On the Geological Structure of the Low Grade Metamorphic Region in the South of River Kinokawa and Petrofabric of Quartz in the Quartz Schist in the Region

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On the Geological Structure of the Low Grade Metamorphic Region in the South of River Kinokawa and Petrofabric of Quartz in the Quartz Schist in the Region

By

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Abstract

In the crystalline schists region on the south of River Kinokawa, a gentle syncline is found. Albite-porphyroblast bearing schists (the so-called spotted schists) lie on the non-spotted schists. Synorogenic intrusive rocks consisting of epidiorite, serpentinite and peridotite are observed in the spotted schists area. Constituting rocks of the spotted schists area are actinolite-epidote-chlorite schist, glaucophane-clinozoisite-chlorite schist, black schist, piedmontite-quartz schist, actinolite or riebeckite-garnet-magnetite-quartz schist and other quartz schists. Those of the non-spotted schists area are black schist, phyllitic sandstone, green schist and stilpnomelane-quartz schist.

In the region under consideration, the dimensional parallelism of rock-forming minerals is in agreement with the direction of the synclinal axis. The tectonic movement of the region is a three dimensional (stationary) one. Petrofabric patterns of quartz schists are b-girdles. The development of quartz fabric in the quart schist is formed as explained in the following: In the earlier stage occurred crystallization in the foliation parallel to s, and in the later stage did formation of (h01)-shear planes accompanying formation of needle quartz with or without recrystallization of quartz grains. Most of the point maximum type show the effect of recrystallization along the (h01)-shear plane in the "mehr und ungleichscharige Deformation". Optimum development of recrystallization of quartz in alkaliamphibole-bearing quartz schists or in stilpnomelane-calcite-quartz schists takes place on the presence of molecules of alkaliamphibole or stilpnomelanes in a liquid phase of still later stage.

Introduction

The low grade metamorphic region in the south of River Kinokawa is a part of the Sambagawa metamorphic region. It is generally accepted that the Sambagawa crystalline schists has originated from Carboniferous-Permian rock suite by the low grade regional metamorphism through late Permian and early Triasic periods.

The Sambagawa crystalline schists of the region in the south of River Kinokawa consist of black schist, phyllitic sandstone, quartz schist and green schist. Their original rocks are black shale, graywacke, chert and basic volcanic ejecta of the Carboniferous-Permian stage.

In this paper the writer describes the stratigraphy and the geological structure of the spotted schists (albite-porphyroblast bearing crystalline schists) area and the petrofabric of quartz schist. He discusses also the development of quartz fabric and the petrogenesis of the quartz schists.

The writer wishes to express his sincere thanks to Mr. MASAO IWASAKI, for many useful suggestions, and to the school teachers in SIBUTA, SIMURA, OOZU and TOMOBUTI, for help to the writer's field survey. He is also indebted to Messers. HEIZABURO MURAYAMA and HISAITI FUJII for preparation of thin sections. A part of the fund for this study has been defrayed by the Grant in Aid for Fundamental Scientific Research of the Ministry of Education.

Stratigraphy and Geological Structure

In Table 1 are shown the stratigraphy in the region on the south of River Kinokawa.

Table 1.

Formation	Thickness	Constituting rocks.
Riumon	500 M	A chief composite member is black schist with green schists accompanying quartz schists.
Iimori	500 M	The main composite member is the albite-actinolite-epidote-chlorite schist accompanying sericite, sphene, ilmenite, calcite and quartz as accessory minerals. The glaucophane schists distinguishing the Iimori formation from the other formations occur intercalatedly as thin beds or films in the albite-actinolite-epidote-chlorite schists. Component minerals of the glaucophane schist are glaucophane, clinozoisite, chlorite, sphene and ilmenite. In the glaucophane schists, riebeckite-garnet-magnetite-quartz schists are intercalated. In the albite-actinolite-epidote-chlorite schists, some thin beds of ribeckite-garnet-magnetite-quarts schist are intercalated.
Kitayama	500～300 M	The main composite member is the albite-actinolite-epidote-chlorite schist with some thin actinolite or riebeckite-garnet-magnetite-quartz schists. The albite-actinolite-epidote-chlorite schists have sericite, sphene, ilmenite, quartz, calcite and tourmaline as the accessory minerals.
Sibuta	500 M	Ditto
Tomobuti		The chief composite rock is the black schist. The other composite rocks are phyllitic sandstone and green schist with stilpnomelane-calcite-quartz schist. The component minerals of the green schists are actinolite, epidote, chlorite, albite, sericite, sphene and quartz. The phyllitic sandstone is a metagraywacke.

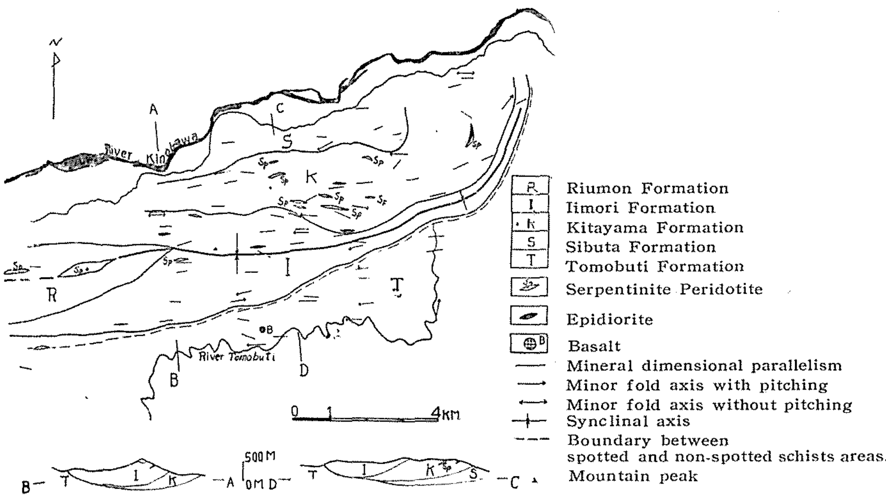

Fig 1. Geological map of the region in the south of River Kinokawa.

