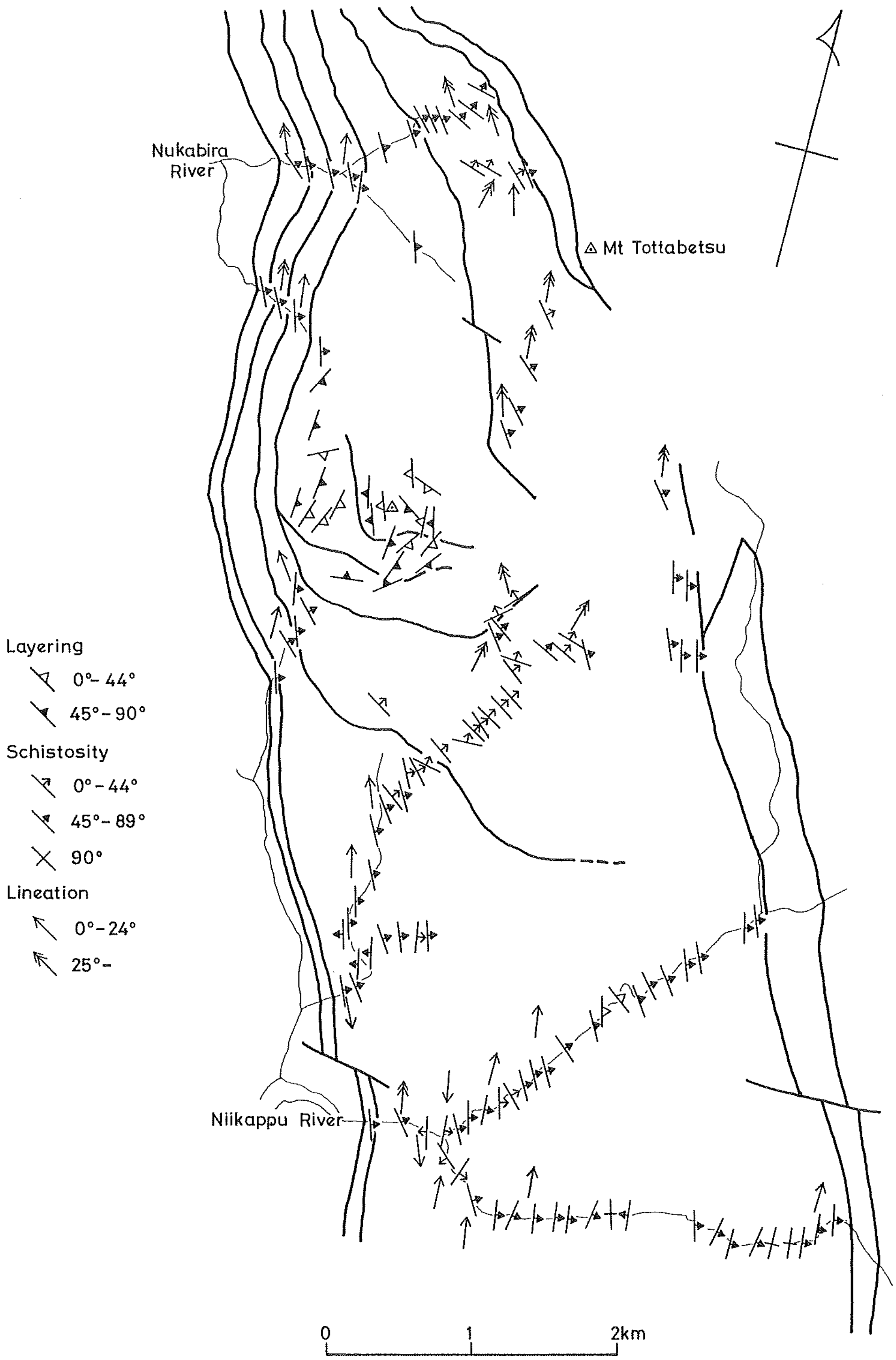

Fig. 2 Tectonic map of the Mt. Poroshiri district.

cumulate rocks. Except for olivine gabbro, gradational rocks between each rock type are present. Various secondary minerals such as amphibole, spinel, anthophylite, corundum and chlorite are present in most of the rocks.

Structurally the complex can be divided into two parts; the Nukabira part and the Poroshiri part. The latter can be further subdivided into Lower and Upper Zones on the basis of lithofacies and layering although in places metamorphic alternation may obscure some of the primary features. The Nukabira part to the north is composed of plagioclase-rich cumulate rocks. The Lower Zone of the Poroshiri part is characterized by macro rhythmic layering between plagioclase-rich layers and olivine-rich layers. The Upper Zone consists of macro rhythmic layering between olivine-rich and gabbroïc layers. The structure of the Poroshiri part is basin-like although it is disturbed by thrusts. The structure of the Nukabira part is a monocline which is approximately concordant with the schistosity of the surrounding rocks.

The rocks in the Nukabira and Poroshiri parts especially those of the Nukabira part become more schistose toward the west and narrow schistose zones are developed inside the Nukabira part of the complex and trend N-S with steep dips to the east.

Petrography

Although many primary features are obscured by alternation, the original nature can still be observed.

1) Olivine gabbro

Unaltered olivine gabbro consists of plagioclase (45%), clinopyroxene (45%) and olivine (10%). In places the rock changes gradually to amphibole-rich rocks as shown in Fig. 3.

Olivine typically has a reaction rim when it is in contact with plagioclase in which "synantetic minerals" (Sederholm, 1916) such as amphibole, spinel and occasionally orthopyroxene are formed with progressive reaction. During this process olivine disappears and the plagioclase adjacent to olivine is altered to a symplectite of radial fibrous amphiboles and spinels. Clinopyroxene is replaced by fibrous amphibole accompanied by the disappearance of secondary spinel. Also numerous needles of amphiboles occur in the margins of plagioclase.

2) Troctolite

Fresh troctolite is composed of olivine (50%) and plagioclase (50%). Both plagioclase and olivine may be replaced by very fine fibrous amphibole, spinel and a granular mosaic of amphiboles. In more plagioclase rich rocks, unaltered plagioclase remains although olivine is completely replaced. In those rocks richer in olivine fresh olivine remains while plagioclase is altered (Fig. 4). With

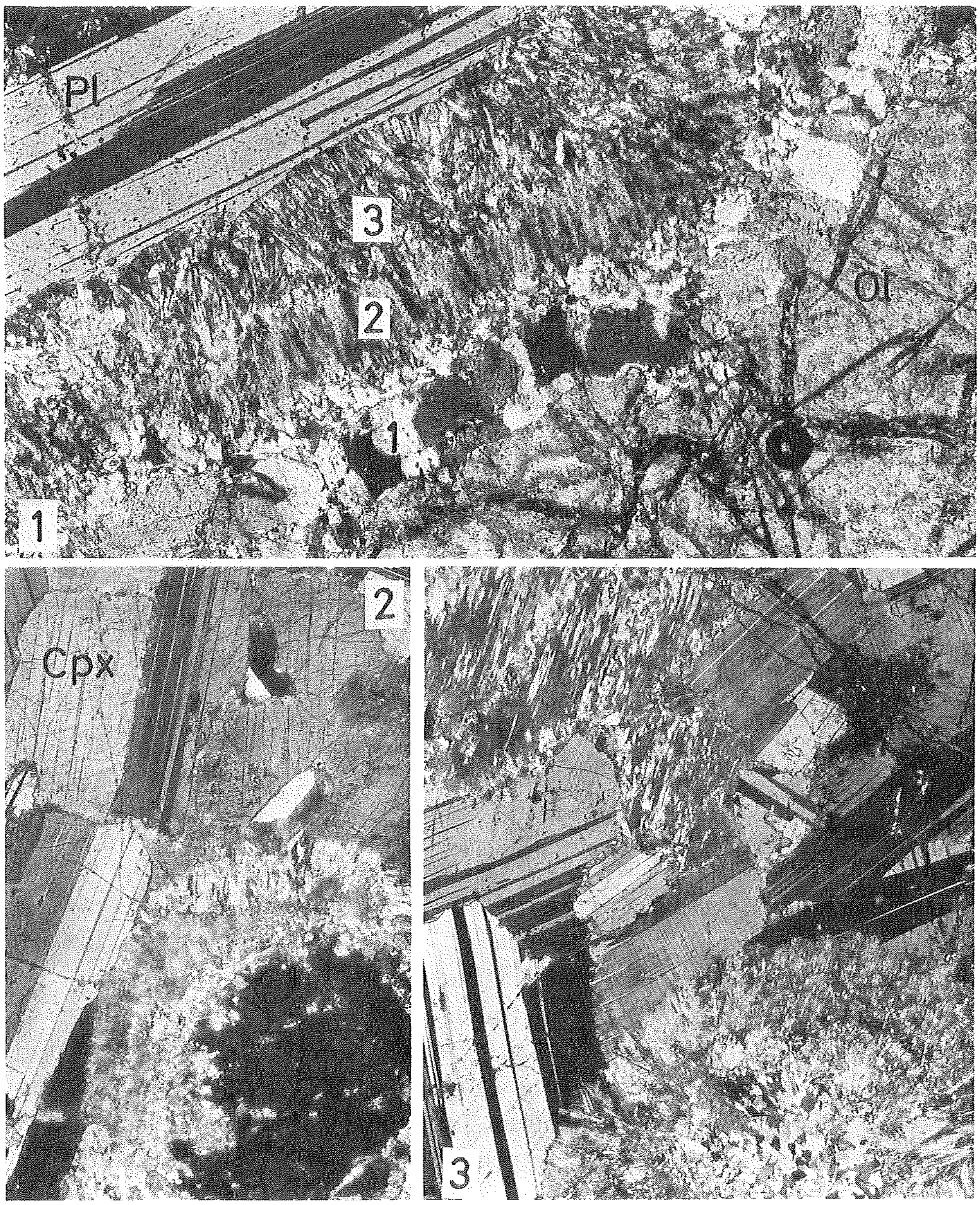

Fig. 3 Altered process of olivine gabbro.

1. Formation of reaction rim between olivine and plagioclase. From olivine to plagioclase the reaction rim is composed of following order, amphibole granules (1), symplectite of radial fibrous amphiboles and spinels (2) and amphibole needles (3). The width of the rim is 0.4mm. X 100.
2. Progress of the reaction. The width of the rim is about 1mm. X 20.
3. Disapprearance of olivine replacing by granules of amphibole. Replacement of clinopyroxenes by amphiboles is beginning. X 10. 01; Olivine, Pl; Plagioclase, Cpx; clinopyroxene

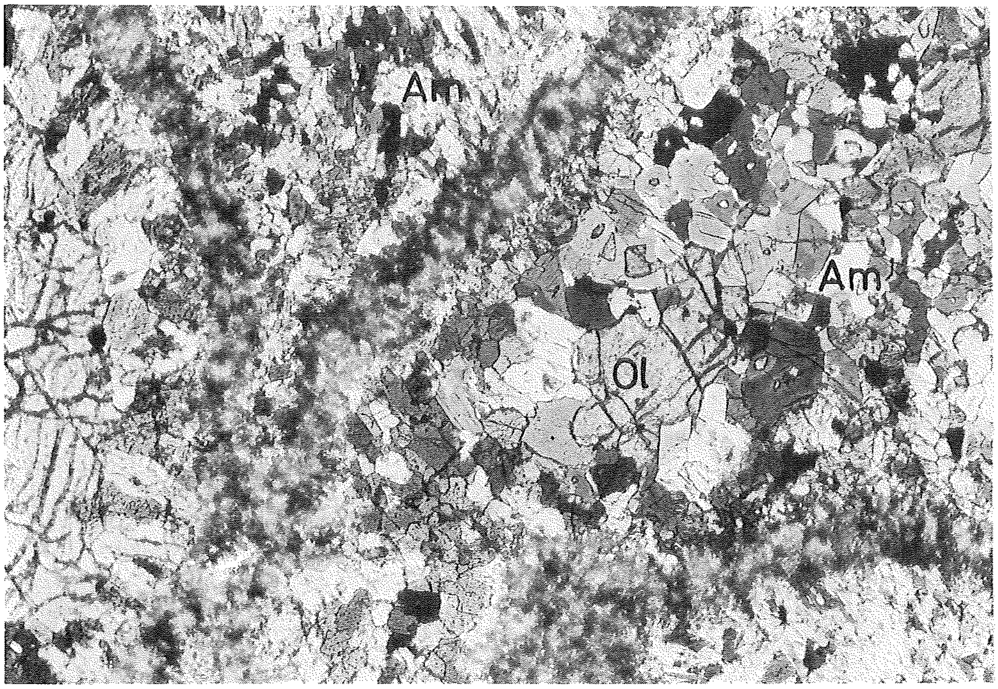

Fig. 4 Meta olivine-rich troctolite. Dim part is composed of symplectite of spinels and amphibole corresponding to original boundary between olivine and plagioclase. No plagioclase is remanined. X 50. Ol; Olivine, Am; Amphibole

progressive alteration anthophyllite may appear in plagioclase-rich troctolites after the disappearance of olivine (Fig. 5). The primary texture of the rock is easily seen as secondary spinel typically marked the original boundary between plagioclase and olivine. The presence of chlorite, together with fibrous amphibole and spinel obscures the original texture.

