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STRUCTURAL EVOLUTION OF THE KAMISHIBETSU GNEISS

By

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(With 25 Text-Figures and 3 Plates)
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CONTENTS

Introduction

In the axial part of the island of Hokkaido, a prominent tectonic zone constituted of various kinds of metamorphics and plutonics is revealed as the orogenic centre of the island.

In the southern half of the axial part, it is represented as a closely continuous metamorphic zone, however, its northern continuation becomes less prominent and is separated into some small aureoles that occur in an indistinct arranged zone. The causal basis of such an unequal disposition of the metamorphic zone is probably attributable to the fact that the metamorphic niveau pitches down to the north and so the protruded heads only crop out as the separated small aureoles in the northern district. The Okushibetsu plutonic complex now under consideration, that lies in the northern part of central Hokkaido, is considered as the one of the representatives of such aureoles.

The complex is composed of various kinds of small plutonic masses and associated gneiss and hornfels; their petrographical features are in striking accordance with that of the southern portion of the metamorphic zone.

A peculiar gneiss which is named "Kamishibetsu gneiss" is disposed in the northern periphery of a small gabbroic mass that constitutes a part of the Okushibetsu plutonic complex.

It lies only in the contact zone of the intrusive body with 500 m width and stretches to a length of about 4 km. Although the area of the gneiss is so small, it deserves close inquiry because it offers an excellent example of the petroblastesis which is furnished by the growth of large plagioclase porphyroblast and biotite, quartz and potash feldspar, and further because it attacks in similar fashion the adjacent gabbroic body and converts its character to coarse tonalitic facies.

This study attempts to offer a brief description of the petrography and of the petrofabric analysis of hornfels, schistose hornfels and petroblastic gneiss respectively; further the study intended to contribute to the dating of the events of the structural evolution.

The lineation has two significations in the tectonic history; at the first stage, the direction of movement is normal to the lineation, however, in the second stage, the movement takes a course nearly parallel to it. The crossed girdle of quartz orientation developed by the non-rotational deformation corresponding to the movement of the later stage is formed subsequent to the rotational strain forming the biotite girdle which is referred to as the movement of earlier stage.

Generally speaking, it is suggested that there may be a fundamental relation between the petroblastesis and the petrofabric in the case when its quartz orientation shows a crossed girdle which independently developed to biotite girdle.

The author gratefully acknowledges the cordial guidance of Professor J. Suzuki, Asst. Professor M. Hunahashi, and the assistance of the collaborators in the Hidaka Research Group who have suggested the problems and offered helpful criticisms. Especially, he wishes to record his grateful thanks to Mr. S. Sako of the Geological Survey of Hokkaido who helped him not only in the laboratory work but also in the field observations.

Geological setting

The Kamishibetsu gneiss is disposed in the western part of the Okushibetsu plutonic complex (Fig. 1). To the northeastern side, it grades to non-metamorphic Hidaka group which is composed of slate, interbedded with schalstein and limestone. They are considered presumably Jurassic in age. In the southwestern side, it is closely bounded by a gabbroic complex. It streches from northwest to southeast and its detailed tectonic mapping suggests that it is a kind of tectonic zone of the same direction.

The zonal distribution of the rock species now referred to in the gneiss zone is as follows from northeast to southwest; slate, biotite hornfels, cordierite hornfels, garnet bg. schistose hornfels and petroblastic gneiss. The garnet bg. schistose hornfels changes gradually to the gneiss with concordant form but is discontinuous to hornfels being separated by severe sheared zone of the same direction. So, an apparent gap can be observed in the structural evolution between the hornfels zone and the zone of the gneiss with the schistose hornfels from the tectonic point of view. To express it in other words, the hornfels and the cordierite hornfels are disposed in every part of the Okushibetsu plutonic complex, however, the schistose hornfels in local occurrence belongs to the same structural unit with the gneiss which occurs only in this region.

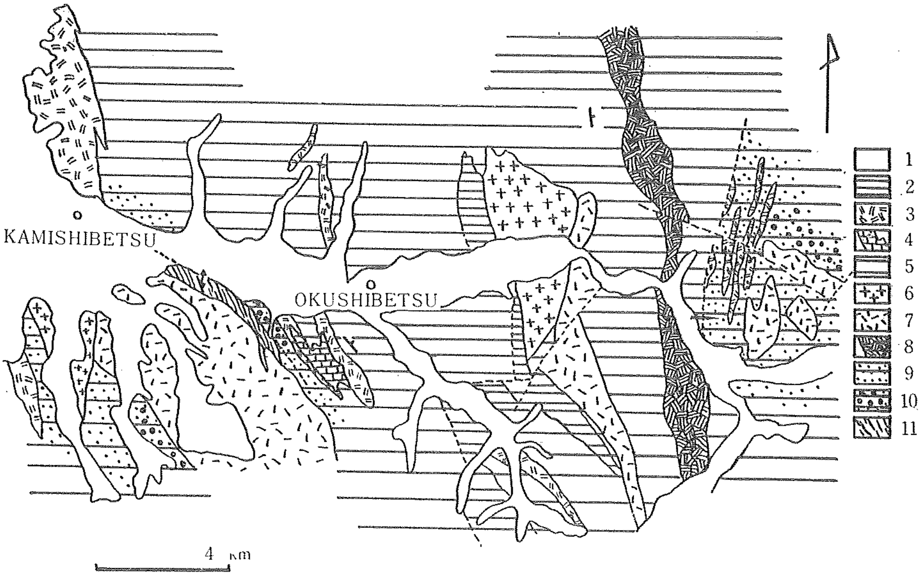

Fig. 1. Geological sketch map of the Okushibetsu plutonic complex; 1. Alluvium and Diluvium, 2. Tertiary, 3. Schalstein, 4. Limestone, 5. Slate, (3, 4, 5 consist the Hidaka group), 6. Granite, 7. Gabbro, 8. Diabase, 9. Hornfels, 10. Cordierite hornfels, 11. Kamishibetsu gneiss. (After S. Sako, modified by the author)