The discriminations between the Sibuta, the Kitayama, the Iimori and the Riumon formations were made by tracing the piedmontite schists as the key beds. The stratigraphical relations between these formations are conformable.

The Kitayama and the Sibuta formations occupying the north wing of the syncline disappear on the southern side of the syncline, and the Iimori formation rests directly on the Tomobuti formation.

The piedmontite schists occur not only in the two alternated beds of green and black schists intercalated between the three thick green schists of the Iimori, the Kitayama and the Sibuta formations, but also in the Iimori formation with the black schist. The component minerals of these piedmontite schists are albite, piedmontite, sericite, garnet and alkaliamphibole.

Albite-porphyroblasts are found in all the schists of the Riumon, the Iimori, the Kitayama and the Sibuta formations.

In Fig. 1 are shown the geological structure of the region under consideration. It is a synclinal structure with a gently curved axis. The boundary between the spotted and the non-spotted schists areas is situated in the uppermost part of alternations of the green and the black schists of the Tomobuti formation. Many faults are seen in the region, but no large extent effect of them on the structure can be recognized. Synorogenic intrusive rocks consisting of epidiorite, serpentinite and peridotite are observed only in the spotted schists area.

Minor Fold

In the region minor folds are seen almost everywhere and all of them are true flexure folds. Their dimensions are from several centimeters to one meter. As a whole their trends are parallel to the synclinal axis and show a westward pitching except for "a-fold" in the Tomobuti formation in Amano village (Fig. 1).

Shape of these minor folds varies greatly as competence of the rocks does. Incompetent rocks like the quartz schists having originated from cherts occur in smaller drag folds.

As for angle of inclination of axial plane of the fold, those in the Tomobuti and the Iimori formations are high, while in the Kitayama and the Sibuta are low.

Lineation

With the exception of the three cases shown below, the directions of dimensional parallelism of minerals on the foliation plane (s) parallel to the bedding plane are nearly east-west as shown in Fig. 1 and 2.

1) In some places of the north-eastern part of the region where beds strike northerly, the directions of the dimensional parallelism of albite-porphyroblasts of spotted green schist are nearly north-south, despite the coincidence of parallelism of actinolite with the direction of the whole areal lineation.
2) In alkaliamphibole quartz schists and glaucophane schists, large alkaliamphibole and glaucophane have their c-axes parallel to the foliation planes and oriented at random.
3) In stilpnomelane quartz schists, the stilpnomelanes have no preferred orientation.

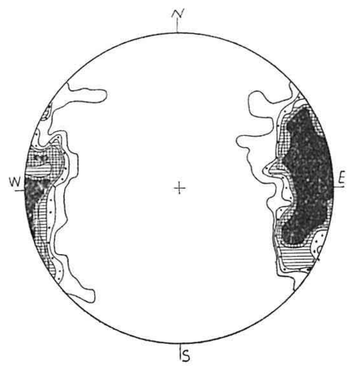

Fig. 2. 164-lineations (dimensional parallelism of rock-forming minerals projection on the upper semisphere, except those of albite porphyroblast at the north-estern part of the region 0-1-2-3-4-5 %<

In Bizan (Ootakisan)[5] and Kotu[6] districts, directions of the dimensional parallelism of the component minerals in glaucophane schists are oblique or perpendicular to that of the dimensional parallelism of albite-spotted actinolite green schists, but both directions are comformable in the region south of River Kinokawa. The lineations by mutual crossing of S-planes trend nearly east-west.

Except the lineations mentioned above, we find that the lineation by crossing of the S-planes and the lineation like slickenside trend oblique or perpendicular to the direction of dimensional parallelism of minerals.

Considerations on the character of tectonic movement of the region in the south of River Kinokawa.

G. KOJIMA holds[4] that the structure of spotted schists area of the Sambagawa crystalline schists region are characterized by the overturned fold. However, the structure of spotted schists area in the region under consideration is not an overturned folds, but a gentle syncline.

In the previous paper[7] the writer held that the tectonic movement of the Sambagawa crystalline schists region is of three dimensional, because the dimensional parallelism of the rock-forming minerals is in agreement with the direction of the folding axis. As already mentioned, the dimensional parallelisms of albite-porphyroblast trend nearly north-south in the north-eastern part, despite of the coincidence of the parallelism of actinolite with the direction of the whole areal lineation. What does this deviation mean? It means that in the later stage of tectonic movement, the a-lineation and a-fold are formed as a result of local compressions caused by the stretching of rock in the direction of the folding axis (the direction of the least resistance), and those a-structures (a-lineation and a-fold) are in reality b-structure of the three dimensional tectonite. The inclusions of actinolite and sphene in the albite-porphyroblasts comfirm that the crystallizing stage of the albite-porphyroblast is later than the crystallizing stage of actinolite, and that the formation of the dimensional parallelism of albite-porphyroblast trending nearly north-south occurs after that of actinolite trending nearly east-west. Moreover, the random orientations of the glaucophane, the alkaliamphibole and the stilpnomelane are due to their later crystallization in the period of the tectonic movement.

From the considerations on the geological structure and the relation of the mineral dimensional parallelism to the geological structure, there is no doubt about conclusion that the tectonic movement of spotted schists area in the region under consideration is a stationary movement.

On the quartz schist

Types of the quartz schists and their occurrence.

According to their petroparagenesis which represent their different petrographical characters, M. Iwasaki classified[8] the quartz schist of the Sambagawa metamorphic region into the following three types:

a) Quartz schists alternating with or intercalated in the green schists.
b) Quartz schists alternating with or intercalated in the black schists.
c) Independent quartz schists in the black schists.

