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Author(s)	Kizaki, Koshiro
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PETROFABRICS OF THE OSHIRABETSU DOME IN THE SOUTHERN HIDAKA METAMORPHIC ZONE, HOKKAIDO, JAPAN.

by

Koshiro KIZAKI

(With 51 Text-Figures)

Contributions from the Department of Geology and Mineralogy,
Faculty of Science, Hokkaido University, No. 635

Introduction

In this paper, some structural investigation on the migmatite dome of the Oshirabetsu mountain area is described. The dome is a easterly protruded portion of the main migmatite belt in the southern terminal region of the Hidaka metamorphic zone. That zone is enclosed by Jurassic and Cretaceous non-metamorphosed geosynclinal sedimentaries that constitute the N-S stretched axial zone of the island of Hokkaido. It is considered that the zone was produced by the alpine orogenic movement and that it represents the embrionic part of the island.

In the southern half of the island, the metamorphic zone runs along the Hidaka mountain range as a continuous belt about 140 km long, with 15 km width. It is composed of migmatites as its core facies, surrounded by zonally arranged gneisses and hornfelses; it is intimately associated with igneous intrusives of various kinds.

At the southern terminal region of the metamorphic zone, the migmatite expands into as a fan shaped area and diverges into three structural units. The northerly branch spreads around the Oshirabetsu mountain area, while the central part is a continuation of the main zone from the north. The other forms a large cordierite migmatite dome around Toyonidake in the southern branch. (Fig. 1)

Detailed field observations have been followed by microscopic fabric analysis of selected specimens of the area. The results of these studies, together with a discussion of their bearing upon the tectonic style of the rock involved, are the substance of this paper. The intimate relations between deformation and mineralization are also touched upon.

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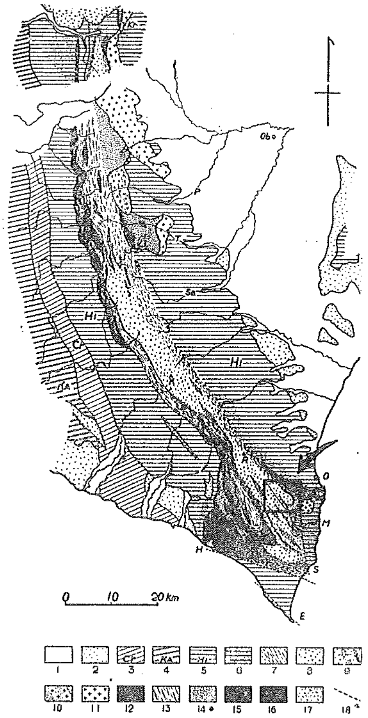

1. Quartanry formation
2. Tertiary formation,
3. Cretaceous formation,
4. Kamuikotan group,
5. Hidake group,
6. Hornfels,
7. Gneiss,
8. Migmatite,
9. Granitic migmatite,
10. Gncissose granite,
11. Granite,
12. Schistose gabbro,
13. Gneissose gabbro,
14. Gabbro,
15. Olivine gabbro,
16. Peridotite,
17. Recent volcanic rocks,
18. Fault,

Ob: Peridotite,
O: Oshirabetsu,
M: Meguro,
S: Saruru,
E: The cape Erimo,
H: Horoman.

Fig. 1. Geological sketch map of the Hidaka metamorphic zone. (After Hidaka Research Group)

General Geology

In the southern terminal region of the metamorphic zone now under consideration, generally speaking, the migmatite mass of each structural unit is surrounded by banded gneiss, which grades into schistose hornfels at its outer margin. At the Oshirabetsu mountain area, the circumstances are the same. The central part of the dome is made up of cordierite migmatite which trends to the NE with a width of 3 km. Its northern continuation merges into the main migmatite zone, which dips monoclinically to the NE, while the southern part ends in a dome-like structure surrounded by banded gneiss. A narrow zone of banded gneiss and schistose hornfels of 500 m width fringes about the northeastern side of the migmatite mass. Inasmuchas a continued intrusive body of gabbro occurs between the banded gneiss and the schistose hornfels, their boundary relation is obscure. On the south-eastern side of the dome, the width of the banded gneiss zone is also narrow and a conspicuous sheared

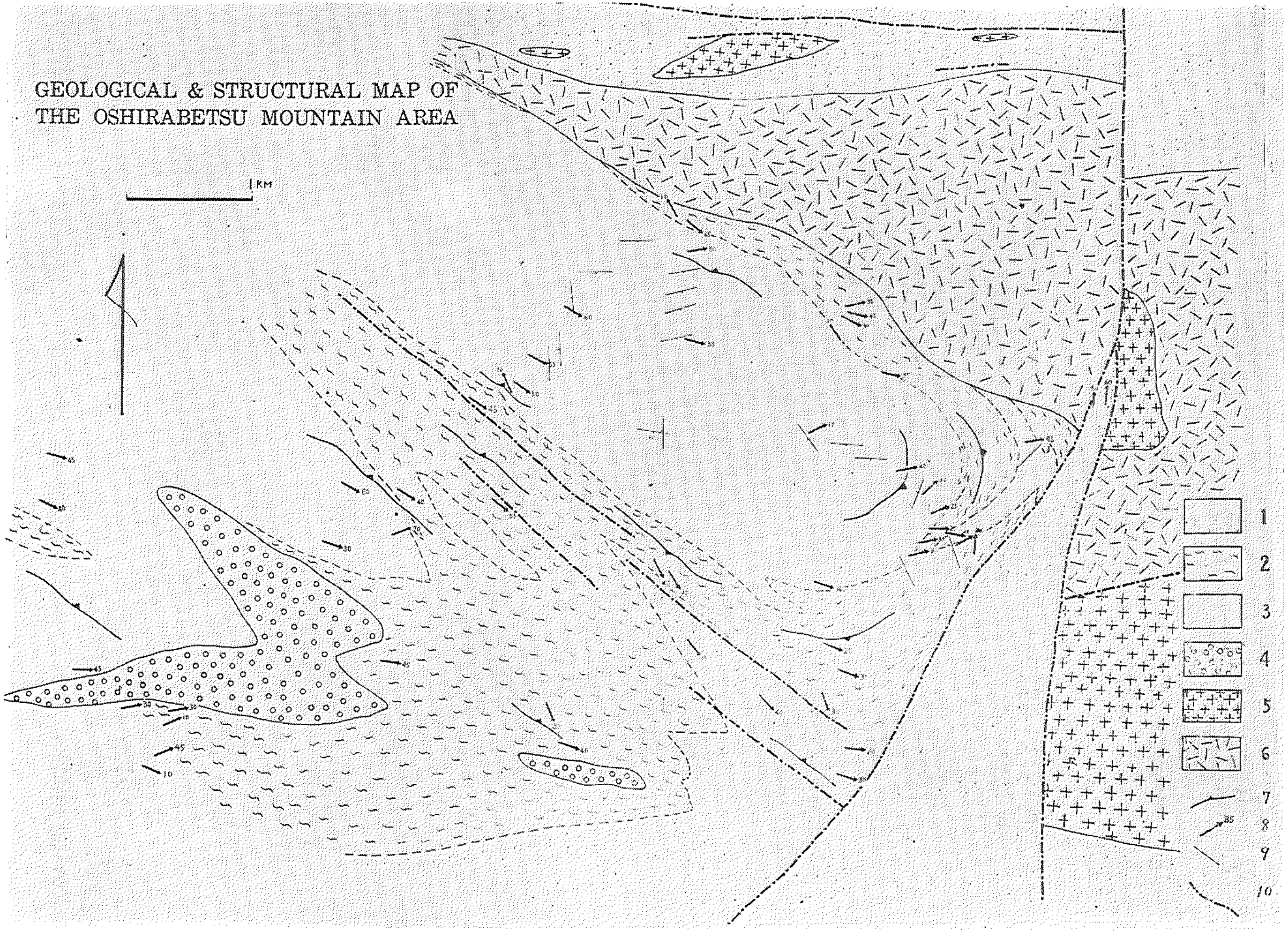

Fig. 2. Geological and structural map of the Oshirabetsu mountain area.

1. Hornfels, 2. Banded gneiss, 3. Cordierite migmatite, 4. Granitic migmatite,
5. Granite, 6. Gabbro, 7. Foliation, 8. Lineation,
9. Joint, 10. Fault and sheared zone.

zone separates the dome from the vast hornfels field and granitic intrusives. The synclinal area between the main migmatite zone and the Oshirabetsu dome, is occupied by banded gneiss and schistose hornfels with a NW trend; many sheared zones run along this zone. As mentioned above, being separated by tectonic lines at the outer margin of the banded gneiss zone, the Oshirabetsu dome is clearly revealed as one of the structural units of the region. (Fig. 2)

The main migmatite zone of the region has a width of 5 km and shows a N30W trend. The chief rock species of the zone is cordierite migmatite; it contains some gneissose migmatitic part and echelon-like disposed granitic migmatite bodies. The Toyonidake dome lies on the southern edge of the region. A structural nature like that of the Oshirabetsu dome is also observable in this area. The dome overturns toward the southwest and its southwestern slope is cut by a thrust fault in contact with schistose hornfels.

Generally speaking, the contact relation of each rock zone is gradually transitional and there is no marked discordant relation. However, the cordierite migmatite contains many block-like inclusions of gneiss and schistose hornfels and metamorphosed calcareous nodules which may denote an indubitable sedimentary origin. Granitic sheets and some leucocratic rocks and diabasic dykes are observed along the sheared zones.

Petrography

Every rock species of the area, is constituted essentially of plagioclase, biotite and quartz, of which the characters are shown in TABLES 1 and 2.

On the foliation plane of schistose hornfels, there occur flattened parallel spots of biotite which are the aggregate of minor ones. The gradual change to the banded gneiss is obvious.

The banded gneiss is characterized by the foliation being defined by alternate layers of biotite and quartz. Accessory constituents are orthoclase, muscovite, cordierite, fibrous sillimanite, apatite and opaques.