3) Olivine-rich rocks (olivine-rich troctolite, wehrlite and dunite)

These rocks are dealt with together because of the gradational relationship between them. In all the rocks olivine forms more than half the volume. The olivine is typically fresh when plagioclase and pyroxene are completely altered. Rarely, the olivine is replaced by serpentine. Therefore primary textures are still recognizable in these olivine-rich rocks although the relative amounts of primary plagioclase and pyroxene can not be determined.

4) Anorthositic rocks

Even in considerably altered rocks in which chlorite is developed most of the plagioclase remains. Occasionally plagioclase is recrystallized to a mass of fine granules, making the primary texture obscure.

The relationship between primary unaltered rocks and their altered equivalents is given in Table 1.

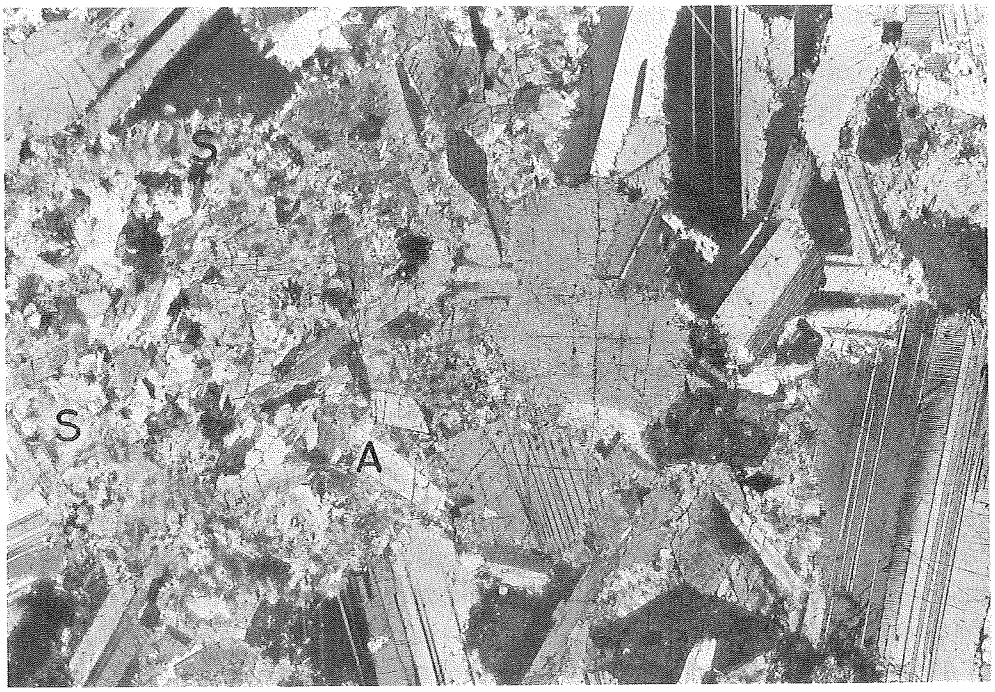

Fig. 5 Meta plagioclase-rich troctolite of the Nukabira part. Euhedral anthophyllite grows across the sympletite (dim part) of fibrous amphibole and spinel. A shape of seggregation of mafic minerals are rounded, suggesting original shape of olivine. X 20. A; Anthophyllite, S; Symplectite

Table 1. Classification of the rocks

Fresh rocks		Altered rocks		
Unaltered rock name	Mineral assemblage	Type 1	Type 2	Altered rock name
dunite	ol ≫ pl, px	ol ≫ amph	ol > chl, amph	olivine rich rock
pl wehrlite	ol > px, pl	ol > amph, (sp)	ol, chl, amph	
ol-rich troctolite	ol > pl > px	ol, amph > sp	amph, chl, ol	
ol gabbro	pl, px > ol	amph, pl > sp	amph > pl, chl	amphibole rich rock (meta troctolite)
troctolite	pl, ol ≫ px	amph > sp, (ol, pl)	amph, chl	
pl-rich troctolite	pl > ol > px	pl, amph, anth > sp	pl, amph > chl	plagioclase rich rock (meta anorthosite)
anorthosite	pl ≫ ol, px	pl ≫ amph	pl > amph, chl	

ol; olivin pl; plagioclase px; clinopyroxene amph; amphibole chl; chlorite anth; anthophyllite sp; spinel

Layered Sequence and Rhythmic Layering

1) Division of the rocks

The Mt. Poroshiri Layered Complex is divided into three parts; Nukabira part and Lower Zone and Upper Zone of the Poroshiri part. Each is represented by characteristic lithofacies and layering. The Nukabira part is mainly composed of plagioclase cumulates. Extreme alteration, shearing and uncertainty of the structural position makes it impossible to correlate the rocks with those of the layered sequence centered on Mt. Poroshiri. The Lower Zone of the Poroshiri part is composed of macro layering between plagioclase-rich cumulates and olivine-rich cumulates. The Upper Zone is characterized by the appearance of clinopyroxene as a cumulus phase.

1-a. Nukabira Part

The predominant rock type of the Nukabira part is a plagioclase cumulate although they are altered in various degrees to anthophyllite or chlorite bearing feldspathic rocks. Rhythmic layering, as illustrated in Fig. 6, is recognized. Each individual layer shows faint graded bedding as indicated by the modal variation of mafic spots (olivine). The layering strikes approximately N10°W and dips 75°E and is roughly concordant with schistosity of the area.

The only relict primary mineral in the rocks is unzoned cumulus plagioclase which is euhedral and shows a faint paralell arrangement of the long axis (igneous lamination). Intercumulus minerals are almostly absent although small amounts of amphibole after pyroxene are occasionally present. Original olivine is absent but the form of its replacement products suggests that olivine might have also been a cumulus phase (Fig. 5). The primary texture was probably a plagioclase-olivine adcumulate.

Three cumulus olivine layers which have a thickness of less than 10m have been found in the Nukabira part. The layers have a uniform appearance and

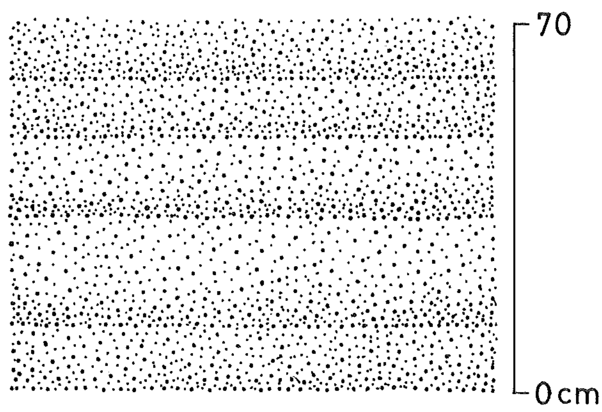

Fig. 6 Appearance of rhythmic layering of the Nukabira part.

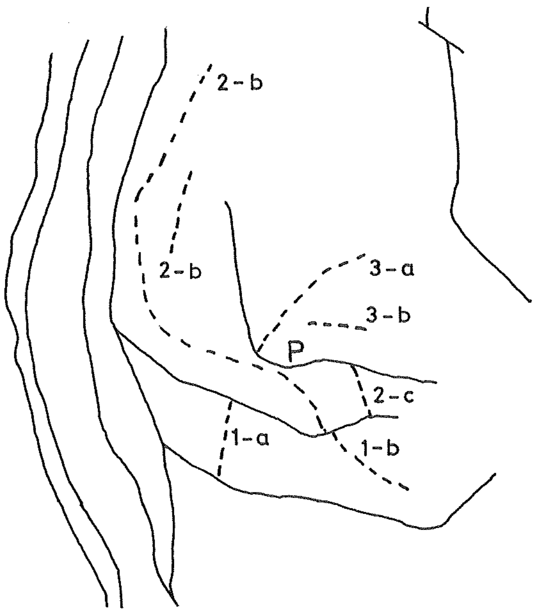

Fig. 7 Localities of geologic columns represented in Fig. 8 P; Mt. Poroshiri

have sharp boundaries with the feldspathic rocks.

The thickness of the Nukabira part of the complex is estimated to be around 1000m.

1-b. Lower Zone of the Poroshiri Part

The Lower Zone of the Poroshiri part is mainly exposed in the vicinity of the North-Cirque of Mt. Poroshiri. The Lower Zone is rhythmically layered between plagioclase-rich cumulate layers (tens of meters in thickness) and olivine-plagioclase cumulate layers (tens of meters in thickness). It is clear from the geologic column of Fig. 8 that the plagioclase-rich cumulate layers are predominant. The thickness of the Lower Zone is at least 600m.

Plagioclase-rich cumulate layers

The plagioclase-rich layers are similar to those in the Nukabira part but are more obvious in the field (P1. 2-4). Within each of the plagioclase-rich macro layers, fine scale rhythmic layering (cm scale) is present between plagioclase-rich and comparatively olivine-rich layers. The contact between the top of the fine scale plagioclase-rich layers and base of the fine scale olivine-rich layers is sharp, and that betwen the top of the olivine-rich layers and base of plagioclase-rich layers is gradual. Therefore the upper plagioclase-rich part and the lower olivine-rich part comprise one individual layer. Such layers typically range from 20cm to a maximum of 2m in thickness. The modal amount of

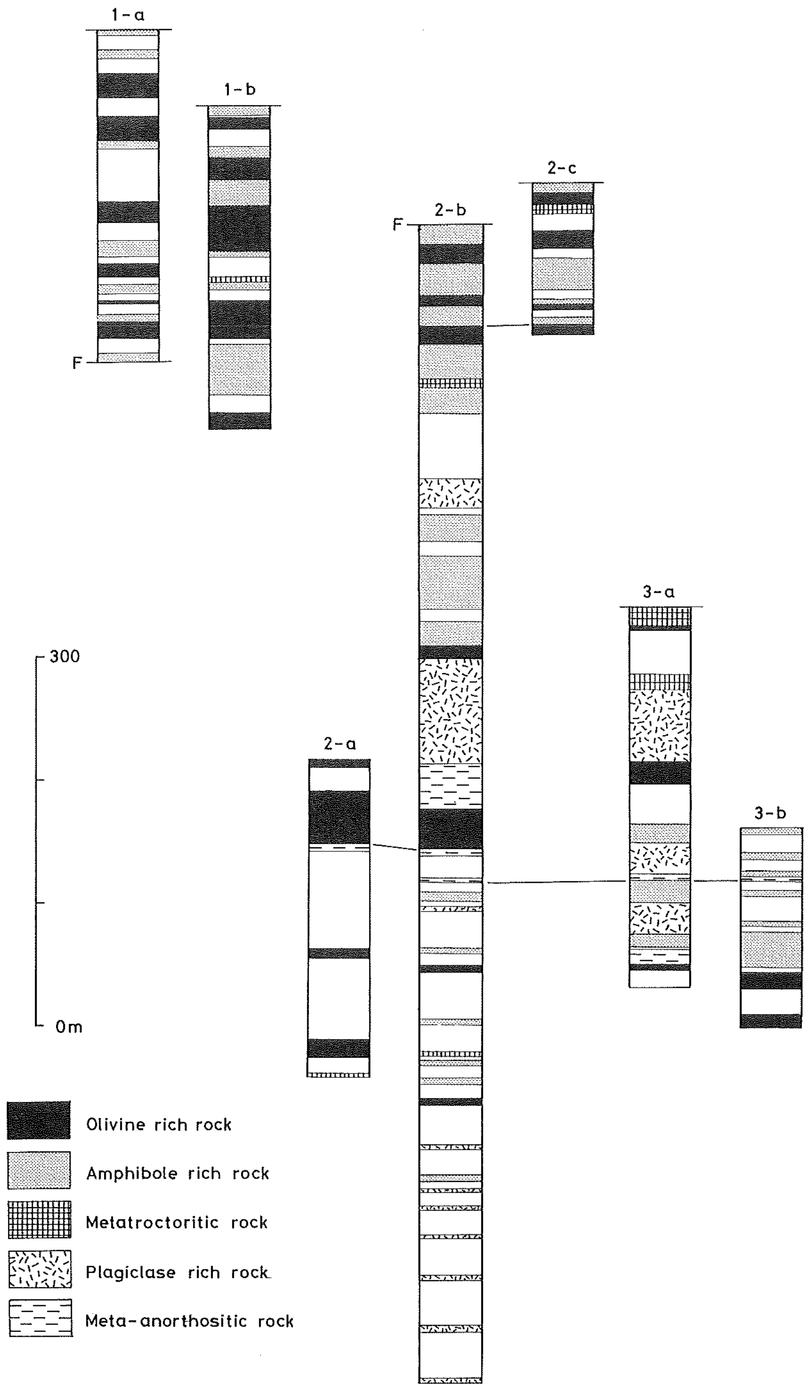

Fig. 8 Geologic columns showing the sequence of the Poroshiri part.