Most of the quartz schists in the region on the south of River Kinokawa belong to the first type. In addition, it is possible to subdivide the quartz schists of this region into the following three types according to their petroparagenesis:

First type) Quartz schists intercalated in the thick green schists of the Kitayama, Sibuta and Iimori formation.
Second type) Quartz schists in the alternated beds of the green and the black schists situated between the thick green schists.
Third type) Quartz schists with the green schists in the Tomobuti formation.

1) Quartz schists of the first type:

Actinolite-garnet-magnetite-quartz schist (Sibuta & Kitayama formations)

Riebeckite-garnet-magnetite-quartz schist (Sibuta, Kitayama & Iimori formations)

As for the compositional minerals, we can find also sericite, epidote, calcite and hematite. There exist no transitional rocks between the green schists and the quartz schists of the first type.

2) Quartz schists of the second type:

Alkaliamphibole-piedmontite-quartz schist

Sericite-quartz schist

The sericite-quartz schists occur as independent beds and transitional rocks between the piedmontite-quartz schists and the green schists. The alkaliamphibole of the piedmontite-quartz schists is colorless with strong dispersion in thin sections. Moreover, similar colorless alkaliamphiboles occur zonally surrounded by riebeckite* in the riebeckite-garnet-magnetite-quartz schist of the Iimori formation. Therefore, it is probable that the colorless amphibole belongs to the riebeckite series. In the Sambagawa crystalline schists, similar amphiboles have been reported from Bizan (Ootakisan)[5)], Sazare mine[10)], Sirataki mine[11)] and Iratu near Betusi mine[9)].

It is interesting that the piedmontite quartz schist lies only in the alternated beds of the green and the black schists.

3) Quartz schists of the third type:

Chlorite-quartz schist

Stilpnomelane-quartz schist

The later have stilpnomelane and calcite as principal component mineral. The rocks correspond to the leading type in M. IWASAKI's classification[8)] concerning the occurrence of the stilpnomelane in the Sambagawa crystalline schists. We can find no quartz schist bearing stilpnomelane as the principal component in the Kitayama, the Sibuta and the Iimori formations which bear thick green schists as principal constituent. This fact is in agreement with the following statement of G. KOJIMA[3)] and M. IWASAKI[8)] concerning the occurrence of stilpnomelane quartz schists in the Sambagawa crystalline schists: "The stilpnomelane-quartz schist accompanying the thick green schist shows rare occurrence".

In the spotted schists area, the quartz schist bears albite-porphyroblasts. The albite-porphyroblast showing heterogeneous distribution in the quartz schist, lies in the ferromagnesian mineral layer of the quartz schist. As a result of the drag folding the quartz schist appears thicker than its true thickness. The true thickness is from several centimeters to a few meters.

Microscopic texture of the quartz schist (Refer to plate)

As mentioned above, the stretching and the parallelism of the rock-forming minerals in the region under consideration occur parallel to the folding axis. The present writer uses the parallelism of rock-forming minerals as the fabric axis b.

* While the printing of the present paper, A. MIYASHIRO & M. IWASAKI reported that the similar amphiboles from Bizan belong to magnesioriebeckite[21)]. The present writer has revised the identification after them.

The description of his microscopic observation of the texture is in the main of the ac-section.

The quartz of the quartz schist can be divided into three descriptive types[13]: crush quartz, needle quartz and recrystallized quartz.

The texture of quartz aggregate can be divided into the following descriptive types: crush or needle quartz granular texture, recrystallized quartz granular texture and heterogenetic texture.

In the quartz schist of the region, with the exception of a part of recrystallized quartz, quartz mostly shows the longest dimension in the direction of b and the shortest in that of a. The same fact has been reported by K. KANEHIRA[12] concerning the quartz schists in this region.

It is not easy to descriminate crush quartz from needle quartz. Crush quartz has the longest dimension in the direction perpendicular or oblique to its principal axis. Crush quartz shows a strong undulatory extinction and is not bounded by plane surfaces. Needle quartz is longest in the direction parallel to its c-axes and in rare cases bounded by rhombohedron. Needle quartz shows a strong undulatory extinction.

Recrystallized quartz granular texture consists chiefly of equidimensional, recrystallized quartz; and the needle quartz or crush quartz granular texture is consisted mainly of equidimensional, needle or crush quartz. However, we rarely find crush quartz granular texture.

Heterogenetic texture consists of large crush or needle quartz and fine crush or needle or recrystallized quartz. In this texture, fine quartz mostly is recrystallized quartz.

Feature of petrofabric in ac-thin sections from the quartz schists in the region.

In Fig. 3 are shown the localities of the quartz schists, whose fabrics are stated beneath, also the brief feature of the fabric diagram and the dip of foliation.

In all ac-sections of quartz schists from the region, we find the developments of foliation banding parallel to s and of $(h0l)$-shear plane, by tracing the dimensional parallelism of sericite, magnetite, chlorite, garnet, piedmontite and amphiboles. In some sections the $(h0l)$-shear planes are found in the dimensional parallelism of quartz and/or in the formation of recrystallized quartz along the planes having certain directions. In addition, we find the following features in ac-sections from quartz schists in the region.

a) Crush quartz granular texture

1049, Chlorite-quartz schist from the Tomobuti formation.

Fabric diagram: Fig. 4

Crush quartz having its longer dimension parallel to s is bounded by irregular faces, but is not bounded by crystal faces.

