# *On the Gneissose Granites of Minakata-Kashio District Nagano Prefecture, Central Japan*

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## Introduction

It is well known that various granitic rocks are distributed in the Inner Zone along the Median Tectonic Line, and that their mutural relations are very complicated. Formerly (1953) the writer pointed out the distinct zonal distributions which were arranged orderly from west to east in the formes of coarse-grained hornblende-biotite granite (Ikuta granite), migmatite (gneissose granite) and mylonite in the Minakata-Kashio district of Nagano Prefecture.

Looking with another eye upon these arrangements, the trends of inner structures such as the gneissosity or the arrangements of xenoliths cross obliquely both these zonal distributions and the Median Tectonic Line. The similar occurrence has also been recognized by N. Yamada in the Takatō district (1953) and recently by M. Hashimoto (1957).

In the present paper, the writer will describe the field occurrence and petrography of the gneissose granites of the Minakata-Kashio district and will give some genetical interpretations of them.

The term of "gneissose granite" is used here in a broad sense to include granite, adamellite, trondhjemite, granodiorite and quartz-diorite. All of these rocks are characterized by the remarkable gneissosity without exception and are genetically related to the hornblende-biotite gneisses which are considered as exotic in this district.

## Geological Outline and General Characters of the Metamorphic and the Granitic Rocks

The Minakata-Kashio district is situated at the north-eastern margin of the Ryōke Zone, between the Tenryū River and the Median Tectonic Line. (Fig. 1). The Koshibu River, a great branch of the Tenryū River runs from east to west in the southern part of this district. In the neighbouring districts many investigaters such as R. Sugiyama (1939~41), T. Takeda, *et al.*

(1951), the present writer (1953, 1956), K. Ishii, *et al.* (1955), M. Hashimoto (1955, 1957), J. Kimura (1956), N. Yamada and K. Kawada (1955), Ryōke Research Group (1955), and Y. Hayama (1956), made geological and petrological studies. The results of those researches have been summerized and compiled in the geological map by Ryōke Research Group.

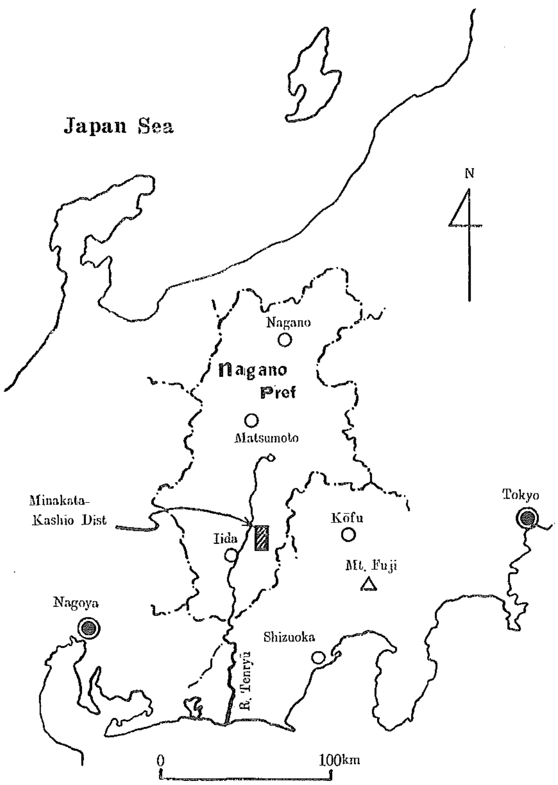


**Fig. 1.** Outline map of Central Japan, showing the situation of the present district.

As shown in the annexed geological map, granitic rocks of various types occupy the major portion of the present district, and they are arranged in Ikuta granite zone, Takisawa granite zone, Gneissose granite zone, Augen granite*zone, Mylonite zone from west to east in parallel with the Median Tectonic Line. In spite of the zonal arrangement in large scale, the general trends of the inner structures of these granites obliquely cut the trends of those arrangements and the Median Tectonic Line, and this inner structure is indicated by the gneissosity and the parallel arrangement of the xenoliths, and is the NE–SW trend consistent with the general trends of the Ryōke Metamorphic Complex of Central Japan. Along the eastern side of the Median Tectonic Line, running along the valleys of the Kashio and the Aoki Rivers, the Sambagawa Metamorphic Zone is distributed.

A part of the large mass of the Ryōke metamorphics occupies the northern region of this district, while those metamorphics are distributed only as xenolithic masses in granitic rocks in almost all other regions.

The Ryōke Metamorphics in the northern region consist mainly of hornfelsic rocks and fine- to medium-grained, somewhat massive (sometimes they have an aplitic or schistose appearances) bearing sillimanite and cordierite,

* It is a marginal facies of the gneissose granite along the mylonite zone.

which have been referred to sillimanite zone by Y. Hayama (1956). Contrasting with above the xenolithic masses are usually hornfelsic gneisses or partly banded gneisses which have often been converted into compact hornfelsic rocks by the polymetamorphism due to granitic intrusions.

The granitic rocks of this district are divided into the following four main types, according to the sequence of intrusion,

1) The Hiji tonalites
2) The Gneissose granites
3) The Takisawa granites
4) The Ikuta granites

The second group will be treated mainly in this paper, and to other groups will be described bliefly.

The Hiji tonalites occur in the northern region of this district and have been studied by M. Hashimoto (1955, 1957), and as to those in the farther north by J. Kimura (1956). The term "tonalite" will be used here in a broad sense to include from gabbroic to granodioritic rocks though various rock types of different mineral compositions are distinguished from one other. All of them are generally characterized by strong schistosity, and by the remarkable banding of melanocratic (diabasic～amphibolitic) and leucocratic (granodioritic) layers similar to the lit-par-lit injection (Plate 1, Fig. 1, 2).

The Hiji tonalitic complex is composed mainly of schistose tonalite accompanied with subordinate meta-gabbro and schistose granodiorite. This body occurs in elongated form with N-S direction extending about 25 km. along the inner side of mylonite zone. Farther northwardly its width becomes gradually narrower and at last disappears in the east of Takatō. Generally speaking, the northern part of this body is more basic and the banding is more outstanding.

Tracing this body to the south, it gradually changes into more massive and less-banding acidic facies. In the vicinity of Shitoku, medium-grained and schistose granodioritic facies predominates, but somewhat more basic or banded facies are found in the eastern area of the present district, carrying numerous diabasic or gabbroic xenoliths.

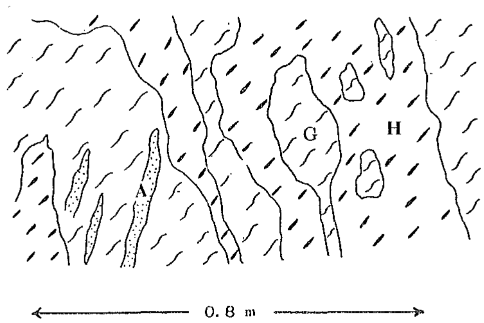


Fig. 2 Vertical section at the north of Shitoku, Minakata-mura. (Sketched by Y. Hayama)
G : Gneissose granite.
H : Hiji tonalite.
A : Aplite in gneissose granite.

It is often difficult to distinguish these acidic or massive facies from the gneissose granite described below.

As shown in Fig. 2, the Hiji granodiorite shows finer-grained and somewhat massive appearances, when they are in contact with the gneissose granites.

At the Iwakura-zawa, several masses of the gneissose granites which are elongated parallel to the schistosity of the Hiji tonalite, are found among the latter. Though it is difficult to make clear whether the former is invaded by the latter or *vice versa*. The boundaries between the gneissose granite and the Hiji tonalite are usually distinct, though not always sharp, but sometimes gradational. Any proofs of contact effect cannot be found in both sides of the boundaries. From the point of distribution the gneissose granite seems to be formed after the Hiji tonalites, but the time-interval of these two intrusions is thought to be negligible.

The gneissose granites include adamellite, trondhjemite, granodiorite tonalite and a little two-mica granite. All of them are characterized by a salient gneissic appearance (though some of them are remarkably porphyritic) and metamorphic texture in parts.

The large masses of hornblende-biotite gneiss are found in the Kadoishi-zawa, Mt. Takamori～Nakayama and Matsuyoke～Karayama, but the other small masses are found especially in the northern half of the present field. They are believed to correspond to the migmatite of K. Ishii *et al.* (1955).

Besides the hornblende-biotite gneiss, there are many inclusions of such metamorphosed basic igneous rocks as meta-gabbro or meta-diabase and meta-sediments.

The gneissose granite in question, has been described as porphyritic granite (Sugiyama 1939), as hybrid rocks (Takeda *et al.* 1951), as migmatite (Yamada 1953), as schistose medium-grained hornblende-biotite-granite (Ishii *et al.* 1955) and as migmatite derived from gneisses (Ryōke Research Group, 1955). It may possibly be designated as granitic gneiss. But, as described before, all gradation being observed between the extremities of the granitic gneiss and porphyritic granite, though various kinds of these rocks have intermingled one other elsewhere, excepting those which show the extreme gneissic appearance and may be called hornblende-biotite gneiss. Accordingly, they are indicated in the annexed map as gneissose granites and hornblende-biotite gneisses.

In the compiled geological map of Ryōke zone of Central Japan (1:200,000), this body is separated from the other granitic masses and its southern margin was not recognized exactly. In the farther south it becomes more granitic in the vicinity of Kitayama, Toyo-oka-mura, extending farther to the south-west. According to the Geological Map of Enasan (1:75,000), it may be an extension of the Tenryūkyō granite occuring in the vicinity of Tenryūkyō.

Therefore, this body may be referred to the north-eastern part of the Tenryūkyō granite which is one of the largest batholiths of the Ryōke zone of Central Japan. Surely, some of the coarse-grained porphyritic facies of the rock in question, appearing in the vicinity of the Kuwabara Fall, are lithologically identical with the Tenryūkyō granite.

It is interesting that the present mass is distributed parallel to the Madian Tectonic Line, despite its irregular outline.

The boundary between this mass and the adjacent rock is complicated but it is very harmonic in the form of interfingers with the general trend of the Ryōke Zone of this district. Though the elongated distribution of the mass is rather parallel to the Median Tectonic Line, the inner structures are almost constant, being similar to the general structural trend of the Ryōke Zone of the neighbouring district. The intersection between the inner structure and the elongation of the mass is the interesting problem above mentioned. It may owe to the later invasion of the Ikuta granite.

The most porphyritic variety of the coarse-grained gneissose granite is predominant at the eastern margin along the mylonite zone. It has been named "Augen Granite" or "Augen Gneiss". The gneissose granites gradually pass into the mylonite through the transitional zone of "Augen Granite" or blastoporphyritic gneiss. The writer is to make references concerning the mylonite in the later paragraph.