The main part of the Oshirabetsu dome is made up of cordierite migmatite. It has medium and foliated texture to some degree but is often massive. The microscopic texture is medium granoblastic with slight evidence of strain. The constituents are sodic plagioclase, quartz, biotite, cordierite and orthoclase. Cordierite appears as greyish green spots most of which are altered to pinite. Orthoclase occurs frequently replacing the plagioclase with considerable myrmekite. Accessory constituents are muscovite, apatite, zircon, titanite, fibrous sillimanite, garnet and opaques.

TABLE I. Texture, mode and grain size of each rock species.

	schistose hornfels		banded gneiss		cordierite migmatite		granitic migmatite	
texture	spotted schistose		banded		granoblastic		granoblastic	
	mode	grain size	mode	grain size	mode	grain size	mode	grain size
quartz	22.1	0.1	34.6	0.2	34.9	max.2.0 0.4	29.4	1.0
biotite	27.1	max.0.5 0.1	33.1	max.0.9 0.5	20.2	max.0.7 0.5	13.2	max.2.0 1.0
plagioclase	47.5	0.1	27.0	0.4	41.0	max.2.0 0.5	52.4	max.4.0 2.0
muscovita	—	—	0.8	0.3	0.8	0.5	—	—
orthoclase	—	—	1.7	0.4	2.1	0.4	4.2	1.5
etc.	3.3		2.8		1.0		0.8	
	100.0		100.0		100.0		100.0	

Granitic migmatite is massive, sometimes porphyritic biotite quartz diorite. Pheoncrysts of fresh coloured feldspar (a sodic andesine) occur frequently at the parts transitional to the cordierite migmatite. Generally, the contact with cordierite migmatite is gradual but sometimes there is a sharp boundary. The constituents are plagioclase, quartz, biotite, orthoclase and hornblende in locally. Orthoclase occurs frequently in large porphyroblasts with partial perthite and replaces plagioclase with considerable myrmekite.

Megascopic and Microscopic Structures

The structural elements of the Oshirabetsu dome such as foliation, lineation, joints and faults, are shown in Figure 2.

Foliation: The rocks within the area have one kind of obvious megascopic s-plane. This will be referred to throughout this paper as foliation. It is rather pronounced, as in the banded gneiss and schistose hornfels, but is feebly represented in some of the cordierite migmatite and the granitic migmatite. The foliation is defined by the dominant orientation of platy minerals such as mica. The banded gneiss has a well-marked foliation defined by alternations of layers enriched with quartz and biotite.

The layering in the banded gneiss may be the result of metamorphic differentiation, either chemical or mechanical. The trends of foliation planes are indicated in Figure 2.

Joints: The system of joints is observed only in the cordierite migmatite part of the dome. The most constantly occurring joints have two trends, an EW or ENE-WSW directed group and a NS or NNW-SSE directed group. Their dips are nearly vertical. Some minor faults and sheared zones parallel to the directions of the joints are observable. These trends of joints cross obliquely to the lineation. They consequently fail to show *ac* joint or tension joint but are examples of a shear joint. They may be considered as synonymous with a crevasse in a glacier.

Lineation: The conspicuous feature of the megascopic fabric is the lineation on the foliated plane which is present in almost all the rock types. It is most marked in the banded gneiss and schistose hornfels but so weak in the cordierite migmatite as often to be unobservable. The visible lineation is defined by the following features.

1) Parallel orientation of mineral grains such as biotite, invariably define the lineation.

2) The orientation of the axes of microfolds sometimes marks and are parallel to the orientation of mineral grains.

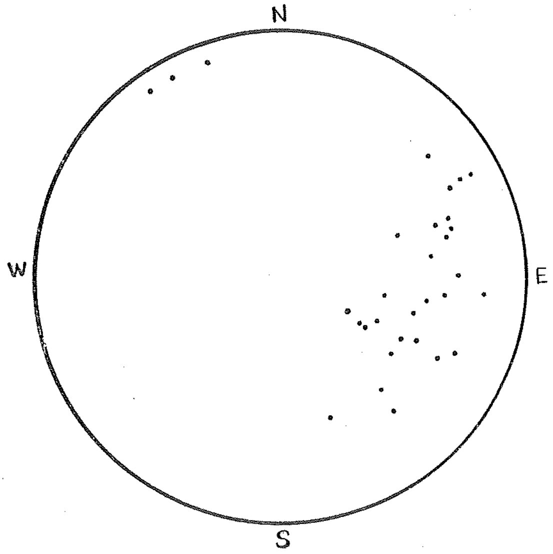

Fig. 3. Diagram showing orientation of lineations

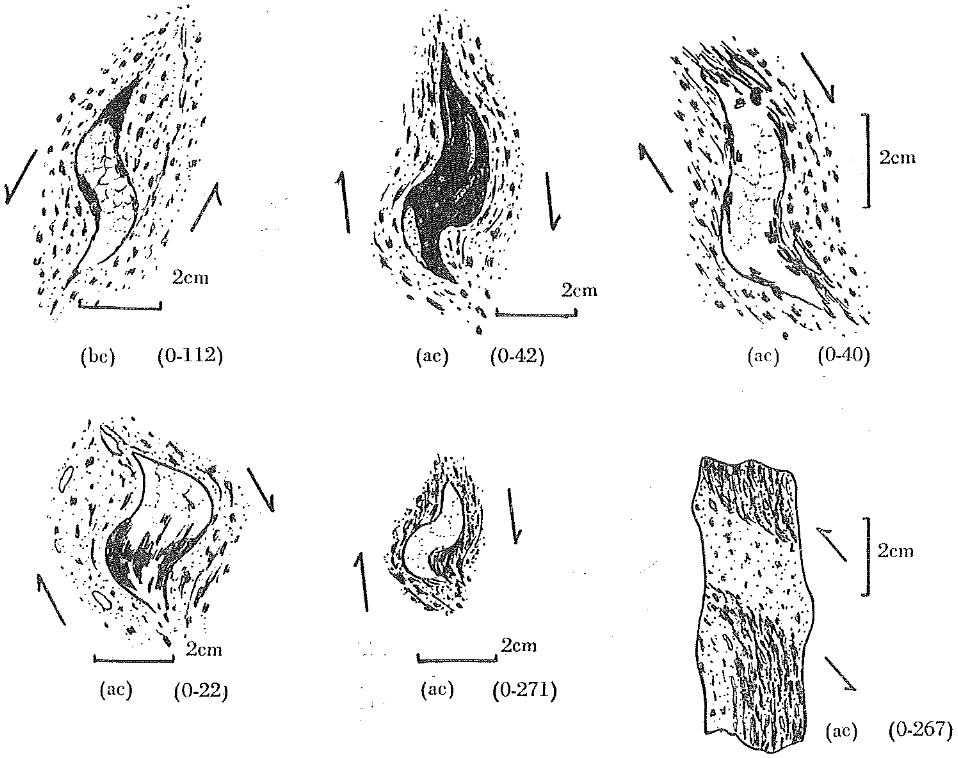

Fig. 4. The occurrence of palaeosomes and quartz pools.

The orientation of the lineation is shown in Figure 2; it dips always to the southeast, 15°–60°. The dip is more gentle in the center of the dome than in the outer portions. (Fig. 2 and 3)

B-axes: There is much discussion on the problem whether lineation is parallel or normal to the direction of movement, as is the controversy on the Caledonian movement in Norway and the Scottish Highlands. The writer came to a conclusion as to that problem by the field observations and the inspection of hand specimens in the area. In the cordierite migmatite, there are many deformed inclusions of gneiss and schistose hornfels (palaeosomes) and also quartz pools. Their shapes preserve the lineation. (Fig. 4) The deformation represented in Figure 5, however, means

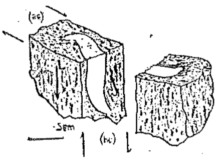

Fig. 5. Quartz pool in cordierite migmatite.

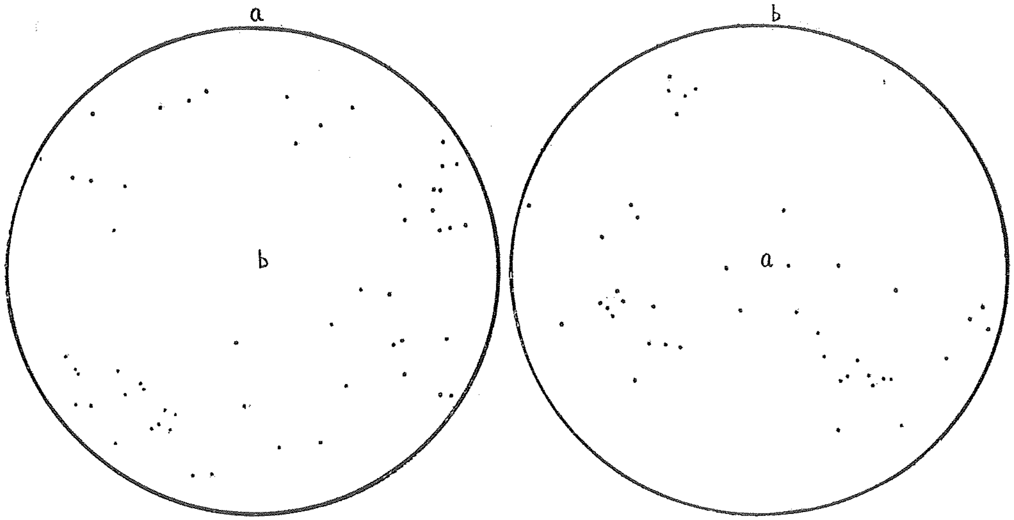

Fig. 6. Axes of guartz grains from Fig. 5.