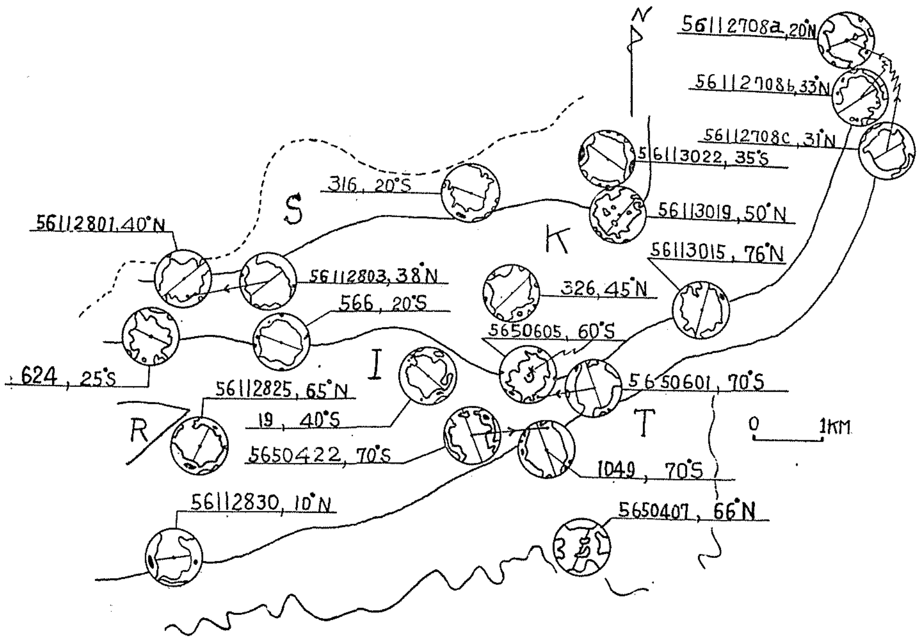

Fig. 3. The locality of the quartz schist, and the brief feature of the fabric diagram.

b) Needle quartz granular texture

56113015, Alkaliamphibole-piedmontite-quartz schist from the Kitayama formation.
Fabric diagram: Fig. 5

The longer dimensions of needle quartz are nearly parallel to s_1 and s_2. A part of the quartz grains lies in a triangle enclosed by s, s_1 and s_2.

566, Alkaliamphibole-piedmontite-quartz schist from the Kitayama formation.
Fabric diagram: Fig. 6

The needle quartz grains having their c-axes parallel to s_3 and s_4 or perpendicular to s are predominant.

5650605, Alkaliamphibole-piedmontite-quartz schist from the Kitayama formation.
Fabric diagrams Fig. 7

We find a small fold in the thin section. Further we see s_1 produced parallel to the axial plane of the fold and s_2 also existent.

56112825, Riebeckite-garnet-magnetite-quartz schist from the Iimori formation.
Fabric diagram: Fig. 8

In the foliation parallel to s, the longer dimensions of the quartz are parallel to s_1. From the fabric diagram we find that the bounded plane surfaces are rhombohedron.

56113022, Riebeckite-garnet-magnetite-quartz schist from the Sibuta formation.
Fabric diagrams: Fig. 9

This is composed of crush and needle quartz and the quartz recrystallizing along s_2. Most of the needle quartz have their c-axes parallel to s_1 and s_2. In the recrystallized quartz, their larger dimensions and c-axes are perpendicular to s_2. The feature of the texture is in good harmoney with the fabric diagram. The maximum near the pole of s_2 corresponds both to the orientation of needle quartz grains, which have their c-axes parallel to s_1, and to the orientation of the recrystallized quartz along s_2, and the maximum near the pole of s_1 corresponds to the orientation of the needle quartz grain having their c-axes parallel to s_2.

56112803, Riebeckite-garnet-magnetite-quartz schist from the Kitayama formation.
Fabric diagram: Fig. 10
The longer dimensions of needle quartz are parallel to s, s_1, s_2, and s_3.
565061, chlorite-sericite-quartz schist from the Iimori formation.
Fabric diagram: Fig. 11

Considered here are mostly needle quartz and in part recrystallized quartz. In the needle quartz the c-axes are parallel or subparallel to s, s_1, s_2 and s_3.

21, Chlorite-epidote-magntite-quartz schist from the Iimori formrtion.
Fabric diagram (Partial fabric): Fig. 12

A segregated quartz layer 4.5 mm in thickness is composed of needle quartz grains and some fine recrystallized non-elongated quartz crystals. In needle quartz the c-axes are parallel to s_1, s_2 and s_3.

c) Heterogenetic texture

56112708a, Sericite-quartz schist from the Kitayama formation.
Fabric diagram: Fig. 13

This is a transitional rock between actinolite-epidote-chlorite schist and alkali-amphibole-piedmontite-quartz schist (561112608b & c). The foliation parallel to s makes a lensoid form bounded by s_1 and s_2. It is an aggregate of large crush quartz grains, medium quartz grains and small recrystallized quartz crystals.

56112708b, Alkaliamphibole-piedmontite-quartz schist from the Kitayama formation.
Fabric diagram: Fig. 14

This lies on 57112708c and shows the optimum development of (*h0l*)-shear plane accompanying the recrystallization of quartz. But we found no recrystallization along (*h0l*)-shear plane in a thin section, in which petrofabric investigations were made.

The segregated lenses parallel to s are composed of medium crush quartz grains and fine recrystallized quartz crystals.

56112708c, Alkaliamphibole-piedmontite-quartz schist from the Kitayama formation.
Fabric diagram: Fig. 15

This is composed of medium and large crush quartz and fine recystallized quartz.

56112801, Alkaliamphibole-piedmontite-quartz schist from the Sibuta formation.
Fabric diagram: Fig. 16

This is an aggregate of fine needle quartz, whose c-axes are parallel or sub-parallel to s_3 and s_4, but sometimes perpendicular to s.

326, Sericite-quartz schist from the Kitayama formation.
Fabric diagram: Fig. 17

This is composed of crush quartz having the c-axes parallel to s and of fine recrystallized quartz crystals. The development of s_1 is more predominant than that of s_2.

d) Recrystallized quartz granular texture

316, Actinolite-garnet-magnetite-quartz schist from the Sibuta formation.
Fabric diagram: Fig. 18

The foliation consisting of ferromagnesian and quartz layer, has definite banding structure and runs parallel to s. The quartz crystals show nearly non-undulatory or weak undulatory extinction and have their larger dimensions parallel to c-fabric axis.