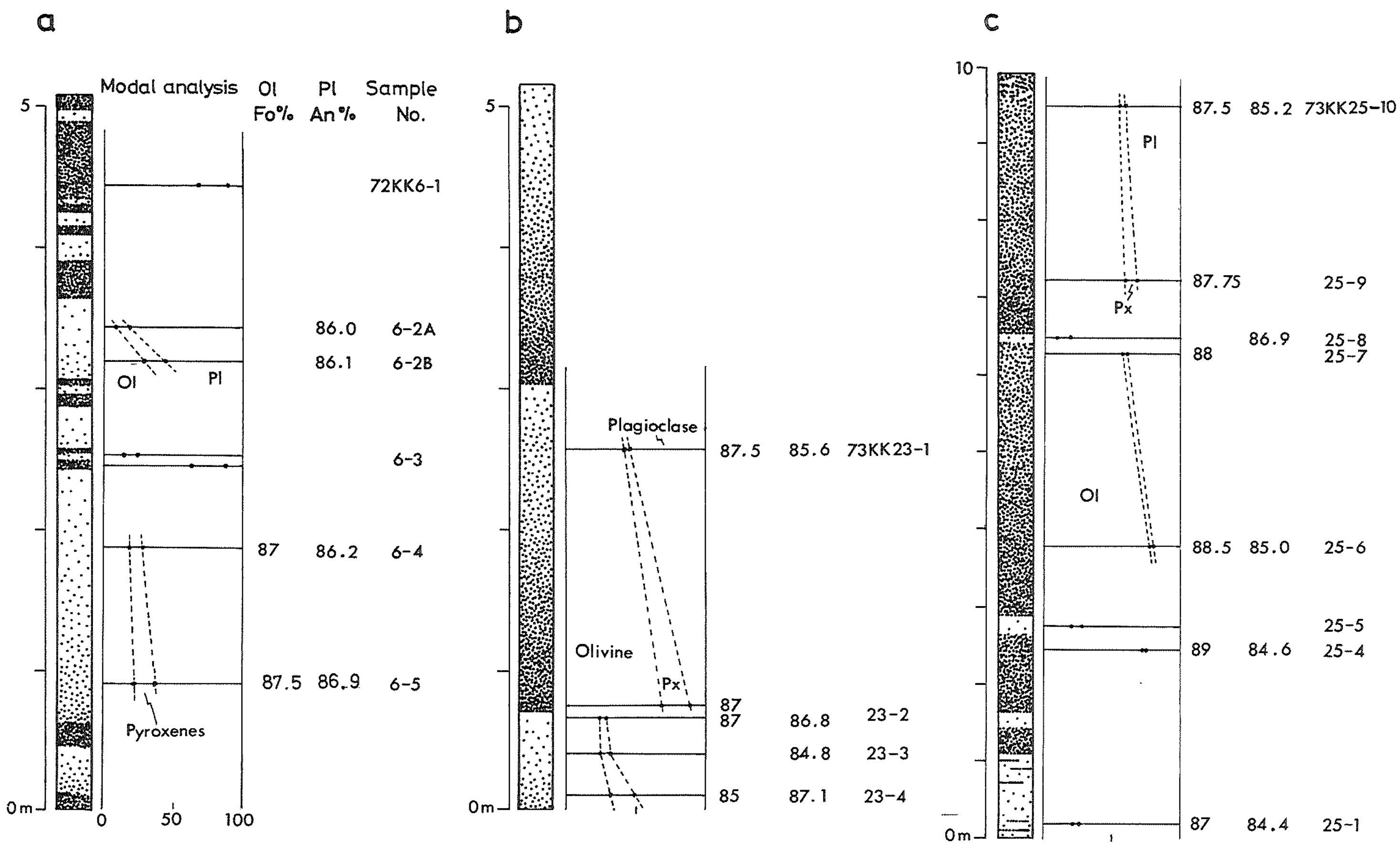

Fig. 9 Some features in rhythmic layering from the olivine-rich macro layers of the Lower Zone. Compositions of cumulus minerals and model variations are shown, but the plagioclase shown in C are heteradcumulus crystals.

plagioclase increases near the base of each individual layer, though the quantity rarely exceeds about 35%. Each individual layer is therefore gradationally stratified.

The textural features of a representative individual stratified layers are given in Plates 5-1, 2 and 6-1. Cumulus minerals are mainly plagioclase with smaller amounts of olivine. Rarely, olivine occurs as intercumulus ophitic to poikilitic grains (Pl. 6-1). Clinopyroxene is the main intercumulus mineral and does not exceed 10% in volume. The small amount of zoning in the plagioclase indicates that the textures are mesocumulus. Igneous lamination, as indicated by the dimensional orientation of plagioclase, is common in the stratified layers.

A disturbed structure, is seen at one exposure and is illustrated in Pl. 5-1.

Olivine-rich cumulate layers

Like the macro plagioclase-rich layers the macro olivine-rich layers show conspicuous fine rhythmic layering. Two types in fine rhythmic layering are present. One type consists of the alternation of olivine-rich layers and plagioclase-rich layers and the other type consists of larger scale rhythmic gradational layers. The former type of layering is illustrated in Fig. 9-a and Pl. 2-2, and the latter is illustrated in Fig. 9-b and Pl. 3-1 and -2.In the former type, the contact between the top of the plagioclase-rich layer and base of the olivine-rich layer is usually more abrupt than between the base of the plagioclase-rich layer and the top of the olivine-rich layer. The modal variation (Fig. 9) clearly indicates that the relative amount of plagioclase increases upward in each layer. The thickness of individual layers ranges from a few cm to about 2 meters in the layered olivine-rich – plagioclase-rich rhythmic layers and is generally about 2 meters for the larger scale gradational layers (Fig. 9). Where the modal amount of plagioclase increases, igneous lamination is typically developed.

Olivine and plagioclase are cumulus minerals and clinopyroxene is intercumulus. The modal amount of intercumulus clinopyroxene is much more than in the macro plagioclase cumulate layers described above. On the basis of zoning in cumulus plagioclase the texture ranges from mesocumulus to orthocumulus. In the olivine-rich layers plagioclase may occur as poikilitic intercumulus grains (Pl. 7-2). Those rocks in which poikilitic plagioclase is present have a heteradcumulus texture.

Many disturbed structures are present (pl. 3-3; Pl. 4-3, 4, 5; Fig. 11-a, b) and are described in more detailed below.

Irregular pegmatitic clinopyroxenite and anorthosite veins cut the layering. The clinopyroxenite veins always cut across the layering but many of the anorthosite veins strike parallel with the layering. In some instances the clinopyroxenite veins continue as disrupted fragments as shown in Pl. 4-2 suggesting that the formation of the veins was contemporaneous with that of the host rock.

1-c. Upper Zone of the Poroshiri Part

The Upper Zone of Poroshiri part is exposed in the East-Cirque of Mt. Poroshiri. The observed thickness of this zone is approximately 400m. The upper limit is unknown because of faulting. The Upper Zone is represented by the alternation of macro layers (tens of meters in thickness) of olivine-rich troctolitic and gabbroic composition. Similar layered rocks occur as 5 Km long block to the west of the layered complex of Mt. Poroshiri and may correspond to the rocks of the Upper Zone that have suffered extensive shearing. The development of fine rhythmic layering is rare, and each macro layer is more or less uniform in appearance. The observable boundaries of the macro layers are very irregular and parts of the gabbro are enclosed within the olivine-rich rocks and *visa versa.* Geologic colummns of the Upper Zone observed in the East-Cirque wall are given in Fig. 10.

The olivine-rich layers are composed of cumulus olivine and a small amount of cumulus plagioclase. Clinopyroxene and a small amount of orthopyroxene are intercumulus. Olivine is always more than 50 modal % and plagioclase is generally between 10 to 30 modal %. Olivine is euhedral, plagioclase subhedral to ahhedral and clinopyroxend ophitic to poikilitic. Zonal structure is well developed in plagioclase (Pl. 8-2 and 3). The rocks have an orthocumulus texture.

The gabbroic layers are composed of cumulus plagioclase, clinopyroxene and a small amount of olivine. Olivine is about 10% in volume. Plagioclase is typically euhedral and is strongly zoned. Clinopyroxene crystals are euhedral (Pl. 9-2) to anhedral (Pl. 9-1). The clinopyroxene is also zoned. The texture is orthocumulus. Igneous lamination resulting from the dimensional orientation of plagioclase is present in some horizons.

The Upper Zone is characterized by the occurrence of many pegmatitic veins as shown in Fig. 10. They range from a few cm to two meters in thickness, and have a sharp boundary with the host rocks. Most of the pegmatitic veins have a WNW-ESE trend and are vertical. The veins are composed of plagioclase, clinopyroxene and a small amount of olivine. The grain size may reach 20cm in length for a single crystal.

2) Disturbed Structures

Disturbed structures of the layering are often seen in the Lower Zone. However, as mentioned by Hess (1960), it is difficult to see disturbed structures where rhythmic layering is not well developed, so that in Mt. Poroshiri they may be present in the Upper Zone, but are not seen in field

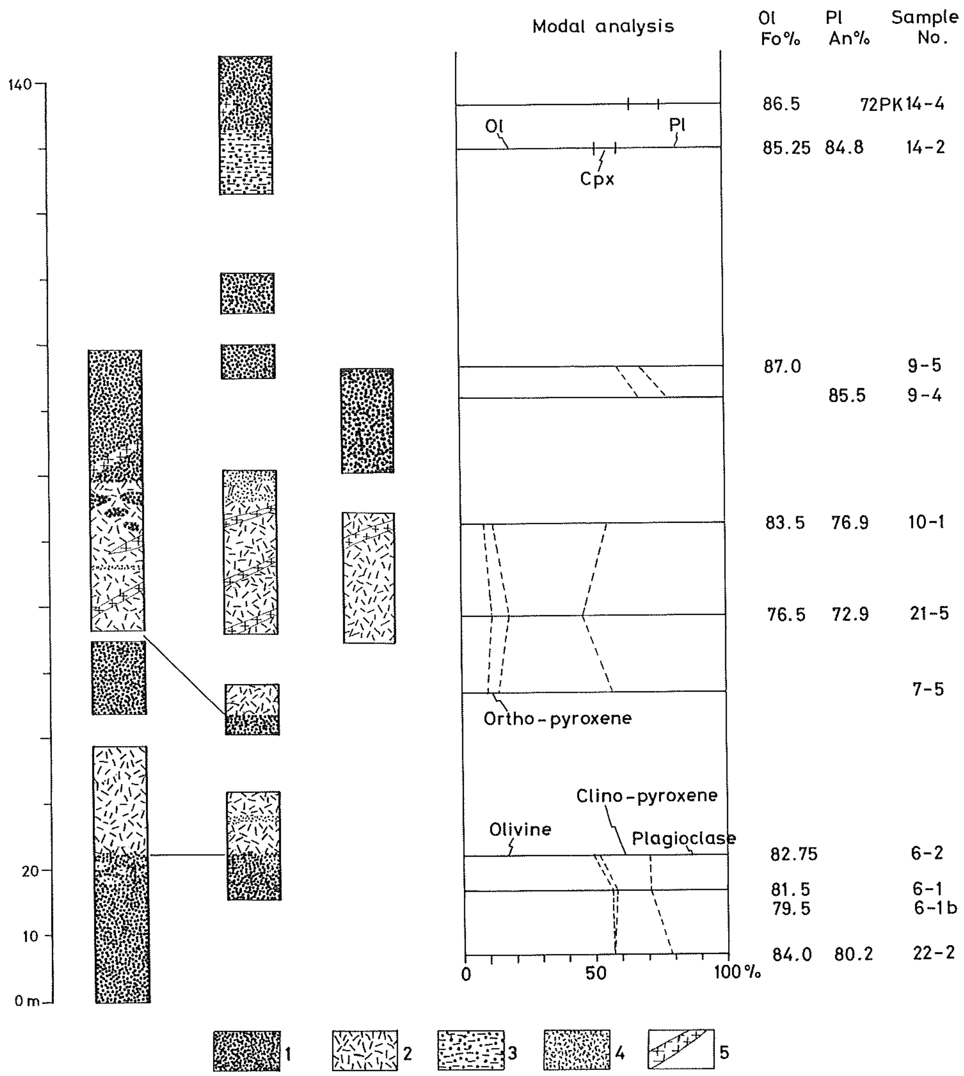

Fig. 10 Geologic columns from the East-Cirque of Mt. Poroshiri, corresponding to the Upper Zone. The composition of cumulus olivine and plagioclase, and modal analysis are shown.