Small masses which are designated the Takisawa granite occur in the vicinity of the Matsuyoke-bridge and Karayama, and each of them has a closed outline. This rock is composed mainly of coarse-grained biotite-hornblende granite characterized by the directional arrangement of somewhat idiomorphic hornblende prisms. The elongation of these masses and the inner structure are generally concordant to the general structural trend of the present field. Only two evidences that indicate the relation with the neighbouring rock have been found. In the vicinity of Matsuyoke-bridge, a narrow hornblende granite vein obliquely injects into the gneissose granite. This rock is similar to the Takisawa granite in lithological characters, though it is shown to be rather acidic than the main body. On the other hand, near Karayama, large xenolithic masses of the Takisawa granite are found in the Ikuta granite. However, the problem whether they are xenolith or not, has still not been clarified, because the field evidence of contact between both granites could not yet be found.

If the assumption mentioned above is correct, it would easily be concluded that the Takisawa granite invaded between the gneissose granites and the Ikuta granite.

Another type is designated here as the Ikuta granite. It occurs in the western part of the area, and it is composed of granodiorite and granite. According to the previous study of the writer (1953) and the Geological Map of Iida (1:50,000), the Ikuta granite of the present field occupies the north-eastern margin of the batholith which extends to the south-west towards the Tenryū River, but the distribution of this rock is entirely limited in this area and is not found in the west of the Tenryū River.

It is usually characterized by coarse-grained and fairly massive appearances (in some cases slightly schistose or somewhat porphyritic), and by roughly idiomorphic biotite-flakes and normal granitic texture under the microscope. Although the foliation is usually indistinct, it is indicated by the arrangement of biotite schlierens or by the sub-parallel arrangement of enclosed rock-fragments.

In the south of Shitoku, the schistose and porphyritic muscovite-bearing granite occurs, which is a variety of Ikuta granite contaminated by meta-sediments, more basic and schistose variety being, on the other hand, found here and there as a contaminated facies with basic igneous rock.

A lot of xenoliths of basic igneous rocks and meta-sediments are found. All of them range in parallel with the general structural trend of the Ryōke Zone of the district. The basic igneous rocks are composed mainly of quartz-diorite and meta-diabase which are similar to basic xenoliths in the gneissose granites. It is interesting that their distributions are fairly limited in the vicinities of Kamitōge～Takisawa and Takigawa～Tamura (Toyo-oka-mura). Most of them are comtaminated by the granite, on the other hand, granitic rocks are converted to granodioritic or quartz-dioritic rocks. In these contaminated granodiorite or quartz-diorite, cummingtonite appears frequently as if green hornblende is replaced by cummingtonite.

Small xenoliths of meta-sediment, on the other hand, are common throughout the batholith, and they consist mainly of compact polymetamorphosed hornfels. Both psammitic and pelitic types are recognized. In the latter, fresh cordierite porphyroblasts occur frequently and the structure of original banded-gneiss is entirely destroided. On the other hand, psammitic sediment retains the features of banded-gneiss and is usually accompanied by fine-grained granitic rock perhaps due to local granitization. The different effects of the granite are reflected in the characters of the original rocks. In this case, psammitic rocks are easily converted to the granitic rocks by the enlargement of grain-size with the feldspathization.

From the lithological point of view, it may be said that they correspond to the Mitsuhashi granite of the Dando district.

Approaching to the boundary towards the gneissose granites, this rock becomes more acidic and somewhat porphyritic in appearance and changes into the gneissose granites, and it is often difficult to distinguish them from the gneissose granites in the field.

Although, at a glance, the outline of the mass in question is simply closed, the boundary between the gneissose granites and the Ikuta granite is very complicated. At several places, the contacts of both rock-types are recognized (Fig. 3), but we are unable to find any such thermal effect on both sides as the contact between the Hiji tonalites and the gneissose granites. In the south of Shitoku, a continuous outcrop of a border of both rock types is displayed along the Shitoku River. Here, the Ikuta granite gradually passes into the gneissose granites. In another contact, the Ikuta granite is injected into the gneissose granites and the latter shows a more or less dislocated xenolithic appearances, as shown in Fig. 4.

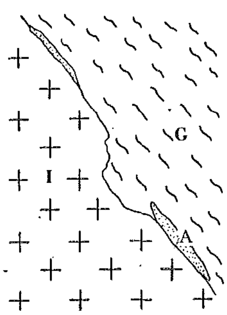


**Fig. 3** Vertical section at south of Shitoku.
G : Gneissose granite.
I : Ikuta granite.
A : Aplite in gneissose granite.

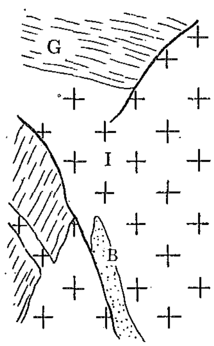


**Fig. 4** Horizontal section at south of Shitoku.
G : Gneissose granite.
I : Ikuta granite.
B : Basic igneous rock in Ikuta granite.

Mylonites (the so-called "Kashio-gneiss") are distributed in the inner (western) side along the Median Tectonic Line, and the mylonite zone is more than 1 km. in width in the vicinity of Ochiai. Its width is relatively narrower in the southern or the northern area. The direction of the elongation of the zone is about N 10° E and may be traced for a long distance along the almost straight belt with variable width. Numerous joints are displayed in the mylonite, therefore it is very irresistible against the mechanical weathering accordingly the mylonite zone can well be traced by topographical observation.

Usually, the mylonites exhibit a salient gneissosity and its trend is N 15°~20° E, though the dip is variable owing to the conspicuous minor folding and steep dipping in both sides. The marked lineations are also shown by the wrinkles on the gneissosity plane. The direction of the lineation is within the range of N 10°~20° E, pitches to the north with 10°~25°, and it is exactly parallel to the axis of minor folding.

The mylonites have been classified into the "porphyroid-like rocks" and the "hälleflinta-like rocks" by S. Nakamura (1906) and S. Ushimaru (1927), while K. Ishii (1927, 1955) divided them into the following three types, *i. e.* hornblende-gneiss, hälleflintaic gneiss and porphyritic biotite-gneiss, and R. Sugiyama (1941) divided systematically them into several types from the genetical point of view.

The writer will classify them again into three types based on the degree of mylonitization as follows.

1. Ultra-mylonite; the texture of the original rock is lost, being characterized by the striking recrystallization of quartz and mica. Showing the siliceous-hornfelsic feature under the microscope and cherty appearance in the field. Most of the hälleflinta-like rocks may be included in this class.

2. Medium-mylonite; characterized by strong gneissosity and granular feldspar (mostly plagioclase) which are arranged parallel to the gneissosity. Microscopically, lenticular plagioclase surrounded by fine-grained matrix composed mainly of quartz, mica and feldspars, and the plagioclase grains sometimes directly surrounded by biotite strings. Frequently the original rocks may be identified by such remnant crystals as hornblende of basic rock, almandine from gneiss, or the plagioclase of certain chemical composition. And most of porphyroid-like rocks belong to this class.

3. Less highly mylonitized rock; the original texture is fairly recognized, showing remarkable protoclastic texture. Most of the transitional rocks between the mylonite proper and the granitic complex belong to this class.

Many authors have noticed that the hälleflinta-like rocks generally predominate near to the Median Tectonic Line. While, R. Sugiyama (1939) considered that the hälleflinta-like rocks might have invaded into the porphyroid-like rocks. Surely, in many outcrops, as R. Sugiyama has observed, the hälleflinta-like rocks seem to be injected into the porphyroid-rocks. These "hälleflinta-like rocks" are, however, characterized by highly recrystallized quartz and these quartz grains are arranged in bands along the gneissosity. Fine-grained biotite are also recrystallized and arranged parallel to the contact with the neighbouring-rock. As mentioned above, these hälleflinta may suggest that the ultra-mylonite had once been under considerably mobile state when the recrystallization of quartz had progressed and probably it was injected in a plastic flow into the neighbouring-rocks.

Porphyroid-like rocks gradually pass, through the transitional zone of several alternation of highly mylonitized rocks and slightly mylonitized rocks into the gneissose granite. However, the rapid transition is observed and there is the marked difference of the structural trends between the mylonite and the granitic complex. Accordingly, some dislocations are expected between both complexes.

## The Gneissose Granites

### *Mode of Occurrence*

As described before, the gneissose granites include various rock types which are grouped from the genetical viewpoints. Their color indices and quartz : plagioclase : potash-feldspar ratios are very variable as shown in Fig. 5 and 6.

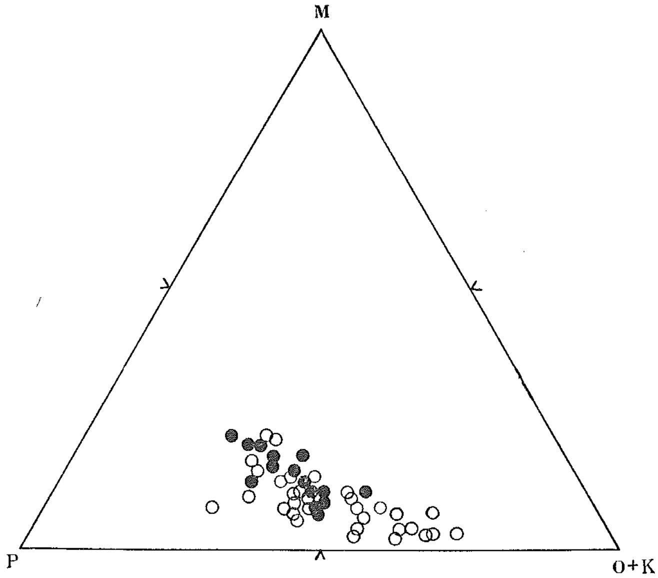


**Fig. 5** Diagram illustrating Quartz+K-feldspar (Q+K): Plagioclase (P): Total Mafics (M) ratios.
circle : Gneissose granites.
solid circle : Hornblende-biotite gneiss.