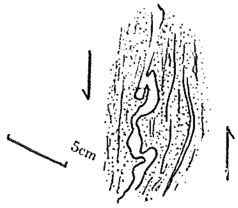

Fig. 7. Microfolding in schistose hornfels (ac).

that the movement is normal to the lineation and also weakly parallel to the lineation at the same time. The orientation of quartz axes of this quartz pool, demonstrates the girdle normal to the lineation with little tendency toward a girdle parallel to the lineation. (Fig. 6) The girdle normal to the lineation represents the partial movement normal to the lineation as noted by SANDER (1950). Furthermore, the axes of the microfolding in the schistose hornfels and the banded gneiss are parallel to the lineation. (Fig. 7)

Consequently, the principal partial movement is normal to the lineation and therefore the lineation of this area is *b*-lineation.

Microscopic Fabric

The preferred orientation of grains has been studied in seventeen specimens of schistose hornfels, banded gneiss, cordierite migmatite and granitic migmatite. The fabric diagrams of quartz, biotite, plagioclase and muscovite have been prepared from thin sections oriented parallel or subparallel to the *ac*-plane of the fabric. The texture, grain size and mode of each rockspecies are shown in TABLE 1.

The mineralogy of each specimen is simple; quartz, plagioclase, biotite, and the other important minerals are flakes of muscovite and orthoclase cementing intergranular space.

Quartz:

Quartz grains are xenomorphic occurring among the other minerals; they fractured and undulatory but often large grains of blastic nature are found. Undulatory extinction is marked but is not always existent in the same thin section. Generally, the existence of no large fresh porphyroblastic quartz indicates undulatory extinction; the core part of it indicates higher refractive index than the outer part and always contains gaseous or liquidous inclusions. Besides that, as a rule, the orientation of gaseous inclusions has the parallel arrangement. Such orientations of inclusions are called "Böhm lamellae".* Some of them are so-called deformation lamellae which appear as narrow, bright lines and light up just before extinction. The lamellae have also a higher refractive index than the grain itself.

The orientation of quartz axes shows the *ac* girdle as a rule. (Fig. 8–Fig. 28) In schistose hornfelses and banded gneisses, quartz orientation takes the form of distinct girdle, and its maxima have symmetry with respect to *s* surface (foliation plane) being near the maxima II, IV, VI according to SANDER (1930) and FAIRBAIRN (1949).

There are two girdles in some specimens (Fig. 17, Fig. 12); inner girdle does not show distinct symmetry with respect to maxima. FAIRBAIRN holds that the inner girdle as described now, is a residual orientation. (FAIRBAIRN 1949)

In cordierite migmatite, quartz orientation shows the imperfect *ac* girdle and its maxima show point symmetry with respect to *b*; it has no symmetry of maxima in Figure 18 and Figure 19. An example of plane symmetry with distinct foliation as in gneisses, is shown in Figure 16. The diagram in Figure 18 especially shows the concentration of the quartz axes of the specimen illustrated in Figure 4. It is distinctly that conspicuous external rotation with respect to *b* has occurred. In Figure 15, is shown a diagram of the banded gneiss which is transformed to a mylonite by intense shearing and so has become granulated. In this case, the quartz orientation does not show *ac* girdle but shows a tendency toward the accumulation of the maxima IV, VI.

All the maxima of each specimen of the area, are projected on the synoptic diagram according to SANDER, GRIGGS & BELL and FAIRBAIRN in

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* When the deformation lamellae have recrystallized to the parallel orientation of gaseous or liquidous inclusions, this texture is called BÖHM lamellae. (BÖHM 1883, HIETANEN 1938, FAIRBAIRN 1949)

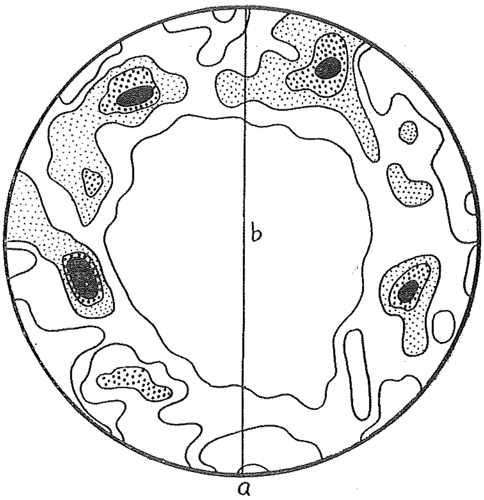

Fig. 8. 260 quartz axes from schistose hornfels (0–267). Contours 1–2–3–4%.

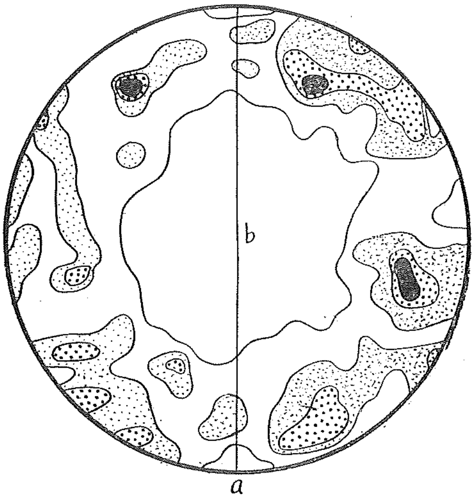

Fig. 9. 299 quarz axes from banded gneiss (0–271). Contours 1–2–3–5%.

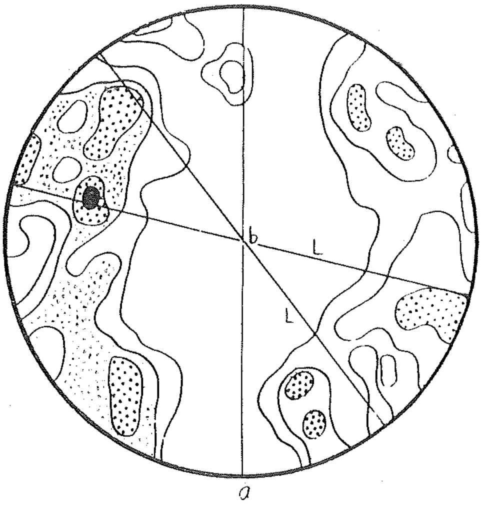

Fig. 10. 110 quartz axes from banded gneiss (0–11). Contours 1–3–5–6%.

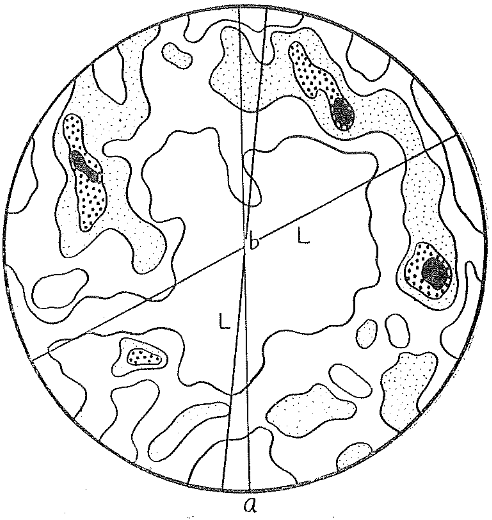

Fig. 11. 246 quartz axes from banded gneiss (0–19). Contours 1–2–3–4%.

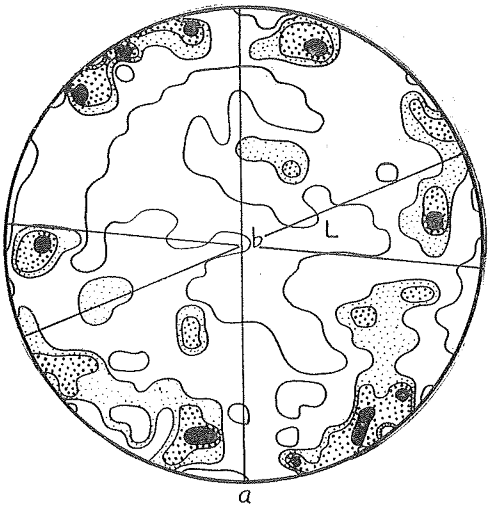

Fig. 12. 164 quartz axes from banded gneiss (0–121). Contours 1–2–3–4%.

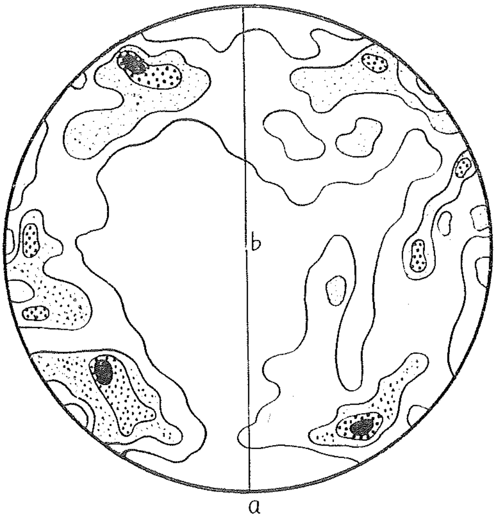

Fig. 13. 196 quartz axes from banded gneiss (0–106). Contours 1–2–3–4%.

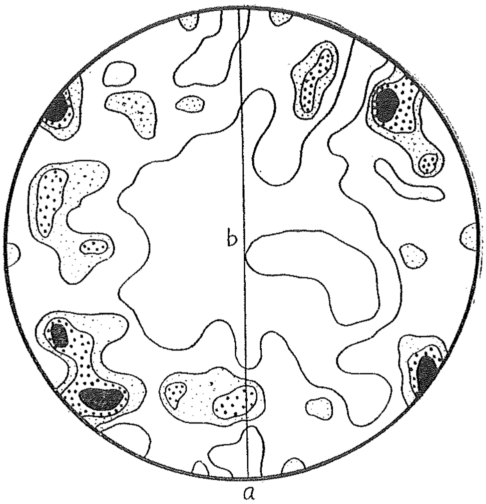

Fig. 14. 184 quartz axes from banded gneiss (0–269). Contours 1–2–3–5%.