1. Olivine-rich rocks, 2. Gabbroic rocks, 3. Troctolitic rocks, 4. Amphibole-rich rocks these can not presume the primary rocks, 5. Gabbroic pegmatite.

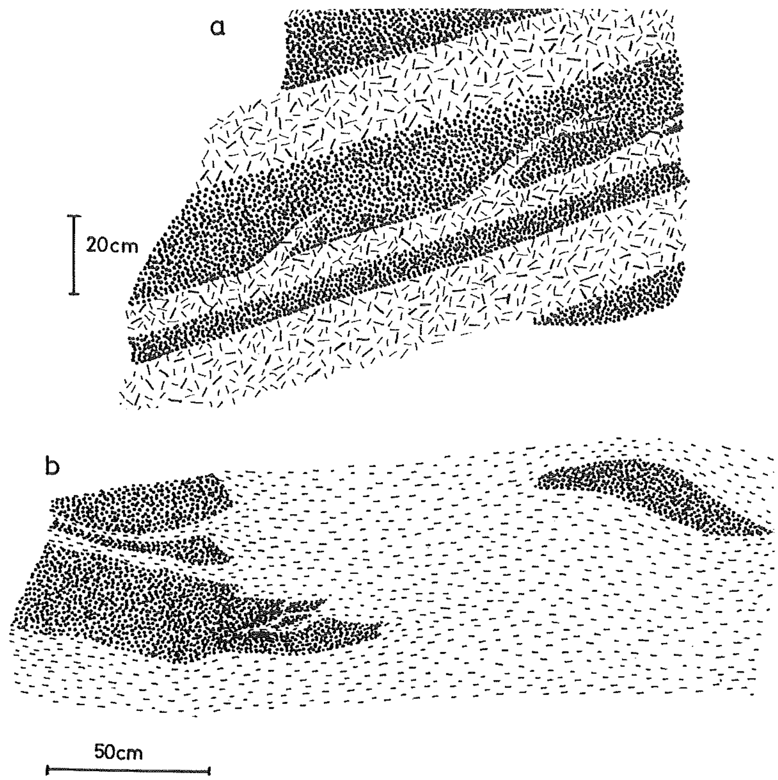

Fig. 11 Disturbed structures of the Lower Zone in the North-Cirque of the Mt. Poroshiri, a skech (a) represents branching structure and (b) represents brecciated structure.

exposure. Two types of disturbed structures are distinguished (P1. 4-3, 4).

One type of disturbed structure, here termed "branching structure" (Fig. 11-a), is very similar to that figured by Hess (1960, P1. 7) in the Stillwater Complex. The disturbed structures shown in P1. 4-5 are probably representative of the initiation of a branching-type structure. Those structures illustrated in Fig. 11-b and P1. 4-1 may represent a more advanced stage of the branching structure. In all of the disturbed structures the underlying plagioclase-rich layers intrude the overlying olivine-rich layers. The plagioclase-rich layers are orthocumulates, indicating that they solidified with cooling below the crystal-liquid interface and therefore contained a considerable amount of uncrystallized intercumulus liquid. On the other hand the olivine-rich layers are heteradcumulates and would have become solid very near or at the crystal-liquid interface without an appreciable drop in temperature (Wager and Brown, 1968). Consequently movement of the cumulus pile would have largely taken along the still, unsolidified plagioclase-rich layers which behaved plastically and intruded, and sometimes brecciated, the overlying solidified olivine-rich layers.

Similar kinds of disturbed structures are observed in many basic layered intrusions, e.g. Rhum (Brown, 1956; Wadsworth, 1961), Duke Island (Irvine, 1964), Stillwater (Hess, 1960) and Kiglapait (Morse, 1968).

The boundaries of the macro layers in the Upper Zone are irregular. Fig. 12 represents one example showing that olivine-rich rocks intrude and brecciate gabbroic rocks. This is the opposite of that observed in the Lower Zone. The textures of both rock types are orthocumulate and so such structures may have resulted from the injection of magma rather than to some disturbance in unconsolidified cumulates.

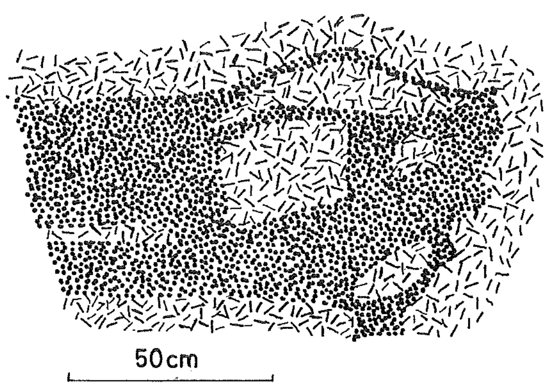

Fig. 12 Disturbed structures of the Upper Zone.

Textures

Textures in layered igneous rocks have considerable significance in relation to the conditions of solidification. Their interpretation is based on the concept of crystal settling and the relationship between cumulus (originating outside the rocks in which they are now formed) and intercumulus (in situ crystallization) material. Wager, Brown and Wadsworth (1960) have proposed a cumulus nomenclature for the textures of basic-ultrabasic rocks which can be summarized as following.

An *orthocumulate* solidifies beneath the crystal-liquid interface in which the cumulus crystals and intercumulus magma constitute a closed system. The cumulus crystals are therefore markedly zoned due to a change of liquid composition with a decrease in temperature.

An *adcumulate* completes its solidification at the crystal-liquid interface in an open system so that there is free diffusion between the intercumulus liquid and overlying magma. The cumulus crystals are enlarged by material of the same composition at the same temperature until the intercumulus liquid is used up. The cumulus crystals are therefore unzoned.

Mesocumulates have textures intermediate between those of ortho- and adcumulates.

A *heteradcumulate* contains large poikilitic plates of unzoned intercumulus minerals. Like adcumulates they probably solidify at the top of the cumulates pile.

The textures of the rocks of the Mt. Poroshiri Layered Complex can be interpreted according to the above cumulate nomenclature. Near the bottom of individual layers, i.e. those represented in Fig. 9-a and b, the textures are orthocumulus. Near the top of the same layers, the textures are mesocumulus to adcumulus. In both the lower and upper parts of an individual layer clinopyroxene is intercumulus, and plagioclase and olivine are cumulus. The modal variation, shown in Fig. 9-a and b, indicates that adcumulus growth increases toward the top of individual layers. There must have been some time gap before the overlying layers were deposited. Such a time gap may have been responsible for adcumulus growth which implies a continual diffusion process between the intercumulus liquid and the overlying magma. On the other hand, succesive precipitation of crystals obstructs adcumulus growth and results in rapid burial which favours orthocumulus growth.

As mentioned before, the textures of the plagioclase cumulates in the Nukabira part may be adcumulus. In the Lower Zone of the Poroshiri part, the macro layers of the plagioclase-rich cumulates have mesocumulus to adcumulus textures. The olivine-rich cumulates have mesocumulus to orthocumulus textures. In the Upper Zone the gabbroic layers and olivine-rich layers both have orthocumulus to mesocumulus textures.

Modal Variation

All of the rocks in the Poroshiri Complex contain variable amounts of secondary minerals. Samples in which the secondary minerals do not exceed 10% in volume were chosen for more detailed study because in such rocks it is possible to estimate the primary textural relations.

Plagioclase, olivine and clinopyroxene represent more than 95% of the rocks of the complex. Orthopyroxene and chromite are accessory primary minerals. Modal variation is shown in Fig. 13.

The rocks of the olivine-plagioclase cumulate macro layers of the Lower Zone plot near the olivine-plagioclase side of the ol-pl-px diagram of Fig. 13 and it is evident that an increase in plagioclase is accompanied by a decrease in clinopyroxene. Modal variation from the base to the top of an individual layer is represented by arrows in Fig. 13. The decrease in the amounts of clinopyroxene is related to the amount of adcumulus growth in the rocks.

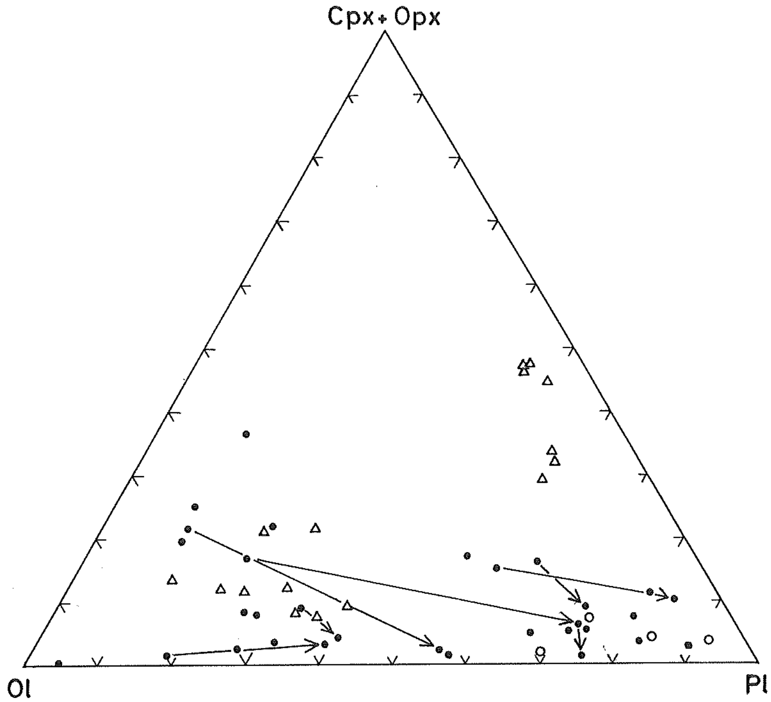

Fig. 13 Modal analysis on a triangular diagram of olivine-plagioclase- (clinopyroxene+ orthopyroxene).
Arrows show the variation from base to top of individual layers. (solid circles; olivine-rich macro layers of the Lower Zone, open circles, plagioclase-rich macro layers of the Lower Zone, open triangles; Upper Zone)

Unfortunately, most of the plagioclase-rich macro layers in the Lower Zone are altered, so that the primary modal proportion was gained for only four samples. The results plot near the plagioclase apex of the plagioclase-olivine side and overlap some of the olivine-plagioclase cumulate rocks of the Lower Zone. Pyroxene does not exceed 10% in volume. The exact primary modal proportion for rocks of the Nukabira part is unknown but they probably plot in the range of the plagioclase-rich cumulates of the Poroshiri part.

The two rock types in the Upper Zone are clearly defined by the clustering of points in Fig. 13. The cluster of points nearer the olivine apex fall in the field of the Lower Zone olivine-plagioclase cumulates while the more feldspathic rocks plot in a distinctly different region than those of the plagioclase-rich rocks of the Lower Zone in that they are more pyroxene rich.