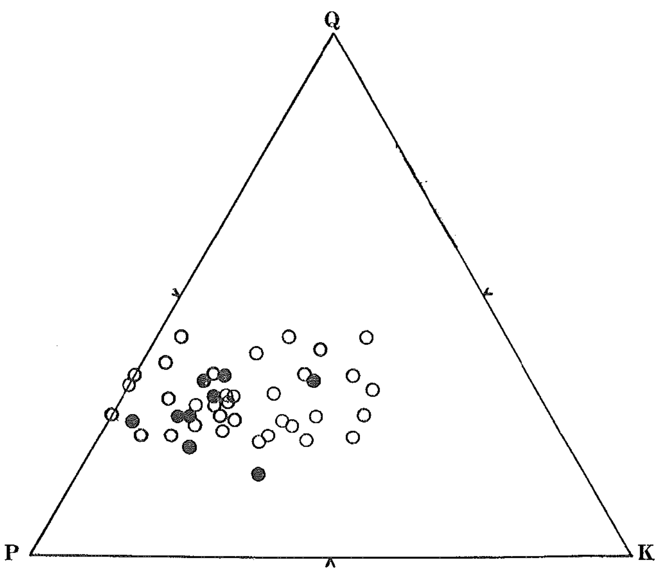


**Fig. 6** Diagram illustrating Quartz (Q): Potash-feldspar (K): Plagioclase (P) ratios.
circle : Gneissose granites.
solid circle : Hornblende-biotite gneiss.

The gneissose granites are classified, according to their mineralogical composition, into the following types; granite, adamellite, trondhjemite, granodiorite, basic trondhjemite and tonalite.

All of them, however, are characterized by a salient gneissosity, and their grain-sizes are variable, some of them being remarkably porphyritic.

Furthermore, these different rock types are not maintained as the individual large masses, but they mutually change into each other even in one outcrop.

Their own characteristics are followed by their distribution, the porphyritic gneissose granodiorite~adamellite, the predominat members of the gneissose granites, are exposed dominatly at the Kuwabara~Shitoku area, and at the southern margin of the present field. One of them, the variety carrying the tabular feldspar is hardly to be distinguished from the Tenryūkyō granite. Another variety of the fine-grained gneissose tonalite is exposed at the Kadoishi-zawa. The porphyritic granite and the adamellite are developed in the eastern margin along the mylonite zone as found at Koshibukyō, and in the vicinity of Zeni which is situated on the western margin of the mass in question. The extreme variety carrying eye-shaped feldspars has been named Augen-granite. It is found along the mylonite zone and at the north of Shitoku.

The highly gneissose variety which is characterized by the platy arrangement of large biotite flakes is found in the neighbourhood of hornblende-biotite gneiss, for example, at Matsuyoke. All gradations are observed between the two extremities, the hornblende-biotite gneiss and porphyritic granite.

In everywhere the medium-grained hornblende-biotite gneiss is closely accompanied by the gneissose granites. The large masses of the hornblende-biotite gneiss are found in the central area of the gneissose granites body, and smaller masses, the arrangements of them are usually parallel to the direction of the gneissosity of the gneissose granites, are found frequently in northern half of the gneissose granites.

The contacts between the hornblende-biotite gneiss and the gneissose granites are observed at several places. There the medium-grained hornblende-biotite gneiss gradually passes into the gneissose granites through the gneissose granodiorite or tonalite which show the intense gneissosity, and is often named coarse-graind gneiss. It is noteworthy that the transition from the gneissose granodiorite to the more granitic facies is quite gradual, while the transition from the hornblende-biotite gneiss to the gneissose granodiorite or tonalite is rather abruptly but not sharp. Nearer to the contact with the gneissose granodiorite, the grain-size and the mineral composition of the hornblende-biotite gneiss are scarcely changed. The gneissose granodiorite may be considered as a representative of the coarser-grained facies of the hornblende-biotite gneiss rather than the front of the gneissose granites.

Sometimes, the coarser-grained granitic facies are found in the large masses of hornblende-biotite gneiss, and the above mentioned relations are also recognized here.

Besides of them, the fine- or medium-grained gneissose trondhjemite and the medium-grained two-mica granite are developed, as the local facies, in the neighbourhood of xenoliths in the gneissose granites.

The large xenolithic masses of basic igneous rocks occur in the gneissose granite in the south-east of Okeya and in the north-east of Takisawa. They consist mainly of fine- to medium-grained quartz-dioritic rocks accompanied by trondhjemitic net-work-veins (Plate 1, Fig. 3) and micro-gabbroic rocks which may be the unmetamorphosed rocks of the former. Many smaller masses of basic and intermediate rocks are found throughout the gneissose granites.

The basic xenoliths are easily distinguished from the Hiji tonalites by the lacking of the characteristic banding and by more massive appearance though sometimes narrow (1∼2 cm. in width) quartzo-feldspathic veins are developed parallel to the schistosity (Plate 1, Fig. 4). These xenolithic basic rocks, however, pass usually into the gneissose granite, several instances of these contacts are described in the succeding paragraphs.

In the west of Ginaiji, is distributed the gneissose tonalite containning many diabasic relics and large porphyroblasts of plagioclases. The gneissose tonalite is also contact with the porphyritic gneissose granodiorite through the fine-grained gneissose trondhjemite of the transitional facies (Fig. 7). Here, the aplite veins from the trondhjemite inject into the gneissose tonalite.

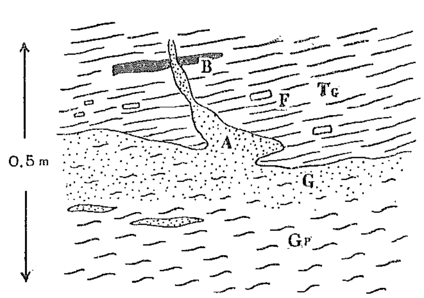


**Fig. 7** A sketch of vertical section at Ginaiji, Ōjika-mura.
B : Basic relic.
TG : Gneissose tonalite.
Gp : Porphyritic gneissose granite.
G : Fine-grained gneissose granite (Transitional rock).
A : Aplite. F : Feldspar phenocrysts.

At Ōshira-sawa, south of Okeya, the gneissose granite injects into the gneissose granodiorite, the latter gradually passes into massive micro-gabbro through the transitional schistose quartz-diorite.

An interesting relation, on the other hand, is observed at Ōkubo-bora, west of Shitoku. Here, the medium-grained gneissose granodiorite includes small sausage-like xenoliths of meta-diabase (Plate 2, Fig. 1). The fine-grained schistose granite is usually placed between both rock types. Also it gradually changes to the medium-grained granodiorite, the boundary between the meta-diabase and the fine-grained granite is usually sharp. Except that it has a faint schistosity, its lithological characters of the fine-grained schistose granite are similar to those of the Kadoshima granite after H. Koide. On the other hand, the medium-grained gneissose granodiorite is frequently met with in the coarser-grained gneissose granites.

Another relation at the Kuwabara Fall is shown in Plate 2, Fig. 2. Here the coarse-grained gneissose granite includes the meta-diabasic xenolith. Numerous trondhjemitic veins are observed in the meta-diabase along its contact with the adjacent rock. These veins are resembled to the lit-par-lit injection veins found in gneisses, and are ptygmatically folded and cut by the net-work veins.

As other basic xenolithic rocks are the amphibolites (may be called the basic hornfels) occuring here and there in the gneissose granite. The comparably large masses are shown in the annexed geological map. The mode of occurrence observed at Nakayama is shown in Fig. 8. At this outcrop, the basic hornfels is in contact with the medium-grained hornblende-biotite gneiss through intermediate aplite zone. The boundaries between each zone are distinct, but the gneissosities of them are almostly identical.

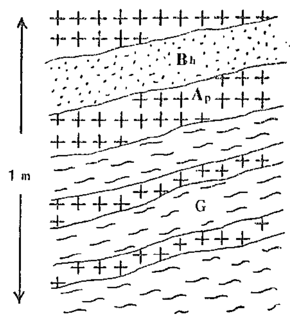


**Fig. 8** Vertical section at Nakayama, Ōjika-mura.
Bh : Basic hornfelsic rock (amphibolite).
Ap : Aplite.
G : Gneissose granite.

Xenoliths from the Ryōke metamorphics are also common in the gneissose granites. Relatively large masses of them are found in the vicinities of Okeya~Koshibukyō, Karayama and the west of Onadaka. They belong mainly to the banded-gneisses derived from pelitic~psammitic sediments. Generally they are converted to compact hornfelsic rocks due to the thermal effects of the gneissose granites, and often pass gradually into the gneissose granite through the transitional fine-grained granite. One of the xenoliths of the banded-gneiss observed at Koshibukyō is shown in Fig. 9. Here the gneiss passes gradually

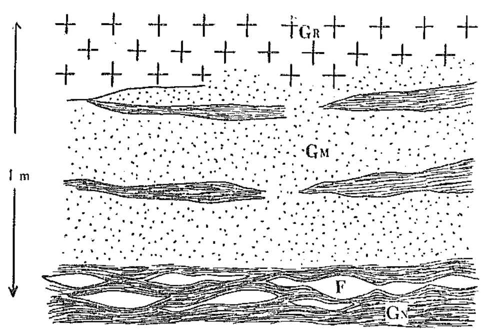


**Fig. 9** Vertical section at Koshibukyō, Ōjika-mura.
GN : Banded-gneiss.
F : Concreational feldspathic veins.
GM : Fine-grained schistose aplite.
GR : Gneissose granite.

into the gneissose granite through the fine-grained schistose granite, and the concretional feldspathic veins are developed in the gneiss along its contact with the gneissose granite. According to H. Ramberg (1949, 1952), these veins are unable to develop under a hydrostatic condition but formed by the same mechanism as the formation of the porphyroblasts in gneiss or schist.

At Karayama, southern end of the present field, the hornfelsic gneisses are characterized by the prevalence of neumerous ptygmatic veins. They are usually converted into compact hornfelsic rocks, though at the very contact with the wall rocks they become to a chocolate-colored and more compact rocks. The gradual changes from the gneiss to the gneissose granites are, however, observed in other places. Along these boundaries, are frequently developed the fine-grained gneissose granite with muscovite or patches of biotite.

Sometimes aplites are injected along these boundaries, the wall of aplite towards the wall rock being always sharp.

Aplitic or trondhjemitic minor intrustions are distributed universally not only in the gneissose granites but in the xenolithic masses. Most of them might be developed contemporaneously with the respective wall rocks. For instance, many of the aplitic veins or dykes in the gneissose granites frequently cut the wall rocks in some place, but their tails are generally extinguished into the wall rocks. Perhaps, most of which may be treated as a acidic secreation.

## *Petrography*

### (a) **Gneissose Granites**

(1) **Gneissose tonalite.** The gneissose tonalite is dark greenish colored, fine- to medium-granied rock characterized by a remarkable gneissosity. Some of them reveal the banding brought by alternations of dark-colored basic layers and light-colored quatzo-feldspathic layers. When the light-colored bands become narrow, simultaneousely the rock becomes finer-grained, and it is named the hornblende-biotite gneiss. Sometimes the aggregates of biotite flakes are observed among the coarser-grained and non-banded variety.