56112830, Riebeckite-garnet-magnetite-quartz schist from the Iimori formation.
Fabric diagram: Fig. 19 and Fig. 27 (Partial fabric)

In the foliation parallel to s, the elongated quartz crystals have their larger dimensions parallel to s_1 and s_2. There we find along s_1 also recrystallized quartz layers, whose fabric is given in Fig. 27. This partial fabric is of similar character to the total fabric in Fig. 19.

56113019, Riebeckite-garnet-magnetite-quartz schist from the Sibuta formation.
Fabric diagram: Fig. 20

The quartz crystal is compoped of elongated or non-elongated crystals, and the larger dimension of the elongated crystal has no regular direction.

624, Riebeckite-garnet-magnetite-quartz schist from the Iimori formation.
Fabric diagram: Fig. 21

In the foliation parallel to s, the dimensional orientations of the garnet, magnetite and riebeckite are parallel to s_1 and s_2. The plane s_2 is more predominant than the development of s_1. Generally, the quartz crystals show non-elongated crystal shape.

5650422, Riebeckite-garnet-magnetite-quartz schist from Iimori formation.
Fabric diagram: Fig. 22

The quartz crystal is composed of elongated and non-elongated shape crystals, and the elongated shape crystals have their larger dimensions parellel to s, s_1 and s_2.

19, Alkaliamphibole-piedmontite-quartz schist from the Iimori formation.
Fabric diagram: Fig. 23

Most of the quartz crystals show elongated grain shapes, and their larger dimensions are parallel to s, s_1 and s_2. Small part of them have larger dimension parallel to c-fabric axis than the dimension parallel to a-fabric axis. In Table 2 are shown results of the statistic measurements[14] of relations between orientations of quartz crystal and their elongations along the fabric b-axis in bc thin sections from the rock.

Table 2

Orientation type / c : b	I	II	III	IV	V	Total
1.5 : 1～1 : 1.5	17	24	46	64	47	198
1 : 1.6～1 : 2.5	54	26	83	109	48	320
1 : 2.6～1 : 3.5	83	33	53	91	40	300
1 : 3.6～1 : 4.5	49	13	21	47	16	146
1 : 4.6 over	149	17	24	51	11	161
Total	352	113	227	371	162	1225

The Romans numerals in Table 2 correspond to those given in the synoptic diagrams of SANDER[15] and FAIRBAIRN[19]. s_1 and s_2 cross s at low angles. Therefore, we may correlate the numerals of Table 2 with those of synoptic diagrams of SANDER and FAIRBAIRN with some allowances.

5650407, Stilpnomelane-quartz schist from the Tomobuti formation.

Fabric diagram: Fig. 24

A part of s_1 comes in union with s, and the foliation forms a slender lensoied form resembling a slant S letter. The quartz crystal shows non-elongated crystal shape.

12, Recrystallized quartz along s in the sericite-quartz schist from the Tomobuti formation.

Fabric diagram: Fig. 25

In the rock composed of needle quartz, we find the recrystallized quartz crystals along s_1 and its branches running parallel to s_2.

13, Recrystallized quartz at the periphery of large brecciated quartz lens in the black schist from the Tomobuti formation.

Fabric diagram: Fig. 26

From the correlation of texture explanation to the fabric diagram of each quartz schist having the recrystallized quartz granular texture, we recognize that the recrystallization is caused by the formation of the *(h0l)*-shear plane accompanying the formation of the needle quartz grain. We find also that the recystallized quartz crystals are in part oriented with their principal c-axes perpendicular to the shear planes which cause the recrystallization.