Small amounts of orthopyroxene and chromite are contained in most of the rocks. As is evident from Fig. 14, the modal variation of orthopyroxene and chromite are opposite from each other. As the plagioclase/(olivine + plagioclase) ratio increases, the amounts of orthopyroxene increases while the amount of chromite decreases. Generally the amount of orthopyroxene in the Upper Zone is greater than in the Lower Zone at the same plagioclase/(olivine + plagioclase) ratio. On the other hand, the relation between the Lower and Upper Zone chromite contents is just the reverse. The modal variation in the individual layers (arrows in Fig. 14) of the Lower Zone are also opposite.

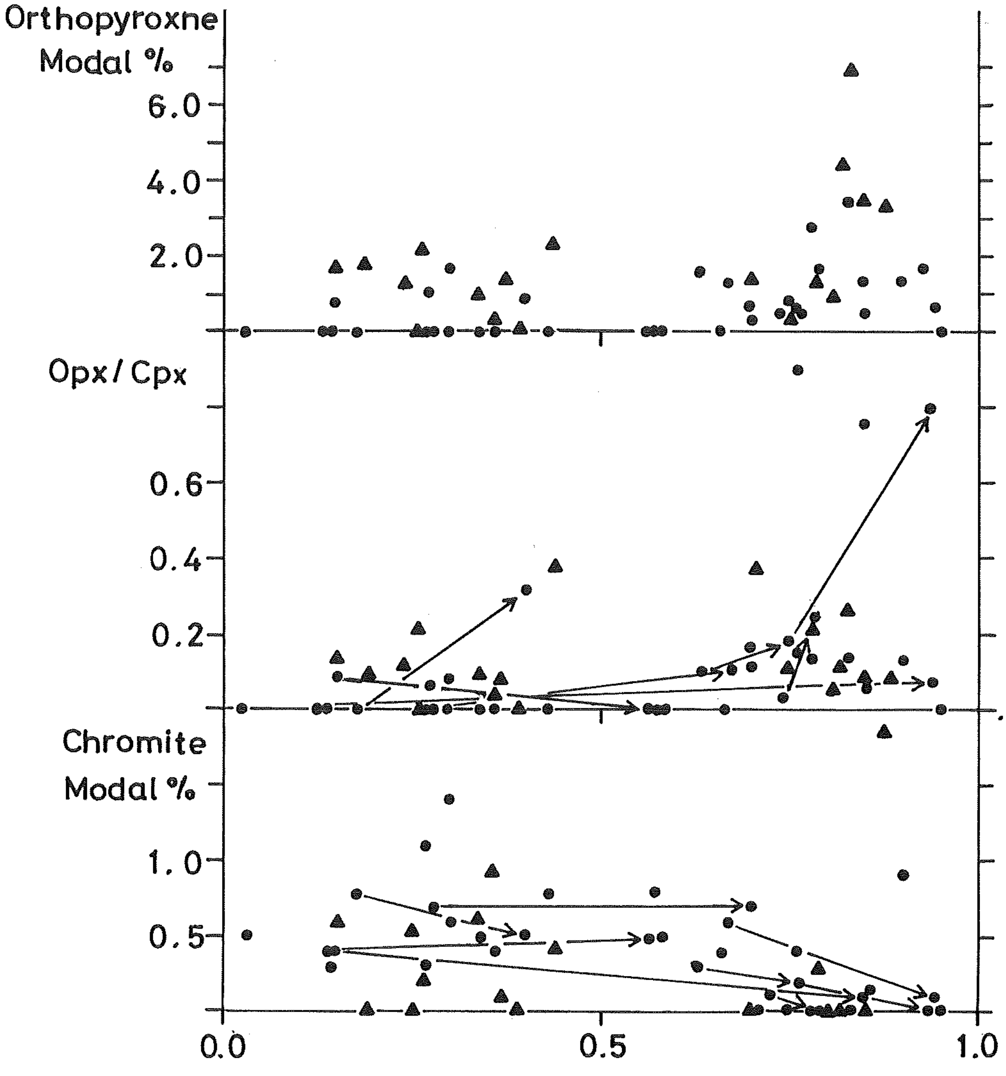

Fig. 14 Modal analysis of orthopyroxene, Opthopyroxene / clinopyroxene and chromite against the ratio of plagioclase / (plagioclase + olivine). Variations from base to top of the individual layers are shown by arrows. (solid circles, Lower Zone, solid triangles; Upper Zone)

Cryptic Layering

Olivine composition was determined by the X-ray method of Yoder and Sahama (1957), and each composition is the average of five runs using silicon as an internal standard. The An content of the plagioclase was determined by the universal stage using the method of Tobi (1963) because of high An contents and well developed albite-carlsbad complex twinning. The An molecule is the average of the measurement of 10 to 20 grains in each section.

Cumulus minerals in the Poroshiri Complex are mainly plagioclase and olivine. There is no constant variation in cryptic layering in the whole complex. However, compositions of olivine and plagioclase from the Upper Zone have lower An and Fo contents than those in the Lower Zone. The Fo content of cumulus olivine in twenty-four samples from the Lower Zone varies from Fo 89 to 84 and most are included in the range between Fo 89 to 86. Twelve samples from the Upper Zone show a variation from Fo 87 to 76.5, and except for two samples, all the rest range from Fo 85 to 76.5. A similar tendency is seen in the An contents of plagioclase, which range from An 87 to 84 in the Lower Zone and from An 85.5 to 73 in the Upper Zone.

Fig. 9-a, b, c show the compositional variation of cumulus olivine and plagioclase in the fine-scale rhythmic layering of the olivine-plagioclase cumulate layers of the Lower Zone. Four cases represented in Fig. 9-a and c show that the Fo and An contents decrease upward in a layer, and two other cases in Fig. 9-b show the reverse tendency. In Fig. 9-b, the amount of intercumulus clinopyroxene decreases markedly upward in a layer, whereas in Fig. 9-a and c only a small decrease is apparent. In the upper part of the layer represented in Fig. 9-b the amount of adcumulus growth is marked and results in a decreasing amount of pyroxene whereas in cases Fig. 9-a and 9-c, the increasing amount of adcumulus growth is less. Therefore, in cases of the Fig. 9-a and 9-c, regular variation in the composition of the cumulus mineral is present whereas in cases of Fig. 9-b extensive orthocumulus growth may influence the composition of the cumulus minerals and strong adcumulus growth will preserve the original composition of the cumulus crystals.

Cryptic layering is very irregular in the Upper Zone as shown in Fig. 10, although the olivine-rich layers tend to have higher An and Fo contents than in the olivine-poor gabbroic layers. Such irregularity may have resulted from repeated injections of new magma or some change in the physical condition of crystallization (cf. Brown, 1956; Wadsworth, 1961; Wager, 1968). Field evidence supports the former suggestion, as mentioned before.

A plot of An% against Fo% (Fig. 15) shows a good correlation except for pegmatitic olivine and plagioclase and indicates regular increase of An%

together with Fo%. The relation between An% and Fo% in the Poroshiri Complex resembles to that of the Skaergaard Intrusion (Fig. 16).

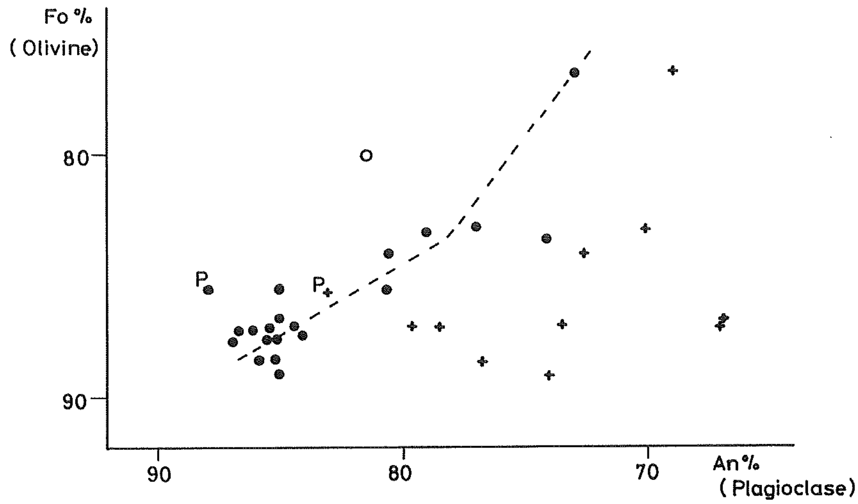

Fig. 15 The composition of olivines plotted against the composition of plagioclases. (solid circles; cumulus olivine-cumulus plagioclase, crosses; cumulus olivine-intercumulus plagioclase, open circles; intercumulus olivine-cumulus plagioclase, P; pegmatitic rocks)

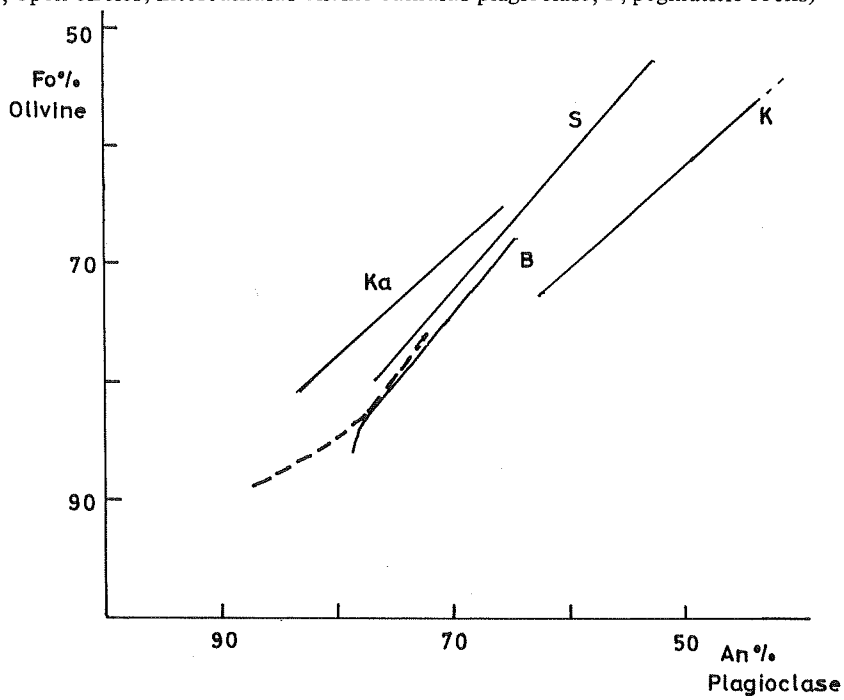

Fig. 16 Correlation of the composition of cumulus olivine against cumulus plagioclase with other layered intrusion. S; Skaergaard, B; Bushveld, K; Kiglapait, Ka; Kap Edward Holm, broken line; Poroshiri

Conclusion

1) Correlation between the basic rocks in the Western Zone of the Hidaka Metamorphic Belt and Mt. Proshiri Layered Complex

The Mt. Poroshiri Layered Complex and metagabbro of the Western Zone have common features. The banded structure of the metagabbro is similar to the gabbroic layers of the Poroshiri part, and also in the modal proportion, texture and dimensional orientation of plagioclase (Hashimoto, 1961). The initial stage metamorphism in the rocks is marked by the formation of actionlite reaction rims between olivine and plagioclase, and the replacement of clinopyroxene by actinolite (Grapes, Hashimoto and Miyashita, in preparation). Similarly relic plagioclase in both rocks has a characteristic purple colour (Hashimoto, 1961). These facts suggest that the metagabbro of the Western Zone was originally similar to the relatively unmetamorphosed rocks of the Mt. Poroshiri Complex.

2) Some preliminary comments on the formation of the Mt. Poroshiri Layered Complex

The presence of cumulate textures indicates that the rocks were formed under static conditions. The mode of cryptic layering and field evidence suggest that the rocks did not solidify by a simple fractionation process, but that influxes of new magma occurred from time to time, especially during the formation of the Upper Zone. Textural evidence indicates that the rate of accumulation increased toward the upper exposed horizon. Metamorphism in the complex probably occurred during tectonic uplift after solidification. A detailed examination of the metamorphism will be given in another paper. A study, now in progress, of the chemistry and mineralogy of the rocks will shed considerably more light on the subjects dealt with in this paper and will be published at a later date.