Petrography

a) Hornfelses. Cordierite hornfels consists chiefly of mosaic quartz, plagioclase (An30), biotite, all of which are of equal size (0.1 mm) without obvious preferred orientation. Cordierite distributes partially in a concentrated manner at the immediate outer margin of the adjacent gabbroic body, and the others are contained in the hornfels as thin banded alternation of 5 mm thickness with normal biotite hornfels.

b) Garnet bg. schistose hornfels which is coarser (0.3 mm) than biotite hornfels and cordierite hornfels, consists of plagioclase, quartz, biotite and garnet with preferred orientation. Plagioclase is represented in the form of small poikilitic growths with limited myrmekitic texture, and generally shows no twin. However, to certain extent, its large porphyroblasts (5 mm) together with biotite, quartz and muscovite are scattered or embedded in the schistose hornfelsic base as veins, just like a lit-par-lit injected vein. The coarser part develops side by side, to form a granitic gneiss.

c) The gneiss is composed mainly of petroblastic rocks with preferred orientation of constituting minerals is formed by alternative changing of schistose hornfels and petroblastic veins at the outer margin of the gneiss. Petroblastic gneiss contains essentially plagioclase (An33), quartz, biotite, potash feldspar and accessory muscovite, garnet, chlorite and opaques. Plagioclase (5 mm) is anhedral including tiny plagioclase grains, biotite flakes and garnets; occasionally it is an aggregate of smaller grains (Fig. 2). Accordingly, plagioclase indicates two generations viz., the stages of the neocrystallization in hornfels and of the porphyroblastesis in gneiss. Potash feldspar show many features of crystallization of a later stage than other minerals do and usually exhibits a replacement growth consuming all other minerals: plagioclase, biotite, quartz and

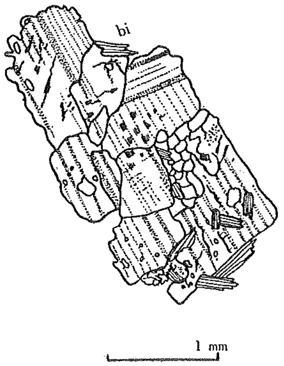

Fig. 2. Plagioclase porphyroblast, an aggregate of smaller ones.

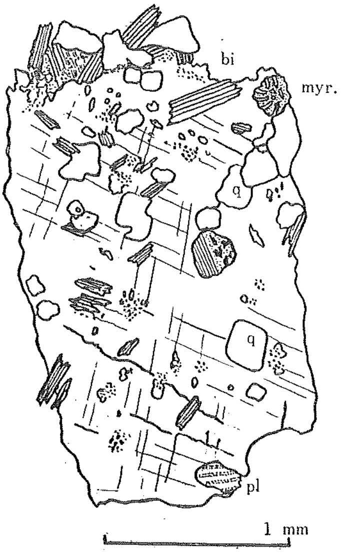

Fig. 3. Porphyroblast of potash-feldspar including plagioclase (pl), quartz (q), biotite (bi) and myrmekite (myr).

muscovite grains (Fig. 3).

d) Basic rocks. The amphibolite which is constituted of fine brown hornblende and plagioclase, takes a sheet-like form of a few metres thickness interbedded in the gneiss. The metasomatic effects are revealed in the forms of coarser part like that of the gneiss, but also they are represented by the scattered plagioclase porphyroblasts in the fine grained amphibolite. Norite and hornblende gabbro which occupy the northern marginal part of the gabbroic complex are in contact with the innerside of the gneiss; blocks of these basic rocks about 50×70 cm are kept in the gneiss as a palaeosome owing to the petroblastesis of the gneiss. Generally, in these rocks are scattered plagioclase porphyroblasts (An50), the same occurrence as in the schistose hornfels. The original plagioclase of the rocks is euhedral with clear albite-carlsbad twin; porphyroblastic plagioclase is anhedral, occasionally showing mantleblast. Also in this case, plagioclase indicates two generations as does the gneiss.

Structure

a) Schistosity

The distribution of the gneiss and schistose hornfels ranges to N50W along the northern boundary of the gabbroic complex and shows the general trend of this region as indicated by the bedding of the slate and the limestone (S_1). However, the schistosity of them (S_2) cuts across the general bedding and indicates discordant form. The direction of relative movement can be determined according to a minor drag folding or *s*-structure at the polished surface in (*ac*), horizontal plane of the schistose hornfels. Therefore, the direction of partial movement is illustrated in Figure 4.

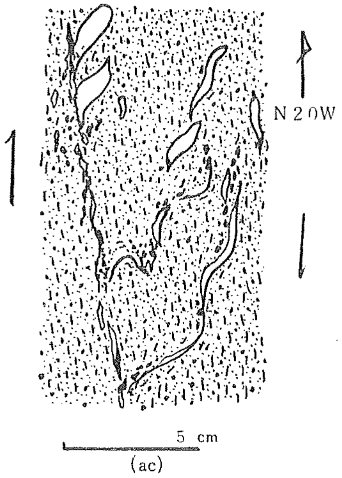

Fig. 4. A drag folding in (ac) and direction of movement

It is observed that many quartz veins transect the schistosity of the schistose hornfels at an angle of about 30 degrees (N40W) (S_3). Such an occurrence is called fracture cleavage or shear cleavage the same as the schistosity of schistose hornfels (S_2).

Consequently, it may be inductively concluded that these schistosities S_2, S_3 may be shear cleavages due to the wrench fault of N50W direction which is indicated geologically by the horizontal shift of the schalstein bed in the geologic map.

b) Lineation

A very pronounced lineation covers the schistosity (S_2) which is regionally observed in schistose hornfels and gneiss. It is due to mineral elongation especially to parallel orientation of biotite blades. The lineation plunges consistently almost vertically or about 80 degrees to north. The lineation is a *b*-lineation because it is formed by a partial movement normal to it either in hand specimen or geologically as stated already.