Petrofabric diagrams

Legends

2∼3% 3∼4% 4∼5% 5%<

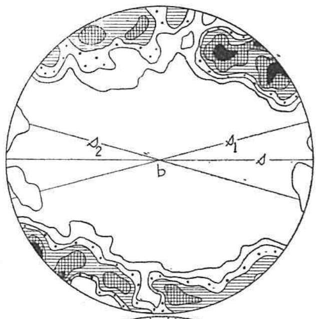

Fig. 4. 1049, 200 quartz axes

1-2-3-4-5%<

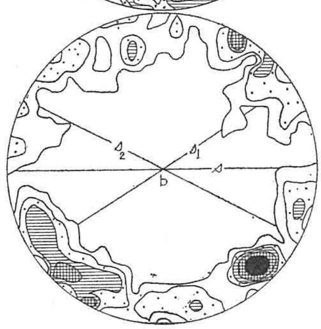

Fig. 5. 56113015, 200 quartz axes

0-1-2-3-4-5%<

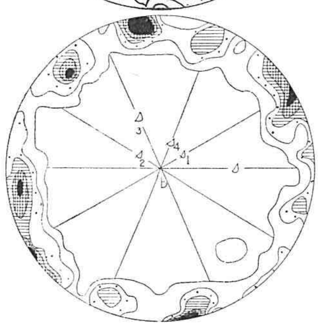

Fig. 6. 566, 200 quartz axes

0-1-2-3-4-5%<

Fig. 7. 5650605, 200 quartz axes

0-1-2-3-4-5%<

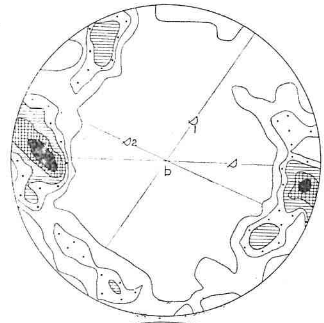

Fig. 8. 56112825, 200 quartz axes

0-1-2-3-4-5%<

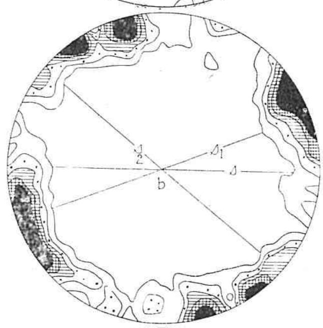

Fig. 9. 56113022, 200 quartz axes

0-1-2-3-4-5%<

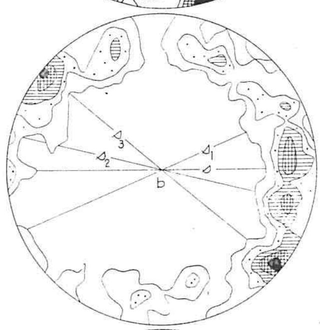

Fig. 10. 56112803, 200 quartz axes

0-1-2-3-4-5%<

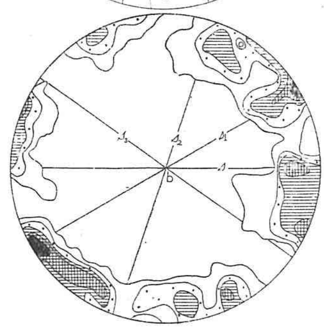

Fig. 11. 5650601, 200 quartz axes

0-1-2-3-4-5%<

Petrofabric diagrams

Legends

2~3% 3~4% 4~5% 5%<

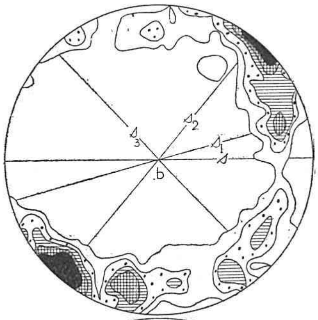

Fig. 12. 21, 200 quartz axes 0-1-2-3-4-5%<

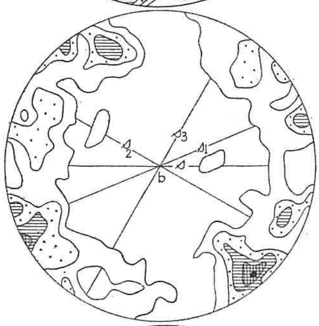

Fig. 13. 56112708 a, 200 quartz axes 0-1-2-3-4-5%<

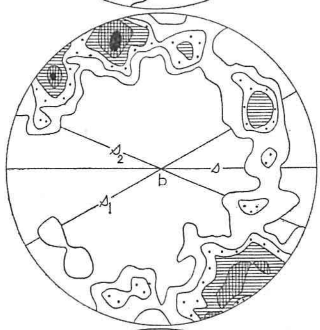

Fig. 14. 56112708 b, 200 quartz axes 0-1-2-3-4-5%<

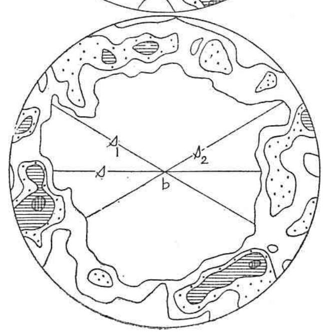

Fig. 15. 56112708 c, 200 quartz axes 0-1-2-3-4%

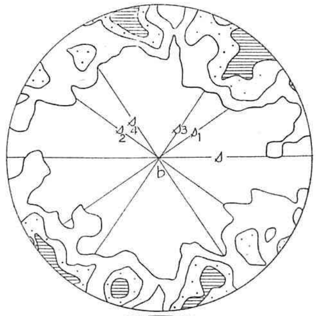

Fig. 16. 56112801, 200 quartz axes 0-1-2-3%

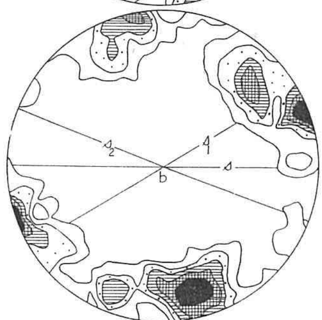

Fig. 17. 326, 200 quartz axes 0-1-2-3-4-5%<

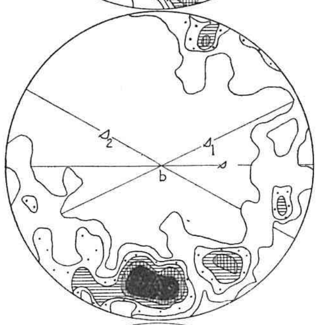

Fig. 18. 316, 200 quartz zaxes 0-1-2-3-4-5%<

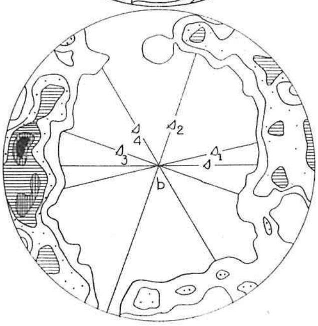

Fig. 19. 56112830, 200 quartz axes 0-1-2-3-4-5%<

Petrofabric diagrams

Legends

2～3%　3～4%　4～5%　5%<

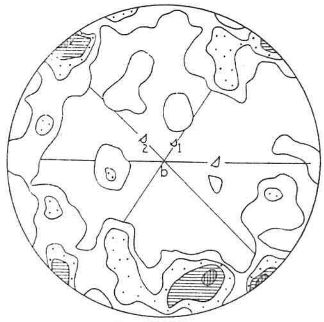

Fig. 20. 56113019, 200 quartz axes

0-1-2-3-4%

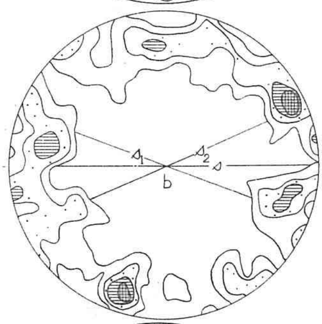

Fig. 21. 624, 200 quartz axes

0-1-2-3-4%

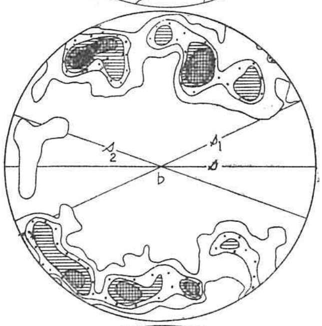

Fig. 22. 5650422, 200 quartz axes

0-1-2-3-4-5%<

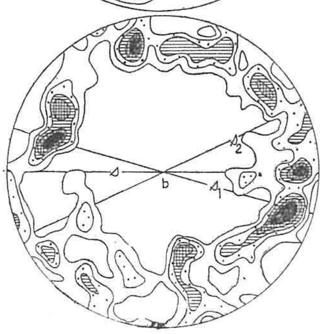

Fig. 23. 19, 200 quartz axes

0-1-2-3-4-5%<

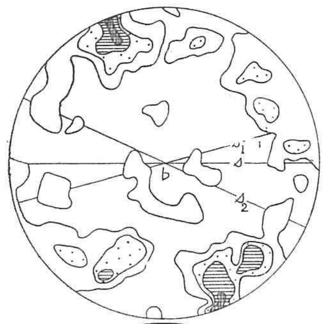

Fig. 24. 5650407, 200 quartz axes

0-1-2-3-4%

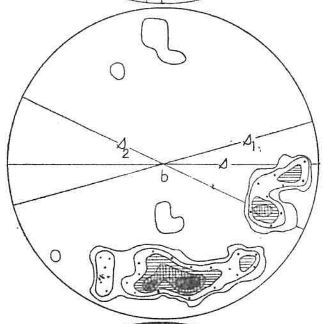

Fig. 25. 12, 70 quartz axes

0-1-2-3-4-5%<

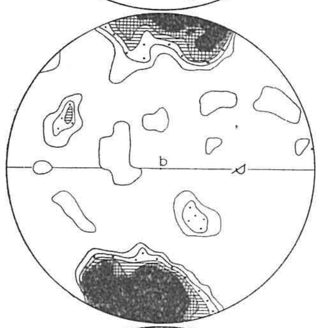

Fig. 26. 13, 200 quartz axes

0-1-2-3-4-5%<

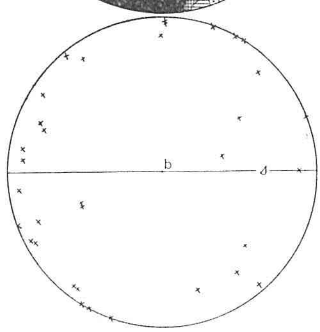

Fig. 27. 56112830, 30 quartz axes

Discussion

Concerning the development of fabric in tectonite, SANDER holds[15][16] the following principles: the variation and the development of the fabric depend on the formation of the shear plane accompanying the brecciation and the recrystallization of minerals. His principles are in agreement with the data concerning the fabrics mentioned above.

In the region on the south of River Kinokawa, in the earlier stage the crystallization occurred along the foliation, and in the later stage the formation of (*h01*)-shear plane took place accompaning the formation of the needle quartz grain with or without recrystallization.

What is the relation between the development of texture and that of quartz orientation in the quartz schist?

As mentioned already, large part of quartz, with the exception of a part of recrystallized quartz, is stretched in the fabric b-axis. In the quartz schist, the orientations of c-axes of quartz are nearly perpendicular to the fabric b-axis. Therefore, it follows that the quartz is stretched in the direction $[m:r]$, as emphasized by E. M. ANDERSON[18].