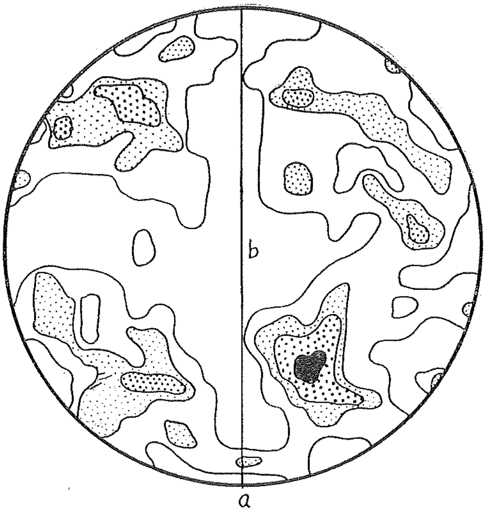

Fig. 15. 244 quartz axes from mylonitic banded gneiss (0–109). Contours 1–2–3–4%.

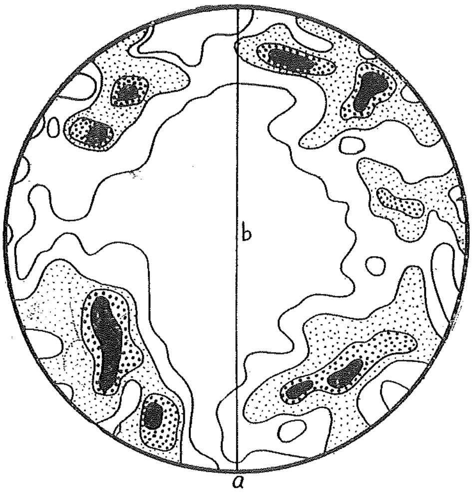

Fig. 16. 170 quartz axes from cordierite migmatite showing intense foliation (0–250). Contours 1–2–3–5%.

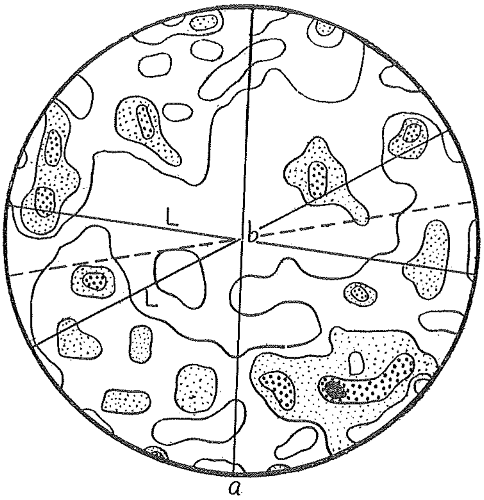

Fig. 17. 232 quartz axes from cordierite migmatite (0–105). Contours 1–2–3–4%.

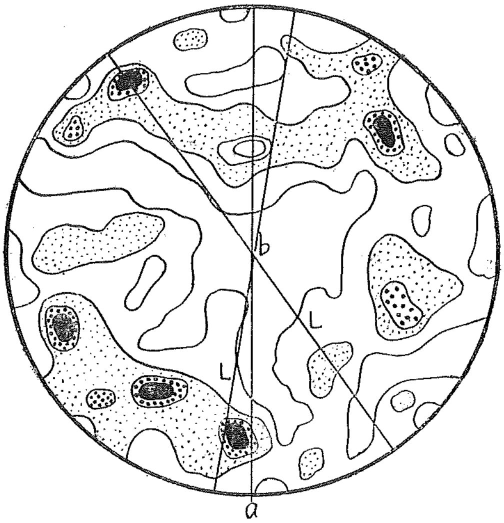

Fig. 18. 170 quartz axes from cordierite migmatite (0–22) in Fig. 4.

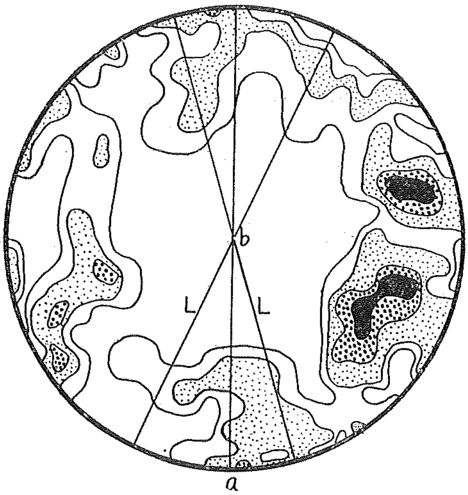

Fig. 19. 100 quartz axes from cordierite migmatite (0–23). Contours 1–3–4–6%.

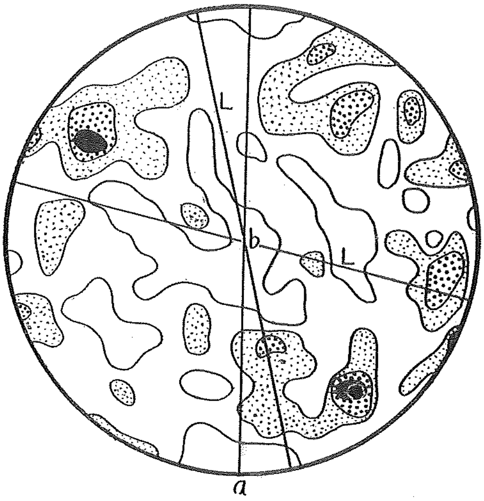

Fig. 20. 183 quartz axes from cordierite migmatite (0–43). Contours 1–2–3–4%.

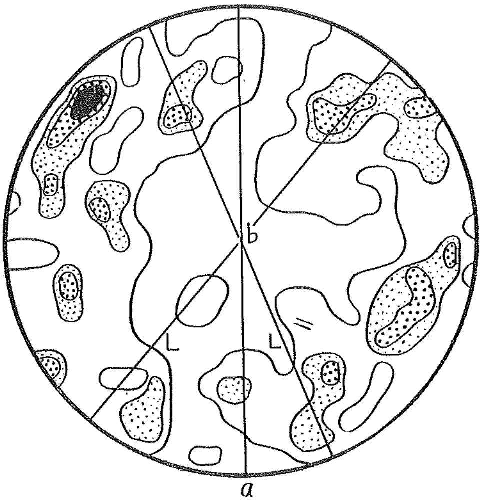

Fig. 21. 145 quartz axes from cordierite migmatite (0–60). Contours 1–2–3–5%.

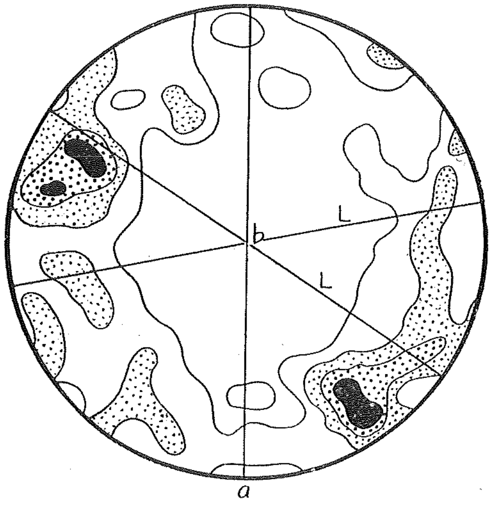

Fig. 22. 130 quartz axes from cordierite migmatite (0–220). Contours 1–3–4–5%.

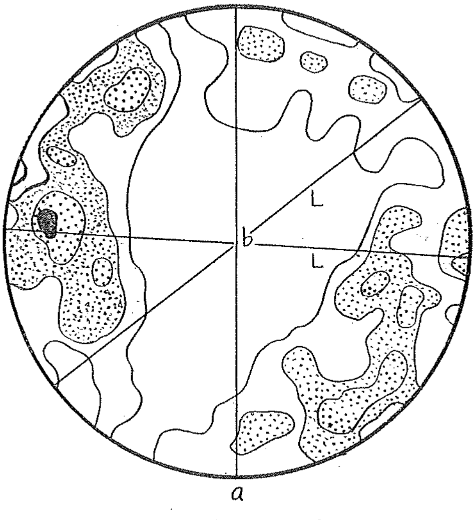

Fig. 23. 180 quartz axes from cordierite migmatite (0–221). Contours 1–3–5–7%.

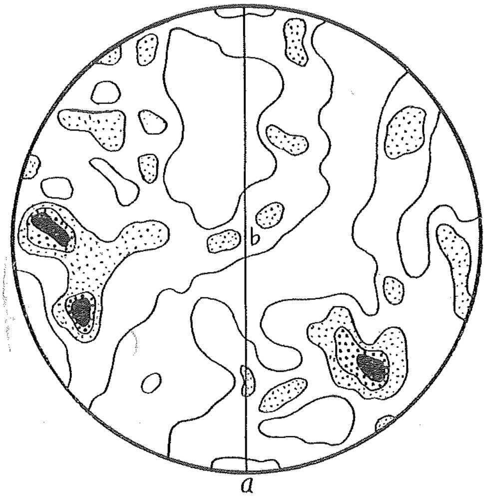

Fig. 24. 130 quartz axes from granitic migmatite (0–231). Contours 1–2–3–5%.

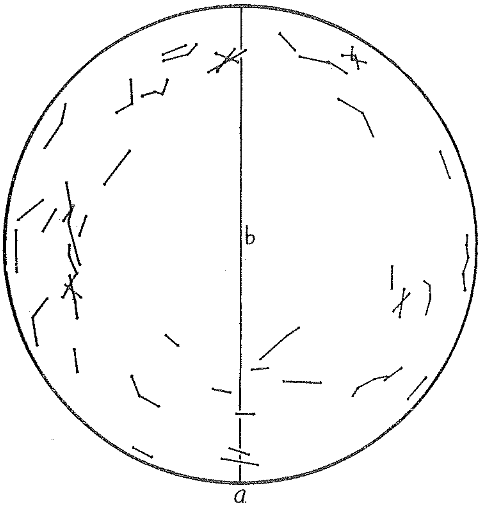

Fig. 25. Trend lines of axes within individual strained quartz grains (undulatory extinction) from cordierite migmatites.