However, in a polished specimen in (*bc*), a weak drag folding is discovered as well as in (*ac*). Is it possible that the lineation may be *a* and *b* at the same time? It will be rather possible in case the movement

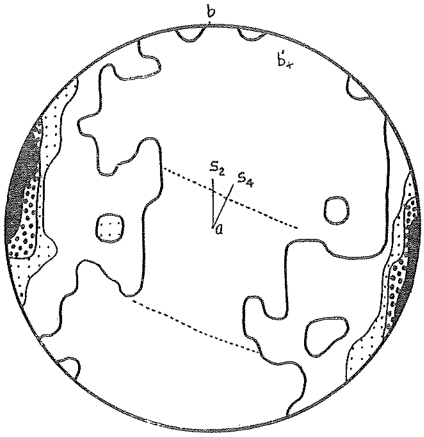

Fig. 5.

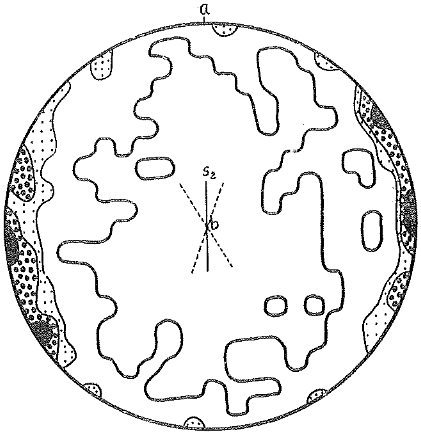

Fig. 6.

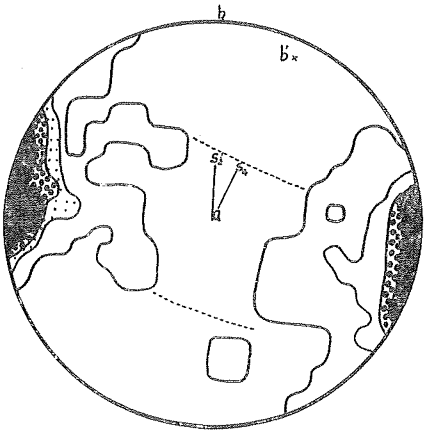

Fig. 7.

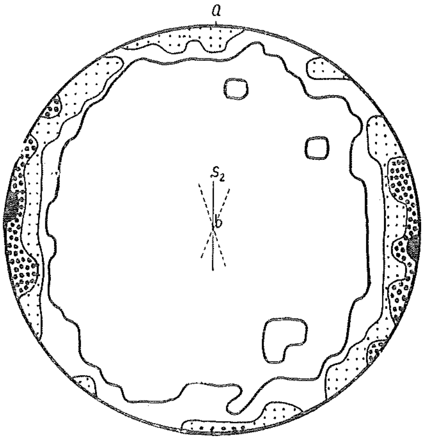

Fig. 8.

Fig. 5. 250 poles of [001] of biotite in (bc) of specimen os21; contours 1-3-6-10-13 per cent.

Fig. 6. 290 poles of [001] of biotite in (ac) of specimen os21; contours 1-3-5-7 per cent.

Fig. 7. 200 poles of [001] of biotite in (bc) of specimen os29; contours 1-3-5-10 per cent.

Fig. 8. 250 poles of [001] of biotite in (ac) of specimen os28; contours 1-3-5-10 per cent.

parallel to the lineation would have happened just after the formation of *b*-lineation, and that it would have been weaker than normal. So is the case in question.

Fabric analysis

Twenty orientation diagrams were prepared which are two sections

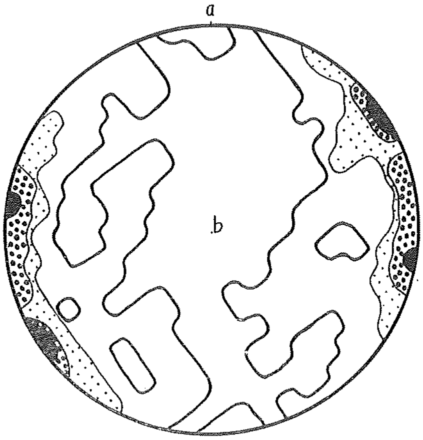

Fig. 9.

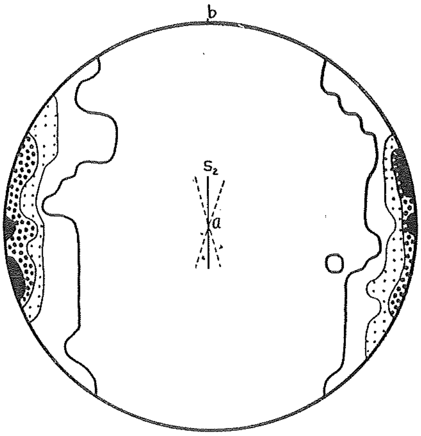

Fig. 10.

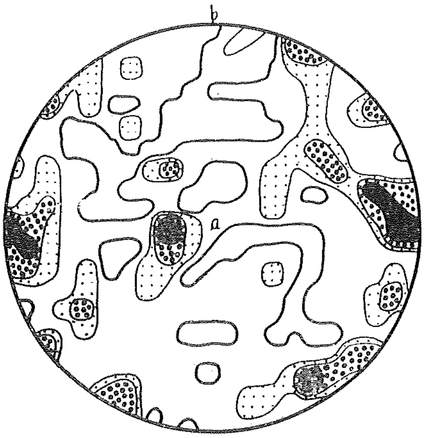

Fig. 11.