In the previous paper[14] the present writer assumed, with M. J. BUERGER[17], that the lineage in quartz is parallel to the prism face, and further assumed that in the initial stage of the deformation the lineage lies as an obstacle to lattice-translation, and that a further deformation brings on translation parallel to the lineage.

The present writer holds the following opinions concerning the development of quartz fabrics:

In the early stage, undeformed quartz having c-axis perpendicular to the foliation plane is crystallized in the foliation banding. In the later stage, the shear plane (*h01*) is formed accompanying the formation of needle quartz grain and then the recrystallization. In the initial stage of the deformation of quartz, the translation, conforming its translation direction $[m:r]$ with the fabric b-axis, occurs in every plane inside the quartz crystal parallel to the (*h01*)-shear plane, and produces undulatory extinction of the quartz. However, the extent of the translation is diminished by the presence of the lineage parallel to the prism face. The sequence of translation to the limit in every plane inside the crystal depends on the width of each plane intercepted betweens the lineage planes. In other words, planes of larger width have to go longer distance to the limits. Therefore, a crystal having c-axis perpendicular to the shear plane is the first to come to the limit.

A crystal slipping to the limit in a plane parallel to the shear plane results in rupture and brings on a translation parallel to the lineage surface. The translation in the lineage surface parallel to the prism face bears the $[m:r]$ as the translation direction. The translation direction is in the facric b-axis, in which we find the stretching of the crystal.

Besides, accompanied by the brecciation of the crystal, the recrystallization of the quartz grain occurs along the (*h01*)-shear plane. According to SANDER's statistic measurements[15][16] of the orientation of recrystallized quartz, later recrystalization may obliterate most of the needle shape, leaving the crystal axis orientation as the evidence of the process. However, in the quartz schists from the region in the south of River Kinokawa, later recrystallizations leave no crystal axis orientation.

The present writer is of the following opinion concerning the data given above: In a schist from Tyrol, the differential movement along the shear plane accompanying recrystallization is still as active as in the stage of the formation of needle quartz. But in the schists from the region in the south of River Kinokawa, the differential movements along the shear planes accompanying recrystallization have a weak effect on the fabrics in comparison with that of the recrystallization. Thus, in the recrystallized quartz granular textures, the maxima due to the orientations of recrystallizd quartz are often found near the poles of the planes exerting the effects on the recrystallizations of the quartz.