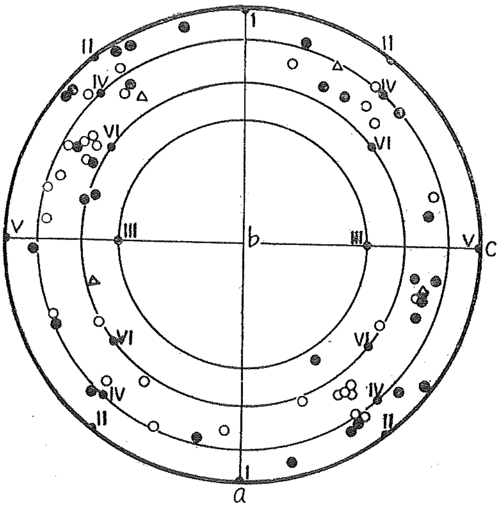

Fig. 26. Composite diagram of quartz axes orientation showing positions of maxima on the synoptic diagram of average positions of known quartz maxima by Sander and Griggs & Bell and Fairbairn. Filled circle: banded gneiss, unfilled circle: cordierite migmatite, triangle: schistose hornfels.

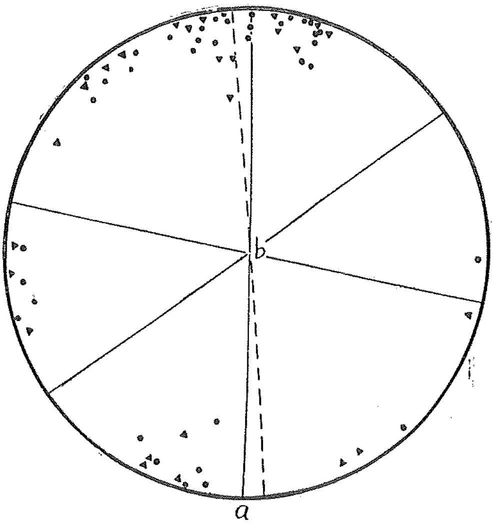

Fig. 27. Poles of Böhm lamellae in quartz grains (filled circles) and that of fractures in plagioclase grains (filled triangles)

Figure 26. It is notable that the maxima of all the fabric diagrams tend to concentrate to the maxima II, IV, VI indiscriminately. The trend lines of axes within an individual undulose quartz grain, are shown in Figure 25. The migration of axes indicates clearly the occurrence of the rotation of axes within the grain perpendicular to *b*.

The fabric of granitic migmatite differs from that of schistose hornfels, banded gneiss and cordierite migmatite indicates $b \wedge b'$ girdle.

BÖHM lamellae are more or less observable in banded gneiss and cordierite migmatite but not in schistose hornfels. Some of these lines are confined to individual grains, while others cut through several neighbouring grains without deflection. Furthermore, fractures are found within plagioclase parallel to the BÖHM lamellae in two directions, occasionally in three or four directions. (Fig. 27) Their plane orientation is parallel to *b*. (INGERSON & TUTTLE 1945) The dips of these fractures and the BÖHM lamellae have local accordance.

Discussion

Girdle: Girdle is almost always present in varying degree in tectonite, especially *ac* girdle as abundantly observed in this study, is the most common type. There are three hypotheses on the origin of girdle. One of them—according to FAIRBAIRN (1949)—*ac* girdle is associated with rotational movement about *b*. A second is that it could be caused by successive changes in the direction of the movement without any rotation of grains necessarily occurring. The third explanation of *ac* girdle orientation may be that it occurs through the development of microfolds.

So, concerning the present case, the displacement of axes within individual undulose quartz grain (Fig. 25) may prove that internal rotation about *b* has occurred. It is considered to be a case of intragranular plastic deformation which is due to the rotation by partial movement about *b*, *r* operating as the gliding plane, $m:r$ as the gliding direction. The distribution of axes resulting girdles may represent the loci of the grain axes which either have not yet attained this desired position or have been shifted out of it by subsequent rotation.

The rotation of axes indicates only the internal rotation controlled by the movement plane, especially in mylonitic rock (Fig. 15) which does not show *ac* girdle but the tendency toward the accumulation of maxima IV, VI as the result of intense movement; the maxima show the plane symmetry as in schistose hornfels and banded gneiss. The fabric of cordierite migmatite formed in connection with external rotation, shows the sym-

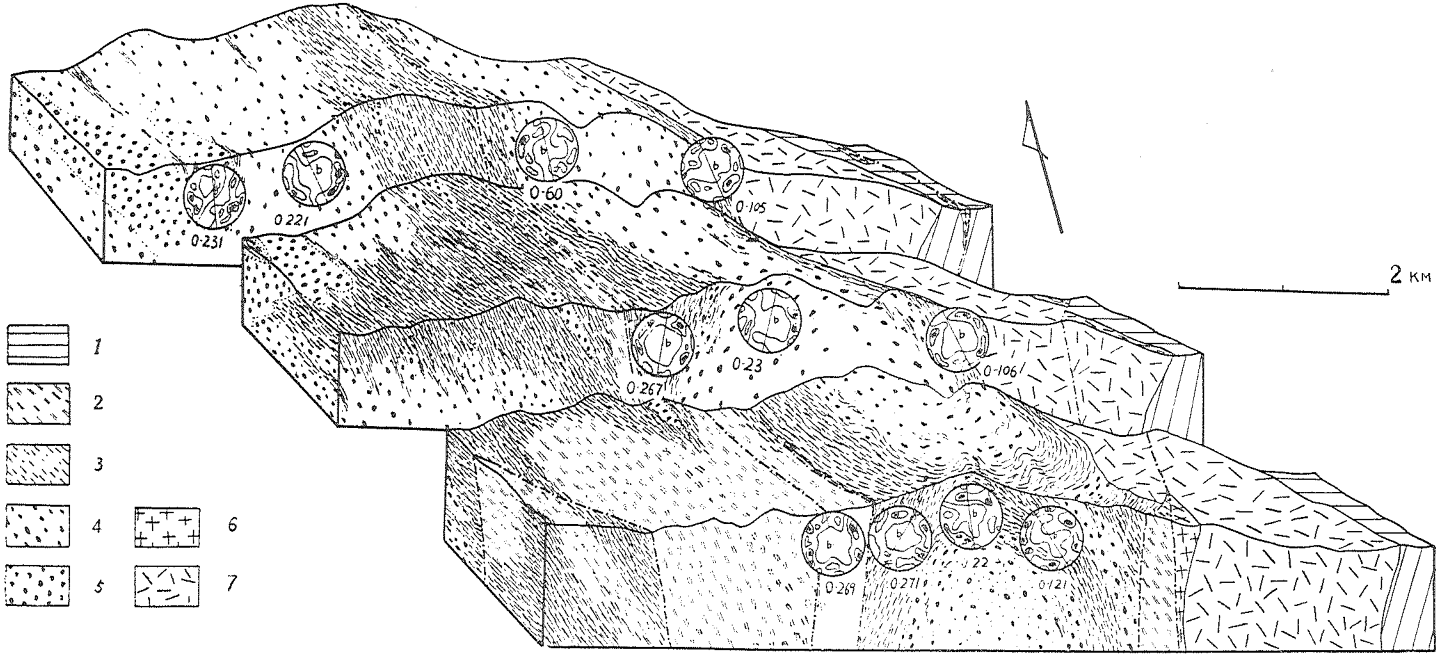

Fig. 28. Block diagram of the Oshirabetsu migmatite dome and quartz fabrics.

1. Hornfels,
2. Schistose hornfels,
3. Banded gneiss,
4. Cordierite migmatite,
5. Granitic migmatite,
6. Granite,
7. Gabbro.

metrical maxima with respect to *b*, or no symmetry at all.

Despite the indication of *ac* girdles and the same tendency of the maxima to concentrate in every rock species of this region, the difference in the symmetry of fabrics shows that the decrease of plasticity caused by migmatization may cause to occur not only the external rotation about *b* but also a weak movement parallel to *b*, and may come to disturb the symmetry in the cordierite migmatite. (Fig. 28)

Maximae: According to the distribution of maxima (Fig. 26) it seems that the maxima of all fabrics have the same tendency toward the concentrating to maxima II, IV, VI although the rocks are of different species. The fabric of the mylonitic gneiss shows fine grained quartz caused by intense differential movement as described above. It may be suggested that the more the intense differential movement has acted, the more crystallographic control to the orientation of quartz axes has become conspicuous.

There are two hypotheses respecting the orientation of quartz maxima; the fracture hypothesis of SANDER and GRIGG & BELL, and the translation hypothesis of SANDER and SCHMIDT. GRIGGS & BELL by means of experimental deformation developed SANDER's idea of the orientation mechanism of quartz axes. The hypothesis is based on the assumption that in the initial stage of deformation, quartz grain is fractured into elongated, needle-like fragments having axes. These needles have then been rotated approximately into the shearing plane with their axes parallel to the direction of movement. Later recrystallization may have obliterated most of the needle shape, leaving only the crystal axes orientation.

However, in this case, no trace of needle quartz can be discovered; only the displacement of axes within individual undulose quartz grain is indicated. Accordingly, the translation hypothesis may be supported, as stated above in the paragraph on girdle, rather than the fracture hypothesis.

Progressive stages in the mechanical deformation of quartz appear to take the following forms:

i) plastic deformation by undulatory extinction, slight displacement of axes.
ii) intense undulatory extinction, displacement of axes; rupture between the units.
iii) intragranular rotation of axes with submicrsocopic deformation.
iv) if intense movement occurs, it may produce granulation.
v) recrystallization (porphyroblast).

These processes may be only the several behaviours in certain sections in the later phase of a long metamorphic history. Furthermore, it is important to take into consideration the relation between the growth or the decrement of quartz by migration of silica and some associated movement.

Lamellae: Lamellae have been often described in connection with the deformation of quartz crystal. BÖHM (1883) stated that an apparent fine lamellation formed by fluid, gaseous and solid inclusions in the quartz were often concentrated along certain planes. The apparent lamellae in quartz became known as "BÖHM lamellae".