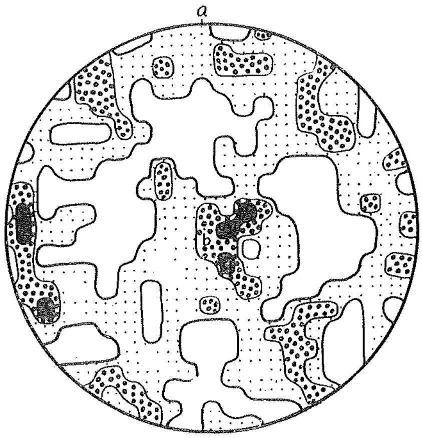

Fig. 12.

Fig. 9. 150 poles of [001] of biotite in (bc) of specimen os23; contours 1-3-5-7 per cent.

Fig. 10. 132 poles of [001] of muscovite in (bc) of specimen os28; contours 1-5-10-20 per cent.

Fig. 11. 502 quartz [0001] axes in (bc) of specimen os20 of schistose hornfels; contours 1-1.5-2-2.5 per cent.

Fig. 12. 380 quartz [0001] axes in (ac) of specimen os21 of schistose hornfels; contours 1-2-3 per cent.

at right angle to each other for one specimen (Figs. 5-23).

Biotite and Muscovite

Figures 5-9 include the biotite blades in the schistose hornfels and the gneiss. A *b*=B axis is obvious and parallel to the lineation; maxima

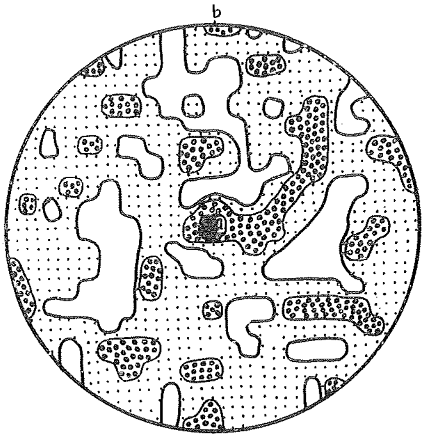

Fig. 13.

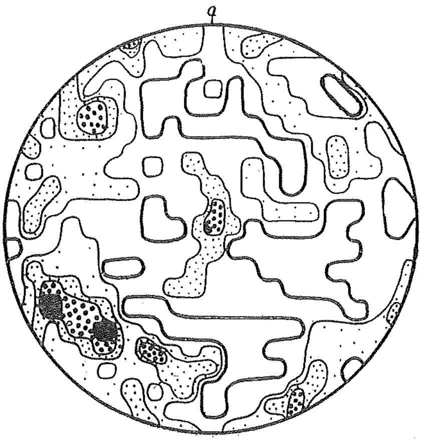

Fig. 14.

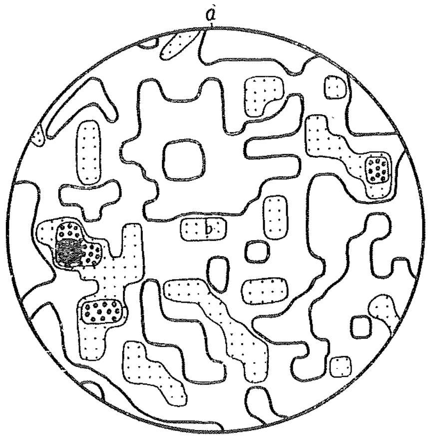

Fig. 15.

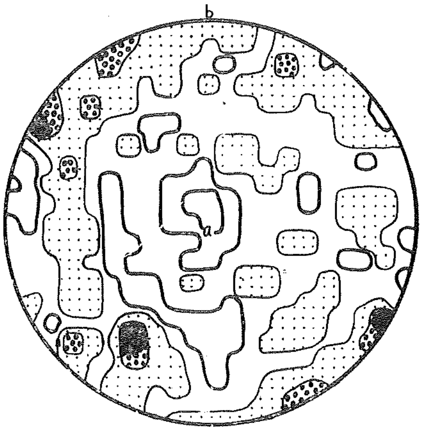

Fig. 16.

Fig. 13. 390 quartz [0001] axes in (bc) of specimen os21 of schistose hornfels; contours 1–2–3 per cent.

Fig. 14. 450 quartz [0001] axes in (ac) of specimen os26 of schistose hornfels; 1–2–2.5–3–4 per cent.

Fig. 15. 365 quartz [0001] axes in (ac) of specimen os28 of schistose hornfels; contours 1–2–2.5–3 per cent.

Fig. 16. 400 quartz [0001] axes in (bc) of specimen os28 of schistose hornfels; contours 1–2–2.5–3 per cent.

within the girdle are the pole of schistosity—the mica flakes are thus mostly in the schistosity (S_2) and others make a girdle, but reorientation is involved in submaxima S'_2; S''_2 is observed in biotite as well as in

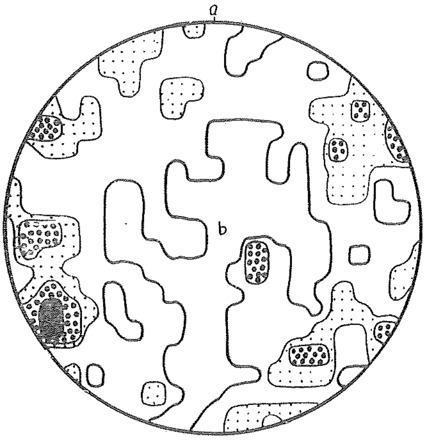

Fig. 17.

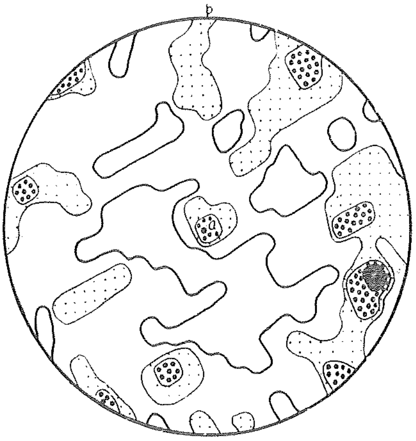

Fig. 18.