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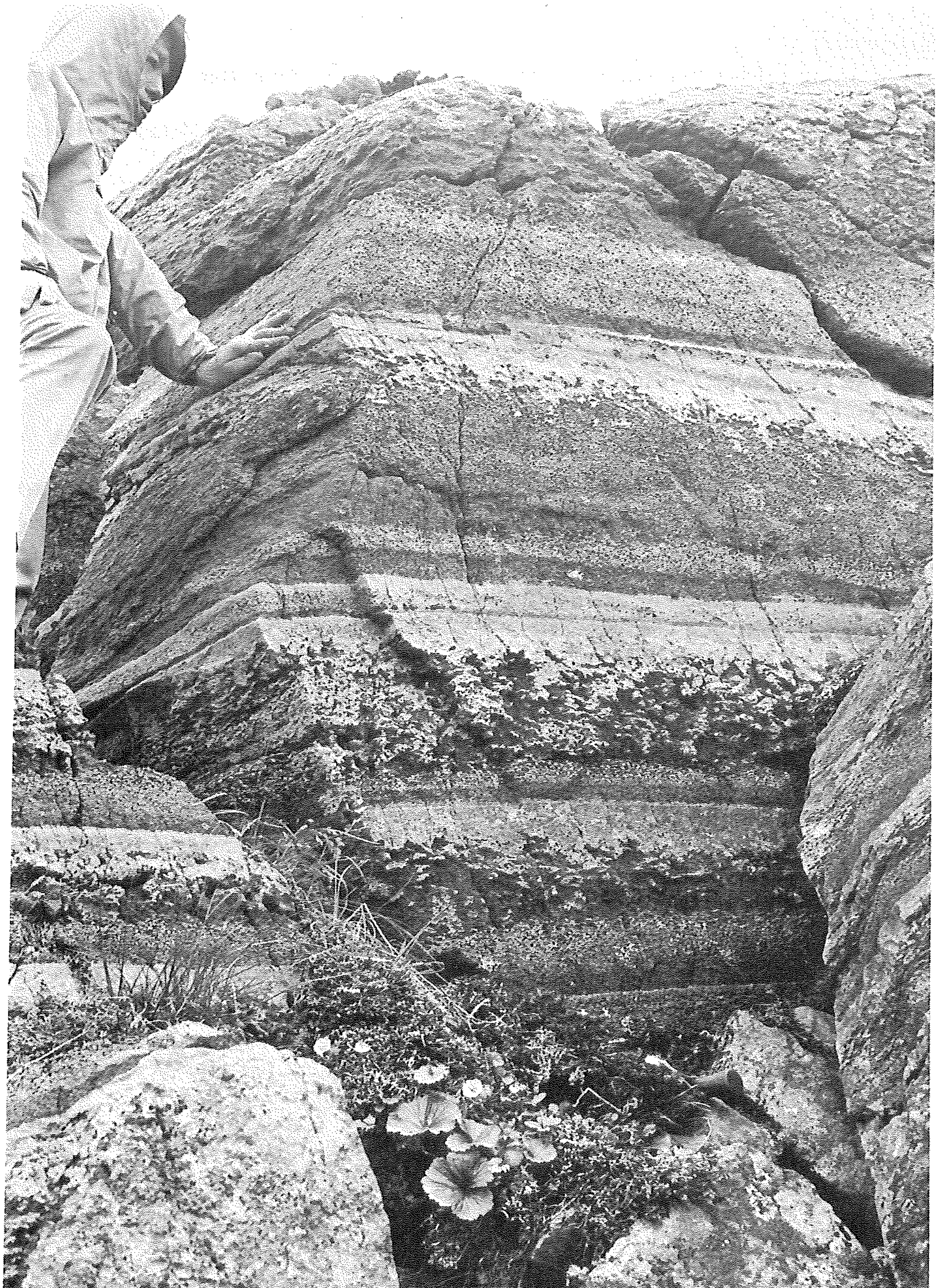


Plate 1: Well developing example of rhythmic layering from the Lower Zone of the Poroshiri part, North-Cirque of Mt. Poroshiri. From base to top in each layer, quantity of olivine decreases and plagioclase increases. Upper part of photograph is uniform olivine heteradcumulate.

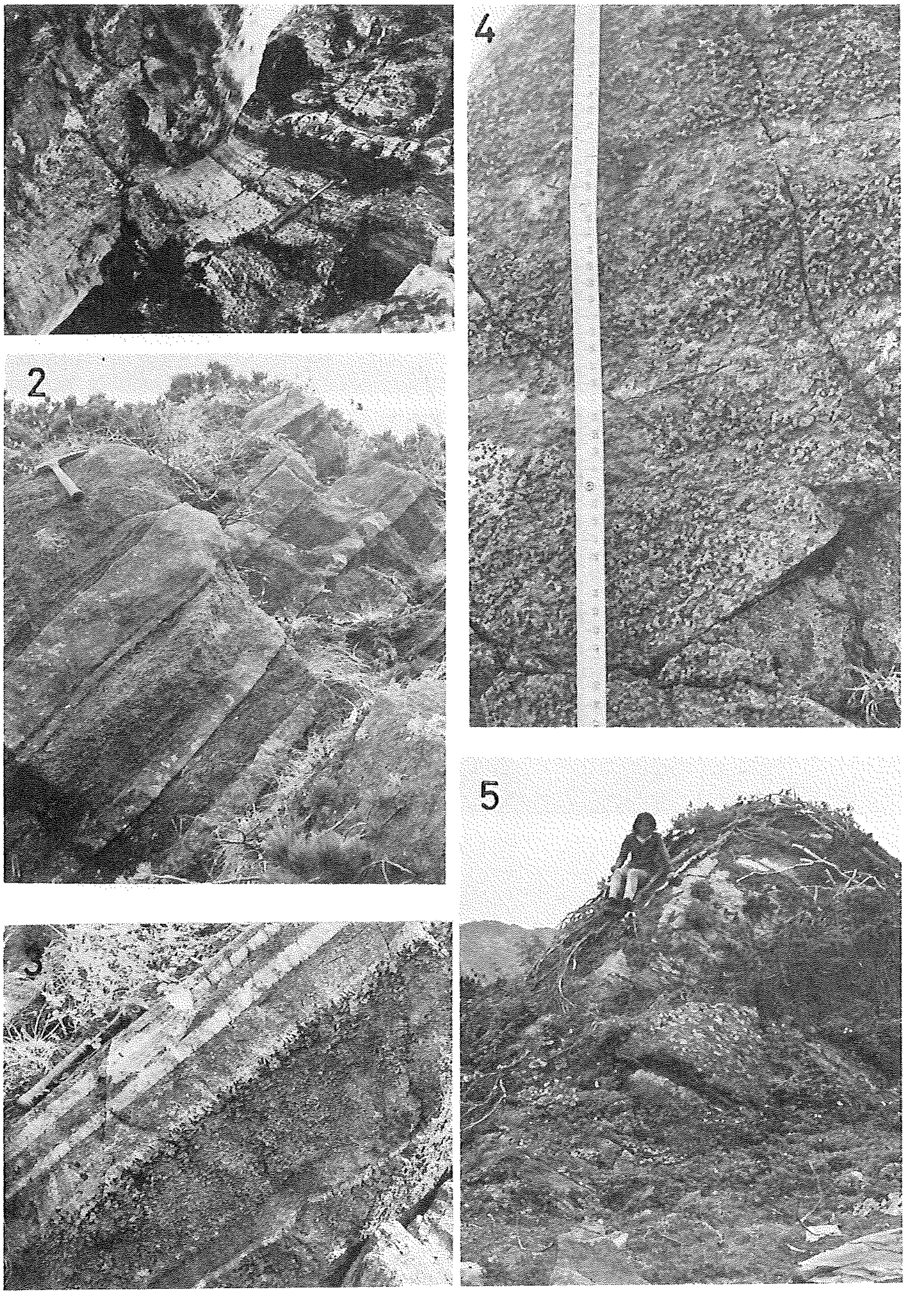


Plate 2: Fig. 1. Faint rhythmic layering of plagioclase cumulate from Nukabira part.

Fig. 2. Rhythmic layering in alternation of olivine and plagioclase cumulate layers from the Lower Zone of the Poroshiri part. Boundaries between them are sharp.

Fig. 3. Vertical growing of plagioclase (harristic structure) against the layering in the Lower Zone. Grain size increasing upward.

Fig. 4. Rhythmic layering in plagioclase-rich layer from the Lower Zone. Exposing rounded minerals are olivines surrounded by spinel and amphibole rims.

Fig. 5. Rhythmic layering in olivine-rich macro layer from Lower Zone of the Poroshiri part.

Plate 3: Fig. 1. Well developed example of finely stratified layering from the Lower Zone of the Poroshiri part.

Fig. 2. Larger span (2m) of rhythmic gradational layers is obvious. The base and the top of the layer is shown by broken line.

Fig. 3. Alternation of plagioclase-rich and olivine-rich layers. Note the disturbed structures.

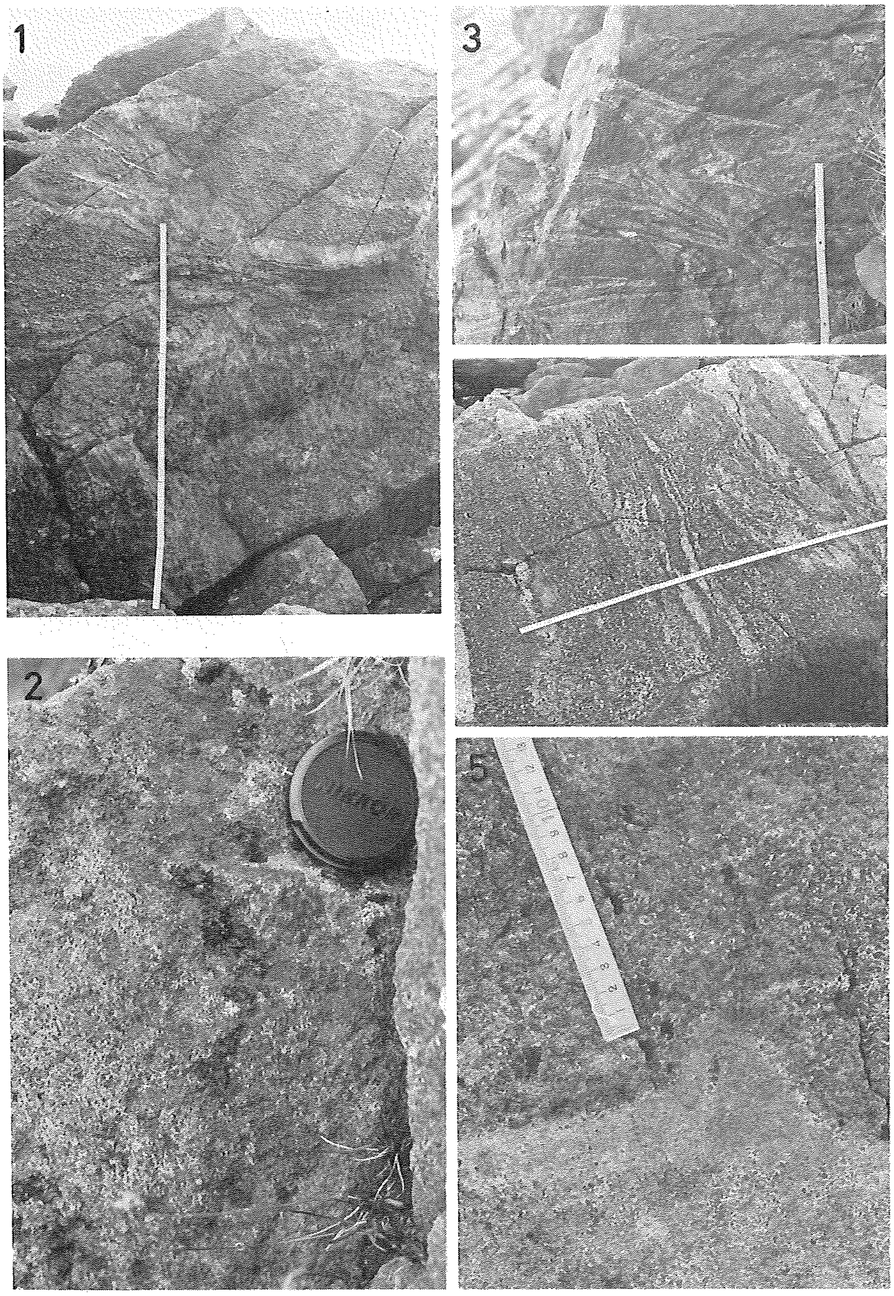
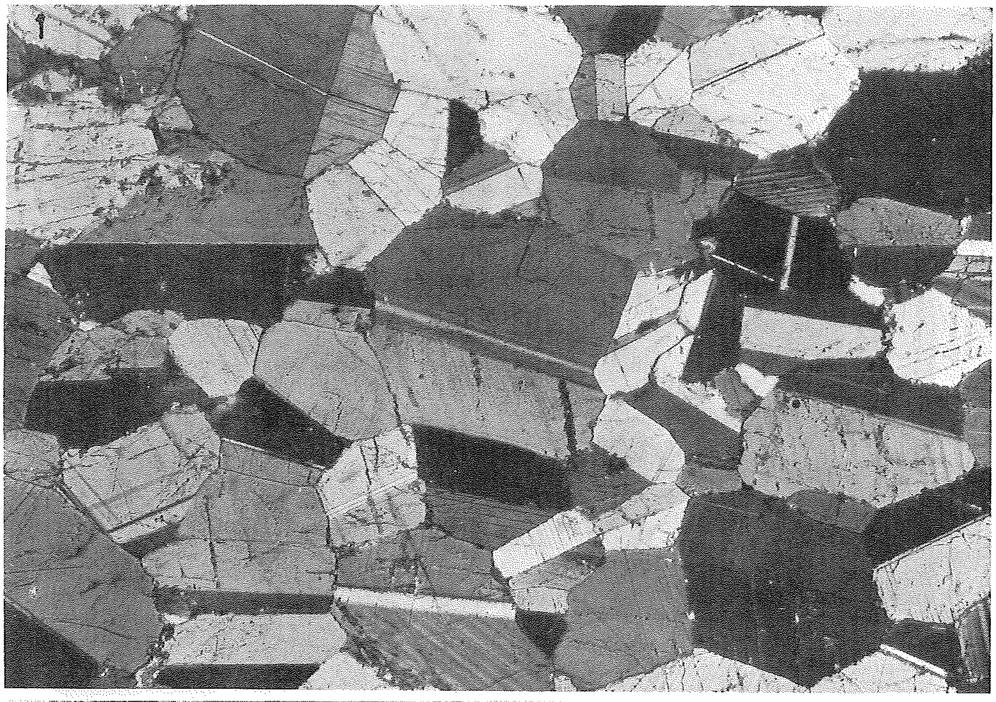