It has been considered by many authors that the lamellae had connection with the orientation of quartz axes. (MÜGGE 1896, SANDER 1930, FAIRBAIRN 1939, HIETANEN 1938) Recent analysis cast doubt upon the glide line hypothesis on lamellae. INGERSON and TUTTLE (1945) concluded that although lamellae developed subnormal to axes, crystallographic control of lamellae is lacking in quartz grains. RILEY (1947) maintained that the axes orientation was unrelated to the lamellae developing at a late stage in the deformation history of the rocks. TURNER (1948) held that lamellae would all be of late development and the associated axis orientation should be considered as an independent and earlier phase of deformation. NAKAYAMA (1949) regarding the lamellae as gliding plane, discussed the relation between the elongation of quartz grains and the orientation of axes. WEISS (1954) concluded that visible deformation lamellae and band could play no part in the evolution of the prefered orientation of axes in the grains in which they occurred, and the deformation structure were formed during the process of granulation. He described also minute inclusions and rarer open planar fractures which occur close to the *ac*-planes of the equivalent of megascopic *ac*- and sub *ac*-joint.

In the present case, BÖHM lamellae vary to deformation lamellae in some part of the same grain. They therefore may be a recrystallized relict structure of deformation lamellae as suggested by HIETANEN and FAIRBAIRN. As indicated above, the fractures within plagioclase grains parallel to the lamellae of quartz and lamellae poles occupy a narrower, more restricted zone than axes. (Fig. 27) It is clear, accordingly, that the orientation of the lamellae represents sealed fractures and that the orientation has been produced by later movement normal to *b*, in the metamorphic history. That movement produced fractures and then in some part deformation lamelae have recrystallized to BÖHM lamellae. The irregularity of the orientation in every specimen may suggested the localization of movement at some later stage.

Biotite and Muscovite:

There are some differences in grain size, colour and refractive indices of the biotite in each rock. (Table 2)

TABLE 2. Colour and refractive indices of each rock species.

	schistose honrfels	banded gneiss	cordierite migmatite	granitic migmatite
color	X: pale brownish green	pale greenish brown	pale brown	pale greenish brown
	Y: reddish brown	reddish brown	brown	brown
	Z: reddish brown	reddish brown	reddish brown	brown
refractive indices (r)	1.637–1.643	1.634–1.642	1.643–1.647	1.644–1.648

The foliation is weak or absent; undulatory extinction and bending of biotite are prominent in cordierite migmatite. In schistose hornfels and banded gneiss (Fig. 29–Fig. 35), biotite blades are well aligned in foliation and represent lineation, especially in the latter, well marked foliation is defined by the biotite-rich layers. The poles of (001) of biotite are projected. All diagrams of schistose hornfels, banded gneiss and cordierite migmatite, show the maxima at *c* coinciding with the poles of the foliation; but in granitic migmatite, cleavage poles are not parallel to *c*. These fabrics show more or less *ac* girdle in proportion to the intensity of schistosity. The diagrams of several banded gneisses, show especially the tendency toward the incomplete girdle. The diagrams of cordierite migmatite show in general perfect girdles. In specimen 0–22 (Fig. 38) the occurrence of external rotation about *b* is clear as suggested by the quartz fabric.

Discussion:

It seems that the high concentricity of cleavage poles in banded gneisses may suggest the intense differential movement which occurred during the production of the rock.

In cordierite migmatite, being a migmatitized gneiss, the external rotation about *b* as shown by specimen 0–22, may attain a weak schistosity and so *ac* girdle. It is considered accordingly that maximum at *c* represents residual orientation. (SAHAMA 1936, WEISS 1954)

From the viewpoint of the orientation of biotite, schistose hornfels, banded gneiss and cordierite migmatite are associated with each other,

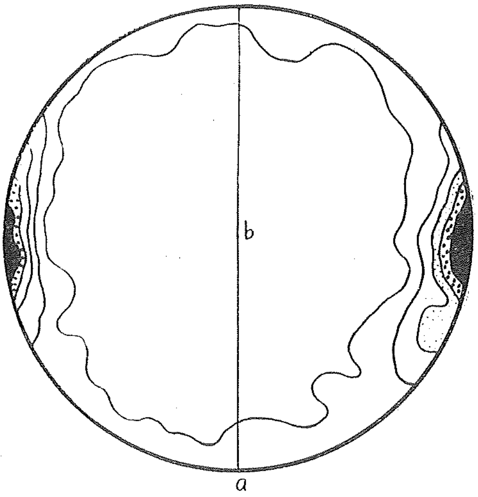

Fig. 29. 150 cleavage poles of biotite from schistose hornfels (0-267). Contours 3-6-9-12-17%.

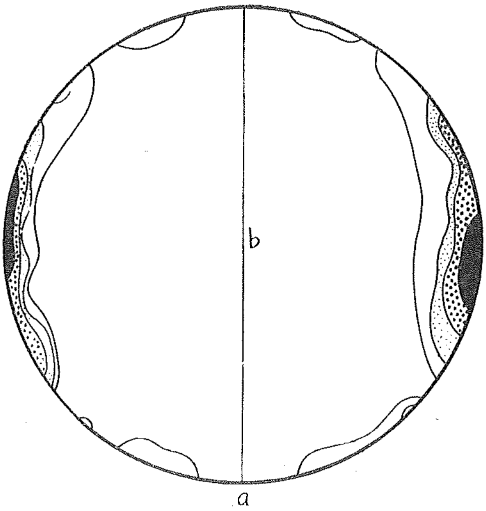

Fig. 30. 100 cleavage poles of biotite from banded gneiss (0-271). Contours 3-7-9-19%.

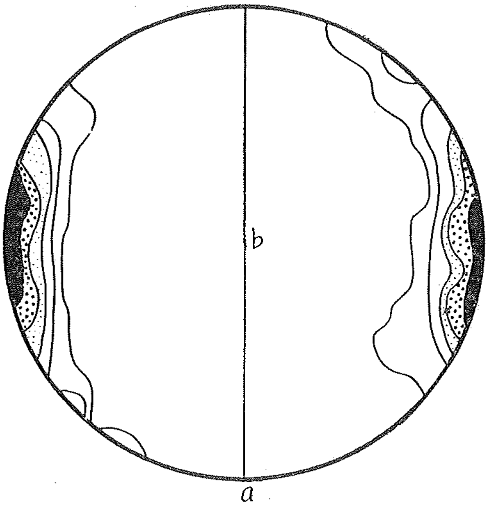

Fig. 31. 104 cleavage poles of biotite from banded gneiss (0-11). Contours 1-6-9-12-21%.

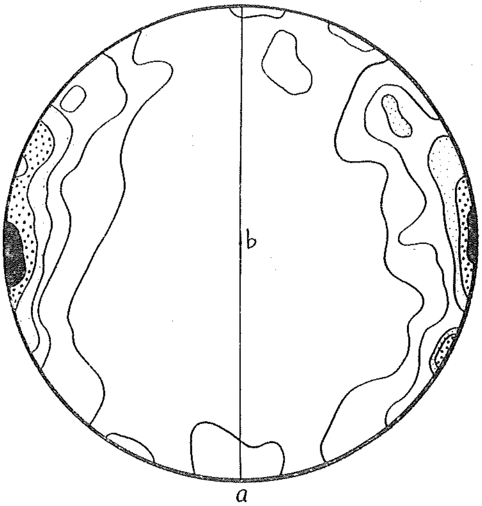

Fig. 32. 145 cleavage poles of biotite from banded gneiss (0-19). Contours 1-3-6-9-11%.

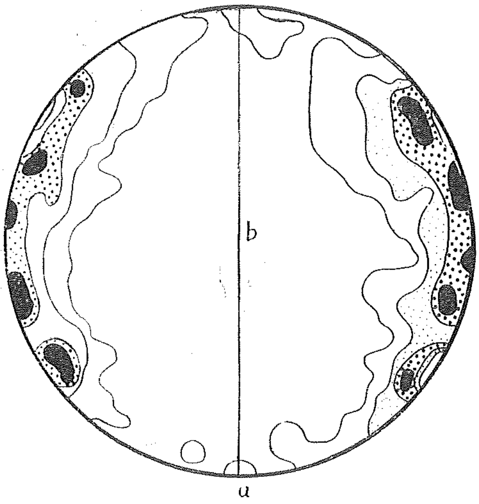

Fig. 33. 208 cleavage poles of biotite from banded gneiss (0–121). Contours 1–3–5–7%.

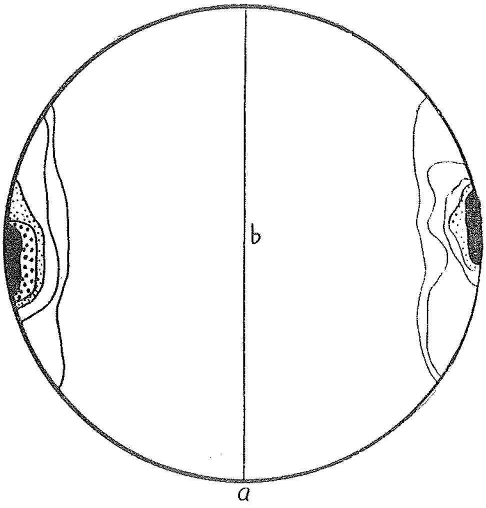

Fig. 34. 86 cleavage poles of biotite from banded gneiss (0–106). Contours 1–9–15–23–38%.

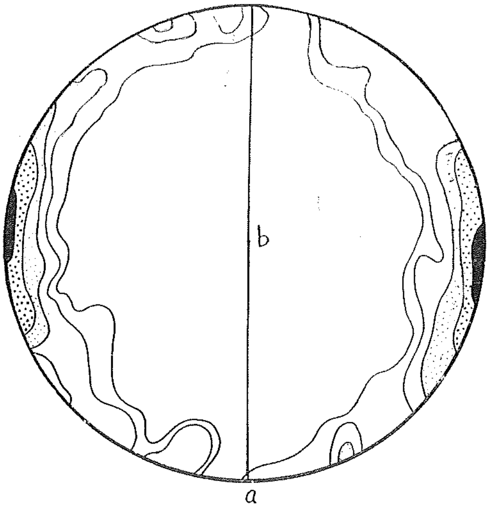

Fig. 35. 107 cleavage poles of biotite from banded gneiss (0–269). Contours 3–6–9–11%.