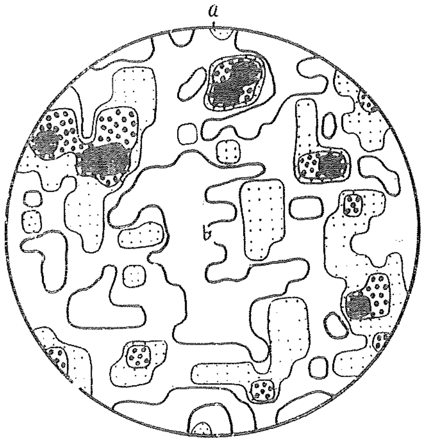

Fig. 19.

Fig. 17. 300 quartz [0001] axes in (ac) of specimen os23 of petroblastic gneiss; contours 1-2-3-4 per cent.

Fig. 18. 400 quartz [0001] axes in (bc) of specimen os23 of petroblastic gneiss; contours 1-2-3-4 per cent.

Fig. 19. 283 quartz [0001] axes in (ac) of specimen os27 of petroblastic gneiss; contours 1-1.5-2.5-3 per cent.

muscovites. The muscovite which has crystallized later than the biotite in the stage of the petroblastesis, shows a pole diagram (S-tectonite) with two maxima in *c*, involving in non-rotational strain (Fig. 10). The inclination of *ac* girdle within *bc* is about 25 degrees in Figures 5,7. Accordingly, the position of *b* ought to be that of b′ and S_4 may be formed

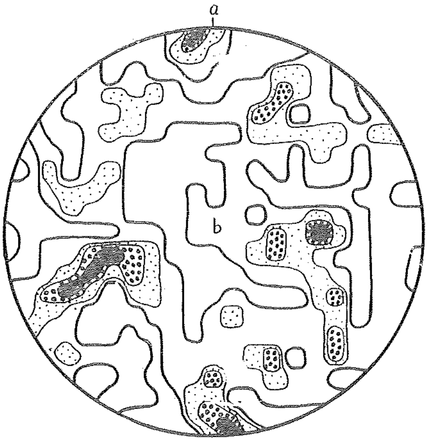

Fig. 20.

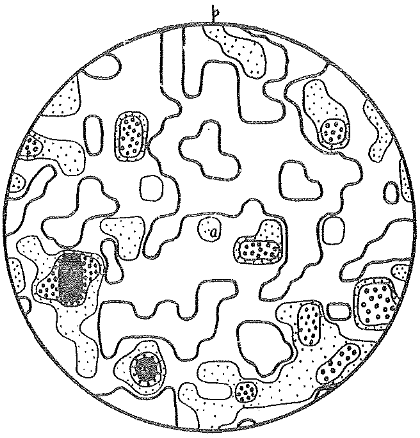

Fig. 21.

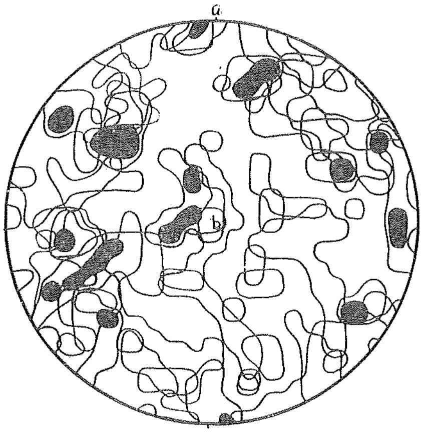

Fig. 22.

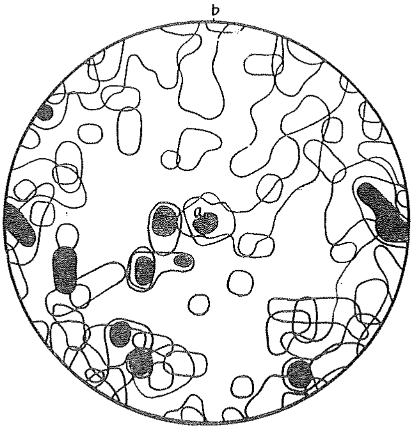

Fig. 23.

Fig. 20. 250 quartz [0001] axes in (ac) of specimen os29 of petroblastic gneiss; contours 1-2-2.5-3.5 percent.

Fig. 21. 270 quartz [0001] axes in (bc) of specimen os29 of petroblastic gneiss; contours 1-2-2.5-3.5 per cent.

Fig. 22, 23 Synoptic diagrams of quartz [0001] axes distribution (2 per cent).

but they fail to be found practically in the polished specimens. In thin section, S_4 can be discriminated from S_2 because biotite flakes indicating S_2 are transected by the other biotite arrangement S_4. The inclinated *ac* girdle of biotite may mean a movement parallel to *b*, by reorientating as mentioned above. These facts suggest that the Hidaka group in the northeast was thrust upon the gabbroic complex at the later stage of the tectonic sequence in this region.

The intensity of the thrusting was not so much stronger than the strength of the lateral movement which produced the *b*-lineation because it may have failed to consume the *ac* girdle with maxima in *c* to bring forth a new pattern. Only quartz represents a superimposed pattern in *bc*.

Accordingly, the lineation in question is capable of two interpretations: parallel and normal to the tectonic transport at the same time but main *b*-lineation is strong and subsequently $b'=a$ lineation is so weak to be unobservable.

Quartz Fabric

The orientation diagrams of quartz are prepared in Figures 11-21. Although they present a very complicated pattern in fabric due to the combination of a few indistinct girdles even in one diagram. Two sets of crossed girdles as well as an obscure *ac* girdle, may be recognizable as shown in two synoptic diagrams (Figs. 22, 23). So, it is noticeable that this particular quartz pattern consists of four girdles in *a* section as well as in *b* section. It has not been analysed anywhere though the crossed girdle has frequently been done. The duplicated fabric as well as the deviation of *a*, *b* and *c* axes as a result of partial movement will make the diagrams complicated more and more.