Plate 4: Fig. 1. Disturbed structure in plagioclase-rich macro layer of the Lower Zone of the Poroshiri part. Scale is 1m.

Fig. 2. The layering of host rock is approximately horizontal in the plate, but the clinopyroxenite vein (black portion) developes vertically against the layering. The host rock is olivine heteradcumulate and almostly does not contain clinopyroxene.

Fig. 3, 4. Slump structures develope in olivine-plagioclase cumulate layers in the Lower Zone of the Poroshiri part.

Fig. 5. "Beginning" of the branching structure, underlying plagioclase-rich layer protrudes into the overlying olivine-rich layer.



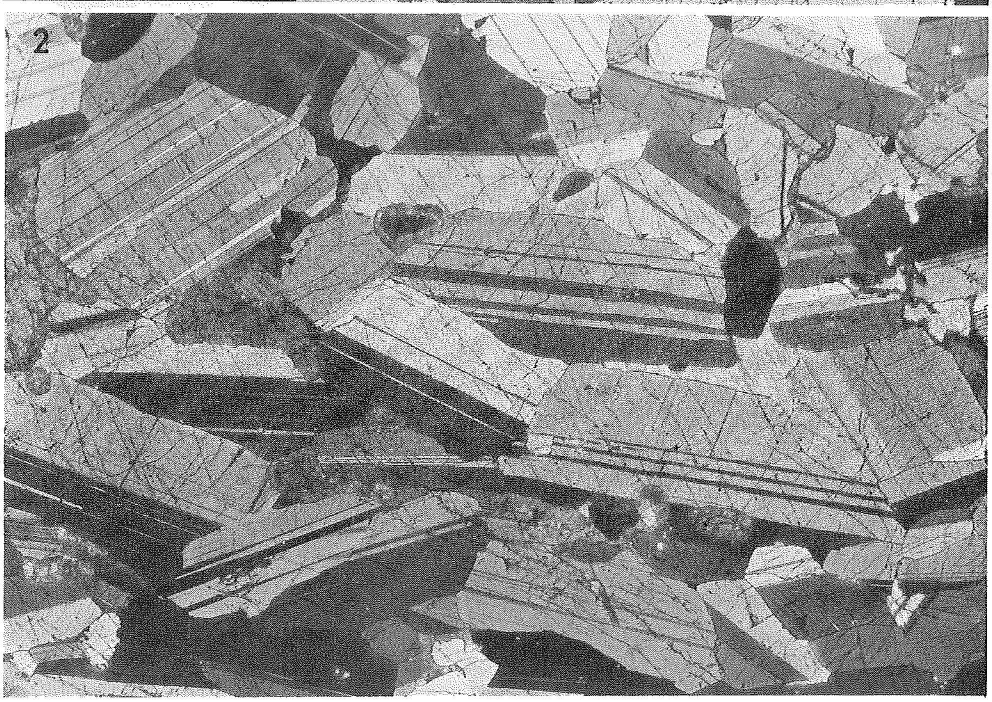
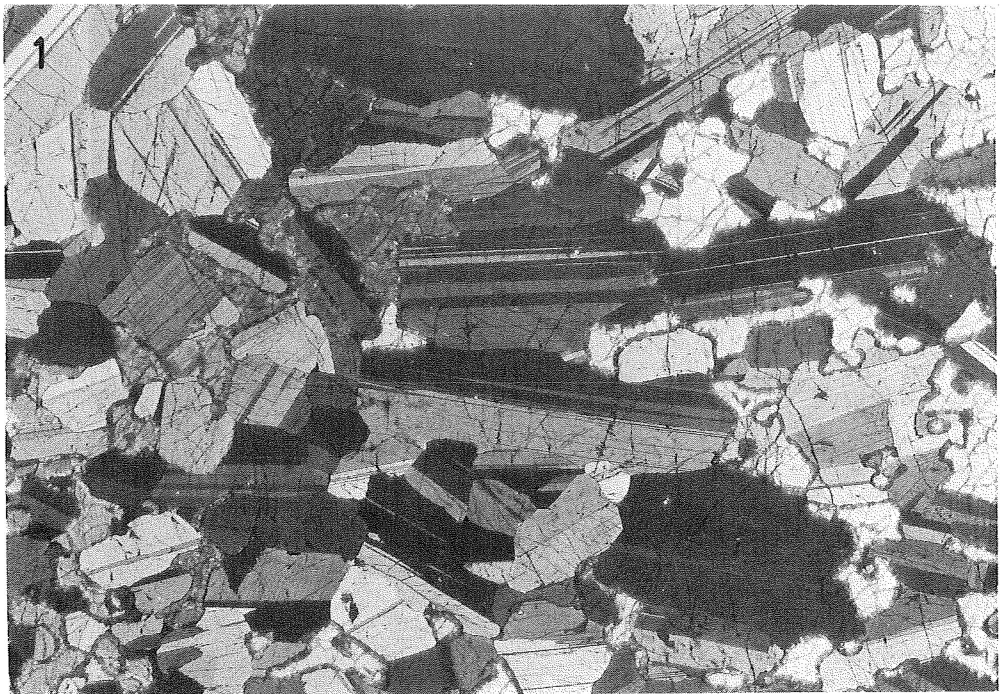


Plate 5: Fig. 1. Plagioclase adcumulate of the plagioclase-rich macro layer of the Lower Zone. Zoning of plagioclase is almostly absent. X 50.

Fig. 2. Plagioclase mesocumulate of the plagioclase-rich macro layer of the Lower Zone. Intercumulus minerals include olivine and clinopyroxene. Slight zoning is observable in the cumulus plagioclase. X 20.



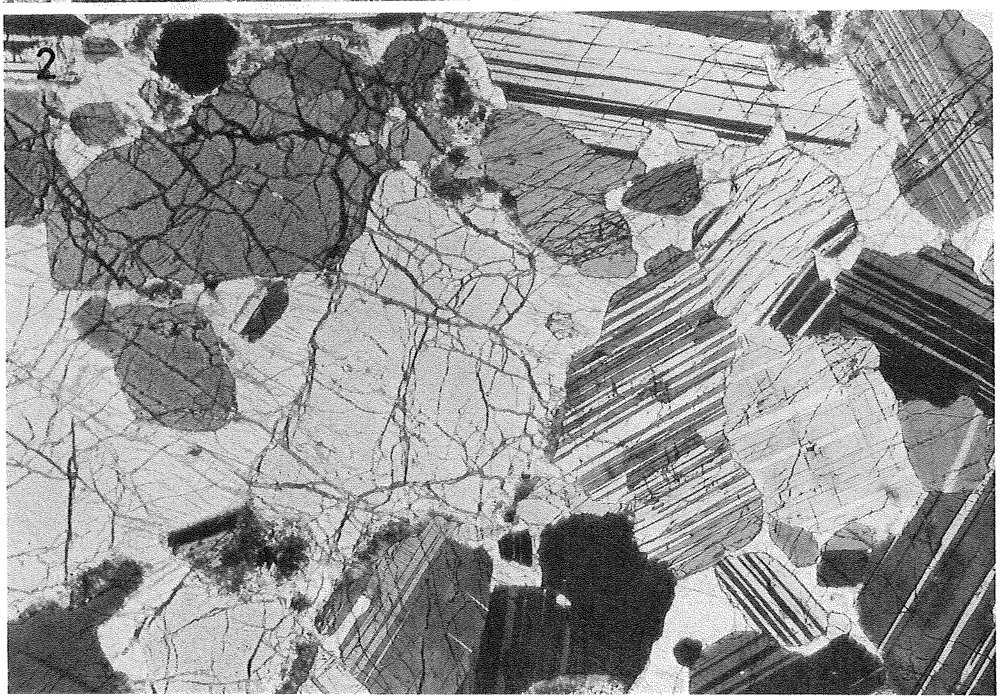
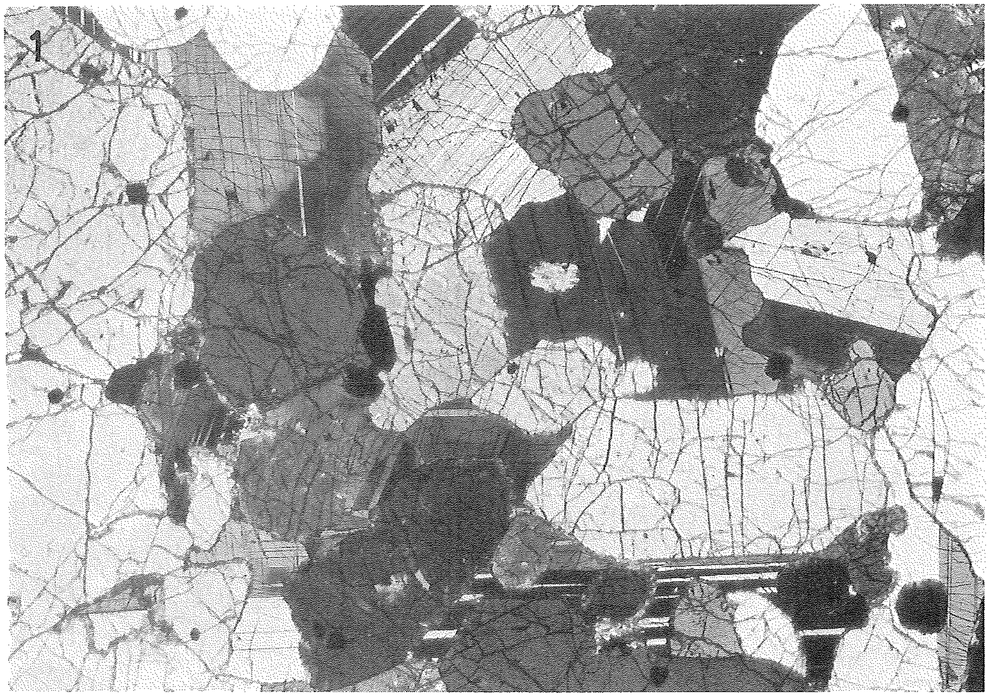


Plate 6: Fig. 1. Plagioclase heteradcumulus texture from the plagioclase-rich macro layer of the Lower Zone. Poikilitic to ophitic intercumulus minerals are olivine. Zoning of plagioclase in absent. X 20.