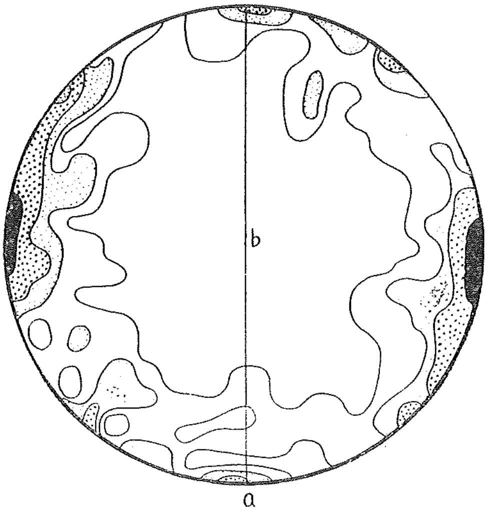

Fig. 36. 130 cleavage poles of biotite from cordierite migmatite (0–205). Contours 1–3–6–9%.

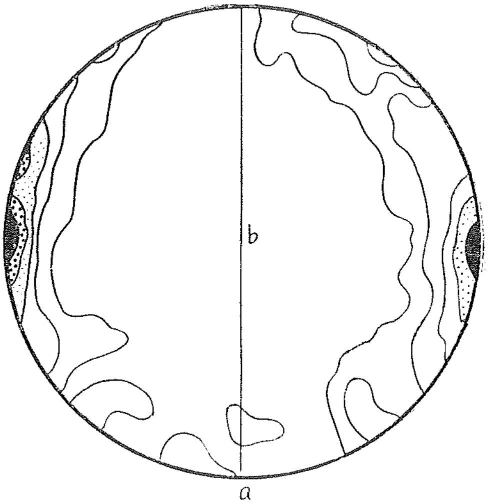

Fig. 37. 171 cleavage poles of biotite from cordierite migmatite (0-105). Contours 1-4-8-14-18%.

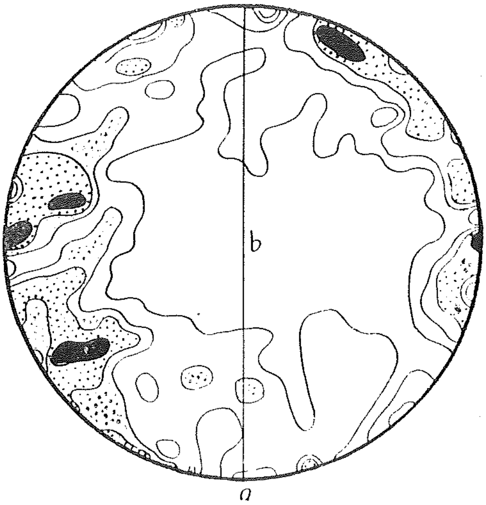

Fig. 38. 162 cleavage poles of biotite from cordierite migmatite (0-22). Contours 1-2-3-5%.

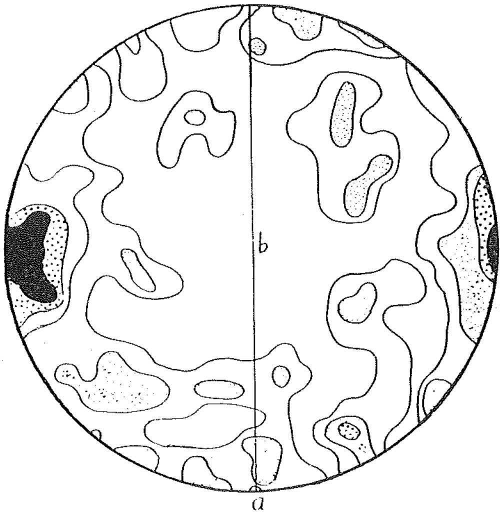

Fig. 39. 100 cleavage poles of biotite from cordierite migmatite (0-23). Contours 1-3-4-5%.

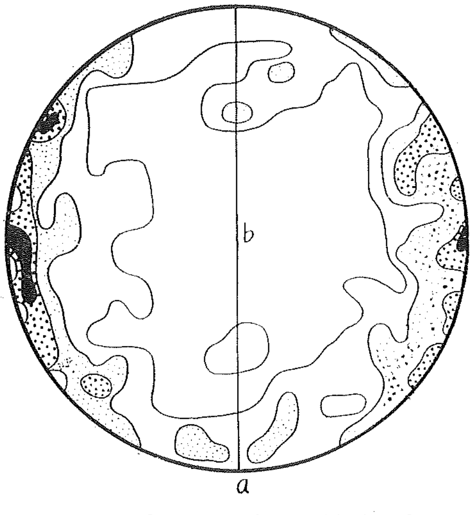

Fig. 40. 162 cleavage poles of biotite from cordierite migmatite (0-43). Contours 1-3-5-7%.

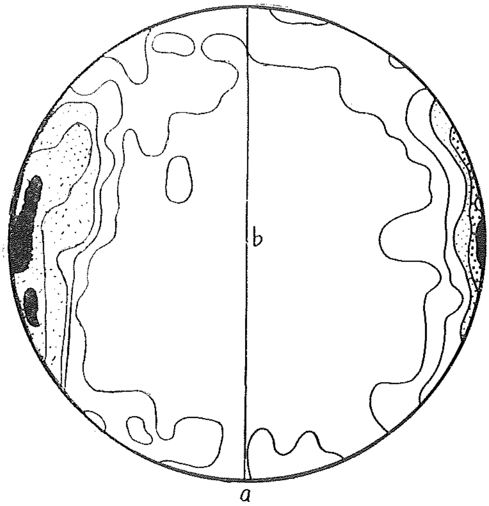

Fig. 41. 171 cleavage poles of biotite from cordierite migmatite (0–60). Contours 1–3–5–7–9%.

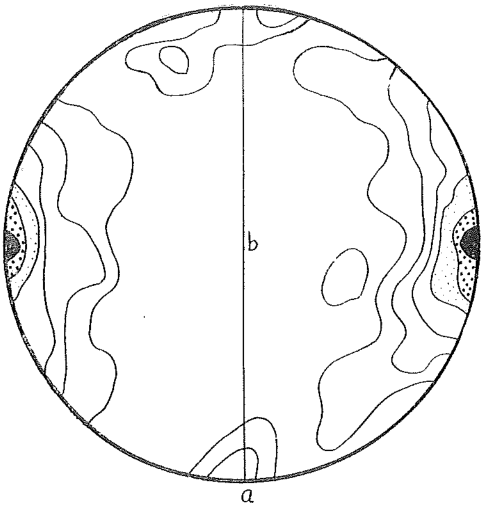

Fig. 42. 145 cleavage poles of biotite from cordierite migmatite (0–220). Contours 1–4–7–10–14–16%.

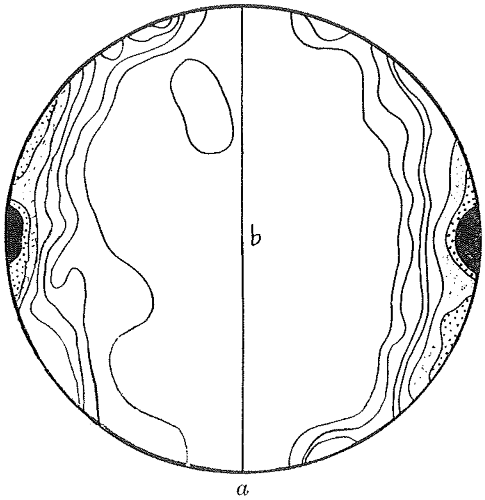

Fig. 43. 130 cleavage poles of biotite from cordierite migmatite (0–221). Contours 1–3–5–7–9–10–13%.

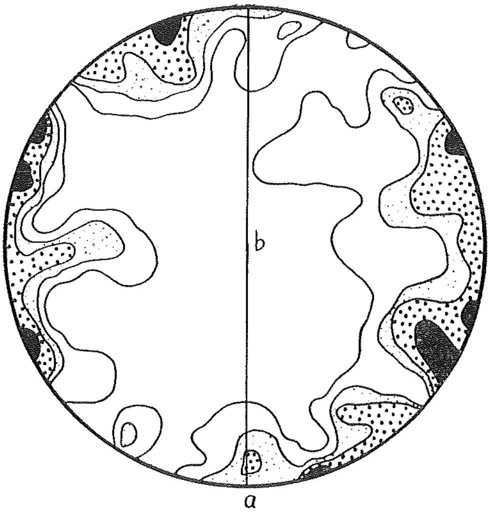

Fig. 44. 120 cleavage poles of biotite from granitic migmatite (0–231). Contours 1–2–3–5%.

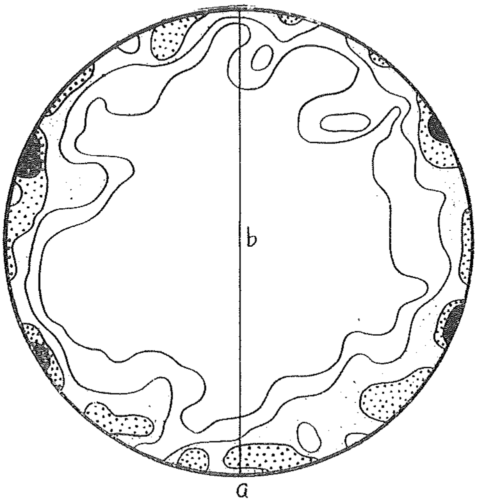

Fig. 45. 111 cleavage poles of muscovite from cordierite migmatite (0-19, 0-23, 0-43, 0-221). Contours 1-3-5-9%.