In the case of biotite, it was obvious that the movement of deformation parallel to *b*-lineation had been weaker than that normal to *b*, but in quartz fabric, the deformation pattern normal to *b* is superimposed by a pattern of deformation parallel to *b* of various intensity. This is evidence that quartz reorients with relative ease, while the more stable biotite fabric has failed to respond to the deformation. A small girdle about *a* is observed in Figure 16.

It would appear consequently that the crossed girdle is the most important matter in this subject. In thin section, it is frequently observed that the optic axis of a quartz grain has been about normal to that of the nearby or neighbouring grain and further the (*okl*) texture of quartz grain has been found as shown by Figure 24 a, b. The undulatory banding of quartz is normal to the optic axis, in spite of the general view which may be parallel to the c-axis (Fig. 24 c). As indicated by the (*okl*) texture of quartz grains, the crossed girdle would have been formed by the compression normal to (*ab*), subsequent to *ac* girdle. The shear surface (*okl*) and (*hol*) may cover a shear stress direction within the "permissible zone" advocated by Schmidt (Fairbairn, 1949, p. 209). This is the restricted forward movement. Though the quartz diagrams are very complicated and indistinct, they can be seen to be composed of some crossed girdles with minor girdles which may be the products of the non-rotational strain at the later stage of deformation history, preceded by the rotational strain has demonstrated by the minor structure and biotite girdles as noted above.

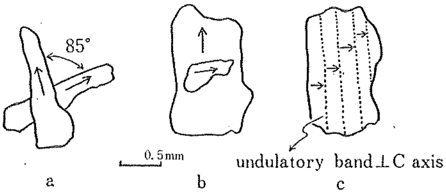

Fig. 24. The (*okl*) texture of quartz grain the petroblastic gneiss (↑ =C axis)

The crossed girdle represents a common fabric of the granulite according to the studies of SANDER (1930), SAHAMA (1936), WENK (1943) etc. The current explanation of granulite quartz orientation is a non-rotational strain with emphasis on a flattening deformation (Mehrscharige Gleitung).

Sequence of events

Bedding of the Hidaka group (S_1) with intercalation of limestone and schalstein is the oldest structure in this region.

Schistosity (S_2) formed oblique to the bedding (S_1) about 30 degrees due to a wrench fault along the strike of the bedding involving shear cleavage or fracture cleavage during the metamorphism and recrystallization in the depth.

The rotation and shearing about *b* are observed either in the polished specimens or in biotite girdles of *b* sections. Furthermore, shear fracture (S_3) is indicated partly by quartz veins oblique to S_2.

S_4 was not observed either in the field or in polished specimen in which only minor drag fold in (*bc*) can be seen, except for the biotite fabric which was indicated by the inclination of the S_2. Macroscopically, the lineation may therefore indicate the *a*-lineation at the last stage of the sequence though it is very weak, because the direction of the thrusting up coincided nearly with the lineation.

Accordingly, the schistosity S_2 and shear fracture S_3 are involved in the lateral shift along the tectonic zone north 50 degrees to west and invisible S_4 may be caused by thrusting up from northeast side of the zone to the southwest side slightly with vertical shift. (Fig. 25)

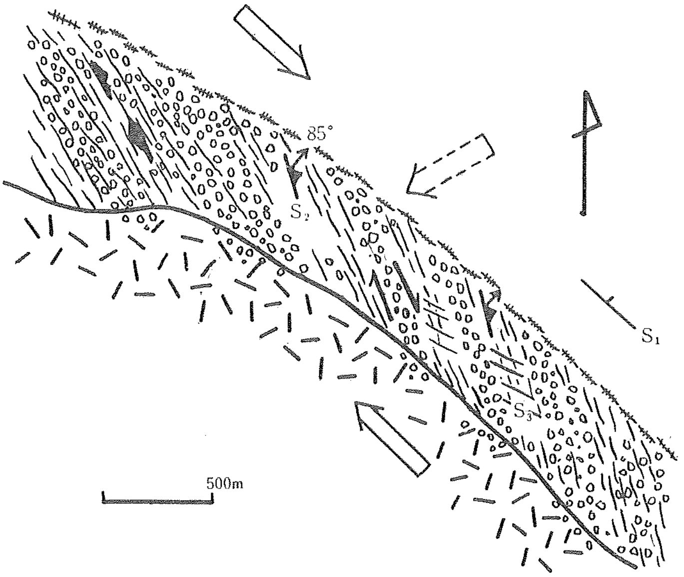

Fig. 25. Schematic tectonic map of the Kamishibetsu gneiss; arrows denote the direction of movement, the arrow by broken line represents the thrusting up at the later stage.

From the microscopical point of view, girdle orientation of biotite is symmetrical with the megascopic fabric, whereas the muscovite and quartz are asymmetrical with respect to the megascopic fabric and biotite orientation. The biotite girdle may indicate a rotational strain, while a non-rotational strain is prevently indicated in muscovite and quartz orientation. It is concluded that the quartz orientation was developed by the deformation subsequent to that which formed the megascopic fabric and biotite orientation. (cf. SAHAMA, 1936. WENK, 1943. CRAMPTON, 1958).

Petroblastesis and fabric

As stated above, the crossed girdle of quartz orientation emphatically indicates a non-rotational strain subsequent to formation of the biotite girdle, and the muscovite occurring only in petroblastic part shows the orientation of S-tectonite, while the biotite orientation is B-tectonite.

The intrusion of diabase and norite sheet is involved in the formation of S_2, S_3 due to the tectonic movement N50W and signifies a basic forerunner. It is clear that these basic intrusions may be related to the formation of a tectonic rupture of the country rock.

Just following a deformation, the rock forming ions with high energy will migrate to the place where the stress has been released, and will crystallize to form petroblastic rock.