In thin section, the texture is granoblastic and sometimes remarkably poikilitic (Plate 2, Fig. 3). Mafic minerals flock together and show a salient gneissosity.

The essential constituents are plagioclase, quartz, hornblende, biotite and a little potash-feldspar, the last occurs only in the coarser-grained varieties.

*Plagioclase*; - It occurs as allotriomorphic granular crystal, poikiloblastic plagioclases carrying chadacrysts of quartz, biotite and hornblende are found in the coarser-grained varieties. It is basic oligoclase, ranging from $An_{28}$ to $An_{20}$, but rarly andesine $An_{40}$ is found in some varieties. Plagioclase is twinned after albite and pericline laws. The zonal structure is absent. Though the anti-perthite is rarely observed, no myrmekite being found.

*Quartz*; - It is usually interstitial crystal of various size, sometimes it forms mosaic together with granular plagioclases. It shows faint undulatory extinction though generally water-clear with minutes inclusions.

*Hornblende*; - Hornblende is commonly allotriomorphic and corroded by plagioclase and quartz. Frequently it is poikilitic crystal enclosing quartz grains and biotite flakes, and hornblende crystal is sometimes penetrated by quartz veinlets and entirely divided into several pieces, but every separated crystals are optically continuous. On the other hand, the hornblende is sharply cut by biotite flake though it graduarlly alter to biotite. It flocks together with biotite and shows the gneissosity. Its pleochroism is as follow; X=sulpher yellow, Y=light brownish green~dark green, Z=bluish green. Optically negative with $2V=65°\sim72°$, rarely $2V=54°$ (−) observed among the acidic varieties.

*Biotite*; - Biotite is hypidiomorphic or allotriomorphic flake, and it shows remarkable directional arrangement. The poikilitic flake carries the small hornblende grains with quartz. Biotite frequently alter to chlorite along its cleavage or margin. It is pleochroic with X=pale yellow, Y, Z=deep brown~reddish brown.

*Potash-feldspar*; - It occurs as interstitial crystal, and its quantity is very small. Microcline gitter structure is exhibited remarkably.

*Accessories*; - Pyrrhotite, allanite, zircon, titanite, and epidote occur. Often, the first formes large crystal.

(2) **Gneissose granodiorite and their porphyritic derivatives.** Gneissose granodiorite is neutral colored, medium- to coarse-grained and remarkably gneissose rock. The porphyritic variety is coarser-grained and characterized by the development of feldspar porphyroblasts with rounded outline. The porphyroblast becomes often as large as 2 cm. in length, and shows less distinct gneissosity.

In thin section, the texture is granoblastic to granitic, all gradations being observed between both extremities. When it exhibits the granitic texture, the outlines of each crystals are usually not so sharp as observed in the normal granite and fine-grained mosaic aggregates consist mainly of granular quartz and feldspars fill up the interspaces of the coarser-grained granitic textured part. The salient gneissosity is based mainly on the directional arrangement of biotite flakes.

The essential constituents are plagioclase, quartz, potash-feldspar, biotite and hornblende. In the porphyritic rocks, the porphyroblasts consist of both plagioclase and potash-feldspar.

*Plagioclase*; - It occurs as allotriomorphic granular or corroded hypidiomorphic crystals. Sometimes large porphyroblasts (though interstitial) develop as poikilitic crystals with chadacrysts of quartz, and small granular crystals flock together and show the mosaic texture.

It is oligoclase~andesine, ranging from $An_{25}$ to $An_{35}$, but more calcic ones are found rarely. It is twinned after albite and pericline laws, though in the plagioclases twinned after albite-carlsbad law are often observed in granitic textured part. The zonal structure is mostly lacking, the smaller granular crystals are clearer than the larger plagioclases which their inner parts are turbidized often by alteration. Anti-perthitic structure is often observed, and myrmekites develop along its contact with potash-feldspar.

*Quartz*; - Quartz is interstitial crystals in the granitic textured part and corrodes the other minerals. Often granular crystals flock together and show the mosaic texture with feldspars. It is water-clear with minutes inclusions, but undulatory extinction is striking.

*Potash-feldspar*; - It is interstitial and remarkably poikilitic crystal. Sometimes large idiomorphic crystals are observed megascopically, but all of them show interstitial relation towards the other minierals, and it is often twinned after carlsbad law. In some case, many turbidized irregular plagioclases are carried in large perthitic microcline and every isolated plagioclases are optically continuous because the orientation of their twin-lamellae are able to be traced mutually. Microcline structure and perthitic intergrowth are frequently found.

*Biotite*; - It is hypidiomophic flake, and flocks together with hornblende and allanite and forms mafic clots. The directional arrangement of biotite is remarkable. Sometimes it carries poikilitically small quartz grains. It is pleochroic with X=pale yellow, Y, Z=hazzle brown~dark greenish brown, and show strong pleochroic halo around zircon grains. The refractive index of biotite ranging from $\beta$=1, 657 to 1, 669.

*Hornblende*; - Hornblende is usually corroded irregular form. Sometimes ragged hornblende is found (Plate 3, Fig. 4), moreover optically continuous isolated fragments of hornblende are observed in a area, it is suggestive that a large previous hornblende crystal has been extremely corroded by quartz and plagioclase. In some case, hornblende is altered to biotite along the cleavage or margin, and it is observed that hornblende core is sheathed by biotite with the same optic orientation.

It is pleochroic with X=pale yellow, Y=olive green~deep green, Z=deep green~bluish green. Optically negative with $2V=60°\sim68°$, rarely obtained $2V=50°\pm$.

*Accessories*; - Large allanite occurs associated with biotite and hornblende.

Garnet is often found. Besides of them titanite, apatite, zircon and magnetite exist universally.

(3) **Granite and adamellite.** The discrimination between granite and adamellite is used microscopically, both of them are the acidic facies of the gneissose granites. It is light colored, medium- to coarse-grained rock characterized by a salient gneissosity, though most of them are conspicuously porphyritic. Large feldspar poikiloblasts stand out on the weathered surface. The porphyroblast is not always the well-shaped tabular crystal moreover eye-shaped crystal is frequently found.

Under the microscope, the texture is granitic to granoblastic, but the striking granoblastic texture predominates generally in the finer-grained part in a section. (Plate 2, Fig. 4). Also in the coarser-grained part granitic texture predominate. A lot of porphyroblasts of plagioclase and microcline-perthite are found.

The rock consists chiefly of plagioclase, quartz, potash-feldspar and biotite with subordinate hornblende. The relative proportion of constituent minerals is pretty variable.

*Plagioclase*; - Plagioclase is usually hypidiomorphic though intensely corroded by quartz or smaller granular plagioclase, and carries poikilitically quartz and hornblende grains in many cases. Large porphyroblastic crystals develop frequently but their outlines mostly reveal the interstitial relation to the groundmass.

It is oligoclase$\sim$andesine, ranging from $An_{20}$ to $An_{35}$. It is usually twinned after albite and albite-carlsbad laws, and the latter twin-type is found in coarse-grained porphyritic granite which exhibits granitic texture under the microscope.

Large crystals are often bended or strained, therefore the twin-lamellae are bent (Plate 3, Fig. 1) and the extinction is uneven.

Some of turbidized plagioclase exhibit the faint zonal structure (basic andesine core sheathed by acidic clear andesine, Plate 4, Fig 4). Myrmekite and narrow sodic rim occur along its contact with potash-feldspar.

*Quartz*; - It is interstial crystal, and often corrodes other minerals. Sometimes it occurs as the aggregates of granular quartz of various size and form the pool which is observed megascopically as a large quartz. Another time, the trains of many minutes of quartz surround the large feldspar, or its veinlet penetrates frequently into plagioclase crystal. Undulatory extinction is striking.

*Potash-feldspar*; - It is interstitial and remarkably poikilitic, pseudophenocrysts of microcline-perthite are often observed. Microcline structure is commonly distinct but perthitic intergrowth is rather common in large crystal.

*Biotite*; - The characters of biotite are mostly similar to those of the gneissose granodiorite but its amount is larger than the latter. Pleochroism is X=strawish yellow, Y, Z=hazzle brown~dark greenish brown. Refractive index ranging from $\beta$=1,661 to 1,673.

*Hornblende*; - It is not always found in all specimens, and its amount is small (5% of the bulk constituent in maximum) if it is present. The characters under the microscope are similar to ones in the gneissose granodiorite. It is pleochroic with X=pale brownish yellow, Y=olive green~brownish green, Z=bluish green. Optically negative with 2V=52°~65° but sometimes ranging to 72°.

*Accessories*; - Allanite occurs associated with biotite and hornblende. Sometimes titanite veinning into other minerals. Apatite, zircon, iron ore, and garnet are found universally as accessories.

### (b) Hornblende-Biotite Gneisses and their Derivatives

Hornblende-biotite-gneisses are bluish~greenish grey-colored, medium-grained rocks characterized by a salient gneissosity as a results of the platy arrangement of biotite flakes. Sometimes the irregular thin alternations of dark biotite-rich layers and quartzo-feldspathic layers are observed especially in finer-grained variety. In general, the grain-size of the rock increase in the more acidic derivatives.

Under the microscope, the rock exhibits granoblastic equigranular texture. Sometimes large poikiloblasts of plagioclase are found, and rarely it is recognized that the grain-size of the rock increase locally in a section. The directional arrangement of mafic minerals is remarked. Chlorite and aduralia veinlets occasionally penetrate into the other minerals.

The rock consists chiefly of plagioclase, quartz, potash-feldspar, biotite and hornblende. Most of the rocks may be referred to the granodiorite~quartz-diorite, judging from the modal proportions of constituent minerals, which are frequently accompanied by the more acidic derivatives.

*Plagioclase*; - It occurs generally as allotriomorphic granular crystal, sometimes large poikiloblastic crystal is found in the coarser-grained facies. It is basic oligoclase, ranging from $An_{20}$ to $An_{30}$, but the plagioclase of $An_{40}\pm$ is scarcely found as the turbid core of zoned plagioclase. Plagioclase is chiefly twinned after albite and pericline laws except the igneous plagioclase* (Plate 3, Fig. 2). Myrmekite occurs along its contact with potash-feldspar.

*Quartz*; - Usually it is interstital, but sometimes granular ones flock together and it is found megascopically as a large crystal in the acidic derivatives of the gneisses. Undulatory extinction is striking. Large poikilitic

* It is intensely corroded by quartz or granular plagioclase, but it shows the previous lath-shaped form and twinned after albite-carlsbad law.

crystal is often observed.