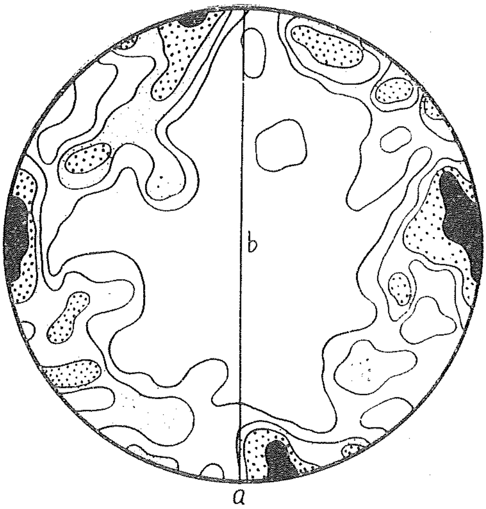

Fig. 46. 112 (010) poles of plagioclase from cordierite migmatite (0-22). Contours 1-2-4-6%.

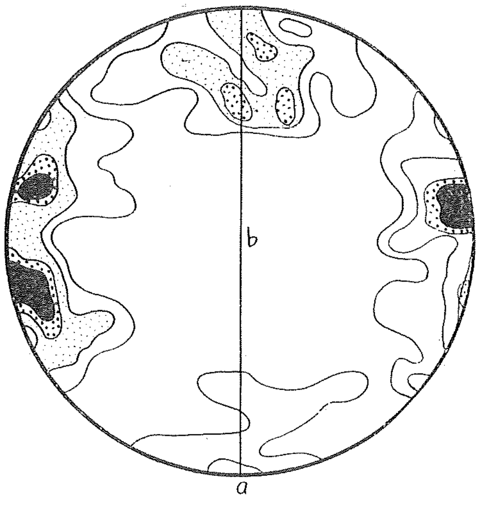

Fig. 47. 100 (010) poles of plagioclase from banded gneiss (0-121). Contours 1-3-5-10%.

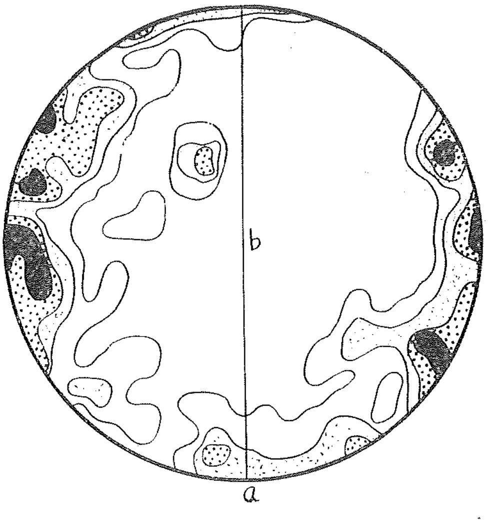

Fig. 48. 81 (010) poles of plagioclase from cordierite migmatite (0-220). Contours 1-3-5-8%.

in respect to their origin. It is considered however that the biotite fabric of granitic migmatite may have been produced under a different environment from other as shown by quartz fabric ($b\wedge b'$ girdle).

Muscovite occurs essentially in cordierite migmatite; it is entirely undeformed and grains are fewer than those of biotite. It is interpreted that muscovite has crystallized out later than biotite, since biotite alters to muscovite at its own margin. Its diagram (Fig. 45) shows preferably similar orientation to the biotite diagram of granitic migmatite and differs from the biotite pattern of cordierite migmatite. It is to be noted that this relationship may be correlated to the fact that granitic migmatite was produced later than cordierite migmatite.

The biotite displays generally a single maximum at *c* in cordierite migmatite, whereas the associated muscovite has two maxima separated by a few degrees, not at *c*. It is interesting that the orientation of muscovite cleavage poles is not in accordance with that of biotite. (CLOOS, E. and HIETANEN 1941)

Plagioclase:

Plagioclase is an essential mineral in the rocks now under consideration and shows preferably round shape, An%20–35, in schistose hornfels, banded gneiss and cordierite migmatite. The poles of (010) of plagioclase grains are here projected. (Figs. 46, 47 and 48)

Each of them has maximum at *c* and shows a tendency toward an incomplete girdle about *b*. The pattern are therefore similar to that of biotite. Accordingly, in specimen 0–22 (Fig. 46) especially, the maximum neighbouring to *a* may be interpreted as having resulted from an external rotation about *b* like that of quartz and biotite.

There are some plagioclases in which one albite lamellae twin parallel to the foliation plane intersects the other twin at a few degrees in the same grain. The latter is filled with dirty inclusions as seen Figure 49. In Figure 50, is shown the lamellae twin intersecting an indistinct zonal structure.

It is considered that these textures may indicate an association be-

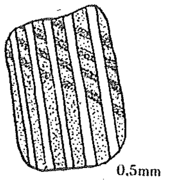

Fig. 49. Newer and older albite twins in plagioclase.

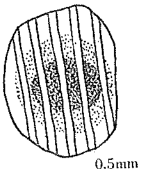

Fig. 50. Zonal structure and albite twin in plagioclase.

tween a newer and an older one. The poles of these older and newer lamellae twins are projected. In Figure 48, the poles of the newer lamellae show the maximum at *c*, while the older ones show the submaximum concentrating about the center of the third quadrant. In Figures 46 and 47, The poles of the older lamellae show a tendency toward concentration into the third quadrant or slightly in the first quadrant. Such tendency as shown by plagioclase grains is also indicated clearly by the diagrams of biotite, 0–121 (Fig. 33), 0–43 (Fig. 40), 0–60 (Fig. 41), 0–220 (Fig. 42) and 0–221 (Fig. 43).

From the above, it is considered that (010) of plagioclase as well as (001) of biotite may indicate a glide plane parallel to the movement plane so that albite lamellae twins may be produced. Every plane of these minerals will show a similar deformation under the received force but plagioclase may be more resistant. The older texture however is not only yet clearly understood in respect to the regional structure.

Some albite twins are cut by a fracture occurring in a later stage of the deformation, compare Figure 51. This phenomenon indicates obviously that some albite twins have been produced at the later stage of metamorphism by means of mechanical gliding on (010).

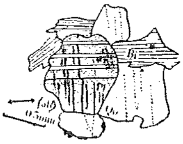

Fig. 51. Diagram showing albite twin parallel to foliation and fructures in plagioclase grain.

GORAI (1950, 1951) proposed a method to distinguish metamorphic rock from igneous rock by means of the difference of the mode of plagioclase twin. Applying his method, HIROTA (1952) and SOTOZAKI (1956) dealt with the metamorphic rocks and the migmatite of the Hidaka metamorphic zone. According to them, *c*-type twin (essentially carlsbad twin) does not occur at all or very rarely in band gneiss and cordierite migmatite, but it frequent in granitic migmatite. They concluded that the former have been the product of a metamorphic process while the latter may have been igneous in origin or may have been in a melted condition.

However, it seems clear that metamorphic rock is associated more or less with regional movement and that the production of plagioclase twin is connected with gliding on foliation as suggested above. The problem of plagioclase twin therefore is to be dealt with from the dynamic point of view as well as from the static one.

Metasomatism

In this paper, is described the deformation and the orientation of component minerals of the metamorphic rocks. These things, deformation and orientation, may have connection with the variation of the character of the constituent minerals and recrystallization of the rocks. These phenomena mentioned above, are some episodes in the later phase of the history of migmatization and granitization. From such a stand point, recrystallization and the occurrence of porphyroblast in the rocks are discussed in the following.

a) BÖHM lamellae of quartz are a relict texture; they are not observed in fresh porphyroblast.

b) It may be due to the recrystallization with gliding which may have occurred after fracturing, that albite twin of plagioclase is produced intersecting the fractures as illustrated by Figure 51.

c) Kalifeldspar fills the space among the other minerals and grows up into large porphyroblasts replacing plagioclase. A certain kalifeldspar retain nothing at all with the proceeding of replacement. It may be suggested that the growth of kalifeldspar has taken place after the fracturing in a late phase of metamorphism.

d) The biotite of banded gneiss which possesses a high concentricity of cleavage poles has the deeper reddish brown colour and lower refractive index, and a higher content of alumina than the other biotites. The banded gneiss in bulk composition is richer in alumina than the other rocks, just like biotite. (KIZAKI 1951, HUNAHASHI et al. 1956) The writer concludes therefore that a structural and chemical culmination is represented in banded gneiss zone.

e) The muscovite which replaces biotite, shows a different orientation pattern from that of biotite in the same rock. The movement affects the lineation: doming, produces the fractures or the cracks in quartz and plagioclase grains, and subsequent recrystallization with the associated movement causes the fractures to disappear or replace the older minerals in a different orientation.

Conclusion

The movement involved in the evolution of the Oshirabetsu migmatite dome, may be essentially normal to lineation. A relative movement of parts has occurred whereby portions of grains, whole grains, aggregates of grains (quartz pools) and palaeosomes are displaced normal to lineation either along the foliation plane, or by rolling (internal rotation or external rotation or microfolding) about *b* in microscopic and megascopic scale. A slight rotation about *a* is recognizable only in cordierite migmatite. The direction of the relative movement in connection with the lineation at every point (Fig. 4) tends toward the center of the dome from northwest to southeast upward, so the dome structure thus may be represented as the total sum of the partial movement about *b*.

The harmony of the fabrics in the above described rock species, except granitic migmatite, may be interpreted as an additional indication of their common origin, namely regional migmatization. The gabbroic sheet bounding the northwest side of the hornfels zone. The sheared zone delimiting the dome may indicate the movement at the last stage of doming and may have association with the intrusion of small granitic bodies, aplites, and diabase dykes.

The writer wishes to record his most grateful thanks to Professor J. SUZUKI, who has given freely of his guidance and valuable advice. Thanks are also due to Asst. Professor M. HUNAHASHI, and the collaborators in the "Hidaka Research Group" who suggested the problem and offered helpful criticism and constant advice throughout the progress of the work. Further, thanks are expressed to the Geological Survey of Hokkaido which made it possible for the writer to carry out his investigation.

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