Although the recrystallization and neocrystallization will be able to occur in plastic and rotational state as stated in the case of the Oshirabetsu dome (KIZAKI, 1956), the crystal growth may be caused by the lowering of the energy level with the rapid release of the stress. This will account for the formation of the petroblastic gneiss in the region. Consequently, the deformation involving crossed girdle may be in intimate relation with petroblastesis. The author expects to gain very useful results by further study on the petroblastesis in a kinematic environment.

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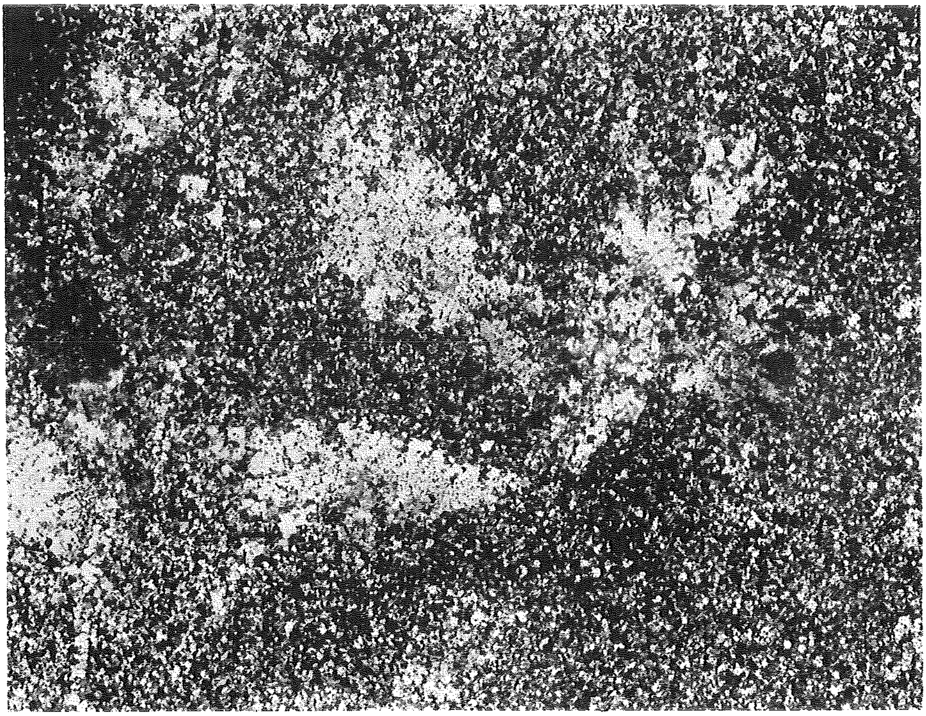
Explanation of
Plate 1

Explanation of Plate I.

a. Photomicrograph of cordierite hornfels. ×10

b. Photomicrograph of garnet bg. schistose hornfels. ×10



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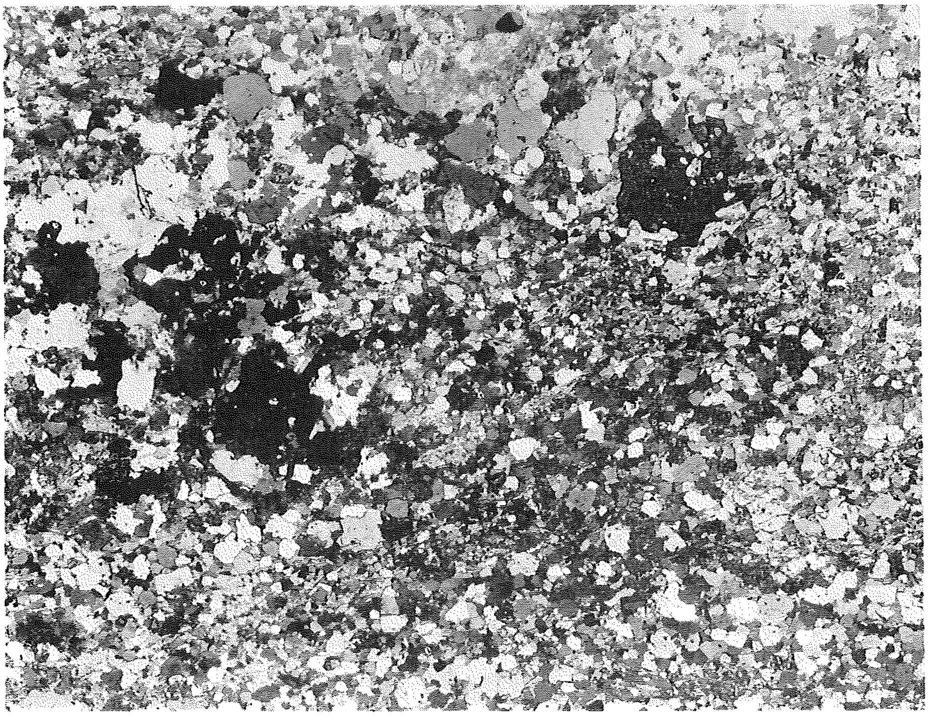