Fig. 2. Plagioclase-olivine orthocumulate of plagioclase-rich layer is included in alternation in olivine-rich macro layer of the Lower Zone. Intercumulus minerals are clinopyroxene. X 20.



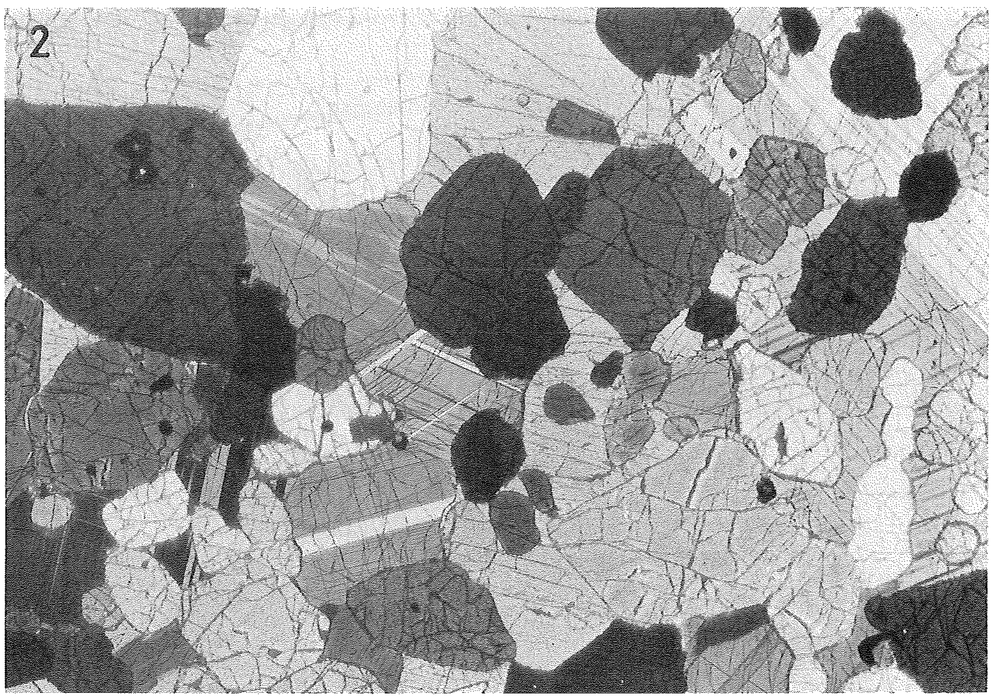


Plate 7: Fig. 1. Olivine orthocumulate or mesocumulate of the olivine-rich layers of the Lower Zone. Cumulus minerals are olivine and small amount of chromite. Zoned plagioclase are intercumulus minerals. A part of the plagioclase may be in the cumulus phase. X 20.

Fig. 2. Olivine heteradcumulate of the olivine-rich layers of the Lower Zone. Cumulus shaped minerals are olivine and small amount of chromite. Poikilitic crystals are plagioclase and clinopyroxene showing no zoning. X 10.

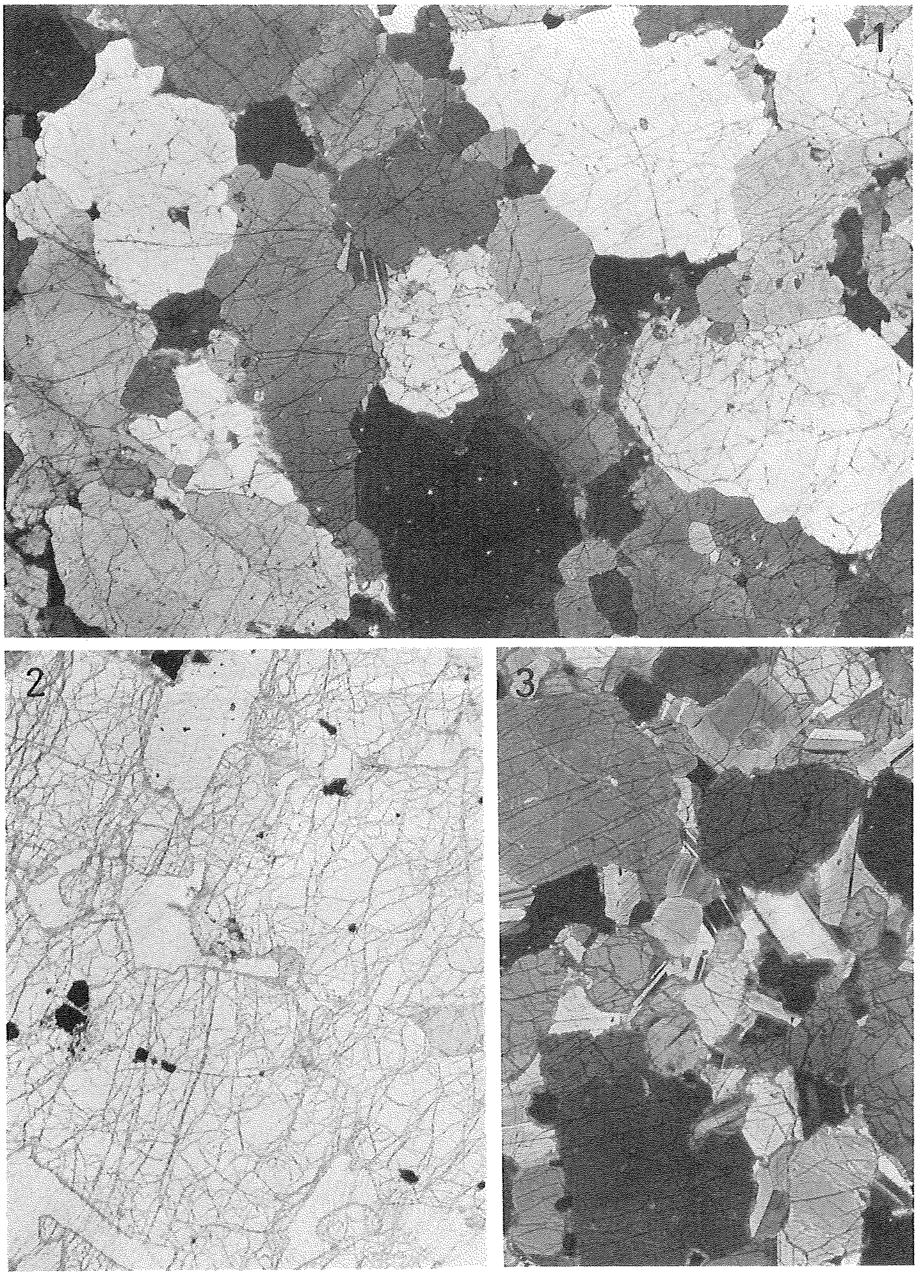
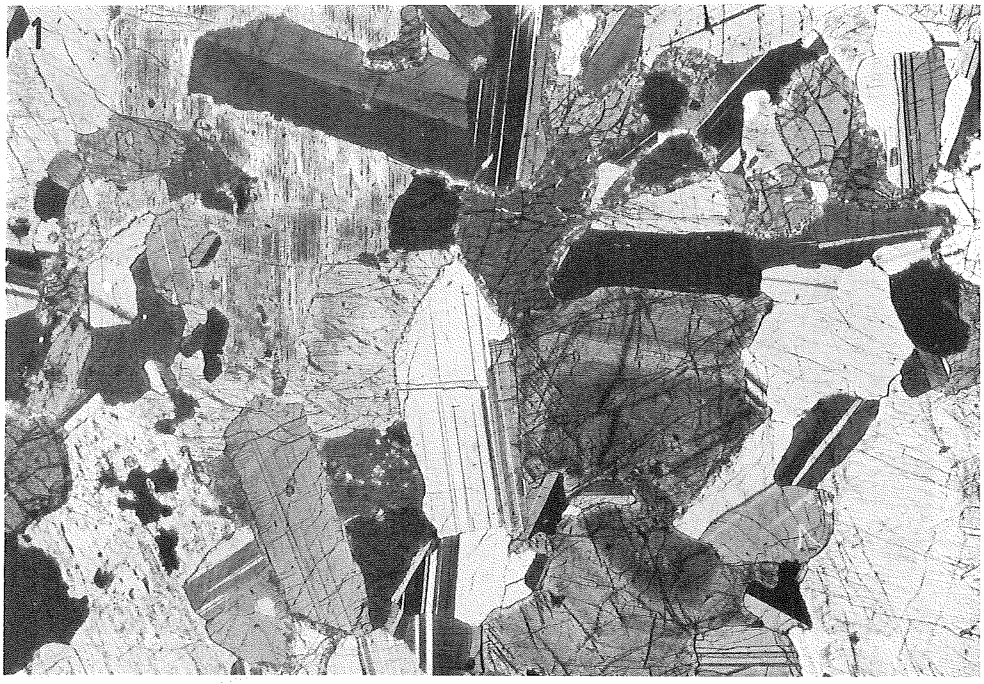


Plate 8: Fig. 1. Olivine mesocumulate of olivine-rich layers of the Lower Zone. The amount of intercumulus plagioclase is very small. X 10.

Fig. 2. Olivine mesocumulate of olivine-rich layers of the Upper Zone. Intercumulus minerals are plagioclase and small quantity of clinopyroxene. Zoning of plagioclase is well developed, although it cannot be seen in the photograph. Small amount of plagioclase may be in the cumulus phase. X 10.

Fig. 3. Olivine orthocumulate of olivine-rich layers of the Upper Zone. Cumulus minerals are olivine and small amount of chromite, and intercumulus minerals are plagioclase and small amount of clinopyroxene. The amounts of intercumulus crystals are greater than in Fig. 2. X 10.



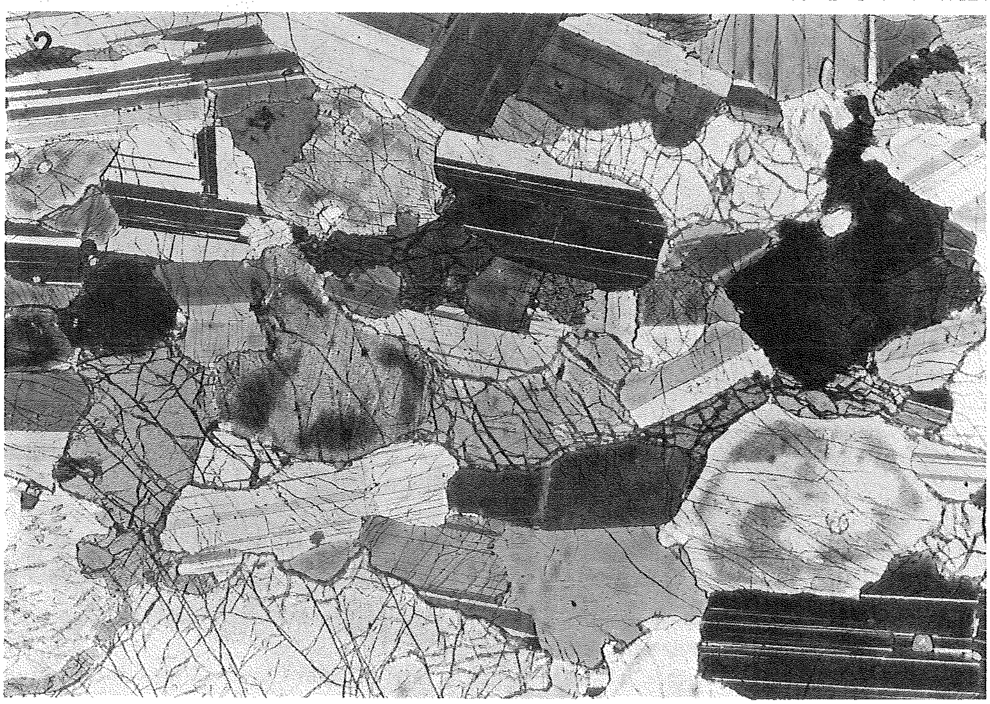


Plate 9: Fig. 1. Plagioclase-olivine cumulate of the gabbroic layers of the Upper Zone. Plagioclase represents zonal structure and intercumulus clinopyroxene also shows conspicuous zoning. Core of the clinopyroxene may be in the cumulus phase. X 20.

Fig. 2. Plagioclase-clinopyroxene-olivine cumulate of the gabbroic layers of the Upper Zone. Plagioclase and clinopyroxene show zoning. X 20.