*Potash-feldspar*; – Potash-feldspar is almostly microcline with gitter structure. It is interstitial and poikilitic crystal. Its amount increases in the acidic derivatives of the gneisses and reaches to 28% of the rock in maximum.

*Biotite*; – Biotite is usually slender hypidiomorphic flake, its parallel arrangement is remarkable. It is pleochroic with X=pale brown~sulpher yellow, Y, Z=brownish black, rarely reddish brown. The refractive index ranging from $\beta$=1, 668 to 1, 671.

*Hornblende*; – Hornblende is intensely corroded ill-formed crystal. It shows the directional arrangement together with biotite flakes. Sometimes it is penetrated by the slender biotite flakes or alters gradually to biotite in some places. The pleochroism is as follow; X=pale yellow, Y=olive green, Z= bluish green. Optically negative with $2V=60^\circ \sim 67^\circ$.

*Accessories*; – Allanite, titanite, magnetite, zircon, apatite and garnet occur as accessory minerals. Frequently allanite is rimmed by epidote, and chrolite after biotite is common.

## (c) **Xenoliths**

(1) **Basic igneous rocks and their derivatives.** The basic rocks in question consist of meta-diabase, meta-gabbro, and quartz-diorite as the derivatives of the formers. The characters of them are very variable.

In general, they are dark-colored, fine- to medium-grained and massive, but sometimes slightly schistose. Sometimes porphyroblastic plagioclase and trondhjemitic net-work-vein develop in the acidic derivatives.

Under the microscope, sometimes the such relicted textures as gabbroic or dorelitic are sufficiently preserved to determine the original rocks, but granoblastic texture is found universally and especially prevalent in more acidic rocks. The parallel arrangement of biotite flakes is remarkable.

The essential constituents of the basic rocks are plagioclase, quartz, hornblende and biotite. A little potash-feldspar is commonly found in the most acidic derivatives which show the fine-grained granitic feature. Rarely, diopsidic pyroxene occurs in the slender belt-shaped xenolith which reveals somewhat dorelitic texture. Cummingtonite is rarely found in the acidic derivative. As accessories, iron ore, titanite, allanite, apatite and zircon occur. Such secondary minerals as chlorite, epidote, calcite and leucoxene are also common.

*Plagioclase*; – The large zoned-plagioclase is intensely corroded by quartz and granular plagioclase, and its labradorite core is frequently turbidized by saussuritization. Also, lath-shaped crystals flock together with pyroxene and hornblende and show the relic-texture of metamorphosed diabase. In some specimens, mottled plagioclases owing to albitization are observed. Besides these igneous plagioclases, the granular and poikiloblastic crystals are found, they are commonly andesine and mostly twinned after albite or pericline laws. On the contrary, plagioclase twinning after albite-carlsbad law is often observed in igneous plagioclase.

*Quartz*; - Quartz is not abundant in less-metamorphosed rock, and its amount incleases in the granitic derivatives. It is commonly interstitial and corrodes intensely the other minerals in acidic derivatives. Undulatory extinction is common.

*Hornblende*; - Hornblende is usually corroded and the ragged crystal. Small rounded crystal is often carried in the plagioclase poikiloblast. The structural relations to biotite are as follow; the small hornblende is carried in large biotite flake, the slender biotite flake penetrates into hornblende, and hornblende gradually alters to biotite accompanied with titanite, accordingly it is occasionally observed that hornblende core is sheathed by biotite with the same orientation. However, hornblende crystals are partly converted to cummingtonite. It is generally pleochroic with X=pale brown~sulpher yellow, Y=olive green~dark green, Z=bluish green. $2V=74^\circ \sim 57^\circ$ (−).

*Biotite*; - Biotite is hypidiomorphic flake. Sometimes, poikilitic crystal is found. The pleochroism is X=pale yellow, Y, Z=light brown. The relations to hornblende are already described above.

(2) **Meta-sediments and their derivatives**. Xenoliths of Ryōke metamorphic are common, though never nearly abundant, in the gneissose granites. They are mostly dark brownish or purplish brown-colored and fine-grained schistose rocks, but sometimes reveal irregular bands brought out the alternations of mafic-rich layers and quartzo-feldspathic layers. In the massive rock, however, the relic banded structure is often observed.

The granitized metamorphics is unable to be distinguished from the fine-grained two-mica granite (the Busetsu granite of H. Koide) by only its appearance. But the granitized rock is differrent from two-mica granite in the mineral assemblage accompanied by considerable amounts of cordierite.

Under the microscope, the texture is hornfelsic, equigranular and markedly schistose. Though individual mineral assemblages are variable, the chief constituents are quartz, plagioclase, microcline, biotite, muscovite, cordierite, and garnet with subordinate sillimanite, tourmaline and allanite.

Cordierite occurs as medium to large porphyroblast in the pelitic metamorphosed sediments and carries biotite and quartz grains. Frequently many crackes filled up by opaque minerals are observed.

Muscovite is hypidiomorphic flake, usually associated with biotite, and the muscovite penetrates frequently into biotite. Ill-formed large poikiloblasts are often observed. Sometimes shimmer aggregates of sericitic mica after aluminous silicate are observed.

Large ill-formed poikiloblast of tourmaline is found in some thin section.

It is pleochroic with E=colorless O=brownish yellow.

Small grains of garnet are often observed but its large porphyroblast is rare. With enlargement of the grain-size of the rock, the occurrence of the microcline porphyroblasts becomes characteristic, also the rock attaines the more granitic appearances.

(3) **Amphibolites.** Amphibolites are dark greenish～greyish colored, fine-grained, and compact, but markedly gneissose. Sometimes the feldspar porphyroblasts are developed and the banded structure is brought out the development of feldsparthic veinlets invaded parallel to the gneissosity.

Under the microscope, the amphibolite exhibits the granoblastic and equigranular texture, the parallel arrangement of biotite is remarkable. It consists mainly of plagioclase, hornblende, biotite, and subordinate quartz. Magnetite and titanite rarely occupies 7～8% of the bulk constituents.

Plagioclase is usually allotriomorphic granular and twinned after albite and pericline laws, sometimes it is poikilitic crystal carrying hornblende and quartz grains. Its composition is andesine ranging from $An_{30}$ to $An_{38}$. The corroded lath-shaped plagioclase occurs occasionally, it seems to assume that the igneous plagioclase is the relic of original igneous rock. (Plate 3, Fig. 3).

## (d) Mylonitized Gneissose Granites

Mylonitic rocks derived from the gnesisose granites are generally characterizes by intense gneissosity and rounded plagioclase crystals. Sometimes the feldspars are eye-shaped with the long axis parallel to the gneissosity, and the rock has been named "Augen-gneiss" or "Augen granite".

Under the microscope, the rock exhibits the porphyritic and mylonitic texture in which the rounded feldspar-phenocrysts are surrounded by the finer-grained and schistose matrix which consist mainly of biotite, quartz and feldspars. The minerals of groundmass are crushed and highly recrystallized, and its gneissose structure is shown by the parallel arrangement and trains of biotite flakes.

As essential mineral, plagioclase, quartz, potash-feldspar, and biotite with subordinate muscovite occur.

*Plagioclase*; - Plagioclase commonly occurs as large and somewhat rounded tabular or granular crystal. The large crystal is usually corroded by recrystallized quartz grains and sometimes cut by quartz veinlet. But in the latter case, though the plagioclase is divided into two or more part, little slip or strain are recongnized in each separated piece (Plate 4, Fig. 2, 3), and large snapped crystal is rarely found. (Plate 4, Fig. 1). Frequently poikilitic and anti-perthitic structure are observed. Large plagioclase is often twinned after albite-carlsbad law. Its composition is acidic andesine ranging from $An_{30}$ to

$An_{35}$. Myrmekite develops along its contact with the microcline. Occasionally the whole crystal of plagioclase is replaced by the myrmekitic aggregate.

*Quartz*; - It occurs as the fine-grained aggregate produced by the intense recrystallization accompanied with crushing, and forms the matrix with biotite and potash-feldspar around plagioclase phenocryst. Undulatory extinction is remarkable.

*Biotite*; - Biotite occurs as small hypidiomorphic flakes, and shows remarkable parallel arrangement. The train or film of biotite flakes surround the plagioclase phenocrysts. Sometimes biotite is gradually altered to muscovite, though the latter penetrates often into biotite. It is pleochroic with X=sulpher yellow, Y, Z=sepia brown. The refractive index ranges from $\beta$= 1,659 to 1,671.

*Potash-feldspar*; - potash-feldspar is mostly microcline with gitter-structure, and interstitial crystal. Sometimes it occurs as large poikiloblast carrying quartz and plagioclase grains. Usually it is free from the strain effect.

*Muscovite*; -It is usually allotriomorphic or hypidiomorphic flake associated with biotite, though sometimes it penetrates into the latter. Large poikiloblast frequently occurs.

*Accessories*; - As accessories, garnet, titanite, allanite, iron ore, zircon and apatite are present.

### (e) **Plagioclase-Twinning**

Throughout the gneissose granites, plagioclase twinnings of various types are commonly observed. The U:A:C ratios in plagioclases of the gneissose granites are determined after Gorai's method (M. Gorai 1951), and shown in Fig. 10 A, B.

In the diagram, the features of the plagioclase-twinnings of the rocks in question are summerized as follows;

(1) In the finer-grained and intensely gneissose varieties, the features of plagioclase-twinnings are similar to those of the hornblende-biotite gneisses, and belong the metamorphic type.

(2) In the coarser-grained and somewhat porphyritic varieties, the plagioclase-twinnings reveal the intermediate characters between the metamorphic and plutonic∼volcanic types (after Gorai), though they approach generally to the A vertex of the U:A:C diagram.

(3) The plagioclase-twinnings of the most granitic varieties belong to the plutonic∼volcanic plagioclase.

On the other hand, the characters of the plagioclase-twinnings of other rocks are considered as follow;

(1) In the hornblende-biotite gneiss, sometimes C-twinned plagioclases are found. Although, all of these plagioclases are somewhat lath-shaped and

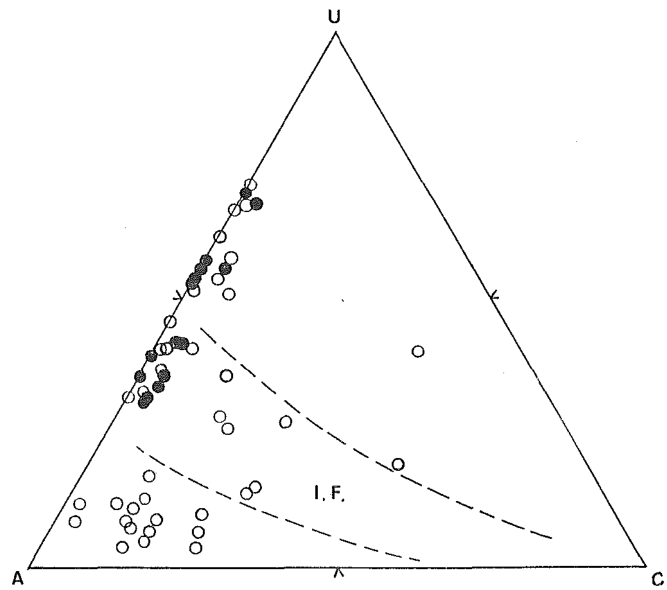


**Fig. 10 A** U:A:C ratios in the plagioclase of the gneissose granites and the hornblende-biotite gneiss.
circle : Gneissose granites.
solid circle : Hornblende-biotite gneiss.