Regarding the relation between the types of the petrofabric diagrams and that of the tectonites, the writer holds that, as is already evident from the descriptions on the texture and the fabric diagram, in the region the quartz schist has the feature of "mehr und ungleichscharige Deformation" showing the character of external rotation. In these quartz schists, the fabric diagram of the quartz belongs to the girdle type or the point maximum type. Most of quartz schists belonging to the latter type have undergone effects of the recrystallization along the shear plane of the "mehr und ungleichscharige Deformation." Thus, so long as the fabrics of the quartz schists in the region are concered, fabric type, either the girdle type or the point maximum type, does not determine the tectonic type, namely, whether the rotational or the non-rotational deformation.

Moreover, as is clear from Fig. 3, no difference of petrofabric pattern is discernible between the spotted schist and the non-spotted schist areas.

Most of the fabrics of the quartz schist in the region are thus made explanable by the present writer's principles, but there remain still uncertain elements in the mechanism of recrystallization.

Is there any relation between the rock types and the degrees of recrystallization?

The examples of the quartz schist having the recrystallized quartz granular texture are given in the following:

1) The quartz schists occuring as thin intercalated beds in the thick green schists of the Iimori, the Kitayama and the Sibuta formations. They are the riebeckite or the actinolite-garnet-magnetite-quartz schists.
2) The stilpnomelane-calcite-quartz schists accompanying green schists in the Tomobuti formation.
3) The Alkaliamphibole-piedmontite-quartz schists.

In this manner, it is interesting to us that the quartz schists bearing alkaliamphibole or stilpnomelane show the optimum development of recrystallization.

According to the well-known informations[20], the recrystallization in crystalline substances occurs under the following conditions:

1) "Temperature increase" and "release of stress" (Annealing recrystaillzation)
2) "Stress too small relative to confining pressure applied for protacted time so that deformation is characterized by intergranular movement and (in presence of a liqued phase) by solution-redeposition phenomena (Load recrystallization)".

There is no evidence that the quartz schist having the recrystallized quartz granular texture suffered more temperature increase and/or release of stress in comparison with other quartz schists having non-recrystallized texture in our region. Therefore, we must consider the second condition concerning the optimum development of recrystallization in the quartz schists bearing alkaliamphibole or stilpnomelane.

According to the same informations concerning the load recrystallization of rock minerals, it requires a liquid phase for optimum development.

As mentioned already, we have the evidence that the molecules forming alkaliamphibole or stilpnomelane continued to remain movable (in the liquid phase) even in the later stage. Thus, the present writer holds that the optimum development of the recrystallization of the quartz crystal in the quartz schists having the alkaliamphibole or stilpnomelane had occurred on the presence of the liquid phase of the molecules which in the later stage formed the alkaliamphibole or the stilpnomelane.

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Fig. 1


Fig. 2

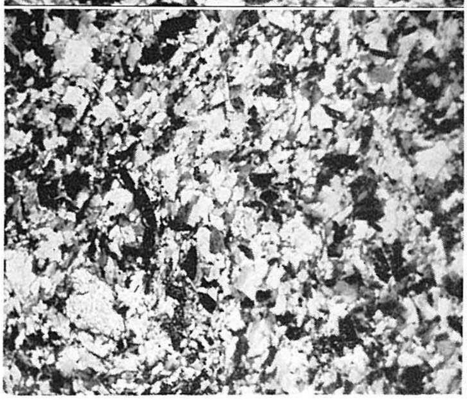
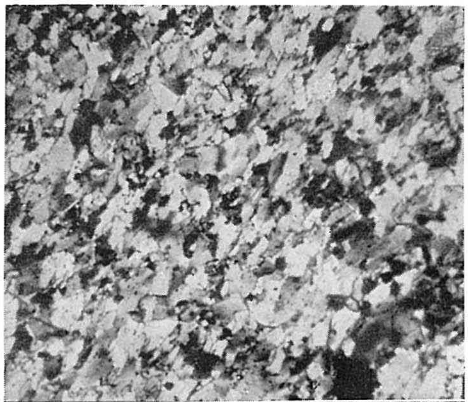

Fig. 3


Fig. 4


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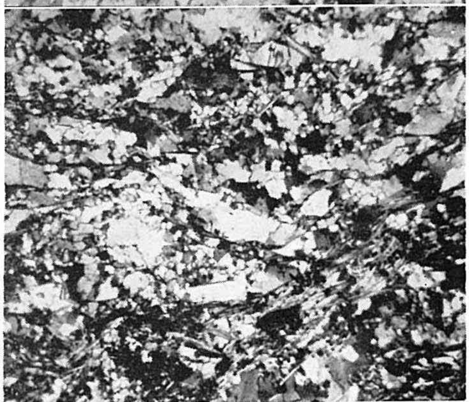
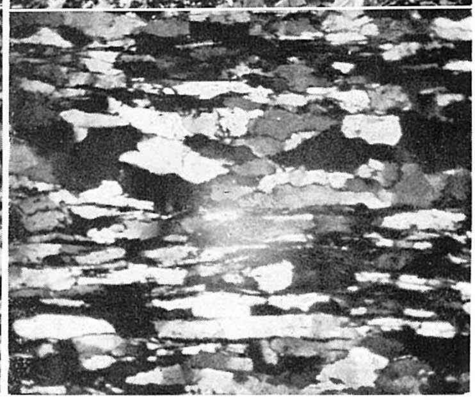


Fig. 6


Explanation of Plate

Photomicrographs of textures in ac-sections of several quartz schists.

Fig. 1. Needle quartz in a piedmontite quartz schist. (566) Crossed nicol. ×40

Fig. 2. Crush quartz granular texture in a chlorite quarite quartz schist. (1049) Crossed nicol. ×40

Fig. 3. Needle quartz granular texture in a piedmontite quartz schist. (5650605) Crossed nicol. ×40

Fig. 4. Needle quartz granular texture in a piedmontite quartz schist. (56113015) Crossed nicol. ×40

Fig. 5. Heterogenetic texture in a sericite quartz schist. (56112708 a) Crossed niol. ×40

Fig. 6. Recrystallized quartz granular texture in a piedmontite quartz schist. (19) Crossed nicol. ×40