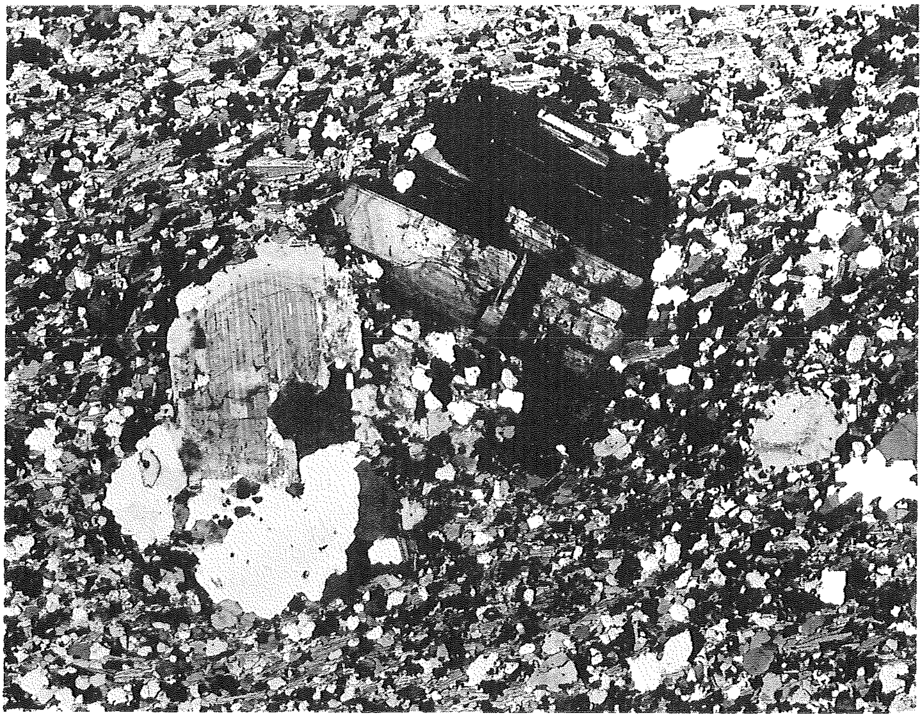
b

Explanation of
Plate 2

Explanation of Plate II.

a. Photomicrograph of plagioclase porphyroblasts in schistose hornfels. ×10

b. Photomicrograph of petroblastic gneiss. ×10



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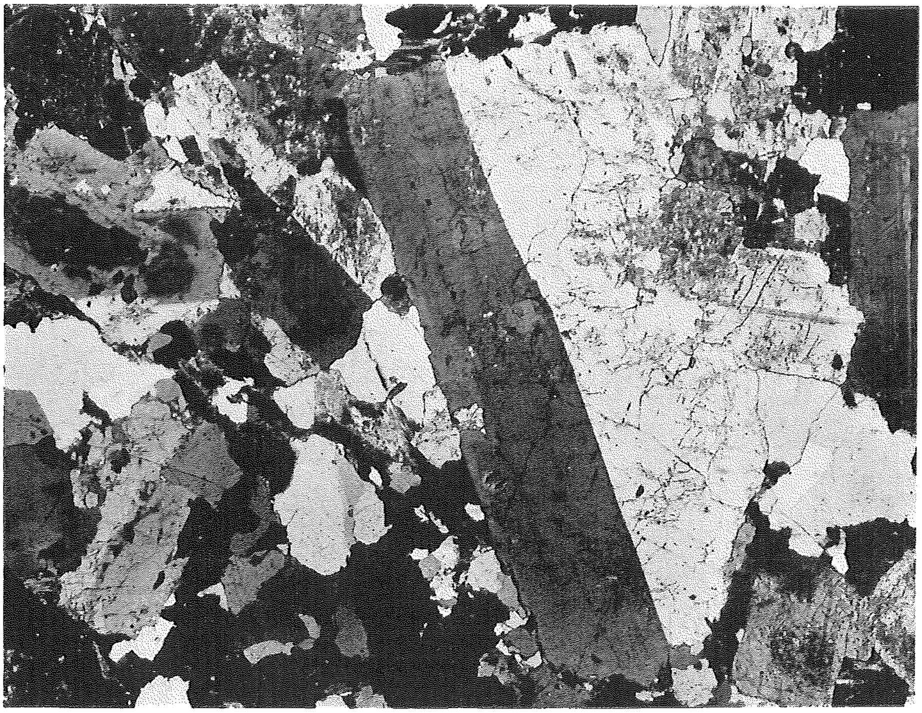


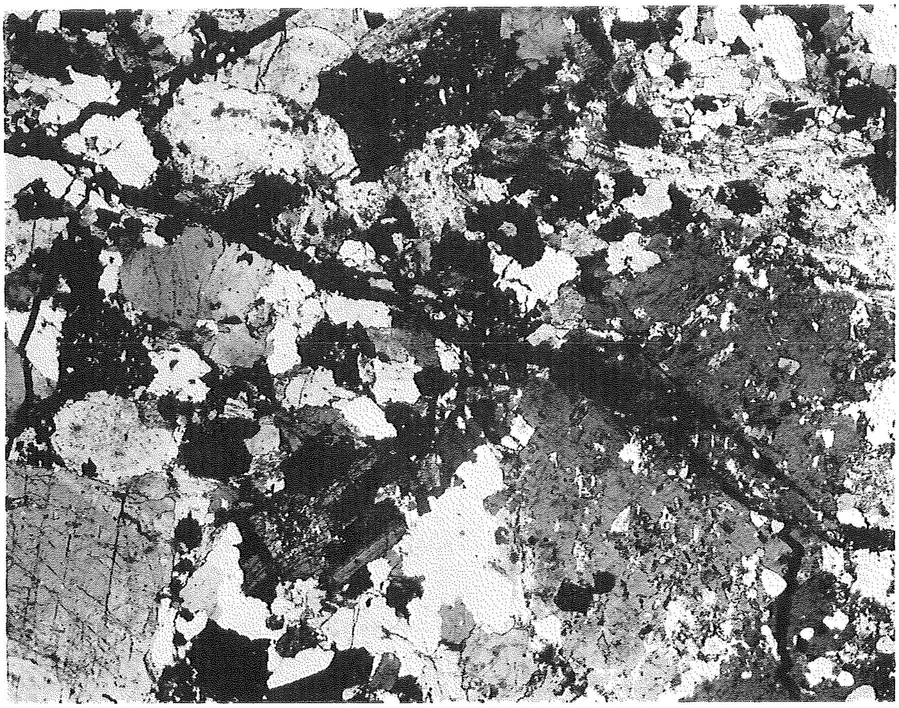
b

Explanation of Plate 3

Explanation of Plate III.

a. Photomicrograph of potash feldspar in petroblastic gneiss. ×10

b. Photomicrograph of plagioclase porphyroblasts in noritic gabbro. ×10



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