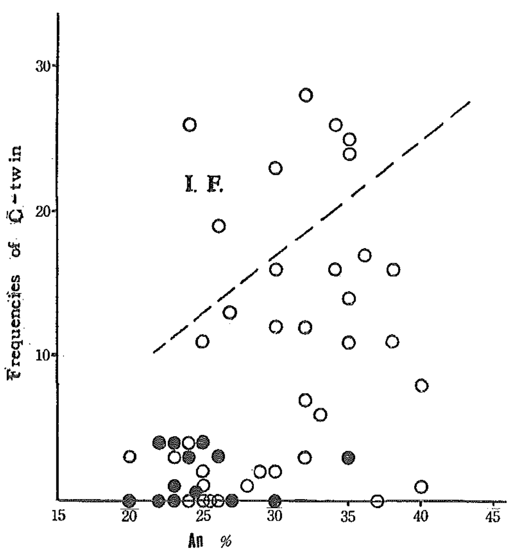


**Fig. 10 B** Relationship between the average An % of plagioclase and the frequencies of C-twin.
circle : Gneissose granites.
solid circle : Hornblende-biotite gneiss.

intensely corroded by other minerals. They are mostly the relic-plagioclases of the original rocks.

(2) C-twins are observed in corroded plagioclase in the metamorphosed basic igneous rocks. A-twined and untwinned plagioclases are richer in more granitic derivatives of basic igneous rocks. In such an end-products of the granitized basic igneous rocks as Kadoshima-like granite, C-twin is hardly observed.

(3) In some amphibolitic rocks, sometimes C-twins are found in the doleritic textured part of the rocks. Such C-twinned plagioclases may be the relic ones of the original rocks.

## Considerations

*The genesis of the gneissose granites.* The intimate relationships between the gneissose granites and the hornblende-biotite gneisses are shown by the field and the petrographic evidences. That is to say, at the place of the contact of both rock types, finer-grained and relatively basic varieties of the gneissose granites are characterized by the enlargement of the grain-sizes of thoso minerals which constitute the hornblende-biotite gneisses. Moreover, the gradual enlargement of the grain-size is accompanied by a small decrease of mafic constituents and some increase of quartz and potash-feldspar, thus the granitic features are formed, though the gneissosity is preserved as it was before. As the final products of the granitization, the porphyritic and more acidic derivatives come to exhibit such igneous appearences as the normal granitic texture and the injection relation to the surrounding rocks.

These facts are convenient to explain the facts that the gneissose granites are abundant in various rock-types and are generally characterized by the metamorphic texture. Namely, the various rock-types of the gneissose granites are respectively representatives of the different stages of the granitization where the hornblende-biotite gneiss was changed into the gneissose granites.

It is not evident that the gneissose granite had surely been in melt-phase, it is fairly expectable that the rock had locally reached a mobile-state at the final stage of the progressive granitization because the acidic variety of the gneissose granites has invaded the neighbouring rocks as shown in Fig. 7.

The highest granitic and porphyritic varieties, *i. e.* the rocks found at Kuwabara Fall and at Koshibukyō, are hardly distinguished from the Tenryūkyō granite of its type-locality. They exhibit largely the granitic texture, and it is frequently observed that the mosaic aggregate consisting of small granular plagioclases and biotites fill up the interspace of the granitic textured part. This textural feature is similarly observed in the Tenryūkyō granite*. The mass of the gneissose granites in the present field is continuously extended to the vicinity of Tenryūkyō. It seems that the gneissose granite of this district is a representative of the marginal facies of the Tenryūkyō granite.

The twinning features of plagioclase provide a criterion for the consideration of the genesis of the gneissose granite. As described before, the changes from the finer-grained rocks to the coarser-grained and somewhat porphyritic rocks are generally characterized by the enlargement of the grain-size accompanied by the increase of C-twinned plagioclase, though their twinning ratios are not plotted on the belt running straightly towards the C vertex of U:A:C diagram, on account of the dominances of A-twins. The further the granitization progresses, the commoner the C-twins of plagioclases become. Moreover, most of C-twins are occupied by the newer-developed plagioclases which often form large porphyroblastic crystals.

Since M. Gorai proposed his hypothesis, the observations of plagioclase-twinning have been performed actively by many authors in various granitic rocks of Japan, and recently M. Gorai (1957) has concluded as follow;

> "More intensely granitized rock is more abundant in C-twins of plagioclases than less granitized rock. [He (1953) has already pointed out that C-twins may be formed in the melt-phase.] This fact may coincide with the field evidences that, in the progressive granitization *in situ*, partial melt-phases are produced bit by bit in the solid rock during the granitization progresses enough."

It cannot be easily concluded that all of C-twins of plagioclases in the gneissose granites have been formed under the melt-phase. In these C-twinned plagioclases, there are idiomorphic plagioclases in granitic dykes invading the gneissose granodiorite and xenoliths, and sometimes ill-formed porphyroblasts in the gneissose granites. In Fig. 11 A, B, open circles show the U:A:C ratios and the relations between the average An % of plagioclases and the frequencies of C-twins of bulk plagioclases in the porphyritic gneissose granites, solid circles show those of groundmass-plagioclases and crosses show those of phenocryst-plagioclases.

As clearly indicated in the diagram, the porphyroblastic plagioclases are prevalent in C-twins and the groundmass plagioclases are prevaent in A-twins but are also richer in C-twins than in the finer-grained and more gneissose varieties of the gneissose granites.

As described before, it seems that some of the porphyritic and acidic varieties have locally attained to a considerable mobile-state. C-twins are found in these rocks which exhibit the injection relation to the surrounding

* About these texture, H. Koide (1942) said that the characteristic mosaic texture may be due to the contamination of the Tenryūkyō granite.

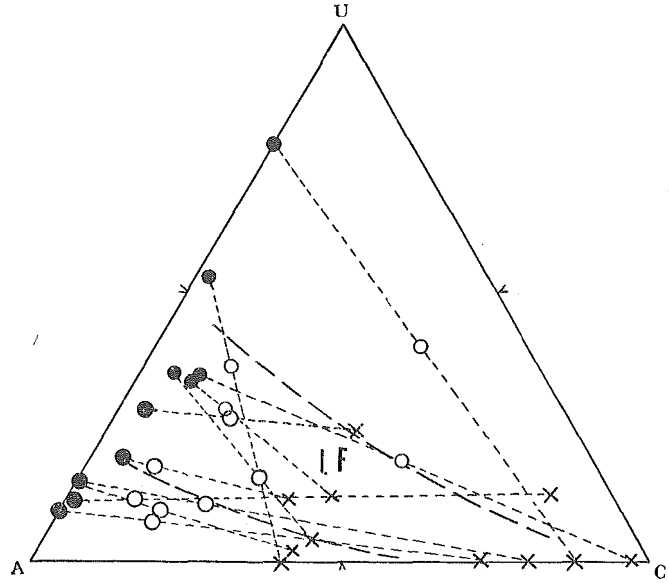


**Fig. 11 A** U:A:C ratios of plagioclases in the porphyritic gneissose granites.
circle : Average of phenocryst and groundmass plagioclase.
solid circle : Groundmass plagioclase.
cross : Phenocryst plagioclase.

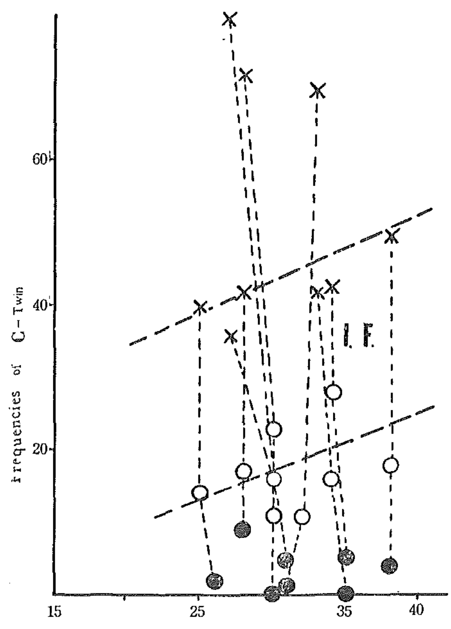


**Fig. 11 B** Relationship between the average An % of plagioclases and the fraquencies of C-twin.
circle : Average of phenocryst and groundmass plagioclase.
solid circle : Groundmass plagioclase.
cross : Phenocryst plagioclase.

rocks. It will be interesting, when we consider the condition of the formation of C-twin, that the porphyroblastic plagioclases in these rocks are rich in C-twins. Therefore the writer believes that porphyroblastic plagioclases are formed under the mobile-state,* and this interpretation is consistent with the field observation.

The hornblende-biotite gneiss, on the other hand, gives a criterion in the consideration of the gneissose granites. The hornblende-biotite gneiss is rather exotic in the Ryōke Zone of the neighbouring district. Because, the Ryōke metamorphics of the neighbouring district consist mostly of the banded gneiss and the schistose hornfels, and the amphibolites and the basic hornfels are hardly found, *i. e.* the Ryōke Metamorphic Zone may be represented by the pelitic∼psammitic and the siliceous sediments. A few thin beds of amphibolites derived from the tuff are only found in the Takatō∼Komagane district, in the Ryōke Zone of the neighbouring district.

The writer believes that the hornblende-biotite gneiss is the relic in the gneissose granites and it has been brought from the different lower formation than the general Ryōke metamorphics, owing to the invasion of the gneissose granites. It is hard to determine by the presence of the relicted igneous plagioclase whether the hornblende-biotite gneiss has derived from the basic igneous rocks or the sedimentary rocks. If it derived from the basic igneous rocks, it should suffer the intense granitization or contamination at lower level under the intense alkali-condition in order to produce the predominant biotite and potash-feldspar which might require the considerable supply of $K_2O$.

Therefore, in any case, about the genesis of the gneissose granites, it may be concluded that the gneissose granites have derived, by the granitization which has progressed at lower level, from the hornblende-biotite gneiss, perhaps under the solid state. And the gneissose granites had invaded into the present area, accompanied by the tectonic movement by which the Ryōke Complex had thrusted up over the Sambagawa Complex, when the granitization had progressed enough to gain the considerable mobility.

Furthermore, as already described, there are several sufficient reasons to believe that the gneissose granites were in the considerable high-temperature when they were brought to the present place. For example, the Ryōke metamorphics carried in the granites have converted to the hornfelsic rocks by the polymetamorphism due to the granite invasion.

*Mylonitization relating to the emplacement of the gneissose granites.* The mylonites deriving from the gneissose granites are characterized by the striking recrystallization under the high temperature and stress. The common

* It is necessary to be the meltphase, but it is sufficiently considerable that the partial-remelting is attained around the porphyroblasts during they have grown.

presences of large bended plagioclases may indicate that these plagioclases have been formed under the intense stress condition*. These plagioclases are corroded by the recrystallized quartz, biotite, and microcline, and microcline has been crystallized at the latest stage, free from the intense stress. When the mylonitization advances to a higher degree, it may become the ultra-mylonite characterized by hornfelsic features.

Sometimes the micro-foldings are found in the mylonite, this fact may deny the expectation that the mylonite has suffered the crushing when the magma has intruded. On the other hand, the rapid transition from the granites to the mylonites and the sudden change of the direction of the trends of the gneissosities between both zones are the difficult problems. The faults, however, are found along the boundary between both zones and they are generally parallel to the Median Tectonic Line.

If the gneissose granites had invaded in fluidal-state the present place, the striking gneissosity of the rocks should be understood as the indication of the flow-structure which has been brought with the aid of the heterogenety of the magma. In this case, naturally, the general structural trends of the Ryōke proper might be lost and another structural trends would be represented by that gneissosity. But the inner-structure of the gneissose granites is harmonic with the general structural trends of the Ryōke zone, and it is traced continuously into the mylonite zone with the rapid but continuous change of the directions. These phenomena may support the interpretation that the granites had been crushed and recrystallized under a solid-state. And in the more advanced process, the crushing and the recrystallization might have made the mylonites considerably mobile, because the ultra-mylonitic derivatives show frequently injection relation to the neighbouring rocks.

The writer concludes that the granitic mylonite of the present district has been formed mainly by the crushing of the gneissose granites along the front of the gneissose granite, when the Ryōke Complex has thrusted up over the Sambagawa Complex, and the gneissose granites of solid-state have invaded the present position from the lower level by the aid of the uplift of the whole Ryōke Complex.

*Basic xenoliths in the gneissose granites.* A lot of xenolithic masses of basic igneous rocks and some of amphibolites are found in the gneissose granites. Sometimes the amphibolite reveals partly the relicted doleritic texture, and these amphibolites are believed to be the derivatives from the basic igneous rocks. Another type of the amphibolites, however, is hardly distinguished from the so-called basic hornfels by its microscopic features

* H. Koide (1942) said that these bended plagioclase may be developed as a strained state in the strikingly contaminated rocks.

and the field occurrences. Some of them are found in the hornblende-biotite gneiss as if it is the relic of the gneiss, but occassionally C-twined and lath-shaped plagioclase are found in these amphibolites. The presence of the igneous plagioclase does not directly and conclusively indicate that the amphibolite originated from the basic igneous rocks.

The basic igneous rocks in the gneissose granites consist mainly of meta-diabase and meta-gabbro. They have been bodily granitized as well as locally granitized. The bodily granitization is characterized by some of the developments of biotite, quartz, and granular plagioclase, and the local granitization is observed along the contact with the gneissose granites and produces the fine-grained granite or the intermediate rocks between both basic igneous rocks and gneissose granites. Whether the granitization of both types has been performed in one stage or two different stages is unable to easily clarify, but it is doubtless that the local granitization has been done directly by the gneissose granites. If the basic igneous rocks were bodily granitized in thc same stage when the hornblende-biotite gneiss was granitized at lower level, *i. e.* the basic igneous rocks were situated the same level where the hornblende-biotite gneiss had exsisted, they must have metamorphosed in the same degree with the gneisses. Therefore, it seems that the basic igneous rocks are caught in the invasional process by the gneissose granites. In other words the basic igneous rocks had already existed in the vicinity of the present position, and the gneissose granites have intruded here. The lack of the characteristic layering of the Hiji tonalites shows that the metasomatic effects which these basic rocks has suffered are different from those of the Hiji tonalite.

## Summary

(1) The granitic rocks occurring in the Minakata-Kashio district, Nagano Prefecture, are divided into four rock masses according to the field occurrences and the petrographic characters, *i. e.* the Hiji tonalites, the gneissose granites, the Takisawa granites and the Ikuta granites in order of the sequence of invasions. And a little time-interval is expected between these invasions.

(2) The gneissose granites are classified into several rock types according to lithological viewpoints, but all of them have been produced from the hornblende-biotite gneiss through the process of granitization. In the granitization process, a certain remelting of the rocks might have taken place locally in the highly advanced stage.

(3) The hornblende-biotite gneiss is rather exotic in the Ryōke Zone of the neighbouring district, and it may represent the formation deeper-seated than general Ryōke metamorphics. And it would have been brought to the present place by the invasion of the gneissose granites.

(4) After the granitization had been almost completed in the lower level, the gneissose granites had invaded the present place in solid-state with subordinate mobile-state.

(5) The invasion of the gneissose granites has been made with the powerful aid of thrusting up of the Ryōke Complex over the Sambagawa Complex of the Outer Zone, *i. e.* the emplacement of the gneissose granites has closely been connected with the tectonic movements that formed the Median Tectonic Line.

(6) The gneissose granites have been strikingly mylonitized in front of the Median Tectonic Line.

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## Explanation of Plates

Plate 1 Fig. 1; Layered Hiji tonalite; melanocratic bands are diabasic and leucocratic bands are trondhjemitic, vertical section at Ōkubo-bora, Minakata-mura.

Fig. 2; Banded Hiji tonalite; characterized by granodioritic layers and dioritic layers, vertical section at Ryūgataru, Minakata-mura.

Fig. 3; Block at Nakayama, Ōjika-mura, Trondhjemitic net-work-veins in the meta-diabase.

Fig. 4; Vertical section at Ōshira-sawa, Ōjika-mura; showing the narrow quartzo-feldspathic veins in fine-grained diabasic xenolith in the gneissose granite.

Plate 2 Fig. 1; Vertical section at Ōkubo-bora, Minakata-mura; sausage-shaped diabasic xenolith in the gneissose granite.

Fig. 2; Vertical section at the Kuwabara Fall, Minakata-mura; trondhjemitic ptygmatic veins develop in the basic xenolith along the contact with the gneissose granite.

Fig. 3; Microphotograph of the gneissose tonalite; shows granoblastic and poikilitic texture. Crossed nicols. (×24)

Fig. 4; Mosaic texture consisting of the fine-grained granular plagioclase with quartz and microcline grains in the gneissose granite. Crossed nicrols. (×24)

Plate 3 Fig. 1; A bended large plagioclase in the gneissose granite. Crossed nicols. (×24)

Fig. 2; A turbidized plagioclase of the igneous type in the hornblende-biotite gneiss. Crossed nicols. (×49)

Fig. 3; Microphotograph of the amphibolite; a plagioclase relic of igneous type is shown at the center of the figure. Crossed nicols. (×49)

Fig. 4; Ragged hornblende crystals in the gneissose granite. All of which are observed in the left side of the figure are optically continuous. Open nicols. (×24)

Plate 4 Fig. 1; A brocken plagioclase in the mylonitized porphyritic granite and a little gap of twinning lamellae of plagioclase cut by quartz veinlets, at right part of the figure. Crossed nicols. (×24)

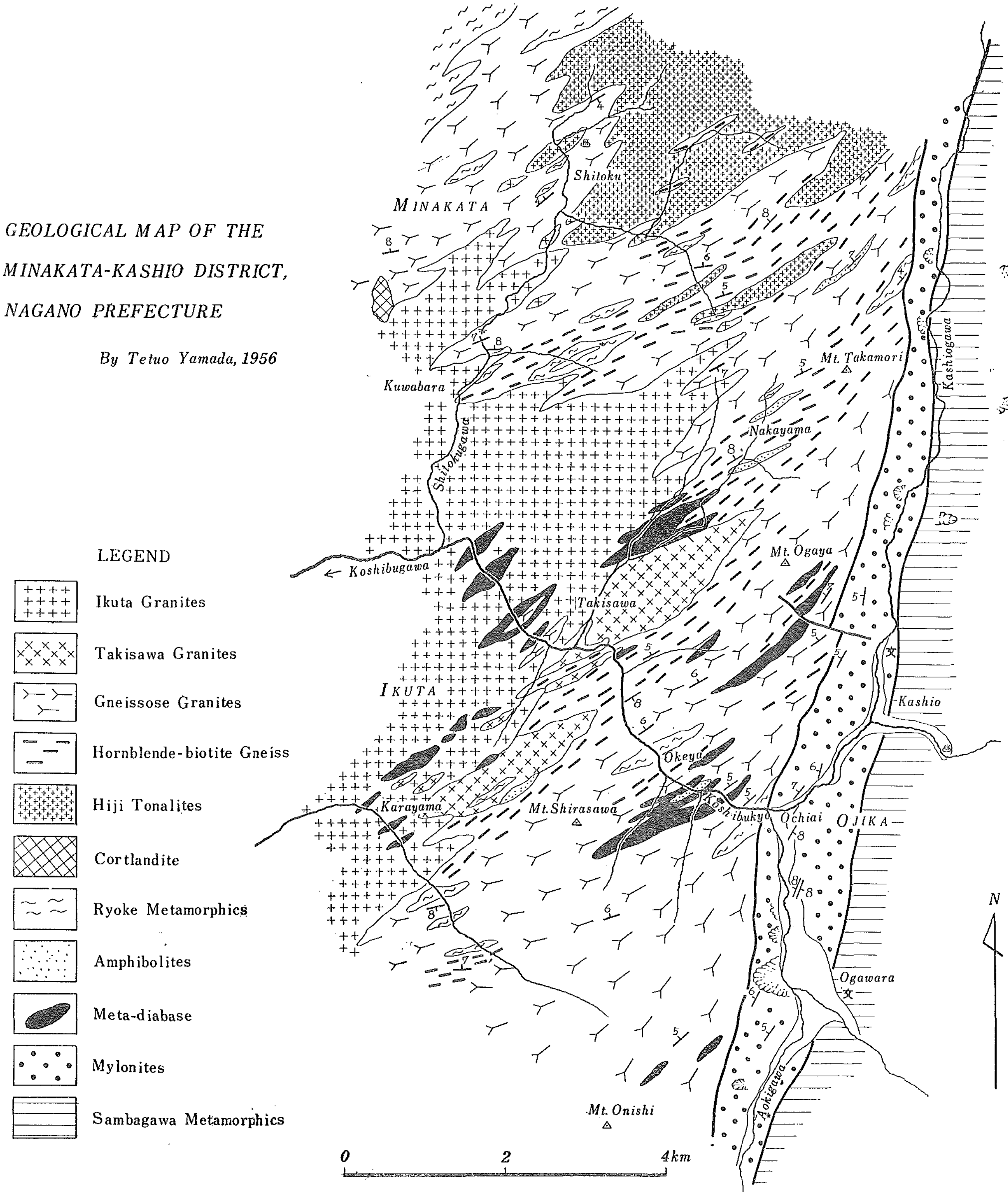
Fig. 2; A plagioclase crystal of slightly mylonitized gneissose granite is cut by quartz veinlet with a little slip. Crossed nicols. (×24)

Fig. 3; A corroded plagioclase in slightly mylonitized porphyritic granite is cut by quartz veinlet without any slip of twinning lamellae. Crossed nicols. (×24)

Fig. 4; A plagioclase crystal in the hornblende-biotite granite, with inclusions of biotite and hornblende grains. Crossed nicols. (×24)

*GEOLOGICAL MAP OF THE MINAKATA-KASHIO DISTRICT, NAGANO PREFECTURE*

*By Tetuo Yamada, 1956*



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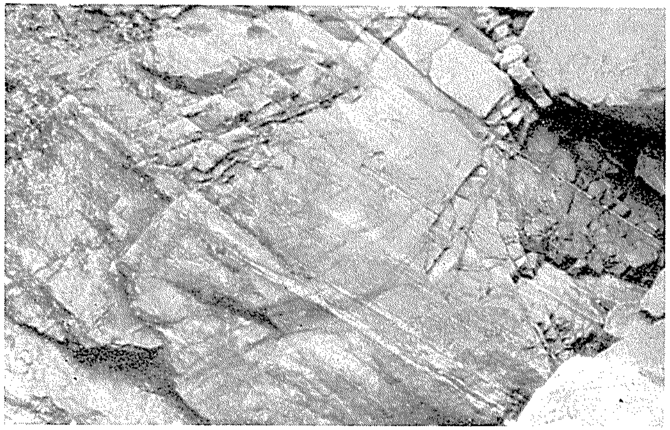

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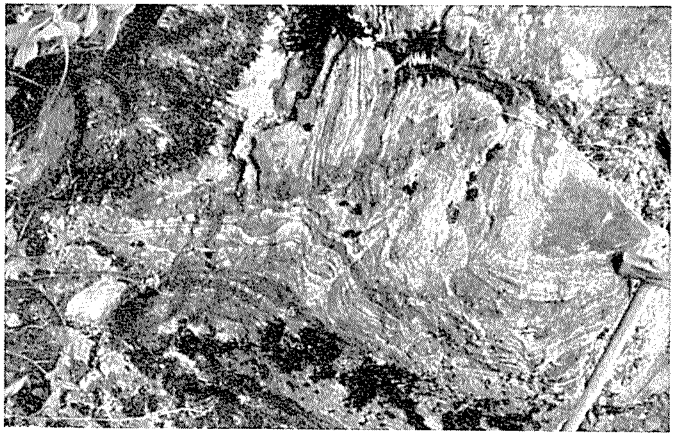

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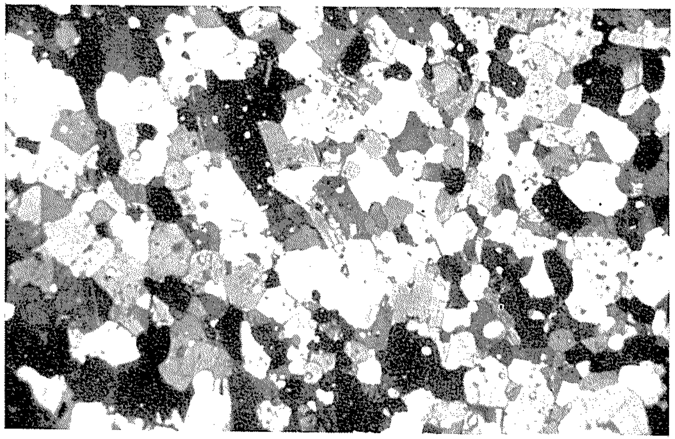

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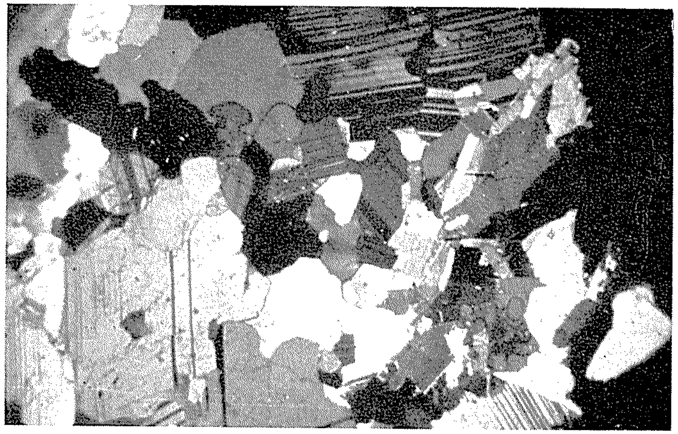

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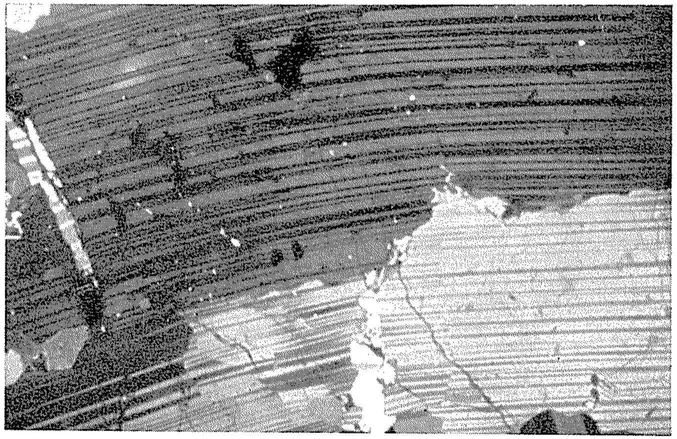

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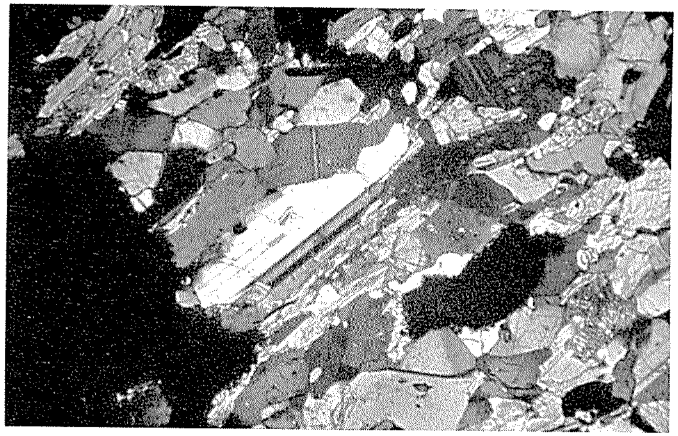

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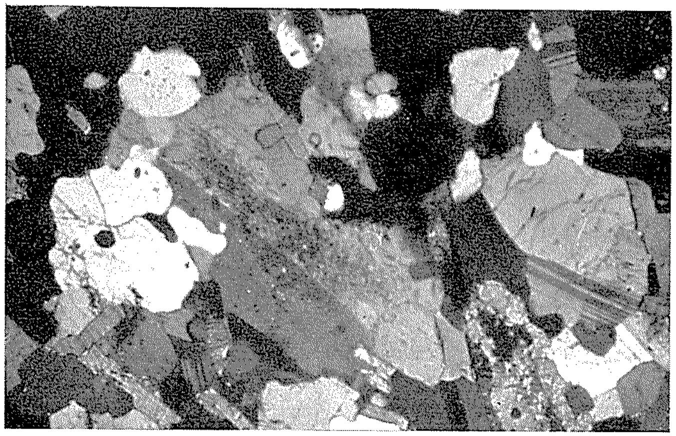

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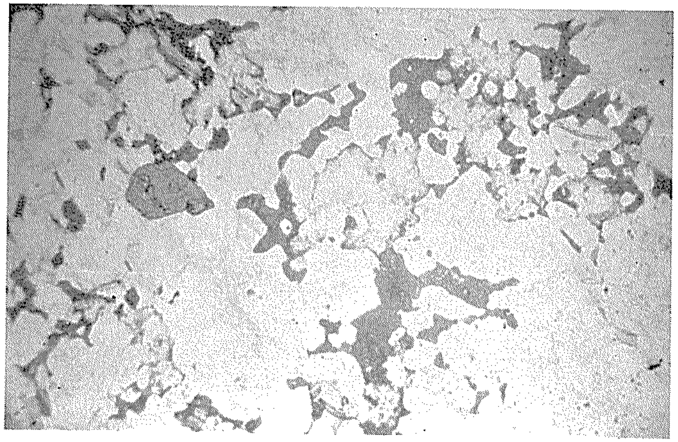

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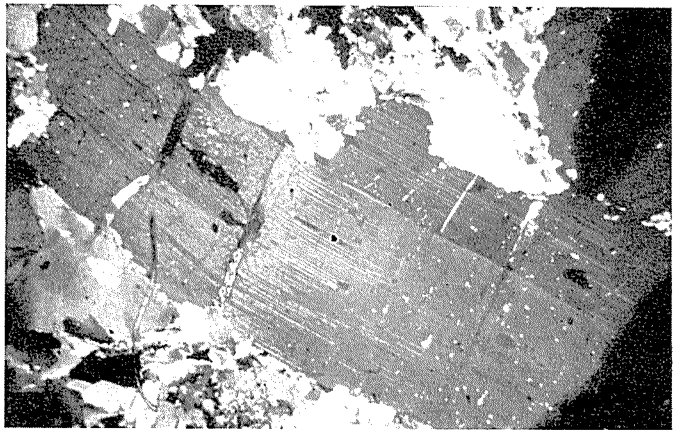

Fig. 1

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